DEVELOPMENT OF STABILISED POPULATION OF COWPEA SEGREGANTS (*Vigna unguiculata* (L.) Walp.) WITH HIGH PROTEIN CONTENT AND GRAIN YIELD

by

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THESIS

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DECLARATION

I, hereby declare that the thesis entitled '**Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield'** is a bonafide record of research done by me during the course of study and the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
26/07/2019

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CERTIFICATE

Certified that this thesis entitled entitled '**Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield'** is a record of research work done independently by Ashni Varghese (2017-11-020) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important pulse crop providing good source of protein and often referred to as poor man's meat. Cowpea is known by various common names such as black eyed pea, southern pea, yard long bean, catjang bean *etc*. It is a versatile crop of which seeds are utilised as pulse, green pods as vegetable, and leaves as forage. Root nodules can fix atmospheric nitrogen and thus play an important role in restoring soil fertility. It is a hardy crop which can be grown as intercrop and also in summer fallows. The crop requires very few inputs and make it valuable crop for resource poor farmers.

Cowpea seeds are rich source of proteins, calories, minerals and vitamins. On dry weight basis, cowpea grain contains 23.4 per cent protein 1.8 per cent fat and 60.3 per cent carbohydrates and it is a rich source of calcium and iron (Gupta, 1988). Cowpea can act as an excellent substitute for animal proteins by resource-poor people and vegetarians because of its high seed protein content. Cowpea seeds are classified into small ($<$12 g/100 seeds), medium (12-18 g/100 seeds) and large ($>$18 g/100 seeds) (Drabo *et al*., 1984).

Cowpea originated in Africa and, India being a secondary centre of diversity for cowpea, possesses huge germplasm and wild relatives. This supplements to the genetic resources of worldwide cowpea collections. High level of diversity exists within the species with large variations in the size, shape and habit of the plant as well as seed size, shape and colour.

Four subspecies of cowpea are recognised, of which three are cultivated. Three major cultivated subgroups of cowpea include *V. unguiculata* ssp. *unguiculata* (dual purpose type), *V. unguiculata* ssp. *cylindrica* (grain type) (Syn: *V. unguiculata* ssp. *catjang, V. sinensis* ssp. *catjang.*) and *V. unguiculata* ssp. *sesqipedalis* (vegetable type). These cultivated subgroups are cross compatible (Peter, 1998), which provide opportunity for combining characters through hybridisation programmes.

Yield improvement in cowpea without compromising protein content is a difficult task to achieve. Developing high yielding varieties of cowpea with high protein content will not only contribute to food security but could also contribute to the alleviation of protein deficiencies. Utilising the existing variability offers limited opportunity in reaching this objective. Hybridisation between genetically diverse parents and selection from the transgressive segregants is found to be a promising opportunity for combining grain yield and protein content.

Selecting superior plants from segregating generations can be done by employing pedigree selection method. Seed yield being final product of many complex physiological and developmental reactions, controlled by array of many genes, varies greatly under different environment conditions. Therefore indirect selection using mostly correlated characters would give more selection efficiency for grain yield. Also the magnitude and type of genetic variability, heritability of different characters and correlation studies help the breeder to determine the selection criteria and breeding schemes to be used for improvement purposes.

Twenty four cowpea hybrids were developed in the Department of Plant Breeding and Genetics as a part of postgraduate research programme in the year 2014 to combine grain yield and protein content. From these hybrids, two hybrids namely H 10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) were identified as superior with respect to yield and protein content (Sarath, 2015).From the F_3 generation of these two crosses, 23 lines were selected by pedigree selection.

In this background the present study is conducted with an objective of pedigree selection from segregating generations of cowpea hybrids for grain yield and protein content.

2. REVIEW OF LITERATURE

The review of literature related to the study on 'Development of stabilised population of cowpea segregants (*Vigna unguiculata* L. Walp) with high protein content and grain yield' is organised into the following sections.

2.1. Variability studies in cowpea

2.2. Heritability and genetic advance in cowpea

2.3. Selection criteria for yield in cowpea

2.4. Correlation studies in cowpea

2.5. Path coefficient analysis in cowpea

2.1. Variability studies in cowpea

The choice of an appropriate selection/breeding method and its success for improvement of quantitative traits largely depends on the extent of genetic variability present in segregating material and gene action. Knowledge on genetic architecture of yield and related traits plays an important role in deciding breeding strategies and methodologies for crop improvement.

Sarath and Joseph (2017) evaluated 24 cowpea genotypes and reported high variability for yield, yield contributing characters and protein content. Grain yield per plant exhibited high GCV and PCV, while protein content recorded low value for PCV and GCV.

Cowpea cultivars with 30 per cent protein content have been released in the African continent (Singh, 2007). Emibiri (1991) reported both additive and dominant types of gene action in *V. unguiculata* for seed protein percentage.

Santos and Boiteux (2013) reported seed protein ranged from 22.5 to 34.1 per cent in 87 F_6 lines derived from 6 cowpea crosses. Accordingly they opined there is opportunity to increase the protein content in cowpea.

Eleven Arkansas cowpea breeding lines were evaluated by Ravelombola *et al.* (2016) and reported that the average seed protein content was 25.4%. Moreover the value ranged from 23.7% to 27.4% with a standard deviation of 1.9%. They observed significant effects of genotype, environment (location), and genotype by environment for the total seed protein content in cowpea. The broad sense heritability (H^2) for cowpea seed protein was 57.8 per cent. The cowpea lines, "Early Scarlet" and 09-204 had the highest seed protein content.

de Silva *et al.* (2016) evaluated forty-four inbred lines and cultivars of cowpea and reported that the inbred lines having the highest protein contents exhibited the lowest grain yields, pointing the prominent phenotypic cost of protein in cowpea seed production. On the contrary, the breakage of the association was observed in a sub group of inbred lines studied such as 'C3Q', 'C3M', 'C2S', and 'CIJ'. These lines exhibited yield approximate to or above 1050 kg/ha and mean protein content of 27 per cent.

Tchiagam *et al.* (2011) screened 10 varieties of cowpea and the values of seed crude protein ranged between 20.79 to 31.78 per cent. Among the F_1 progenies, protein content varied from 22.23 to 32.67 per cent. The value of σ^2GCA / σ^2 SCA ratios showed that, SCA variance was higher than GCA variance component in the study indicating presence of dominant gene action for protein content.

Richard *et al.* (2016) studied variation in seed protein content in 101 cowpea genotypes from genetic resources of IITA and found that seed protein values ranged from (15.06 to 38.50%) with a mean of 25.99 ± 4.82% in dry seeds. Out of the 101 genotypes analysed, only 20 genotypes (representing 19.80%) had protein values greater than 30 per cent, which were considered high protein lines in this study.

Studying yield attributes in F_2 and F_3 generation of the cross IT-38956-1 x KBC-2, the characters such as plant height, primary branches per plant, secondary braches per plant, pods per plant, pod length and seeds per plant exhibited the moderate values for variability (Lokesh and Murthy, 2017).

Studies on F_3 generation of the cross C-152 × V-16, recorded moderate phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) estimates for plant height (15.75 per cent and 12.91 per cent), number of pods per plant (16.29 per cent and 11.42 per cent), number of branches (15.01 per cent and 6.66 per cent), number of seeds per pod (12.60 per cent and 4.77 per cent) and seed yield per plant (10.86 per cent and 4.51 per cent) (Dinesh *et al.*, 2017).

In a study conducted by Sabale *et al.* (2018) in 23 F_2 generation genotypes of cowpea, it was observed that phenotypic coefficient of variation was greater than the genotypic coefficient of variation for all the characters studied *viz.* days to first flowering, days to maturity, number of primary branches per plant, plant height (cm), number of clusters per plant, number of pods per plant, number of pods per cluster, pod length (cm), number of seeds per pod, 100 seed weight, harvest index and seed yield per plant. The high phenotypic and genotypic coefficient of variation was observed for seed yield per plant (37.16,36.25) number of pods per plant (29.73,28.86), number of clusters per plant (26.17,24.83) and number of primary branches per plant (20.76, 19.63), while lowest GCV and PCV was observed for days to first flowering (4.74, 2.6) and days to maturity (3.75, 2.4).

In order to create variability in cowpea, Moalafi *et al.* (2010), hybridized 55 parental lines and evaluated the F_2 generation for variability. They observed that there was increase in number of pods in F_2 generation than in parental lines. They also observed high variability for pod number, 100 seed weight, fodder yield, grain yield and harvest index in the F_2 generation.

Twelve cowpea cross combinations were used for the evaluation of parent-progeny regression, between the F_3 and F_4 generation, for plant height, number of

branches per plant, pod length, number of pods per plant and seed yield per plant. Among these, four cross combinations showed positive and significant parent-progeny regression coefficient. The genetic and phenotypic coefficients of variation were moderate for plant height, pod length and seed yield per plant in F_4 generation (Kalaiyarasi and Palanisamy, 2000).

The highest coefficient of variation values were observed for pod yield (28.62%), grain yield (28.22%), 100 seed weight (25.96%) and shoot weight (25.41%). The lowest coefficients of variation were found with seed set (4.35%) and time to 50 per cent maturity (5.93%) when 30 cowpea genotypes were analysed in Cameroon (Kouam *et al.*, 2018).

The top three characters which contributed most towards the genetic divergence were number of seeds per pod, pod yield per plant and pod weight when a study was conducted in seventeen vegetable cowpea genotypes. High to moderate GCV and PCV values were found for number of pods per plant, pod yield per plant, pod weight, number of seeds per pod and pod length (Chattopadhyay *et al.*, 2014).

The genotypic coefficient of variations (GCV) and phenotypic coefficient of variations (PCV) was found high for plant height, primary branches per plant, seed yield per plant and test weight when 180 cowpea genotypes were evaluated. Harvest index, pods per plant, clusters per plant and flowers per plant showed moderate GCV and PCV value, while days to 50 per cent flowering and days to maturity exhibited low GCV and PCV value (Sharma *et al.*, 2017).

Nair *et al.* (2018) carried out genetic variability study with 25 F_2 inter-specific hybrids of cowpea and their fourteen parents. The results indicated that the characters plant height (67.12%) and green pod yield per plant (40.22%) exhibited maximum phenotypic coefficient of variation whereas least magnitude of phenotypic coefficient of variation for days to first flowering (8.99%) and number of seeds per pod (13.09%). Highest value of genotypic coefficient of variation was registered for plant height (65.29%) and green pod yield per plant (39.89%). The character days to first

flowering (8.35%) followed by number of seeds per pod (11.40%) showed minimum value of GCV.

The performance of 30 genotypes was evaluated by Thorat and Gadewar (2013) and reported high GCV for leaf area index (45.17%) followed by days to 50 per cent flowering (40.04%), plant height (34.71%), number of branches per plant (27.99%), number of pods per plant (24.84%), number of clusters per plant (24.73%) and for days to maturity (18.01%).

2.2. Heritability and genetic advance

Sunil (2017) reported that heritability for grain yield in F_2 generation of two cowpea crosses was 82.93 per cent and 5.76 per cent, whereas the same crosses in F_3 generation recorded heritability of 98.41 per cent and 96.58 per cent respectively. Heritability of seed protein in F_3 generation of the two crosses was 71.20 per cent and 70.93 per cent.

In study in F_2 generation of 24 cowpea crosses by Subbiah *et al.,* (2013), they observed that the heritability estimates and genetic advance was high for traits viz., days to flowering, number of branches per plant, number of pods per plant, pod length, pod weight, crude fibre content of the pods and green pod yield per plant. At the same time, moderate heritability was recorded for plant height. The crude protein content expressed high heritability with low genetic advance which indicated the preponderance of dominant gene action for the trait. For this reason selection in early segregating generation for plant height, number of branches, number of pods, pod length, pod weight and green pod yield is recommended, because of their additive genetic property.

Santos *et al.* (2012) reported transgressive segregation for seed protein content in the F_2 population of cowpea cross IT97K-1042-3 × Canapu, with individual plants displaying up to 34.1 per cent protein content. Generation mean and variance analyses revealed additive gene effects for seed protein content. They suggested that

the seed protein content in cowpea can be improved via standard breeding methods such as by pedigree selection or single pod descent. Narrow sense heritabilities were moderate (47.7%) in the cross IT97K-1042-3 × BRS Tapaihum and high (87.6%) in the cross IT97K-1042-3 × Canapu.

Hazra *et al.* (2007) reported that additive genetic variance was predominant for pod length and weight, and protein content in pods and seeds.

High heritability estimates for seed protein content were also reported by Emebiri (1991) and Nielsen et al. (1993). According to a review performed by Fery and Singh (1997) the broad-sense heritability average for seed protein in cowpea is around 80%.

According to Aliyu and Makinde (2016), when 21 cowpea breeding lines were evaluated, heritability (broad sense) estimates for yield components indicated that seed size recorded highest heritability value (91.0%), while the least heritability (75.0%) was recorded for seeds per pod.

Heritability was reported to be highest for seed yield per plant (95.15) followed by hundred seed weight (94.85), number of pods per plant (94.23), number of seeds per pod (92.10), number of clusters per plant (90.00), plant height (89.61), number of primary branches per plant (89.38) and harvest index (84.15%) in F_2 generation of cowpea studied by Sabale *et al.* (2018). They recorded low heritability for days to first flowering (30.13) and days to maturity (40.80). They reported genetic advance was the highest for seed yield per plant (16.86) followed by number of pods per plant (12.62) and plant height (11.45) and the lowest was for number of pods per cluster (0.33).

Field studies were conducted to evaluate the segregation of the F_3 and F_6 families for seed weight, pod length and days to flowering among cowpea inter-sub specific crosses. A wide range of segregants were observed and families were highly significantly different in the characters studied. Broad sense heritability estimates ranged from 47.8 to 91.1 per cent. Estimates of genetic advance ranged from high to

low and were consistent in both generations for the traits. The F_3 and F_6 generations were not significantly different in all the three agronomic traits (Ubi *et al.*, 2001).

Maximum heritability and maximum genetic gain was found for test weight followed by plant height, primary branches per plant, seed yield per plant and harvest index in a study conducted in 30 genotypes of cowpea (Sharma *et al.*, 2017).

High heritability and genetic gain were observed for plant height, number of branches per plant, pod length and seed yield per plant in F_4 generation of 12 cowpea crosses (Kalaiyarasi and Palanisamy, 2000).

In variability studies in selected varieties of cowpea in IITA, Omoigui *et al.* (2006), observed that broad-sense heritability estimate (H^2) was 98.9 per cent for 100-seed weight, 94 per cent for duration of reproductive phase, 84.5per cent for days to first flower, 83.9 per cent for days to maturity, and 77.3 per cent for harvest index.

In study conducted by Nair *et al.*, (2018) in 25 F_2 interspecific crosses, heritability estimates was highest for green pod yield per plant (98.42%) followed by dry pod yield per plant (97.71%), harvest index (97.31%), pod length (97.18%), seed yield per plant (97.10%), number of pods per plant (96.38%), number of clusters per plant (96.21%)and plant height (94.62%).

Thorat and Gadewar (2013) conducted a study in 30 genotypes of cowpea and observed that heritability was higher for plant height (99.95%), days to 50 per cent flowering (99.73%) followed by days to maturity (99.34%), number of branches per plant (98.78%), number of pods per plant (97.70%), 100 seed weight (96.71) and number of clusters per plant (96.69%). Therefore selection for these characters will be effective. High heritability coupled with high genetic advance was observed for plant height (99.95% and 91.62%), number of pods per plant (97.70% and 64.82%) and number of branches per plant (98.78% and 73.45%).

Studies on genetic variability, heritability and genetic advance carried out with five genotypes of cowpea indicated that high heritability and genetic advance as per

cent of mean were shown by clusters per plant, pods per plant, peduncle length, pod length, dry pod weight, hundred seed weight, seed per pod, number of seeds per plant and seed yield per plant indicating that these traits were controlled by additive genetic effects and could be dependable for grain improvement in cowpea (Nwosu *et al.*, 2013).

High heritability coupled with high genetic advance was observed for several characters including yield per plant, pods per plant, pod length, pod weight, root: shoot ratio and vine length when study was conducted in 66 cowpea genotypes (Manju, 2006).

Sarath and Reshma (2017) reported high magnitude of the phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance for plant height, grain yield per plant and length of the pods in their study in twenty two cowpea genotypes. Seeds per pod and protein content exhibited low PCV and GCV, but high heritability and low genetic gain.

2.3. Selection criteria for grain yield

Yield is a complex trait determined by many component characters and found to have low heritability. In crop improvement programmes, breeders chose to have simultaneous selection for many contributing characters in addition to the major character like yield that is more likely to be influenced by environment. Selection along with yield and its associated components can improve the efficiency of selection in plant breeding programs (Romanus *et al.*, 2008).

According to Millawithanachchi *et al.* (2015) pedigree, single seed descent and modified bulk breeding methods were similar in performance and can equally be used for cowpea variety development. Based on the phenotypic correlations, inter-generation correlations and narrow sense heritability, they suggested that the number of pods per plant and the hundred seed weight can be used as indirect selection criteria for high seed yield in the F_4, F_5 and F_6 generations of cowpea.

In a study conducted by Arunachalam *et al.* (2002) in cowpea segregants, it was found that pedigree selection exhibited more shift in positive direction for yield from F_3 to F_4 compared to bulk and SSD methods.

Four selection procedures *viz.*, single plant selection (SPS), single plant bulk (SPB), bulk single plant (BSP) and selected bulk (SB) were used based on F_3 yield evaluation. Lines arising from these procedures in six crosses were compared in F_8 for yield performance. The differences among the four selection procedures with respect to grain yield were not significant. However, the most high-yielding lines were from the SPS procedure. The mean yields of F_3 lines and bulks and the yields of F_5 and F_8 derived lines were significantly correlated, $r = 0.64^{**}$ and $r = 0.70^{**}$, respectively, indicating the effectiveness of early-generation selection for yield in cowpea (Ntare and Aken'Ova, 1985).

The selection index involving six characters viz. number of fruiting nodes/main stem, number of seeds/pod, number of re-productive branches/plant, 1000-seeds weight, number of pods/plant, seed yield/plant exhibited the highest expected genetic advance (2.03 g/plant) and the maximum relative efficiency (281.94%) in selection in guar genotypes (Ibrahim *et al.*, 2012).

Singh and Mehndiratta (1970) reported that selection based on discriminant function of seeds/pod and 100-grain weight was 24.5 per cent more efficient than direct selection for grain yield in cowpea. Similarly discriminant function of three components such as number of pods/plant, number of grains/pod and 100-grain weight resulted in 33.3 per cent more efficiency than direct selection.

Khanpara (2015) conducted a study in six diverse genotypes of vegetable cowpea and evaluated them for 12 traits and worked to find the best selection index for green pod yield. Selection index involving the green pod yield per plant along with its three components *viz.*, number of pods per plant, pod length and ten pod weight were utilized. This resulted in higher expected genetic gain of 134.90g and a relative efficiency of 135.08 per cent as compared to the straight selection for green pod yield per plant alone. The relative efficiencies of different selection indices

constructed in combinations of two or more characters were ranged from 3.99 to 136.46%, while genetic advance ranged from 3.99 to 136.28g. They reported an increase in genetic gain and relative efficiency with inclusion of an additional trait in the character combination.

Nair *et al.* (2017) suggested selection criteria for yield improvement in cowpea based on simultaneous selection for number of clusters per plant, pod length and green pod yield for vegetable purpose and number of clusters per plant, pod length, seeds per pod and hundred seed weight for seed yield.

A study was conducted by Kasno *et al.* (1999) in 20 cowpea genotypes consisting of 95 F_6 line and 25 parents, local varieties and introduced varieties to study effect of direct selection and multiple trait selection for yield in cowpea. They observed that multiple traits selection using Smith index with a value of 1 to the economic importance for yield, seed size, and pod number, and 0, 0 for days to flowering, days to maturing and plant height was employed. Smith index was superior to single trait selection in expected gain. Selection, index performed from three or more traits provide greater genetic gain than direct selection.

Wilson (2004) suggested that the independent manipulation of yield and protein content, and improvement could be achieved through the selection of individual lines that present either intermediate grain yield and protein content values or mean values above that of the experimental means.

de Souza (2007) suggested that the number of pods per plant can be considered in the indirect selection for higher yield in segregating cowpea populations.

Umaharan *et al.* (1997) evaluated F_2 and backcrosses of a cross between two vegetable cowpea and reported that pod weight had high broad (84%) and narrow sense heritability (75%) and can be effectively selected for in the early generations. They suggested that vegetable cowpea improvement programs should focus on selecting for clusters per plant and average pod weight in the early generations, while selection for dry pod yield could be delayed to later generations. Also they pointed

out that pods per plant may be a useful selection criterion in multi-location trials aimed at selecting for stability of yield.

Adetiloye *et al.* (2017) evaluated the morphological characters to study diversity in 20 cowpea accessions. They suggested that for yield improvement in cowpea, number of main branches, pod numbers, pods per plant, pods per peduncle and seeds per pod should be considered as part of the selection criteria.

2.4. Correlation studies

Correlation analysis gives mutual association between two variables, which guides in determining efficient selection criteria for selecting superior genotypes. Determination of correlation between yield and yield attributes therefore contribute to crop improvement programmes for yield.

Correlation study carried out in F_2 populations of 25 inter-specific crosses and 14 parents by Nair *et al.* (2017). They used Konkan Safed, Konkan Sadabahar, Pusa Dophasali, Pusa Phalguni, PCP- 9723, ACP-109, PCP-97102, V-585, ACP-1264, PCP- 97100 as female parents from *Vigna unguiculata* ssp. *unguiculata* and Konkan wali, Arka garima, UBA-1 and DPL-YB-5 as male parents from *Vigna unguiculata* ssp. *sesquipedalis*. The study revealed that the seed yield per plant exhibited a positive significant correlation with number of pods per cluster, number of pods per plant and dry pod yield per plant.

According to Kar *et al.* (2000) the protein content of pod and seeds did not show any significant correlation with pod yield, implying that selection for protein content should not be detrimental to yield. Hybridisation followed by pedigree method of selection at a later generation simultaneously for protein content as well as yield is advocated for developing desirable plant types.

Association studies in 30 genotypes of cultivated *Vigna unguiculata* revealed that grain yield was positively and significantly correlated with 100 seed weight, number of pods per plant, number of branches per plant, number of nodes per plant,

plant height, plant width, pod length, pod width, seed length, seed width and number of seeds per pod (Kouam *et al.*, 2018).

Significant positive correlation was observed between grain yield and number of pod per plant (r=0.572), hundred seed weight (r=0.504), pod length (r=0.523), number of secondary branches per plant (r=0.450), number of seed per pod (r=0.431), number of primary branches per plant (r=0.339) plant height (r=0.285) in study conducted in eighty cowpea genotypes (Kwon-Ndung and Kwala, 2017).

Santos and Boiteux (2013) reported non-significant phenotypic correlation between seed yield and protein content (-0.19) in cowpea when they evaluated 87 F6 lines derived from 6 crosses under rain-fed conditions in Petrolina, Brazil. Simple correlation coefficient values showed that selection for high protein will not affect grain yield.

According to Saharan *et al.* (2017) when correlation studies are carried out using 60 diverse cowpea genotypes, seed yield/ plant was positively and significantly correlated at both genotypic as well as phenotypic level with number of flowers/plant, number of pods/plant, number of primary branches/ plant, pod length, number of seeds/pod, test weight, biological yield /plant and harvest index. Conversely, days to 50 per cent flowering and days to first pod picking exhibited a significant negative correlation with green pod yield/ plants

Correlation coefficients from 15 cultivars of cowpea grown in three locations proved that grain yield was negatively correlated to protein content(r=-0.87)(Oluwatosin,1997).

Association analysis carried out in 32 cowpea genotypes for green pod yield per plant and other eleven quantitative characters indicated that green pod yield per plant was positively correlated with pod length (r_g=0.456), (r_p=0.312) and sugar content (r_g=0.269), (r_p =0.217) at both genotypic and phenotypic level(Patel *et al.*, 2016).

Adetiloye *et al.*(2017) evaluated 20 cowpea accessions collected from some parts of Nigeria and character association studies was conducted. The results gave

significant positive genotypic correlations and phenotypic correlation between grain yield and number of main branches(r=0.31, 0.21), number of pods per peduncle (r=0.64, 0.72), the number of pods per plant (r=0.58, 0.57), pod length (r=0.48, 0.52), and number of seeds per pod (r=0.55, 0.72).

Correlation study in 60 genotypes of cowpea indicated that seed yield per plant exhibited significant positive correlation with biological yield (0.739), number of pods per plant (0.453), number of flowers per plant (0.429), test weight (0.421), number of pods per cluster (0.373), pod length (0.351), number of seeds per pod (0.343), number of clusters per plant (0.318), harvest index (0.307) and plant height (0.252), at genotypic level (Sharma *et al.*, 2016).

2.5. Path coefficient analysis

Understanding the nature and extent of association between yield and yield related traits is essential for designing selection criteria for yield improvement, for yield is a complex character which is highly influenced by environment. Path coefficient analysis is a technique useful in determining the direct influence of one variable on another and also separates the correlation coefficient into its components of direct and indirect effects. Path coefficient from any cause to the effect is defined as standardised partial regression coefficient of the effect on that cause.

According to Lenka and Misra (1973) path coefficients are classified into various classes as follows- (0.00 - 0.09) negligible, (0.10 - 0.19) low (0.20 - 0.29) moderate, and (0.30 - 0.99) high and more than 1.00 as very high.

In a study of F3 generation of cowpea cross C-152 × V-57817, path coefficient analysis revealed that seed yield was markedly influenced by number pods per plant, number seeds per pod and 100 seed weight owing to the maximum direct effect on seed yield per plant (Dinesh *et al.*, 2017). Under these circumstances, they recommended that traits like plant height, number pods per plant, number seeds per pod and 100 seed weight could be used as selection criteria for grain yield improvement in segregating generations of cowpea.

Path analysis in F4 population of six cross combinations of cowpea was conducted by Kalaiyarasi and Palanisamy (2000) and reported that number of seeds per pod, number of pods per plant and crude protein content had high positive direct effects on seed yield. On the contrary, negative direct effects on seed yield was given by pod length, hundred seed weight, number of branches per plant and crude fibre content. Pod length and hundred seed weight had positive indirect effects on seed yield through number of pods per plant, number of seeds per pod and crude protein content. They suggested the use of the traits such as number of pods per plant, number of seeds per pod, crude protein content and crude fibre content for formulating selection indices in yield improvement programmes in cowpea.

Bhardu and Navale (2011) conducted path analysis in F3 population of cowpea cross Dapoli safed x GC-10 and their parents. The results revealed that grain yield per plant recorded significant and positive correlation with number of pods per plant, biomass at harvest, number of branches per plant, test weight, pod length, and vine length. Number of pods per plant (0.5817) recorded highest magnitude of direct effects on seed yield per plant followed by test weight (0.4464), biomass at harvest(0.2956) and number of branches per plant(0.13).

Path analysis carried out in F2 population of cross IT-38956-1 and KBC-2 indicated that pod length(1.1206) recorded highest magnitude of direct effects on seed yield per plant followed by secondary branches per plant(0.4912) and plant height(0.4081) (Lokesh and Murthy, 2018). They also reported negative direct effect of 100 seed weight, number of primary branches per plant, days to maturity and days to first flowering on grain yield.

Path coefficient studied in 40 promising lines and varieties of cowpea indicated that the yield components such as number of pods/plant, number of grains/pod and 100-grain weight have a large direct effect on grain yield. Multiple regression analysis suggested the three components together account for about 68per cent of yield variation (Singh and Mehndiratta, 1970)

Study on 24 cowpea genotypes indicated that the highest (0.550) and the lowest (0.003) positive direct effects on seed yield were observed for seed weight per pod and plant height, respectively. Days to 50 per cent flowering recorded a negative (-0.129) direct effect on seed yield per plant (Tyagi *et al.*, 2000).

Path coefficient analysis in 32 diverse cowpea genotypes indicated the highest positive direct effect on green pod yield per plant was given by pod length (0.716) followed by days to 50 per cent flowering (0.645), shelling per cent (0.398), number of pods per plant (0.289), sugar content (0.219) and plant height at final harvest (0.204) (Patel *et al.*, 2016).

Path coefficient study in 60 genotypes showed that the highest positive direct effect on seed yield per plant was exhibited by biological yield (0.995) followed by harvest index (0.672), number of pods per plant (0.665).On the other hand, number of flowers per plant (-0.129), days to maturity (- 0.093), pod length (-0.028), seed protein content (-0.018) contributed negative direct effect on seed yield (Sharma *et al.*,2016).

Sarvamangala *et al.* (2012) evaluated twenty cowpea genotypes and reported that clusters per plant, pod length and test weight had a positive direct effect on seed yield and days to maturity had negative direct effect on seed yield.

3. MATERIALS AND METHOD

The present investigation entitled 'Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield' was conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during January 2017 to March 2019. The main objective of the study was to select the best lines from F_4 and F_5 generations showing high yield and protein content and develop stable F_6 populations with high grain yield and protein content. The study was conducted in three experiments.

1) Evaluation of F_4 generation
2) Evaluation of F_5 generation
3) Evaluation of F_6 generation

3.1. Experimental site

The experimental site was at experimental field of Department of Plant Breeding and Genetics, College of Horticulture, situated at the latitude of 10° 32' 52.05" N and longitude of 76° 16' 45.55"E, at the elevation of about 40 m above mean sea level.

3.2. Experimental material

Twenty four cowpea hybrids were developed in the Department of Plant Breeding and Genetics as a part of post graduate research programme in the year 2014 to combine grain yield and protein content. From these hybrids, two hybrids namely H 10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) were identified as superior with respect to yield and protein content and details are given in table 3.1. (Sarath, 2015). In another study conducted in the department evaluated F_2 and F_3 generations of these two crosses for yield and protein content. From the F_3 generation of these two crosses, 23 lines were selected based on number of pods, total grain yield and protein content. They were eight lines from the H 10 (Anaswara

x PKB 3) population and fifteen lines from the H 11 (Anaswara x PKB 4) populations (Sunil, 2017). These selected plants were evaluated in the present study in F_4, F_5 and F_6 generations. The features of the selected plants in, F_2 and F_3 generations are presented in the tables 3.2, and 3.3, 3.4, and 3.5.

Table 3.1. Features of the selected F_1 families

Characters	H 10	H 11
Plant height (cm)	65.20	66.28
Number of branches per plant	8.20	7.92
Days to first flowering	40.35	42.20
Days to first harvest	44.29	52.38
Days to last harvest	105.34	102.39
Number of pods per plant	67.16	65.31
Pod length (cm)	31.28	29.12
Single pod weight (g)	3.64	3.52
Number of seeds per pod	19.57	20.05
Hundred seed weight (g)	23.57	21.20
Grain yield per plant (g)	155.55	146.20
Protein content (%)	30.03	30.06

Table 3.2. Features of individual plants selected and advanced to F_3 generation of cross H 10 (Anaswara x PKB 3)

Plant no.	Height (cm)	Branches/ Plant	Days to first flowering	Days to first harvest	Days to last harvest	Pods/ plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
H10. 1	352.70	6.00	54.00	73.00	109.00	51.00	28.10	3.51	19.60	21.85	168.88	29.30
H10.15	320.90	5.00	61.00	82.00	114.00	45.00	31.40	3.40	22.10	22.72	179.70	28.70
H10.28	309.60	6.00	62.00	79.00	109.00	48.00	28.60	3.37	19.30	22.87	172.61	28.90
H10.41	270.20	6.00	60.00	75.00	120.00	46.00	29.50	3.40	20.70	21.63	165.45	29.30
H10.43	374.70	5.00	58.00	74.00	132.00	47.00	28.40	3.52	19.10	20.75	172.16	28.90
H10.47	342.80	5.00	55.00	72.00	126.00	46.00	28.70	3.50	21.30	21.66	187.29	28.50
H10.69	390.70	7.00	57.00	73.00	117.00	48.00	28.10	3.47	19.60	21.92	173.94	28.70
H10.71	346.50	5.00	63.00	80.00	123.00	48.00	29.60	3.38	20.70	20.55	177.50	29.80

Table 3.3. Features of individual plants selected and advanced to F_3 generation of cross H 11 (Anaswara x PKB 4)

Plant no.	Height (cm)	Branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	Pods/ plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
H11.2	312.10	6.00	56.00	70.00	120.00	52.00	27.40	4.43	19.30	20.05	146.20	29.20
H11.3	395.60	5.00	59.00	74.00	117.00	50.00	28.30	4.21	20.10	22.43	154.73	30.10
H11.11	308.10	6.00	65.00	81.00	121.00	48.00	27.40	3.41	20.30	21.64	153.09	29.40
H11.16	369.80	6.00	58.00	74.00	114.00	54.00	27.40	4.96	20.70	21.73	154.11	28.70
H11.19	358.30	7.00	62.00	80.00	119.00	52.00	29.60	4.08	21.40	21.37	154.78	28.40
H11.34	296.50	5.00	56.00	75.00	117.00	47.00	30.10	3.55	23.20	21.05	152.63	29.10

H11.36	306.70	6.00	54.00	69.00	115.00	49.00	28.60	4.27	22.10	21.23	147.50	29.60
H11.37	301.20	6.00	64.00	79.00	123.00	48.00	28.60	3.61	20.70	20.71	149.62	29.30
H11.39	333.60	7.00	56.00	72.00	120.00	50.00	27.20	3.61	18.50	21.50	156.02	28.70
H11.48	357.90	6.00	60.00	74.00	121.00	53.00	29.40	4.51	20.80	20.84	147.70	29.80
H11.49	377.20	6.00	58.00	75.00	117.00	52.00	25.80	5.02	18.60	22.63	150.31	28.50
H11.50	342.40	6.00	57.00	74.00	118.00	52.00	30.30	3.6	22.40	21.52	152.18	28.50
H11.57	321.50	6.00	60.00	78.00	117.00	50.00	28.10	4.63	21.30	21.79	148.43	28.60
H11.67	368.30	6.00	59.00	76.00	120.00	49.00	27.50	3.58	20.40	22.80	157.61	28.90
H11.105	329.50	4.00	58.00	71.00	121.00	48.00	28.70	4.37	20.50	22.30	148.50	28.10

Table 3.4. Features of individual plants advanced to F_4 generation of cross H10 (Anaswara x PKB 3)

Plant no.	Height (cm)	Branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	Pods/ plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
H 10 1.4	238.10	5.00	52.00	76.00	124.00	39.00	25.30	3.32	17.50	23.51	160.78	25.50
H 10 28.11	351.60	5.00	57.00	81.00	130.00	39.00	20.40	3.63	16.40	19.83	169.16	26.10
H 10 69.1	364.10	5.00	68.00	97.00	143.00	43.00	25.80	4.23	16.40	21.53	160.36	25.10
H 10 69.4	328.30	5.00	63.00	91.00	139.00	45.00	27.00	4.91	16.20	25.15	161.43	26.40
H 10 69.5	272.10	4.00	56.00	79.00	135.00	46.00	25.90	4.25	15.60	23.41	167.17	25.20
H 10 69.7	359.80	5.00	76.00	102.00	134.00	42.00	20.60	3.17	14.50	21.14	165.84	26.60
H 10 69.9	257.50	5.00	56.00	76.00	147.00	42.00	25.80	4.42	16.60	25.75	162.51	25.90
H 10 69.20	415.80	6.00	63.00	91.00	144.00	37.00	25.70	4.19	17.90	21.35	160.62	25.70

Table 3.5. Features of individual plants advanced to F_4 generation of cross H11 (Anaswara x PKB 4)

Plant no.	Height (cm)	Branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	Pods/ plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
H 11 2.20	273.40	5.00	71.00	96.00	143.00	39.00	20.60	3.66	12.70	23.36	162.42	25.90
H 11 3.9	379.20	5.00	52.00	73.00	144.00	46.00	22.70	3.58	12.40	22.83	167.01	25.70
H 11 11.12	327.80	4.00	64.00	84.00	144.00	43.00	26.50	3.74	15.00	20.10	163.21	26.70
H 11 19.19	428.60	5.00	66.00	91.00	142.00	45.00	27.80	4.54	16.80	20.79	165.14	27.20
H 11 34.7	348.50	5.00	70.00	94.00	147.00	36.00	20.30	4.83	14.40	22.73	168.52	27.90
H 11 34.16	312.70	4.00	68.00	90.00	145.00	40.00	26.50	4.52	16.90	21.47	165.62	25.00
H 11 36.1	419.50	6.00	62.00	90.00	144.00	45.00	21.50	3.93	12.80	16.25	163.58	25.30
H 11 49.7	394.30	6.00	57.00	83.00	144.00	43.00	24.30	3.95	15.60	20.55	163.41	26.40
H 11 50.13	381.60	5.00	57.00	76.00	145.00	42.00	25.70	3.89	16.20	24.43	162.34	25.30

3.3. Experimental design

3.3.1. Experiment I: Evaluation of F_4 generation

The experimental material consisted of parent Anaswara and 23 lines from F_4 population of cross H 10 (Anaswara x PKB 3) and cross H 11 (Anaswara x PKB 4). This included 11 lines from cross H10 and 12 lines from cross H11. Twenty seeds of each F_4 lines, along with parent Anaswara were sown in the experimental field of Plant Breeding and Genetics on 25-10-2017(early rabi season). The plot size was 240 m^2. The row-to-row distance was 50 cm and the plant-to-plant distance was 50 cm. Observations were taken on each plants of the population. All field and intercultural operations like main field preparation, manuring, irrigation, weeding and plant protection were followed according to the recommended package of practices of KAU (2011). The pedigree of the experimental material is as in figure 3.1.

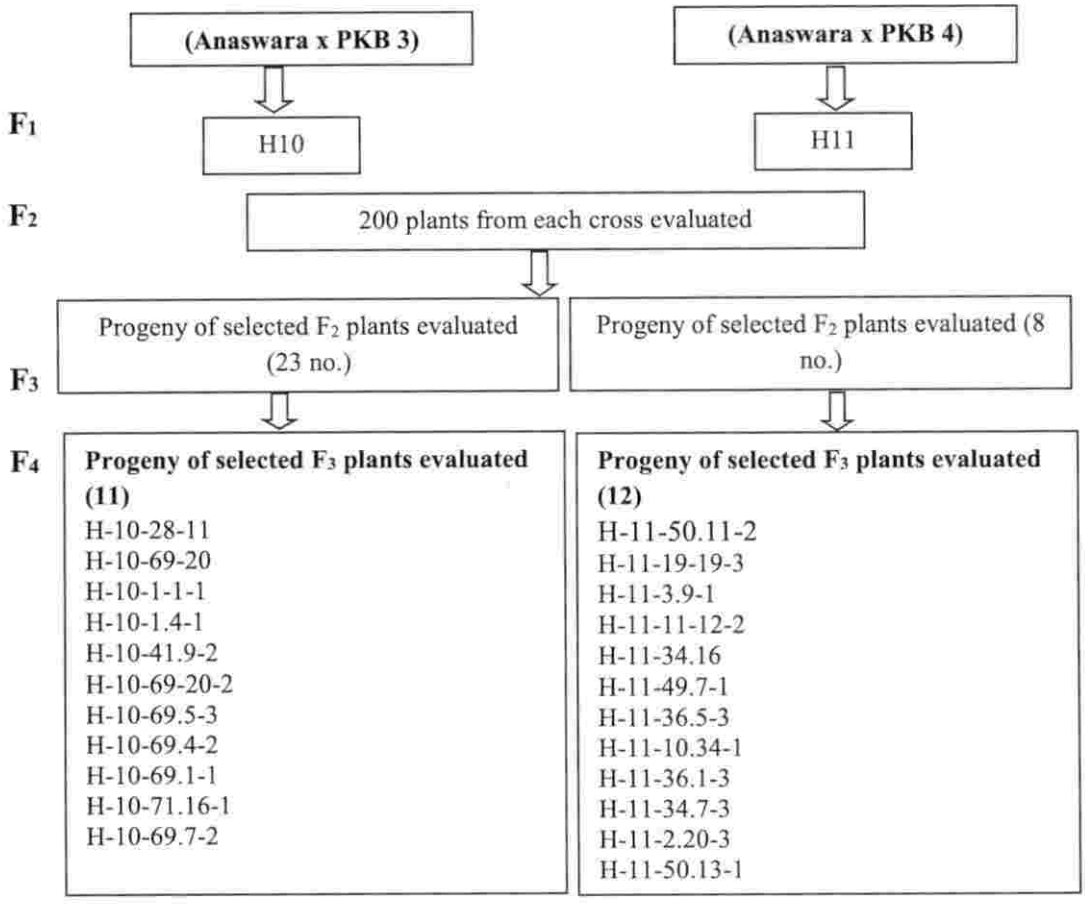

Fig. 3.1 Pedigree of the experimental material

Three days after germination

Thirty days after sowing

Plate 1. Field view of Experiment 1

3. 3. 2. Observations recorded

The observations were recorded for all four hundred and sixty plants and twenty plants of parents. Observations were recorded as below:

3. 3. 2. 1. Plant height (cm)

The height of individual plant was measured in centimetre (cm) from base of the plant to the tip of main stem at maturity.

3. 3. 2. 2. Number of branches per plant

The total number of branches for each individual plant was counted at plant maturity and recorded.

3. 3. 2. 3. Days to first flowering

The number of days taken from sowing to the day on which first flower anthesis occurred was noted for each plant.

3. 3. 2. 4. Days to first harvest

The number of days taken from sowing to the first harvest of the pods was recorded for each individual plant.

3. 3. 2. 5. Days to last harvest

The number of days taken from sowing to the last harvest of the pods was recorded for each individual plant.

3. 3. 2. 6. Number of pods per plant

For an each individual plant, the total number of pods harvested was counted and recorded.

3. 3. 2. 7. Pod length (cm)

At the time of harvest, length of randomly selected ten pods of each plant was taken and the mean value was calculated. It is expressed in centimetre (cm).

3. 3. 2. 8. Number of seeds per pod

The mean value of number of seeds of randomly selected ten pods in each plant was taken and expressed as number of seeds per pod.

3. 3. 2. 9. Dry pod weight (g)

Single pod weight of each plant was obtained by taking average of ten randomly selected pods at the time of harvest in each plant and expressed in grams.

3. 3. 2. 10. Hundred seed weight (g)

The weight of 100 randomly selected seeds from each plant was recorded in grams.

3. 3. 2. 11. Grain yield per plant (g)

The total seed yield of each plant was recorded in grams.

3. 3. 2. 12. Protein content (%)

The protein content of seeds for each individual plant is estimated by Lowry's method (Sadasivam and Manickam, 2008). A detailed procedure is given below.

Reagents needed for protein analysis

Reagent A: 2 % Na_2Co_3 in 0.1 M NaOH

Reagent B: 0.5 % $CuSo_4$ in 1 % Na-K tartarate

Reagent C: 50 ml of reagent A + 1 ml of reagent B (It was freshly prepared)

Folin Ciocalteu reagent (FC reagent)

Protein standard: Bovine serum albumin (100 mg/ 100 ml)

Working standard: 20 ml of protein standard in 100 ml distilled water

Procedure

Cowpea seeds (500g) were powdered using pestle and mortar and 10 ml of distilled water was added to the powdered sample. It was centrifuged at 5000rpm for 10 minutes. From this 0.2 ml of supernatant was taken and made up to 1 ml. A blank was also prepared using 1 ml of distilled water. To this solution 5 ml of FC reagent was added and kept it for 10 minutes. Then added 0.5 ml Reagent C to this and kept for 30 minutes under dark incubation. Blue colour was developed and its optical density was read using spectrophotometer at 660 nm.

Calculation

Different standards were made from the working standard (Bovine serum albumin 0.2 mg/ml) of concentrations 0.04, 0.08, 0.12, 0.16, 0.2 mg/ml and optical density was read in spectrophotometer. A standard curve was plotted using the absorbance value of protein standards against concentration, respectively. From the standard curve, protein content for 100 g of the sample was calculated using following formula.

$$\frac{\text{OD of test sample}}{\text{OD of standard}} \text{ x Concentration of the standard} = \text{X mg/ml}$$

The protein content of the samples was estimated in mg ml^{-1} and it was then expressed as percentage on dry weight basis (g/ g of cowpea grain powdered).

3.3.3. Selection criteria for genotypes

From the F_4 generation of the two crosses (H 10 and H 11), totally twenty five lines were selected based on number of pods, total grain yield, seeds per pod and protein content. This included 13 lines from the cross H 10 (Anaswara x PKB 3) population and 10 lines from the H 11 (Anaswara x PKB 4) population. The criteria was the combination of five factors *i.e.* number of pods/ plant, total grain yield/ plant, seeds per pod, hundred seed weight and seed protein content. The criteria was developed such that it was superior to the parent Anaswara. Individual plants having

minimum of the set value for these four factors are selected and forwarded to the next generation.

No. of pods/ plant: > 34

No. of seeds per pod :>15

Hundred seed weight : >14.5g

Grain yield / plant: > 100 g / plant

Protein content :> 20%

3. 3. 4. Statistical analysis

Data was analysed for mean, variance, heritability and correlation using SPSS statistical package.

3. 3. 4. 1. Estimation of mean and variance of the F_4 population from cross H10 and H11

The mean, variance and range were estimated using the formula given by Singh and Choudhary (1997).

Mean

$$\bar{y} = \frac{1}{n} \sum_{i=1}^{n} (y_i)$$

Variance

$$\text{Variance} = \frac{1}{n-1} \left(\sum_{i=1}^{n} (y_i - \bar{y})^2 \right)$$

Where,

y_i= individual value

y = population mean

Range

Difference between the maximum and minimum values for each character is calculated.

3. 3. 4. 2. Estimation of family mean and variance

The mean and variance value for each of the 12 characters studied are calculated from each F_4 families separately.

3. 3. 4. 3. Estimation of genetic parameters

Based on mean and variance, the genotypic variance, phenotypic variance and coefficient of variances were estimated as suggested by Kurer (2007).

Phenotypic variance

For calculating the phenotypic variance, the individual observations made for each trait on F_4, F_5 and F_6 populations are used.

Phenotypic variance (σ_p^2) = Var. F_4

Where,

Var. F_4 = Variance in F_4 population

Environmental variance

The environmental variance is derived from the average of parent

Environmental variance (σ_e^2) = Var. P = Variance in parent

Where,

Var. P = Variance in parent

Genotypic variance

Genotypic variance (σ_g^2) = $\sigma_p^2 - \sigma_e^2$

Where,

σ_p^2= Phenotypic variance

σ_e^2 = Environmental variance

Genotypic and phenotypic coefficient of variation

According to the formula given by Burton and Devane (1953), the genotypic and phenotypic coefficient of variances were estimated.

Phenotypic coefficient of variance (PCV) = $\frac{\sqrt{\sigma p^2}}{\bar{x}} \; x \; 100$

Where,

σ_p^2= Phenotypic variance

$\bar{x}$= Grand mean

Genotypic coefficient of variance (GCV) = $\frac{\sqrt{\sigma g^2}}{\bar{x}}$ x 100

Where,

σ_g^2= Genotypic variance

$\bar{x}$= Grand mean

Heritability

The ratio of genotypic variance to phenotypic variance is given as heritability in broad sense. It is expressed in percentage (Hanson *et al.,* 1956)

Heritability (H^2) = $\frac{\sigma g^2}{\sigma P^2}$ x 100

Where,

σ_g^2 = Genotypic variance

σ_p^2= Phenotypic variance

Robinson *et al.* (1951) classified heritability as follows

0 – 30 %: Low

31 – 60 %: Medium

>61 %: High

Genetic advance

Robinson *et al.* gave the formula for genetic advance in 1949 as follows.

Genetic advance (GA) = I $\sigma_p H^2$

Where,

I = Intensity of selection at 5 % (1 – 2.06)

σ_P = Phenotypic standard deviation

H^2 = Heritability in broad sense

The value of 'I' was taken as 2.06 assuming 5 per cent are selected.

Genetic advance expressed as percentage over mean (GAM)

GAM = $\frac{GA}{\bar{x}}$ x 100

Where,

GA = genetic advance

$\bar{x}$= general mean of the character

Johnson *et al.* in 1955, classified GAM as follows

0 – 10 % : Low

11 – 20 % : Medium

>20 % : High

3. 3. 5. Correlation analysis

A simple correlation analysis were done by using the formula given by Weber and Moorthy (1952) as follows

Phenotypic correlation (vp_{12}) = $\frac{COV.P_{12}}{\sqrt{Var.P_1} \times \sqrt{Var.P_2}}$

Where,

Cov. P_{12} = Phenotypic covariance of character x_1 and x_2

Var. P_1 = Phenotypic covariance of character x_1

Var. P_2 = Phenotypic covariance of character x_2

3. 3. 6. Path coefficient analysis

To estimate the direct and indirect effects of the yield components of seed yield path coefficient analysis was done using the simple correlation coefficient. This was developed by wright (1921) and used by Dewey and Lu (1959). The path coefficient is the standard partial regression coefficient, which is estimated by setting up simultaneous equation and solving by elimination method or metric inversion method.

$Po_1 + Po_2\, r_{12} + \text{----------} + Pop\, r_1p = ro_1$

$Po_1 + r_{12} + Po_2 + \text{----------} + Pop\, r_2p = ro_2$

$Po_1 + r_1p + Po_2\, r_2p + \text{---------} + Pop = rop$

Where,

Po_1, Po_2, ---------- Pop = Direct path coefficients of variable 1, 2 ..... P on the dependant variables.

r_{12}, r_{13} ---------- r $_1$p -------- rp (p-1) = possible correlation coefficients between various independent variables.

ro1, ro2 ---------- rop = the correlations between dependent variable and independent variables.

The direct effect of i^{th} variable via i^{th} variable was estimated as (Poj x r^{ij}). It is clear that the correlation coefficient is the sum of direct and indirect effect on dependent variable, from the simultaneous equation. Residual effect of P^2 ox was calculated as under:

P_2 ox = 1 (P^2 01 + 2 Po_2 r_{12} + 2 Po_1 Po_3 r_{13} ---------- 2 Po_2 Po_3 r_{23} + -------- P^2 oP).

3. 4. Experiment 2: Evaluation of F_5 generation

The experimental material consisted of parent Anaswara and 23 lines selected from F_4 population of cross H 10 (Anaswara x PKB 3) and cross H 11 (Anaswara x PKB 4). It included 13 lines from cross H10 and 10 lines from the cross H11. Twenty seeds of each of these F_5 lines, along with parent Anaswara were sown in the experimental field of Plant Breeding and Genetics on 23-07-2018 (kharif season). The plot size was 240 m^2. The row-to-row distance was 50 cm and the plant-to-plant distance was 50 cm. All field and intercultural operations like main field preparation, manuring, irrigation, weeding and plant protection were followed according to the recommended package of practices of KAU (2011).

3.4.1. Observations recorded

Same as experiment 1

3.4.2. Statistical analysis

Mean and variance of the F_5 population from cross H10 and H11 were estimated. Family mean and variance were calculated for each of the 12 characters. Further genetic parameters such as PCV, GCV, heritability, genetic advance, GAM were estimated. Correlation studies and path analysis were also carried out in the experiment from segregating generations of both crosses separately.

3.4.3. Selection criteria for genotypes

From the F_5 generation of two crosses (H 10 and H 11), totally twenty two individual plants were selected based on number of pods, number of seeds per pod, pod length, hundred seed weight, total grain yield, and protein content. This included five lines from the H 10 (Anaswara x PKB 3) population and 17 lines from the H 11 (Anaswara x PKB 4) population. The criteria used for selection was combination of six factors as follows. The whole set of plants in F_5 generarion were grouped into two categories *viz.*, one with medium long pods and small seeds closely packed within the pod and the other type with long fleshy pods and bold seeds. Seperate

criteria were used for two types of cowpea observed in F_5 generation.. The following factors are considered for selection.

a) Family average more than that of Anaswara.

Type 1

i. No. of pods - 35
ii. No. of seeds/ pod – 16
iii. Pod length –20 cm
iv. Hundred seed weight-11.5g
v. Grain yield - 85g/plant
vi. Protein – 22%

Type 2

i. No. of pods - 30
ii. No. of seeds/ pod -15
iii. Pod length-24 cm
iv. Hundred seed weight-14g
v. Grain yield - 90g/plant
vi. Protein – 22%

Ten days after germination

Fifty days after sowing

Plate 2. Field view of Experiment 2

3.5. Experiment 3: Evaluation of F_6 generation

The experimental material consisted of parent Anaswara and 22 lines selected from F_5 population of cross H 10 (Anaswara x PKB 3) and cross H 11 (Anaswara x PKB 4). It included five lines from cross H10 and 17 lines from the cross H11. Twenty seeds of each of these F_6 lines, along with parent Anaswara were sown in the experimental field of Plant Breeding and Genetics on 03-12-2018 (late rabi season). The plot size was 195 m^2. The row-to-row distance was 50 cm and the plant-to-plant distance was 50 cm. Each family were planted in three replications in randomised block design. Observations were taken on each individual plants. All field and intercultural operations like main field preparation, manuring, irrigation, weeding and plant protection were followed according to the recommended package of practices of KAU (2011).

3.5.1. Observations recorded

Same as experiment 1 and 2. In addition to this fibre content of green pods (husk alone from pods at vegetable harvest stage) of promising plants was estimated. Also organoleptic evaluation was carried out on green cowpea pods (vegetable cowpea) from the superior plants identified in F_6 generation.

Procedure for crude fibre estimation

To estimate crude fibre, 2 g of dried and powdered sample is boiled with 200 ml 0.255 N sulphuric acid for 30 minutes, maintaining the volume throughout. Then it was filtered through muslin cloth and washed with boiling water until washings are no longer acidic. Then boiled with 200 ml of sodium hydroxide solution for 30 minutes. Filtered through muslin cloth again and washed with 25 ml of boiling 1.25 % H_2SO_4, three 50 ml portions of water and 25 ml alcohol. Then removed the residue and transferred to ashing dish. Dried the residue for 2h at 130+/- 2 ^{0}C. Cooled the dish in desiccators and weighed. It is then ignited for 30 minutes at 600 ^{0}C. Cooled in a dessicator and reweighed.

Calculation

Per cent crude fibre in ground sample= (loss of weight on ignition/ weight of sample) x 100

Organoleptic evaluation of cowpea

Sensory evaluation of the selected tender cowpea pods was done. Score card consisting attributes such as appearance, texture, colour, taste and overall acceptability were used for evaluation. Each attributes was scored using 9 point hedonic scale ranging from one to nine. Fifteen evaluators participated and scored the cowpea with three replication for each parameters. Mean score for each quality attribute over 15 evaluators for each genotypes was calculated. Kendall's coefficient of concordance was used to study the significance of perception between judges and rank the genotypes based on mean rank of different sensory attributes. The hedonic scales were then converted to rank scores and rank analysis was done by Kendall's coefficient of concordance (Siegel, 1956). The scoring chart used is given in appendix 1.

Three days after germination

Fifty days after sowing

Plate 3. Field view of Experiment 3

Appendix I

Organoleptic evaluation of cowpea

Score for various samples

Sample	**Appearance**			**Texture**			**Colour**			**Taste**			**Overall acceptability**		
1															
2															
3															
4															
5															
6															

Scoring criteria

Like extremely -9
Like very much- 8
Like moderately- 7
Like slightly -6
Neither like nor dislike -5
Dislike slightly- 4
Dislike moderately -3
Dislike very much -2
Dislike extremely -1

3.5.2. Statistical analysis

Mean and variance of the F_6 population from cross H10 and H11 were estimated. Family mean and variance were calculated for each of the 12 characters. Further genetic parameters such as PCV, GCV, heritability, genetic advance, GAM were estimated.

ANOVA for biometrical traits

To compare between the 22 F_6 families and parent Anaswara, analysis of variance was carried out using the family average for each of the 11 biometrical traits studied namely, plant height, number of branches, days to first flowering, days to first harvest, days to last harvest, number of pods per plant, single pod weight, pod length, number of seeds per pod, hundred seed weight and grain yield. Table of ANOVA is given in table 3.6.

Table 3.6. ANOVA table

Source	Degrees of freedom	Mean square
Replication	r-1	Mr
Genotype	g-1	Mg
Error	(r-1)(g-1)	Me

Where,

r – no. of replications

g – no. of genotypes

Mr – replication mean square

Mg – genotype mean square

Me – error variance

3.5.3. Selection criteria

From the F_6 generation of two crosses (H 10 and H 11), totally five individual plants were selected based on number of pods, number of seeds per pod, pod length, hundred seed weight, total grain yield, and protein content. This included one line from the H 10 (Anaswara x PKB 3) population and four lines from the H 11 (Anaswara x PKB 4) population. The criteria used for selection was combination of six factors as follows. Separate criteria were used for the two categories. The following factors were considered for selection.

a) Family average more than that of Anaswara.

Type 1

i. No. of pods : >40
ii. No. of seeds/ pod : >16
iii. Pod length :>21 cm
iv. Hundred seed weight : >14.5g
v. Grain yield : >105g/plant
vi. Protein : >20%

Type 2

i. No. of pods : >35
ii. No. of seeds/ pod : >16
iii. Pod length : >26cm
iv. Hundred seed weight : >17.5g
v. Grain yield : >110g/plant
vi. Protein : >21%

4. RESULTS

The study entitled 'Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield' was conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during January 2017 to March 2019. Twenty four cowpea hybrids were developed from which, two hybrids namely H 10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) were identified as superior with respect to yield and protein content. Pedigree selection was carried out in F_2 and F_3 generation and from the F_3 generation, 23 lines were selected based on number of pods, total grain yield and protein content. This included eight lines from the H 10 (Anaswara x PKB 3) population and fifteen lines from the H 11 (Anaswara x PKB 4) populations. These selected plants were evaluated in the present study in F_4, F_5 and F_6 generations along with the check parent Anaswara and the results are presented below.

4.1. Experiment I: Evaluation of F_4 generation

4.1.1. Estimation of means and variance

The mean, range and variance of each character for the F_4 generation of H 10 and H 11 crosses were estimated and are presented in tables 4.1 and 4.2. The salient conclusions from the estimates are given below.

4. 1. 1. 1. Plant height (cm)

The mean value for plant height in F_4 generation of cross H10 was 114.68 cm which is less than of the parent Anaswara (124.16 cm). The values ranged from 80cm to 192cm with variance of 463.43.

Similarly in F_4 generation of cross H11 mean value of plant height was 114.68 cm which is less than of the parent Anaswara. The values ranged from 80cm to 192cm with variance of 569.29.

4. 1. 1. 2. Number of branches per plant

The mean value for number of branches per plant in F_4 generation of cross H10 was 3.64 which was higher than that of the parent Anaswara (3.41). The values ranged from 3 to 6 with variance of 0.51.

Similarly in F_4 generation of cross H11 mean value of number of branches per plant was 3.62 which was higher than that of the parent Anaswara. The values ranged from 3 to 6 with variance of 0.45.

Comparing between H10 and H11 families, it showed that they perform similar in number of branches and is almost in par with parent Anaswara.

4. 1. 1. 3. Days of first flowering

The mean value for days to first flowering in F_4 generation of cross H10 was 46.74 which was greater than of the parent Anaswara (44.83). In the F_4 population of H11, days to first flowering was 46.63. Both the population do not differ with respect to the mean value for first days to flowering. Days to first flowering ranged from 41 to 54 in H10 and in H11, it ranged from 41 to 55 days. The variance for days to first flowering was higher for H10 segregants (8.02) than H11 segregants (7.68).

4. 1. 1. 4. Days to first harvest

In F_4 generation of cross H10, the days taken for first harvest ranged from 56 to 79 days. The average days taken for first harvest was 67.83 in F_4 population of cross H 10 whereas it was 67.21 in H11 cross. In H11 segregants the days to first harvest ranges between 60 and 75. Anaswara took 65.50 days for first harvest.

When both the F_4 population of cross H 10 and H 11 were considered for variability, H 10 cross showed high variability for days taken for first harvest with a value of 13.30.

4. 1. 1. 5. Days to last harvest

In F_4 generation of cross H10, the days taken to last harvest ranged from 82 to 110 days. The average value for days to last harvest was 97.18. The last harvest for Anaswara was 96 days.

In F_4 generation of cross H11, the range for days of last harvest was 79 to 106 days with an average of 96.45 days.

The high variance of 24.43 was observed in cross H 10 than H11 for days to last harvest in F_4 population.

4. 1. 1. 6. Number of pods per plant

Number of pods per plant in F_4 generation of cross H10 ranged from 29 to 45, with an average of 35.41, whereas in cross H11 it ranged from 30 to 44, with mean value was 35.10. Anaswara exhibited 36.25 number of pods per plant.

The high variance (15.76) for number of pods per plant was observed in F_4 population of cross H 10 compared to H11.

4. 1. 1. 7. Pod length (cm)

In F_4 generation of cross H10, the length of the pod ranged from 10cm to 28.30cm, with mean value of 18.44cm. In cross H11 pod length ranged from 10.50 to 26.50 cm with average value of 19.60 cm. The pod length of Anaswara was 20.55 cm.

Comparing variances between two populations, H 10 population exhibited higher variance (14.18) for pod length than H 11 (7.64) population in F_4 generation.

4. 1. 1. 8. Pod weight (g)

In F_4 generation of cross H10, the pod weight ranged from 1.10 to 4.60 g, with an average weight of 1.97g. In H 11 population, pod weight ranged from 1.08 to 3.58g with mean value of 1.89g. Pod weight of Anaswara was 2.49g.

The variability was high in H 10 cross (0.346) when compared to H 10 (0.219) cross in F4 generation.

4. 1. 1. 9. Number of seeds per pod

In F_4 population of cross H10, the number of seeds per pod ranged from 9.5 to 20 with mean value of 13.70. In cross H 11 population it ranged from 9.20 to 19.10 with average number value of 13.67. Anaswara exhibited 14.21 seeds per pod.

The cross H 10 (5.32) showed higher variance than that of H 11 (4.94) cross in F_4 population.

4. 1. 1. 10. Hundred seed weight (g)

The weight for hundred seeds in F_4 generation of cross H10 ranged from 10.30 to 24.90 g with average value of 17.60 g. In cross H 11 population, the hundred seed weight ranged from 12.10 to 23.80 g with an average of 17.97 g. Hundred seed weight of Anaswara was 17.74g.

Cross H 10 (7.78) showed the high variability than H 11 cross (4.88) for hundred seed weight in F_4 population.

4. 1. 1. 11. Grain yield per plant (g)

In cross H 10, the value for grain yield per plant ranged from 41.86 to 161.54 g in F_4 generation. The average grain yield was 86.74g. In F4 generation of cross H 11, the range for grain yield per plant was 47.05 to 169.50 g with an average grain yield of 87.59 g. Anaswara gave a yield of 91.36g per plant.

The cross H 10 (791.99) showed higher variability than that of H 11 cross (673.98) in F_4 population.

4. 1. 1. 12. Protein content (%)

The protein content in seeds ranged from 21.60 to 27.50 per cent in F_4 population of cross H10, with average of 23.90 per cent. In F_4 population of cross H 11, the protein content ranged from 20.64 per cent to 27.1 per cent, with average

protein content of 3.24 per cent. The protein content of Anaswara seed was 22.8 per cent.

The cross H 10 (2.04) showed higher variability for protein content than cross H 11 (1.78) in F_4 population.

Table 4.1. Variability parameters in F_4 generation of cross H10

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F_4 generation for quantitative characters												
P_1	124.16	3.41	44.83	65.50	96.00	36.25	20.55	2.49	14.21	17.74	91.36	22.8
F_4	114.68	3.64	46.75	67.83	97.18	35.41	18.49	1.97	13.70	17.60	86.74	23.90
Variance of parents and F_4 generation for quantitative characters in cowpea												
P_1	444.69	0.44	6.33	4.09	5.27	4.2	7.51	0.22	2.7	0.16	125.02	0.58
F_4	493.43	0.51	8.02	13.31	24.43	15.76	14.18	0.35	5.32	7.78	791.99	2.04
Range of F_4 generation for quantitative characters in cowpea												
Min	80	3	41	56	82	29	10.00	1.10	9.50	10.30	41.86	21.60
Max	192	6	54	79	110	45	28.30	4.60	20.00	24.90	161.54	27.50
Range	112	3	13	23	28	16	19.30	3.50	10.50	14.60	119.68	5.90

Table 4.2. Variability parameters in F_4 generation of cross H11

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F4 generation for quantitative characters												
P_1	124.16	3.41	44.83	65.50	96.00	36.25	20.55	2.49	14.21	17.74	91.36	22.80
F_4	116.52	3.62	46.63	67.21	96.46	35.10	19.60	1.89	13.67	17.97	87.59	23.24
Variance of parents and F_4 generation for quantitative characters in cowpea												
P_1	444.69	0.44	6.33	4.09	5.27	4.20	7.51	0.22	2.70	0.16	125.02	0.58
F_4	569.21	0.45	7.68	6.26	21.67	11.64	7.64	0.22	4.95	4.88	673.98	1.78
Range of F_4 generation for quantitative characters in cowpea												
Min	80.00	3.00	41.00	60.00	79.00	30.00	10.50	1.08	9.20	12.10	47.05	20.64
Max	190	6	55	75	106	44	26.50	3.58	19.10	23.80	169.50	27.1
Range	110	3	14	15	27	14	16	2.50	9.90	11.70	122.45	6.46

4.1.2. Estimation of average and variance of families

The mean and variances for the 12 characters within each family of both crosses are worked out to find the variability within family and is presented in the tables 4.3, 4.4, 4.5, 4.6.

4.1.2.1. Plant height

Comparing the mean value of plant height between families, H-11-10.34-1 exhibited the highest value (140.78 cm) while H-11-3.9-1 gave the lowest value of (94.15 cm). Plant height of Anaswara was 124.16 cm. The mean height of cross H 10 in F_4 generation was 114.68 cm and of cross H11 was 116.52cm.

Variance among family ranged between 120.64 (H-11-3.9-1) and 3353.80 (H-10-1-1-1). Variance of Anaswara was 444.69.

4.1.2.2. Number of branches per plant

Comparing the mean value of number of branches per plant between families, H-11-11-12-2 exhibited the highest value (4.15) while H-10-28-11-2 gave the lowest value of (3.18). Mean value for Anaswara was 3.41. The mean value of cross H 10 in F_4 generation was 3.64 and of cross H11 was 3.62.

Variance among family ranged between 0.08 (H-10-69.5-3) and 0.90 (H-11-19-19). Variance of Anaswara was 0.44.

4.1.2.3. Days to first flowering

Comparing the mean value of days to first flowering between families, H-10-69.4-2 exhibited the highest value (48.25) while H-10-69.5-3 gave the lowest value of (44.91). Mean value for Anaswara was 44.83. The mean value of cross H 10 in F_4 generation was 46.75 and of cross H11 was 46.63.

Variance among family ranged between 3.81 (H-11-36.1-3) and 10.81 (H-11-49.7-1). Variance of Anaswara was 6.33.

4.1.2.4. Days to first harvest

Comparing the mean value of days to first harvest between families, H-10-1-1-1 exhibited the highest value (71.40) while H-10-69.5-3 gave the lowest value of (64.00) by H-10-69.5-3. Mean value for Anaswara was 65.50. The mean value of cross H 10 in F_4 generation was 67.83 and of cross H11 was 67.21.

Variance among family ranged between 2.24 (H-11-19-19) and 36.67 (H-10-1.4-1). Variance of Anaswara was 4.09.

4. 1. 2.5. Days to last harvest

Comparing the mean value of days to last harvest between families, H-10-69-20 exhibited the highest value (105.92) while H-11-19-19 gave the lowest value of (92.38) by H-11-19-19. Mean value for Anaswara was 96. The mean value of cross H 10 in F_4 generation was 97.18 and of cross H11 was 96.46.

Variance among family ranged between 6.42 (H-11-36.1-3) and 64.54 (H-10-71.16-1). Variance of Anaswara was 5.27.

4.1.2.6. Number of pods per plant

Comparing the mean value of number of pods per plant between families, H-10-69.7-2 exhibited the highest value (37.80) while H-10-28-11-2 gave the lowest value of (31.63) by H-10-28-11-2. Mean value for Anaswara was 36.25. The mean value of cross H 10 in F_4 generation was 35.413 and of cross H11 was 35.10.Variance among family ranged between 3.06 (H-11-34.16) and 44.47 (H-10-1.4-1). Variance of Anaswara was 4.20.

4.1.2.7. Pod length

Comparing the mean value of number of pod length between families, H-10-71.16-1 exhibited the highest value (22.65) while H-10-69.5-3 gave the lowest value of (14.55) by H-10-69.5-3. Mean value for Anaswara was 20.55. The mean value of cross H 10 in F_4 generation was 18.488 and of cross H11 was 19.60.

Variance among family ranged between 2.42 (H-11-50.11-2) and 43.24 (H-10-1-1-1). Variance of Anaswara was 7.51.

4.1.2.8. Pod weight

Comparing the mean value of single pod weight between families, H-10-71.16-1 exhibited the highest value (2.62) while H-10-69.4-2 gave the lowest value of (1.44) by H-10-69.4-2. Mean value for Anaswara was 2.49. The mean value of cross H 10 in F_4 generation was 1.97 and of cross H11 was 1.89.

Variance among family ranged between 0.06 (H-11-36.1-3) and 0.66 (H-10-1-1-1). Variance of Anaswara was 0.22.

4.1.2.9. Number of seeds per pod

Comparing the mean value of number of seeds per pod between families, H-10-69.1-1 exhibited the highest value (15.18) while H-11-19-19 gave the lowest value of (11.29) by H-11-19-19. Mean value for Anaswara was 14.21. The mean value of cross H 10 in F_4 generation was 13.70 and of cross H11 was 13.67.

Variance among family ranged between 0.67 (H-11-49.7-1) and 9.63 (H-10-69-20). Variance of Anaswara was 2.70.

4.1.2.10. Test weight

Comparing the mean value of test weight between families, H-10-71.16-1 exhibited the highest value (20.81) while H-10-69.5-3 gave the lowest value of (12.86) by H-10-69.5-3. Mean value for Anaswara was 17.74. The mean value of cross H 10 in F_4 generation was 17.60 and of cross H11 was 17.97.

Variance among family ranged between 0.50 (H-10-69-20-2) and 9.19 (H-10-1-1-1). Variance of Anaswara was 0.16.

4.1.2.11. Grain yield per plant

Comparing the mean value of grain yield per plant between families, H-10-69.7-2 exhibited the highest value (117.30) while H-10-69.5-3gave the lowest value of (66.14) by H-10-69.5-3. Mean value for Anaswara was 91.36. The mean value of cross H 10 in F_4 generation was 86.74 and of cross H11 was 87.59.

Variance among family ranged between 120 (H-10-28-11-2) and 2138.25 (H-10-1-1-1). Variance of Anaswara was 125.02.

4.1.2.12. Seed protein content

Comparing the mean value of seed protein content between families, H-10-69.7-2 exhibited the highest value (25.92) while H-11-36.5-3 gave the lowest value of (21.36) by H-11-36.5-3. Mean value for Anaswara was 22.8. The mean value of cross H 10 in F_4 generation was 23.898 and of cross H11 was 23.24.

Variance among family ranged between 0.02 and 2.62. Variance of Anaswara was 0.58.

Table 4.3. Family average of F_4 generation of cross H10

	Plant height(cm)	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight (g)	No. of seeds / pod	Test weight (g)	Grain yield/ plant (g)	Protein content (%)
H-10-28-11-2	112.27	3.18	48.18	70.90	99.54	31.63	18.60	2.03	13.01	17.94	74.00	23.27
H-10-69-20	107.07	3.57	46.00	68.51	105.92	34.07	17.83	1.77	11.60	18.02	70.51	23.35
H-10-1-1-1	110.10	3.30	48.20	71.40	98.60	31.70	21.31	2.17	13.28	18.51	79.49	25.03
H-10-1.4-1	107.00	3.46	45.00	66.00	96.84	36.30	16.34	1.80	13.95	14.81	75.81	23.94
H-10-41.9-2	114.53	3.53	48.07	66.76	93.30	34.76	16.88	1.77	12.23	17.82	76.90	22.78
H-10-69-20-2	102.36	3.72	48.27	68.81	94.90	33.90	16.89	1.69	13.13	17.81	79.39	23.46
H-10-69.5-3	106.83	4.08	44.91	64.00	97.33	37.16	14.55	1.48	13.42	12.86	66.14	22.96
H-10-69.4-2	122.91	3.41	48.25	68.33	97.33	33.83	16.79	1.44	11.92	17.48	70.79	22.58
H-10-69.1-1	114.50	3.50	46.64	68.14	97.35	37.64	17.09	1.89	15.18	16.27	94.08	23.92
H-10-71.16-1	131.40	3.73	45.60	67.66	94.60	36.93	22.65	2.62	15.01	20.81	116.26	25.61
H-10-69.7-2	118.46	4.13	45.46	67.53	98.20	37.80	22.57	2.55	14.79	20.69	117.13	25.92
Anaswara	124.17	3.42	44.83	65.50	96.00	36.25	20.55	2.49	14.22	17.74	91.36	22.80

Table 4.4. Variance of families of H10

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H-10-28-11-2	379.22	0.16	3.96	8.69	31.67	3.65	5.40	0.14	1.80	1.41	120.00	0.17
H-10-69-20	399.15	0.57	10.62	15.34	46.84	7.61	22.49	0.18	9.63	2.13	283.64	0.22
H-10-1-1-1	3353.80	0.25	8.82	5.78	21.78	43.24	16.19	0.66	2.46	9.19	2138.25	0.01
H-10-1.4-1	630.17	0.77	4.67	36.67	44.47	20.06	3.47	0.10	4.02	0.98	378.80	1.78
H-10-41.9-2	370.77	0.44	8.24	10.86	30.90	7.36	19.40	0.11	7.31	2.19	585.28	0.11
H-10-69-20-2	154.85	0.42	7.02	8.76	15.29	4.69	6.00	0.13	2.67	0.50	141.53	0.63
H-10-69.5-3	140.33	0.08	4.99	15.09	22.61	22.15	3.77	0.11	5.12	1.96	605.37	0.10
H-10-69.4-2	329.36	0.45	4.75	4.06	12.97	5.97	11.31	0.08	6.72	0.50	342.98	0.13
H-10-69.1-1	410.58	0.42	14.09	6.90	18.25	17.48	3.01	0.17	3.48	4.53	513.06	3.47
H-10-71.16-1	616.40	0.64	6.26	2.38	64.54	8.07	5.21	0.53	3.28	3.06	474.18	1.83
H-10-69.7-2	471.12	0.55	2.84	2.70	21.74	13.89	6.74	0.34	6.29	4.31	997.38	2.62
Anaswara	444.69	0.44	6.33	4.09	5.27	4.20	7.51	0.22	2.70	0.16	125.02	0.58

Table 4.5. Family average of F_4 generation of cross H11

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H-11-50.11-2	104.58	3.25	46.66	69.00	98.08	33.33	18.48	1.75	12.58	16.82	72.46	23.33
H-11-19-19	121.30	3.69	47.38	67.07	92.38	34.23	18.70	1.52	11.29	17.19	66.86	23.31
H-11-3.9-1	94.15	3.53	46.76	67.61	94.30	35.84	17.15	1.77	14.94	15.19	82.56	24.22
H-11-11-12-2	114.00	4.15	47.07	66.53	94.92	35.07	20.11	1.85	12.39	19.85	88.13	22.96
H-11-34.16	118.58	3.41	47.75	68.33	97.00	31.83	19.45	1.66	13.39	17.65	76.01	24.50
H-11-49.7-1	128.75	3.75	46.41	66.91	95.91	34.83	21.77	2.17	14.61	16.96	87.93	24.15
H-11-2.20-3	122.05	3.66	46.72	67.44	96.55	37.27	21.43	2.17	15.11	19.22	109.81	23.62
H-11-36.5-3	125.64	3.52	46.00	66.94	96.35	37.35	19.65	2.12	14.57	18.56	100.77	21.36
H-11-10.34-1	140.78	3.85	45.92	66.64	96.00	34.85	20.79	2.20	14.71	20.61	106.88	24.17
H-11-36.1-3	106.38	3.53	45.15	65.30	99.38	34.76	17.10	1.66	12.66	15.98	71.10	22.47
H-11-34.7-3	109.53	3.23	46.92	67.07	100.07	35.46	20.10	1.69	13.08	18.55	86.61	22.39
H-11-50.13-1	102.60	3.80	47.20	68.10	96.70	34.20	19.69	1.87	13.73	18.14	85.82	22.71

Table 4.6. Variance in family H11

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H-11-50.11-2	363.36	0.20	4.79	5.27	6.81	2.42	10.91	0.26	7.70	2.13	636.78	0.03
H-11-19-19	988.23	0.90	10.42	2.24	17.59	11.86	1.82	0.12	1.02	2.32	177.05	0.16
H-11-3.9-1	120.64	0.27	6.53	4.42	17.73	9.64	4.83	0.15	5.65	3.32	683.28	1.79
H-11-11-12-2	365.50	0.14	6.08	4.60	48.58	14.58	8.80	0.27	3.01	2.16	714.49	0.02
H-11-34.16	602.99	0.27	10.02	7.52	26.73	3.06	5.78	0.20	1.87	1.71	280.68	0.02
H-11-49.7-1	609.66	0.39	10.81	6.08	14.27	13.61	1.87	0.14	0.67	0.70	310.01	2.82
H-11-2.20-3	684.76	0.71	9.04	12.50	32.61	13.04	8.72	0.11	5.62	2.33	899.68	2.19
H-11-36.5-3	194.87	0.51	5.75	5.81	12.49	12.74	3.66	0.21	3.73	3.11	480.25	0.36
H-11-10.34-1	337.10	0.29	10.53	6.25	17.38	13.52	8.88	0.33	2.66	3.55	676.19	0.95
H-11-36.1-3	212.26	0.44	3.81	2.40	6.42	5.86	9.51	0.06	7.14	5.37	492.78	0.27
H-11-34.7-3	432.44	0.36	6.41	6.08	8.24	8.77	1.70	0.17	3.07	3.25	264.03	0.29
H-11-50.13-1	448.93	0.40	9.51	4.32	14.01	7.07	4.27	0.09	2.16	2.72	331.18	0.03

4.1.3. Genetic variability studies in F_4 generation

The components of genetic variation such as genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), heritability in broad sense (H^2), genetic advance (GA) and genetic advance under selection expressed as per cent mean (GAM) were estimated for various quantitative characters of cowpea in F_4 population of cross H 10 and H 11 and are presented in the table 4.7 and 4.8.

4.1.3.1. Plant height (cm)

In F_4 generation of cross H 10, the PCV was 19.36 per cent and GCV was 6.08per cent. The heritability for this character was 9.87 per cent. Genetic advance for this character was 4.52. Genetic advance expressed as per cent of mean was 3.94per cent.

In F_4 generation of cross H 11, the PCV was 20.48per cent and GCV was 9.57per cent. The heritability for this character was 21.87 per cent. Genetic advance for this character was 10.75. Genetic advance expressed as per cent of mean was 9.22 per cent.

4.1.3.2. Number of branches per plant

In F_4 generation of cross H 10, the PCV was 19.56 per cent and GCV was 7.06 per cent. The heritability for this character was 13.04 per cent. Genetic advance for this character was 0.19. Genetic advance expressed as per cent of mean was 5.22 per cent.

In F_4 generation of cross H 11, the PCV was 18.56 per cent and GCV was 2.89 per cent. The heritability for this character was 2.43 per cent. Genetic advance for this character was 0.18. Genetic advance expressed as per cent of mean was 5.02 per cent.

4.1.3.3. Days to first flowering

In F_4 generation of cross H 10, the PCV was 6.06 per cent and GCV was 2.77 per cent. The heritability for this character was 21.02 per cent. Genetic advance for

this character was 1.23. Genetic advance expressed as per cent of mean was 2.62 per cent.

In F_4 generation of cross H 11, the PCV was 5.94 per cent and GCV was 2.49 per cent. The heritability for this character was 17.57 per cent. Genetic advance for this character was 1.00. Genetic advance expressed as per cent of mean was 2.15 per cent.

4.1.3.4. Days to first harvest

In F_4 generation of cross H 10, the PCV was 5.38 per cent and GCV was 4.48 per cent. The heritability for this character was 69.26 per cent. Genetic advance for this character was 5.20. Genetic advance expressed as per cent of mean was 7.68 per cent.

In F_4 generation of cross H 11, the PCV was 3.75 per cent and GCV was 2.19 per cent. The heritability for this character was 34.46 per cent. Genetic advance for this character was 1.78. Genetic advance expressed as per cent of mean was 2.64 per cent.

4.1.3.5. Days to last harvest

In F_4 generation of cross H 10, the PCV was 5.09 per cent and GCV was 4.50 per cent. The heritability for this character was 78.43 per cent. Genetic advance for this character was 7.99. Genetic advance expressed as per cent of mean was 8.22 per cent.

In F_4 generation of cross H 11, the PCV was 4.83 per cent and GCV was 4.19 per cent. The heritability for this character was 75.68 per cent. Genetic advance for this character was 7.26. Genetic advance expressed as per cent of mean was 7.53 per cent.

4.1.3.6. Number of pods per plant

In F_4 generation of cross H 10, the PCV was 11.21 per cent and GCV was 9.60 per cent. The heritability for this character was 73.35 per cent. Genetic advance for

this character was 5.99. Genetic advance expressed as per cent of mean was 16.91 per cent.

In F_4 generation of cross H 11, the PCV was 9.72 per cent and GCV was 7.77 per cent. The heritability for this character was 63.91 per cent. Genetic advance for this character was 4.49. Genetic advance expressed as per cent of mean was 12.79 per cent.

4.1.3.7. Pod length (cm)

In F_4 generation of cross H 10, the PCV was 20.37 per cent and GCV was 12.83 per cent. The heritability for this character was 39.71 per cent. Genetic advance for this character was 3.08. Genetic advance expressed as per cent of mean was 16.65 per cent.

In F_4 generation of cross H 11, the PCV was 14.10 per cent and GCV was 1.83 per cent. The heritability for this character was 1.70 per cent. Genetic advance for this character was 0.10. Genetic advance expressed as per cent of mean was 0.49 per cent.

4.1.3.8. Single pod weight (g)

In F_4 generation of cross H 10, the PCV was 29.81 per cent and GCV was 17.99 per cent. The heritability for this character was 36.42 per cent. Genetic advance for this character was 0.44. Genetic advance expressed as per cent of mean was 22.35 per cent.

In F_4 generation of cross H 11, the PCV was 24.76 per cent and GCV was 0.00 per cent. The heritability for this character was 0 per cent. Genetic advance for this character was 0.00 Genetic advance expressed as per cent of mean was 0 per cent.

4.1.3.9. Number of seeds per pod

In F_4 generation of cross H 10, the PCV was 16.84 per cent and GCV was 11.82 per cent. The heritability for this character was 49.27 per cent. Genetic advance

for this character was 2.34. Genetic advance expressed as per cent of mean was 17.07 per cent.

In F_4 generation of cross H 11, the PCV was 16.27 per cent and GCV was 10.97 per cent. The heritability for this character was 45.45 per cent. Genetic advance for this character was 2.08. Genetic advance expressed as per cent of mean was 15.20 per cent.

4.1.3.10. Hundred seed weight (g)

In F_4 generation of cross H 10, the PCV was 15.85 per cent and GCV was 15.69 per cent. The heritability for this character was 98.00 per cent. Genetic advance for this character was 5.63. Genetic advance expressed as per cent of mean was 31.97 per cent.

In F_4 generation of cross H 11, the PCV was 12.29 per cent and GCV was 12.08 per cent. The heritability for this character was 96.72 per cent. Genetic advance for this character was 4.40. Genetic advance expressed as per cent of mean was 24.5 per cent.

4.1.3.11. Grain yield per plant (g)

In F_4 generation of cross H 10, the PCV was 32.45 per cent and GCV was 29.77 per cent. The heritability for this character was 84.21 per cent. Genetic advance for this character was 48.80. Genetic advance expressed as per cent of mean was 56.26 per cent.

In F_4 generation of cross H 11, the PCV was 29.64 per cent and GCV was 26.74 per cent. The heritability for this character was 81.45 per cent. Genetic advance for this character was 43.55. Genetic advance expressed as per cent of mean was 49.70 per cent.

4.1.3.12. Protein content (%)

In F_4 generation of cross H 10, the PCV was 5.97 per cent and GCV was 5.05 per cent. The heritability for this character was 71.56 per cent. Genetic advance for

this character was 2.11. Genetic advance expressed as per cent of mean was 8.82 per cent.

In F_4 generation of cross H 11, the PCV was 5.74 per cent and GCV was 4.71 per cent. The heritability for this character was 67.41 per cent. Genetic advance for this character was 1.86. Genetic advance expressed as per cent of mean was 8.01 per cent.

Table 4.7. Genetic parameters of F_4 generation of cross H10

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H^2	GA	GAM (%)
Plant height	493.43	48.74	444.69	19.36	6.08	9.87	4.52	3.94
No. of branches	0.51	0.07	0.44	19.56	7.06	13.04	0.19	5.22
Days to first flowering	8.02	1.69	6.33	6.06	2.77	21.02	1.23	2.62
Days to first harvest	13.31	9.22	4.09	5.38	4.48	69.26	5.20	7.68
Days to last harvest	24.43	19.16	5.27	5.09	4.50	78.43	7.99	8.22
No. of pods/plant	15.76	11.56	4.2	11.21	9.60	73.35	5.99	16.91
Length of pod	14.18	6.67	7.51	20.37	12.83	39.71	3.08	16.65
Pod weight	0.35	0.13	0.22	29.81	17.99	36.42	0.44	22.35
No. of seeds / pod	5.32	2.62	2.70	16.84	11.82	49.27	2.34	17.07
Test weight	7.78	7.62	0.16	15.85	15.69	98	5.63	31.97
Grain yield/ plant	791.99	666.97	125.02	32.45	29.77	84.21	48.80	56.26
Protein content	2.04	1.46	0.58	5.97	5.05	71.56	2.11	8.82

Table 4.8. Genetic parameters of F_4 generation of cross H11

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H^2	GA	GAM (%)
Plant height	569.21	124.52	444.69	20.48	9.57	21.87	10.75	9.22
No. of branches	0.45	0.01	0.44	18.56	2.89	2.43	0.18	5.02
Days to first flowering	7.68	1.35	6.33	5.94	2.49	17.57	1.00	2.15
Days to first harvest	6.26	2.17	4.09	3.72	2.19	34.46	1.78	2.64
Days to last harvest	21.67	16.40	5.27	4.83	4.19	75.68	7.26	7.53
No. of pods/plant	11.64	7.44	4.20	9.72	7.77	63.91	4.49	12.79
Length of pod	7.64	0.13	7.51	14.10	1.83	1.70	0.10	0.49
Pod weight	0.22	0.00	0.22	24.76	0.00	0.00	0.00	0.00
No. of seeds / pod	4.95	2.25	2.70	16.27	10.97	45.45	2.08	15.20
Test weight	4.88	4.72	0.16	12.29	12.08	96.72	4.40	24.50
Grain yield/ plant	673.98	548.96	125.02	29.64	26.74	81.45	43.55	49.70
Protein content	1.78	1.20	0.58	5.74	4.71	67.41	1.86	8.01

4.1.4. Correlation studies

4.1.4.1. Correlations between quantitative characters in F_4 generation of cross H 10 of cowpea

The phenotypic correlations of seed yield with other quantitative characters in F_4 population of cross H10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) were found using Pearson correlation analysis using SPSS and given in table 4.9 and 4.10.

Correlation analysis showed that grain yield was positively correlated with plant height (0.421), number of branches per plant (0.347), number of pods per plant (0.661), length of pod (0.737) pod weight (0.754), number of seeds/pod (0.806) and test weight(0.639). Grain yield was found negatively correlated with days to first flowering, days to first harvest and days to last harvest.

Positive and significant correlation was found between plant height with number of branches per plant (0.309), number of pods per plant (.327), pod length (0.334), single pod weight (0.391), number of seeds per pod (0.279), hundred seed weight (0.274) and grain yield per plant (0.274). It showed significant negative correlation with days to first flowering (-0.258), days to first harvest (-0.139) and days to last harvest (-0.166).

Number of branches per plant showed significant and negative correlation with days to first flowering (-0.277) and days to first harvest (-0.255). Days to first flowering exhibits significant positive correlation with number of pods per plant (.473), single pod weight (0.272), number of seeds per pod (0.244) and grain yield per plant (0.347).

Days to first flowering showed significant and positive correlation with days to first harvest (0.694) and days to last harvest (0.406). It showed significant negative correlation with plant height, days to first flowering, number of pods per plant, single pod weight, number of seeds per pod and grain yield.

Days to first harvest showed significant positive correlation with days to last harvest (0.441) and hundred seed weight (0.232). It exhibits significant negative correlation with number of pods per plant (-0.450) and number of seeds per pod (-0.176).

Pods per plant gave significant positive correlation with pod length (0.195), single pod weight (0.293), number of seeds per pod (0.527) and grain yield per plant (0.661) .

There was significant positive correlation between pod length and single pod weight (0.781), number of seeds per pod (0.618), hundred seed weight (0.659) and grain yield per plant (0.737).

Pod weight exhibited significant positive correlation with number of seeds per pod (0.611), hundred seed weight (0.599) and grain yield per plant (0.754).

Number of seeds per pod showed significant positive correlation with hundred seed weight (0.187) and grain yield per plant (0.806). Hundred seed weight showed significant positive correlation with grain yield (0.639).

4.1.4.2. Correlation between quantitative characters in F_4 generation of cross H 11 of cowpea

Correlation analysis among quantitative characters in F4 generation of cross H 11 showed that grain yield was significantly and positively correlated with plant height (0.414), number of branches per plant (0. 195), number of pods per plant (0. 731), length of pod (0. 683) pod weight(0.779), number of seeds/pod (0. 790)and test weight (0. 679). Seed protein content showed non-significant positive correlation with grain yield. Grain yield was found negatively correlated with days to first flowering, days to first harvest and days to last harvest.

Significant and positive relation was observed between plant height with number of branches per plant (0.332), number of pods per plant (.245), pod length (0.398), single pod weight (0.320), number of seeds per pod (0.302), hundred seed

weight (0.371) and grain yield per plant (0.414). It showed significant negative correlation with days to first flowering (-0.261), days to first harvest (-0.154) and days to last harvest (-0.162).

Number of branches per plant showed significant and negative correlation with days to first flowering (-0.252) and days to last harvest (-0.242). Days to first flowering exhibits significant positive correlation with number of pods per plant (.170), hundred seed weight (0.208) and grain yield per plant (0.195).

Days to first flowering showed significant and positive correlation with days to first harvest (0.669) and days to last harvest (0.263). It showed significant negative correlation with number of pods per plant and single pod weight.

Days to first harvest showed significant positive correlation with days to last harvest (0.396).

Pods per plant gave significant positive correlation with pod length (0.328), single pod weight (0.491), number of seeds per plant (0.447), hundred seed weight (0.318) and grain yield per plant (0.731) .

There was significant positive correlation between pod length and single pod weight (0.680), number of seeds per pod (0.651), hundred seed weight (0.474) and grain yield per plant (0.683).

Pod weight exhibited significant positive correlation with number of seeds per pod (0.728), hundred seed weight (0.499) and grain yield per plant (0.779).

Number of seeds per pod showed significant positive correlation with hundred seed weight (0.220) and grain yield per plant (0.790). Hundred seed weight showed significant positive correlation with grain yield (0.679).

Table 4.9. Correlation of characters in F_4 of cross H10

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.309**	-0.258**	-0.139	-0.166	0.327**	0.334**	0.391**	0.279**	0.274**	0.421**	0.150
X2		1	-0.277**	-0.255**	-0.105	0.473**	0.148	0.272**	0.244**	0.097	0.347**	0.056
X3			1	0.694**	0.406**	-0.405**	-0.164	-0.190*	-0.318**	0.105	-0.260**	0.211
X4				1	0.441**	-0.450**	0.070	0.023	-0.176*	0.232**	-0.115	0.013
X5					1	-0.156	-0.062	-0.020	-0.161	0.097	-0.083	-0.202
X6						1	0.195*	0.293**	0.527**	0.070	0.661**	0.108
X7							1	0.781**	0.618**	0.659**	0.737**	0.105
X8								1	0.611**	0.599**	0.754**	0.031
X9									1	0.187*	0.806**	0.054
X10										1	0.639**	0.132
X11											1	0.118
												1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

X1 – Plant height (cm)
X2 – Number of branches per plant
X3 – Days to first flowering
X4 – Days to first harvest
X5 – Days to last harvest
X6 – Number of pods per plant
X7 – Pod length (cm)
X8 – Single pod weight (g)
X9 – Number of seeds per plant
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

Table 4.10. Correlation of characters in F_4 of cross H11

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.332**	-0.261**	-0.154	-0.162*	0.245**	0.398**	0.320**	0.302**	0.371**	0.414**	0.190
X2		1	-0.252**	-0.135	-0.242**	0.170*	0.148	0.129	0.095	0.208**	0.195*	0.063
X3			1	0.669**	0.263**	-0.174*	-0.039	-0.161*	-0.128	-0.017	-0.140	0.221
X4				1	0.396**	-0.089	-0.002	-0.055	-0.010	-0.020	-0.058	0.023
X5					1	-0.087	0.059	0.004	0.110	-0.036	0.009	-0.262
X6						1	0.328**	0.491**	0.447**	0.318**	0.731**	0.138
X7							1	0.680**	0.651**	0.474**	0.683**	0.102
X8								1	0.728**	0.449**	0.779**	0.062
X9									1	0.220**	0.790**	0.056
X10										1	0.679**	0.149
X11											1	0 .228
X12												1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

X1 – Plant height (cm)
X2 – Number of branches per plant
X3 – Days to first flowering
X4 – Days to first harvest
X5 – Days to last harvest
X6 – Number of pods per plant
X7 – Pod length (cm)
X8 – Single pod weight (g)
X9 – Number of seeds per plant
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

4.1.5. Path co-efficient analysis for grain yield from F_4 generation of cross H10

Path analysis with direct and indirect effect of various quantitative traits on grain yield was done using unreplicated data from F_4 generation of cowpea cross and the results are presented in table 4.11. The residual effect contribution on grain yield was 0.01438 in analysis with cross H10.

4.1.5.1. Direct effect on grain yield

High positive direct effect on grain yield was given by pods per plant (0.352), number of seeds per pod (0.503) and hundred seed weight (0.491). Negligible negative direct effect was given by number of branches, days to first flowering and pod length on grain yield.

4.1.5.2. Indirect effects on grain yield

Plant height

Low, positive, indirect effect was exerted by plant height through pods per plant (0.115), seeds per plant (0.140) and hundred seed weight (0.134) towards grain yield. Negligible indirect effect was given by plant height through the other characters.

Number of branches per plant

Low and positive, indirect effect was exerted by number of branches per plant through pods per plant (0.166) number of seeds per pod (0.122) towards grain yield. Negligible indirect effect was shown by other characters through number of branches per plant to grain yield.

Days to first flowering

Low and negative, indirect effect was exerted by days to first flowering through pods per plant (-0.142) number of seeds per pod (-0.159) towards grain yield. Negligible indirect effect was shown by other characters through days to first flowering to grain yield.

Days to first harvest

Low and positive, indirect effect was exerted by days to first harvest through hundred seed weight (0.114) towards grain yield. Low negative indirect effect was exerted by days to first harvest through number of pods per plant (-0.158) and number of seeds per pod (0.211) towards grain yield. Negligible indirect effect was shown by other characters through days to first harvest towards grain yield.

Days to last harvest

Negligible indirect effect was shown by other characters through days to last harvest towards grain yield.

Number of pods per plant

Moderate, positive indirect effect was exerted by number of pods per plant through seeds per pod (0.265) towards grain yield. Negligible indirect effect was shown by other characters through number of pods per plant towards grain yield.

Pod length

High, positive indirect effect was exerted by pod length through seeds per pod (0.310) and hundred seed weight (0.323) towards grain yield. Negligible indirect effect was exerted by pod length through other characters towards grain yield.

Single pod weight

High, positive and indirect effect was exerted by single pod weight through seeds per pod (0.307) towards grain yield. Moderate, positive and indirect effect was exerted by single pod weight through hundred seed weight (0.294) towards grain yield. Low, positive and indirect effect was exerted by single pod weight through pods per plant (0.103) towards grain yield. Negligible indirect effect was exerted by single pod weight through other characters towards grain yield.

Number of seeds per pod

Low positive and indirect effect was exerted by number of seeds per pod through number of pods per plant (0.185) toward grain yield. Negligible and indirect effect was exerted by number of seeds per pod through other characters under study.

Hundred seed weight

Negligible and indirect effect was exerted by hundred seed weight through other characters under study.

4.1.6. Path co-efficient analysis for grain yield from F_4 generation of cross H11

Path analysis with direct and indirect effect of various quantitative traits on grain yield was done using unreplicated data from F_4 generation of H11 cross and result are presented in table 4.12. The residual effect contribution on grain yield was 0.0154 in analysis with cross H10.

4.1.6.1. Direct effect on grain yield

High positive direct effect on grain yield was given by number of pods per plant (0.344), number of seeds per pod (0.508) and hundred seed weight (0.439). Negligible positive direct effect was given by plant height, days to first flowering, days to last harvest, pod length and pod weight on grain yield. Negligible negative direct effect was given by number of branches and days to first harvest on grain yield. The result clearly demonstrated that characters number of pods per plant, number of seeds per pod and hundred seed weight were the most yield contributing character to grain yield in F_4 segregating generation of cowpea.

4.1.6.2. Indirect effects on grain yield

Plant height

Low, positive, indirect effect was exerted by plant height through seeds per plant (0.153) and hundred seed weight (0.162) towards grain yield. Negligible indirect effect was given by plant height through the other characters.

Number of branches per plant

Negligible indirect effect was shown by number of branches per plant through other characters to grain yield.

Days to first flowering

Negligible indirect effect was shown by days to first flowering through other characters to grain yield.

Days to first harvest

Negligible indirect effect was shown by days to first harvest through other characters to grain yield.

Days to last harvest

Negligible indirect effect was shown by days to last harvest through other characters to grain yield.

Number of pods per plant

Moderate, positive indirect effect was exerted by number of pods per plant through seeds per pod (0.227) towards grain yield. Low positive indirect effect was exerted by number of pods per plant through hundred seed weight (0.139) towards grain yield Negligible indirect effect was shown by other characters through number of pods per plant towards grain yield.

Pod length

High, positive indirect effect was exerted by pod length through seeds per pod (0.310). Moderate indirect effect was given by hundred seed weight (0.208) towards grain yield and low indirect effect was given by number of pods per plant (0.112) towards grain yield. Negligible indirect effect was exerted by pod length through other characters towards grain yield.

Single pod weight

High, positive and indirect effect was exerted by single pod weight through seeds per pod (0.307) towards grain yield. Moderate, positive and indirect effect was exerted by single pod weight through hundred seed weight (0.294) towards grain yield. Low, positive and indirect effect was exerted by single pod weight through pods per plant (0.103) towards grain yield. Negligible indirect effect was exerted by single pod weight through other characters towards grain yield.

Number of seeds per pod

Low positive and indirect effect was exerted by number of seeds per pod through number of pods per plant (0.153) toward grain yield. Negligible and indirect effect was exerted by number of seeds per pod through other characters under study.

Hundred seed weight

Low positive and indirect effect was exerted by hundred seed weight through number of pods per plant (0.109) and number of seeds per pod (0.111) towards grain yield. Negligible and indirect effect was exerted by hundred seed weight through other characters under study.

Table 4.11. Path analysis with direct and indirect effects on grain yield of F_4 population of cross H10 of cowpea

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	r_{xy}
X1	**0.01783**	-0.00129	0.00610	-0.00495	-0.00025	0.11532	-0.00628	0.02055	0.14006	0.13434	0.414**
X2	0.00550	**-0.00416**	0.00655	-0.00905	-0.00016	0.16675	-0.00278	0.01429	0.12279	0.04775	0.195*
X3	-0.00460	0.00115	**-0.02365**	0.02463	0.00061	-0.14267	0.00309	-0.00997	-0.15993	0.05136	-0.140
X4	-0.00249	0.00106	-0.01641	**0.03550**	0.00067	-0.15871	-0.00131	0.00119	-0.08823	0.11410	-0.058
X5	-0.00296	0.00044	-0.00959	0.01566	**0.00151**	-0.05489	0.00116	-0.00106	-0.08108	0.04740	0.009
X6	0.00584	-0.00197	0.00957	-0.01598	-0.00024	**0.35243**	-0.00367	0.01538	0.26517	0.03434	0.731**
X7	0.00596	-0.00062	0.00389	0.00247	-0.00009	0.06885	**-0.01878**	0.04100	0.31075	0.32382	0.683**
X8	0.00698	-0.00113	0.00449	0.00081	-0.00003	0.10326	-0.01467	**0.05250**	0.30735	0.29430	0.779**
X9	0.00497	-0.00102	0.00752	-0.00623	-0.00024	0.18590	-0.01161	0.03210	**0.50271**	0.09175	0.790**
X10	0.00488	-0.00040	-0.00247	0.00825	0.00015	0.02464	-0.01238	0.03146	0.09392	**0.49109**	0.679**

Residual - 0.01438

Table 4.12. Path analysis with direct and indirect effects on grain yield of F_4 population of cross H11 of cowpea

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	r_{xy}
X1	**0.002**	-0.00333	-0.00273	0.00309	-0.00027	0.08421	0.00117	0.01342	0.15333	0.16294	0.414**
X2	0.00061	**-0.010**	-0.00264	0.002711	-0.00041	0.05863	0.00043	0.00541	0.04836	0.09143	0.195*
X3	-0.00048	0.00253	**0.010**	-0.01344	0.00044	-0.05975	-0.00011	-0.00677	-0.06494	-0.00760	-0.140
X4	-0.00028	0.00135	0.00701	**-0.020**	0.00067	-0.03053	-0.00001	-0.00229	-0.00504	-0.00882	-0.058
X5	-0.00030	0.00243	0.00276	-0.00794	**0.002**	-0.03001	0.00017	0.00018	0.05606	-0.01563	0.009
X6	0.00045	-0.00171	-0.00182	0.00178	-0.00015	**0.344**	0.00096	0.02061	0.22725	0.13956	0.731**
X7	0.00073	-0.00148	-0.00041	0.00004	0.00010	0.11283	**0.003**	0.02856	0.33113	0.20818	0.683**
X8	0.00059	-0.00129	-0.00169	0.00110	0.00001	0.16890	0.00200	**0.042**	0.37012	0.19708	0.779**
X9	0.00056	-0.00095	-0.00134	0.00020	0.00019	0.15379	0.00191	0.03056	**0.508**	0.09656	0.790**
X10	0.00068	-0.00209	-0.00018	0.00040	-0.00006	0.10928	0.00139	0.01883	0.11172	**0.439**	0.679**

Residual - 0.01540

X1 – Plant height (cm)
X2 – Number of branches per plant
X3 – Days to first flowering
X4 – Days to first harvest
X5 – Days to last harvest
X6 – Number of pods per plant
X7 – Pod length (cm)
X8 – Single pod weight (g)
X9 – Number of seeds per plant
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)
r_{xy}– Correlation between the character and grain yield

4.1.7. Selection of superior plants from F_4 generation

Based on the genetic variability studies, correlation and path analysis it was found that the characters like number of pods per plant, hundred grain weight and number of seeds per pod can be simultaneously included along with grain yield for setting selection criteria for selecting superior individual plants.

Selection criteria

The criteria was developed such that it was superior to the parent Anaswara.

No. of pods : > 34

No. of seeds per pod :15

Hundred grain weight : >14.5

Grain yield : > 100 g / plant

Protein content :> 20%

Based on these set criteria, 13 individual plants from cross H10 and 10 plants from cross H11 were selected. The features of the selected plants are given in the table 4.13 and 4.14.

Table 4.13. Features of individual plants selected and advanced to F_5 generation of cross H 10

Plant	Plant height (cm)	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight (g)	No. of seeds / pod	Test weight (g)	Grain yield/ plant (g)	Protein content (%)
H-10-71.16-1-9	126	5	43	67	100	41	24.50	3.13	17.50	21.20	152.11	25.88
H-10-71.16-1-15	170	4	45	68	93	37	27.00	4.60	17.50	21.20	137.27	26.83
H-10-69.1-1-7	116	3	44	67	98	39	18.00	2.20	16.90	17.80	124.95	23.46
H-10-69.1-1-16	135	5	43	66	93	45	17.75	2.39	18.25	15.80	129.75	23.85
H-10-69-5-3-5	110	4	46	57	108	45	17.50	1.98	16.00	14.70	105.80	23.42
H-10-69-5-3-17	120	4	46	67	97	42	18.00	2.07	17.00	14.50	103.53	22.89
H-10-69-5-3-18	120	5	41	57	100	44	14.80	1.90	17.00	14.20	105.30	22.65
H-10-1.4-1-19	145	4	44	61	106	43	18.00	2.26	15.80	16.10	109.38	25.90
H-10-69.7-2-18	155	5	45	69	93	44	24.00	3.04	18.25	18.80	150.96	22.80
H-10-69.7-2-17	140	5	44	69	92	41	28.30	3.80	20.00	19.70	161.54	23.12
H-10-69.7-2-14	135	4	45	66	100	44	20.30	2.50	16.50	22.20	161.17	27.40
H-10-69.7-2-16	150	4	45	69	106	38	24.00	2.50	16.10	23.00	140.07	23.05
H-10-1.4-1-18	120	4	45	67	93	43	17.50	1.95	15.60	16.10	105.30	23.29

Table 4.14. Features of individual plants selected and advanced to F_5 generation of cross H 11

Plant	Plant height (cm)	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight (g)	No. of seeds / pod	Test weight (g)	Grain yield/ plant(g)	Protein content (%)
H-11-3.9-1-1	115	4	45	67	85	44	19.20	2.15	17.01	19.80	148.19	25.18
H-11-3.9-1-7	110	4	44	70	95	38	18.00	2.40	17.20	16.30	105.20	22.80
H-11-3.9-1-10	84	3	51	68	95	37	21.00	2.20	18.10	15.60	104.47	25.25
H-11-2.20-3-14	140	3	51	66	100	44	24.80	2.58	17.60	21.20	164.17	26.42
H-11-10.34-1-16	170	5	44	68	100	41	23.20	2.90	16.80	23.00	158.42	24.29
H-11-10.34-1-18	135	4	49	66	96	41	20.75	2.98	15.02	23.80	146.56	26.23
H-11-36.5-3-8	120	3	43	65	95	41	22.50	2.75	17.00	19.50	135.91	20.64
H-11-36.5-3-15	129	3	45	68	103	39	21.00	3.25	17.00	20.80	137.90	20.99
H-11-49.7-1-8	130	4	50	69	98	37	24.20	2.90	16.50	17.50	117.52	23.80
H-11-34.16-15	155	3	45	71	101	34	25.00	2.80	17.20	21.40	125.14	24.50

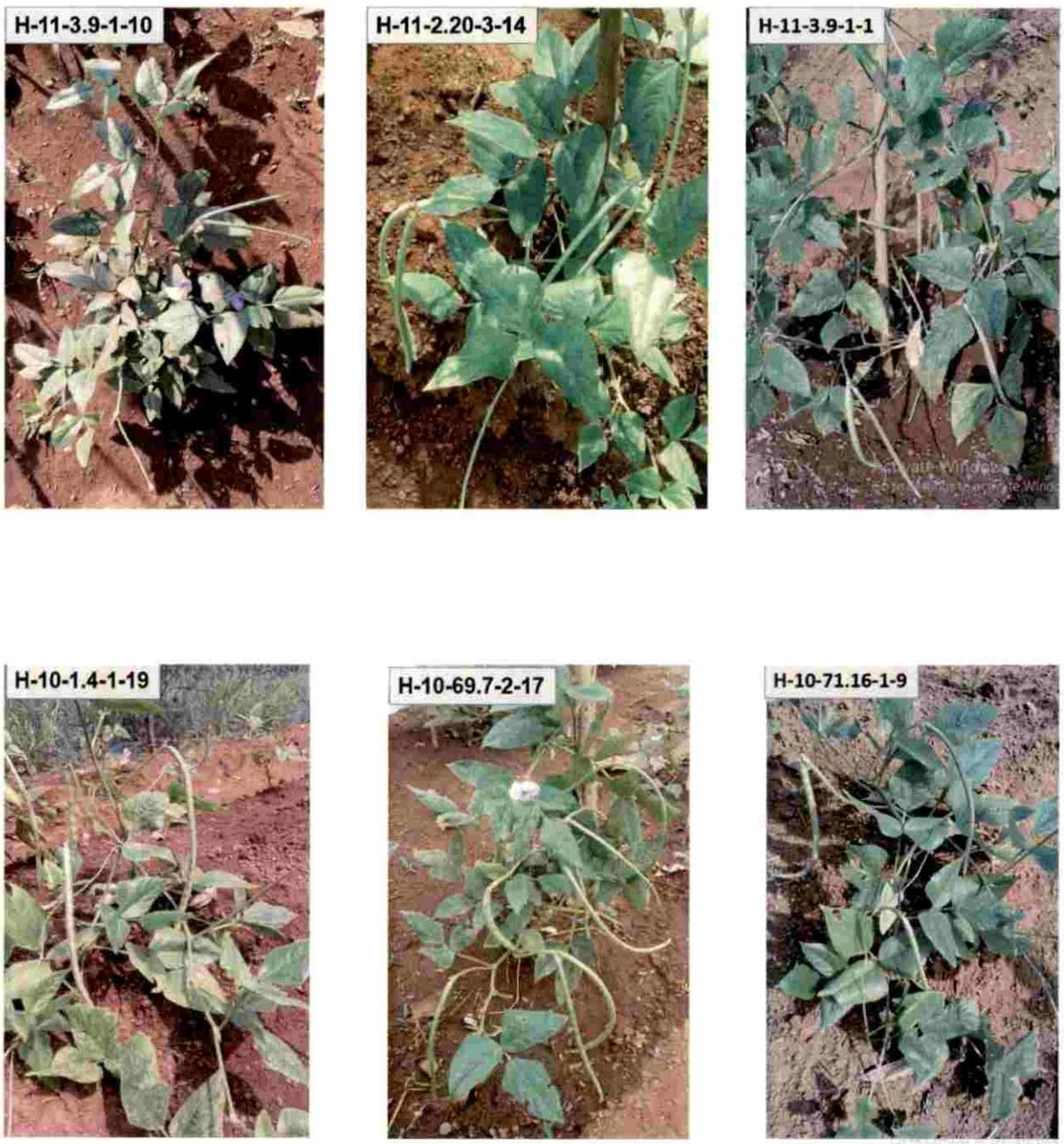

Plate 4. Selected plants from F_4 generation

4.2. Experiment 2: Evaluation of F_5 generation

4.2.1. Estimation of means and variance

The mean and variance of each character for the F_5 generation of H 10 and H 11 crosses are estimated and are presented in tables 4.15 and 4.16. The salient conclusions from the estimates are given below.

4. 2. 1. 1. Plant height (cm)

The mean value for plant height in F_5 generation of cross H10 was 169.37 cm which was less than of the parent Anaswara (202.21 cm). The values ranged from 128cm cm to 262cm with variance of 848.58.

Similarly in F_5 generation of cross H11 mean value of plant height was 201.50 cm which was less than of the parent Anaswara. The values ranged from 130cm to 310cm with variance of 1404.37.

4. 2. 1. 2. Number of branches per plant

The mean value for number of branches per plant in F_5 generation of cross H10 was 3.41 which was higher than that of the parent Anaswara (3.16). The values ranged from 3 to 7 with variance of 0.42.

Similarly in F_5 generation of cross H11 mean value of number of branches per plant was 3.80 which was higher than that of the parent Anaswara. The values ranged from 3 to 6 with variance of 0.72.

Comparing between H10 andH11 families, it showed that they perform similar in number of branches.

4. 2. 1. 3. Days of first flowering

The mean value for days to first flowering in F_5 generation of cross H10 was 59.36 which is less than of the parent Anaswara (59.63). In the F_5 population of H11, days to first flowering was 59.39. Both the population do not differ with respect

to the mean value for first days to flowering. Days to first flowering ranged from 51 to 67 in H10 and H11.

The variance for days to first flowering was higher for H11 segregants (19.90) than H10 segregants (16.03).

4. 2. 1. 4. Days to first harvest

In F_5 generation of cross H10, the days taken for first harvest ranged from 71 to 86 days. The average days taken for first harvest was 78.71 in F_5 population of cross H 10 whereas it was 78.70 in H11 cross. In H11 segregants the days to first harvest ranges between 72 to 85 days. Anaswara took 78.47 days for first harvest.

When both the F_5 population of cross H 10 and H 11 were considered for variability, H 11 cross showed high variability for days taken for first harvest with a value of 15.05.

4. 2. 1. 5. Days to last harvest

In F_5 generation of cross H10, the days taken to last harvest ranged from 112 to 132 days. The average value for days to last harvest was 121.59. In F_5 generation of cross H11, the range for days of last harvest was 112 to 135 days with an average of 121.62 days. . The last harvest for Anaswara was 127.84 days.

The high variance of 26.68 was observed in cross H 11 than H10 for days to last harvest in F_5 population.

4. 2. 1. 6. Number of pods per plant

Number of pods per plant in F_5 generation of cross H10 ranged from 26 to 36, with an average of 30.92, whereas in cross H11 it ranged from 26 to 40, with mean value was 31.75. Anaswara exhibited 29.79 numbers of pods per plant.

The high variance (7.88) for number of pods per plant was observed in F_5 population of cross H 11 compared to H10.

4. 2. 1. 7. Pod length

In F_5 generation of cross H10, the length of the pod ranged from 17 to 28cm, with mean value of 21.48cm. In cross H11 pod length ranged from 18 to 28.40 cm with average value of 23.27 cm. The pod length of Anaswara was 25.15 cm.

Comparing variances between two populations, H 10 population exhibited higher variance (8.55) for pod length than H 11 (7.00) population in F_5 generation.

4. 2. 1. 8. Pod weight (g)

In F_5 generation of cross H10, the pod weight ranged from 1.43 to 3.89 g, with an average weight of 2.30g. In H 11 population, pod weight ranged from 1.38 to 4.73 with mean value of 2.46g. Pod weight of Anaswara was 2.50g.

The variability was high in H 11 cross (0.29) when compared to H 10 (0.20) cross in F_5 generation.

4. 2. 1. 9. Number of seeds per pod

In F_5 population of cross H10, the number of seeds per pod ranged from 13 to 19.80 with mean value of 15.89. In cross H11 population it ranged from 13.1 to 19 with average number value of 15.71. Anaswara exhibited 15.75 seeds per pod.

The cross H 10 (2.40) showed higher variance than that of H 11 (1.97) cross in F_5 population.

4. 2. 1. 10. Hundred seed weight (g)

Hundred seed weight in F_5 generation of cross H10 ranged from 10.45 to 17.52 g with average value of 13.07 g. In cross H 11 population, the hundred seed weight ranged from 10.40 to 18.20 g with an average of 14.37 g. Hundred seed weight of Anaswara was 14.55g.

Cross H 11 (3.57) showed the high variability than H 10 cross (3.24) for hundred seed weight in F_5 population.

4. 2. 1. 11. Grain yield per plant (g)

In cross H 10, the value for grain yield per plant ranged from 47.48 to 102.50 g in F_5 generation. The average grain yield was 65.23g. In F_5 generation of cross H 11, the range for grain yield per plant was 55.40 to 106.10 g with an average grain yield of 72.43 g. Anaswara gave a yield of 68.66g per plant.

The cross H 11 (115.50) showed higher variability than that of H 10 cross (97.99) in F_5 population.

4. 2. 1. 12. Protein content (%)

The protein content in seeds ranged from 22.50 to 25.90 per cent in F_5 population of cross H10, with average of 23.99 per cent. In F_5 population of cross H 11, the protein content ranged from 22.50 to 26.50 per cent, with average protein content of 24.42 per cent. The protein content of Anaswara seed was 23.80 per cent.

The cross H 11 (1.22) showed higher variability for protein content than cross H 10 (1.11) in F_5 population.

Table 4.15. Variability parameters in F_5 generation of cross H10

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F_5 generation for quantitative characters												
P_1	202.21	3.16	59.63	78.47	127.84	29.79	25.15	2.50	15.75	14.55	68.66	23.80
F_5	169.37	3.41	59.36	78.71	121.59	30.92	21.48	2.30	15.89	13.07	65.23	23.99
Variance of parents and F_5 generation for quantitative characters in cowpea												
P_1	462.29	0.14	18.36	17.60	6.92	1.73	1.29	0.07	0.24	0.46	23.85	0.80
F_5	848.58	0.42	16.03	13.33	24.03	3.08	8.55	0.24	2.40	3.24	97.99	1.11
Range of F_5 generation for quantitative characters in cowpea												
Min	128.00	3.00	51.00	71.00	112.00	26.00	17.00	1.43	13.00	10.45	47.48	22.50
Max	262.00	7.00	67.00	86.00	132.00	36.00	28.00	3.89	19.80	17.52	102.50	25.90
Range	134.00	4.00	16.00	15.00	20.00	10.00	11.00	2.46	6.80	7.07	55.02	3.40

Table 4.16.Variability parameters in F_5 generation of cross H11

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F_5 generation for quantitative characters												
P_1	202.21	3.16	59.63	78.47	127.84	29.79	25.15	2.50	15.75	14.55	68.66	23.80
F_5	201.50	3.80	59.39	78.70	121.62	31.75	23.27	2.46	15.71	14.37	72.43	24.42
Variance of parents and F_5 generation for quantitative characters in cowpea												
P_1	462.29	0.14	18.36	17.60	6.92	1.73	1.29	0.07	0.24	0.46	23.85	0.80
F_5	1404.37	0.72	19.90	15.05	26.68	7.88	7.00	0.29	1.97	3.57	115.50	1.22
Range of F_5 generation for quantitative characters in cowpea												
Min	130,00	3.00	51.00	72.00	112.00	26.00	18.00	1.38	13.10	10.40	55.40	22.50
Max	310.00	6.00	67.00	85.00	135.00	40.00	28.40	4.73	19.00	18.20	106.10	26.50
Range	180.00	3.00	16.00	13.00	23.00	14.00	10.40	3.35	5.90	7.80	50.70	4.00

4.2.2. Estimation of mean and variance of families

The mean and variances for the 12 characters within each family of both crosses are worked out to find the variability within family and is presented in the tables 4.17, 4.18, 4.19, 4.20.

4.2.2.1. Plant height

Comparing the mean value of plant height between families, H-11-2-20-3-14 exhibited the highest value (236.22 cm) while H-10-69.1-1-16 gave the lowest value of (141.27 cm). Plant height of Anaswara was 202.21 cm.

Variance among family ranged between 43.21 (H-10-69.1-1-16)) and 2247.33 (H-11-3.9-1-1). Variance of Anaswara was 462.29.

4.2.2.2. Number of branches per plant

Comparing the mean value of number of branches per plant between families, H-11-3.9-1-1 exhibited the highest value (4.31) while lowest value was 3.00. Mean value for Anaswara was 3.16.

Variance among family ranged between 0.00 (H-10-69.1-1-7) and 1.29 (H-10-71-16-1-19). Variance of Anaswara was 0.14.

4.2.2.3. Days to first flowering

Comparing the mean value of days to first flowering between families, H-10-69.5-3-17 exhibited the highest value (62.41) while the lowest value was 55.69. Mean value for Anaswara was 59.63.

Variance among family ranged between 7.15 (H-10-1.4-1-18) and 27.93 (H-10-69.1-1-7). Variance of Anaswara was 18.36.

4.2.2.4. Days to first harvest

Comparing the mean value of days to first harvest between families, H-10-69.7-2-17 exhibited the highest value (81.80) while the lowest value was 76.15. Mean value for Anaswara was 78.47.

Variance among family ranged between 5.56 and 22.00. Variance of Anaswara was 17.60.

4.2.2.5. Days to last harvest

Comparing the mean value of days to last harvest between families, H-11-10.34-1-16 exhibited the highest value (128.76) while the lowest value was 114.08. Mean value for Anaswara was 127.84.

Variance among family ranged between 1.3 and 14.62. Variance of Anaswara was 6.92.

4.2.2.6. Number of pods per plant

Comparing the mean value of number of pods per plant between families, H-11-3.9-1-1 exhibited the highest value (36.69) while the lowest value was 29.80. Mean value for Anaswara was 29.79.

Variance among family ranged between 0.69 and 7.39. Variance of Anaswara was 1.73.

4.2.2.7. Pod length

Comparing the mean value of number of pod length between families, H-11-49.7-1-8 exhibited the highest value (26.38) while the lowest value was 18.35. Mean value for Anaswara was 25.15.

Variance among family ranged between 0.21 and 3.9. Variance of Anaswara was 1.29.

4.2.2.8. Pod weight

Comparing the mean value of single pod weight between families, H-1149.7-1-8 exhibited the highest value (3.43) while the lowest value was 1.61. Mean value for Anaswara was 2.50.

Variance within family ranged between 0.01 and 0.29. Variance of Anaswara was 0.07.

4.2.2.9. Number of seeds per pod

Comparing the mean value of number of seeds per pod between families, H-11-3.9-1-7 exhibited the highest value (17.81) while the lowest value was 13.70. Mean value for Anaswara was 15.75.

Variance among family ranged between 0.07 and 2.21. Variance of Anaswara was 0.24.

4.2.2.10. Test weight

Comparing the mean value of test weight between families, H11-49.7-1-8 exhibited the highest value (16.22) while the lowest value was 11.15. Mean value for Anaswara was 14.55.

Variance among family ranged between 0.09 and 1.14. Variance of Anaswara was 0.46.

4.2.2.11. Grain yield per plant

Comparing the mean value of grain yield per plant between families, H-11-2.203-14 exhibited the highest value (82.60) while the lowest value was 53.80. Mean value for Anaswara was 68.66.

Variance among family ranged between 9.05 and 157.80. Variance of Anaswara was 23.85.

4.2.2.12. Seed protein content

Comparing the mean value of seed protein content between families, H-10-69.7-2-14 exhibited the highest value (25.40) while the lowest value was 22.50. Mean value for Anaswara was 23.80.

Variance among family ranged between 0.05 and 2.13. Variance of Anaswara was 0.80.

Table 4.17. Average of families of F_5 generation of cross H10

	Plant height(cm)	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight (g)	No. of seeds / pod	Test weight(g)	Grain yield/ plant (g)	Protein content (%)
H-10-69.1-1-16	141.27	3.45	57.00	76.45	116.00	30.09	18.82	1.61	15.62	11.39	56.30	24.20
H-10-69.5-3-5	144.92	3.30	58.30	78.23	116.69	30.84	19.41	2.01	15.97	11.15	57.63	23.25
H-10-1.4-1-19	155.72	3.22	58.16	77.83	127.00	30.72	19.38	2.09	17.04	12.19	65.82	22.95
H-10-69.1-1-7	164.28	3.00	59.64	78.42	118.35	31.28	19.24	2.00	16.82	12.04	63.91	23.35
H-10-1-1-1-20	198.90	3.10	60.70	79.70	120.80	30.90	23.17	2.20	14.41	15.30	69.40	24.80
H-10-71-16-1-9	198.90	3.90	60.45	79.00	119.18	30.00	25.69	2.93	15.63	15.62	74.62	24.03
H-10-69.5-3-17	147.58	3.00	62.41	80.25	121.25	31.83	19.65	2.36	16.85	11.53	62.10	23.40
H-10-1.4-1-18	151.70	3.70	57.40	77.70	121.60	31.20	18.35	1.97	14.64	11.36	53.80	22.80
H-10-69.7-2-17	208.00	3.60	59.20	81.80	122.20	31.60	24.06	2.51	13.70	14.82	65.26	25.40
H-10-69.5-3-18	154.77	3.50	59.33	78.61	116.77	32.16	20.06	2.86	17.64	12.22	70.41	22.50
H-10-71.16-1-15	196.80	3.50	60.20	79.80	126.80	30.80	25.00	2.95	15.53	15.74	75.34	25.30
H-10-69.7-2-16	195.90	3.63	60.00	79.00	126.90	31.09	24.93	2.88	14.68	15.05	70.13	25.40
H-10-69.7-2-14	171.40	4.20	57.80	77.60	124.60	30.60	25.56	3.19	16.10	14.14	71.46	24.80
Anaswara	202.21	3.16	59.63	78.47	127.84	29.79	25.15	2.50	15.75	14.55	68.66	23.80

Table 4.18. Average of families of F_5 generation of cross H11

	Plant heig ht	No. of branc hes	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/ plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weigh t	Grain yield/ plant	Protein content
H-11-10.34-1-16	171.23	3.82	59.70	79.52	128.76	30.70	24.27	2.33	14.70	15.64	72.33	25.33
H-11-2.20-3-14	236.22	3.66	29.55	78.94	125.33	32.88	25.10	2.23	15.56	15.99	82.60	24.52
H-11-3.9-1-1	215.00	4.31	55.69	76.15	116.53	36.69	19.83	2.09	16.71	11.51	73.76	25.18
H-11-10.34-1-18	218.36	4.09	59.18	78.27	123.90	32.54	25.30	2.41	15.67	14.21	73.35	24.32
H-11-34-16-1-15	207.91	3.66	60.41	79.66	120.41	30.00	24.57	2.91	15.39	15.12	71.26	23.70
H-11-36.5-3-15	191.73	4.00	57.26	77.00	117.40	30.86	25.68	3.03	15.36	15.18	75.35	23.80
H-11-3.9-1-7	205.83	4.08	60.00	78.91	122.58	32.25	19.87	2.36	17.81	12.21	71.93	23.20
H-11-36.5-3-8	200.58	3.41	61.76	80.76	121.64	30.29	21.81	1.99	13.89	14.90	63.69	24.20
H-11-3.9-1-10	170.75	3.58	58.58	77.50	114.08	31.41	19.54	2.40	17.15	11.38	62.31	23.10
H-11-49.7-1-8	194.50	3.40	61.70	79.70	122.50	29.80	26.38	3.43	16.09	16.23	78.96	25.36
Anaswara	202.21	3.16	59.63	78.47	127.84	29.79	25.15	2.50	15.75	14.55	68.66	23.80

Table 4.19. Variance of families of F_5 generation of cross H10

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H-10-69.1-1-16	43.21	0.47	12.80	6.47	3.80	0.69	0.93	0.13	1.00	0.48	9.05	0.18
H-10-69.5-3-5	221.24	0.23	13.06	13.02	2.23	3.64	0.64	0.02	1.09	0.19	10.49	0.05
H-10-1.4-1-19	287.15	0.18	13.44	13.91	7.05	1.62	0.76	0.08	1.39	0.47	51.13	0.05
H-10-69.1-1-7	257.91	0.00	27.93	21.03	4.24	2.06	2.02	0.10	2.32	0.89	111.31	0.40
H-10-1-1-1-20	462.29	0.09	12.41	9.81	6.96	2.49	3.90	0.03	0.52	0.57	34.82	0.10
H-10-71-16-1-9	589.20	1.29	18.47	10.60	9.36	1.80	0.57	0.11	0.62	0.72	104.02	0.20
H-10-69.5-3-17	70.62	0.00	15.35	18.75	12.38	1.24	1.33	0.08	1.10	0.46	41.42	0.80
H-10-1.4-1-18	123.34	0.67	7.15	5.56	9.37	4.62	0.62	0.01	0.27	0.44	23.25	0.10
H-10-69.7-2-17	920.00	0.80	15.70	10.70	6.70	6.30	0.21	0.05	0.07	0.15	26.63	1.12
H-10-69.5-3-18	337.47	0.26	11.17	12.25	4.06	2.97	0.49	0.08	0.66	0.53	79.77	
H-10-71.16-1-15	1221.95	0.28	19.95	17.06	3.95	5.51	1.33	0.15	1.28	0.44	128.75	0.72
H-10-69.7-2-16	274.09	0.45	23.80	22.00	4.89	2.69	1.41	0.15	2.05	0.71	111.02	0.00
H-10-69.7-2-14	346.30	0.70	12.70	10.30	1.30	1.80	2.01	0.13	2.05	0.09	63.11	0.92
Anaswara	462.29	0.14	18.36	17.60	6.92	1.73	1.29	0.07	0.24	0.46	23.85	0.80

Table 4.20. Variance of families of F_5 generation of cross H11

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H-11-10.34-1-16	484.06	1.15	22.97	16.38	10.06	4.72	1.08	0.14	0.3	0.67	61.75	0.25
H-11-2.20-3-14	2222.06	0.82	17.67	12.05	7.88	7.39	1.21	0.04	0.4	1.02	90.2	0.55
H-11-3.9-1-1	2247.33	0.73	15.23	10.47	4.93	7.39	1.24	0.07	1.64	0.46	157.8	2.13
H-11-10.34-1-18	731.05	0.89	24.96	19.02	7.49	6.67	1.91	0.12	2.21	0.49	107.69	1.14
H-11-34-16-1-15	824.81	0.42	23.9	16.42	14.62	4.18	1.56	0.15	0.84	0.7	90.53	0.81
H-11-36.5-3-15	1014.92	0.85	17.07	11.85	11.11	3.41	0.58	0.19	1.07	0.81	115.03	0.09
H-11-3.9-1-7	362.51	0.62	13.45	20.44	11.53	2.75	0.88	0.16	0.15	1.14	59.3	0.72
H-11-36.5-3-8	1118.38	0.25	13.94	9.19	11.12	1.22	0.37	0.02	0.17	0.15	10.41	0.92
H-11-3.9-1-10	98.93	0.44	18.26	17.72	1.9	3.71	0.56	0.12	0.46	0.32	33.2	0.36
H-11-49.7-1-8	908.05	0.49	12.23	10.67	6.94	4.17	1.21	0.29	1.26	0.85	174.82	0.01

4.2.3. Genetic variability studies in F_5 generation

4.2.3.1. Plant height (cm)

In F_5 generation of cross H 10, the PCV was 17.20 per cent and GCV was 9.75 per cent. The heritability for this character was 45.52 per cent. Genetic advance for this character was 27.32. Genetic advance expressed as per cent of mean was 16.12 per cent.

In F_5 generation of cross H 11, the PCV was 18.60 per cent and GCV was 15.23 per cent. The heritability for this character was 67.08 per cent. Genetic advance for this character was 51.79. Genetic advance expressed as per cent of mean was 25.70 per cent.

4.2.3.2. Number of branches per plant

In F_5 generation of cross H 10, the PCV was 19.04 per cent and GCV was 13.93 per cent. The heritability for this character was 66.67 per cent. Genetic advance for this character was 0.89. Genetic advance expressed as per cent of mean was 26.15 per cent.

In F_5 generation of cross H 11, the PCV was 22.40 per cent and GCV was 11.47 per cent. The heritability for this character was 26.39 per cent. Genetic advance for this character was 0.46. Genetic advance expressed as per cent of mean was 12.15 per cent.

4.2.3.3. Days to first flowering

In F_5 generation of cross H 10, the PCV was 6.74 per cent and GCV was zero per cent. The heritability for this character was zero per cent.

In F_5 generation of cross H 11, the PCV was 7.51 per cent and GCV was 2.09 per cent. The heritability for this character was 7.74 per cent. Genetic advance for this character was 0.71. Genetic advance expressed as per cent of mean was 1.19 per cent.

4.2.3.4. Days to first harvest

In F_5 generation of cross H 10, the PCV was 4.64 per cent and GCV was zero per cent. The heritability for this character was zero per cent.

In F_5 generation of cross H 11, the PCV was 4.93 per cent and GCV was zero per cent. The heritability for this character was zero per cent.

4.2.3.5. Days to last harvest

In F_5 generation of cross H 10, the PCV was 4.03 per cent and GCV was 3.40 per cent. The heritability for this character was 71.20 per cent. Genetic advance for this character was 7.19. Genetic advance expressed as per cent of mean was 5.91 per cent.

In F_5 generation of cross H 11, the PCV was 4.25 per cent and GCV was 2.16 per cent. The heritability for this character was 74.06 per cent. Genetic advance for this character was 7.89. Genetic advance expressed as per cent of mean was 6.48 per cent.

4.2.3.6. Number of pods per plant

In F_5 generation of cross H 10, the PCV was 5.67 per cent and GCV was 3.40 per cent. The heritability for this character was 71.20 per cent. Genetic advance for this character was 7.19. Genetic advance expressed as per cent of mean was 5.91 per cent.

In F_5 generation of cross H 11, the PCV was 8.84 per cent and GCV was 7.81 per cent. The heritability for this character was 78.05 per cent. Genetic advance for this character was 4.52. Genetic advance expressed as per cent of mean was 14.22 per cent.

4.2.3.7. Pod length (cm)

In F_5 generation of cross H 10, the PCV was 13.61 per cent and GCV was 11.57 per cent. The heritability for this character was 84.91 per cent. Genetic advance

for this character was 5.11. Genetic advance expressed as per cent of mean was 23.78 per cent.

In F_5 generation of cross H 11, the PCV was 11.37 per cent and GCV was 10.27 per cent. The heritability for this character was 81.57 per cent. Genetic advance for this character was 4.45. Genetic advance expressed as per cent of mean was 19.13 per cent.

4.2.3.8. Single pod weight (g)

In F_5 generation of cross H 10, the PCV was 21.17 per cent and GCV was 16.76 per cent. The heritability for this character was 70.83 per cent. Genetic advance for this character was 0.71. Genetic advance expressed as per cent of mean was 31.08 per cent.

In F_5 generation of cross H 11, the PCV was 21.87 per cent and GCV was 19.06 per cent. The heritability for this character was 81.57 per cent. Genetic advance for this character was 4.45. Genetic advance expressed as per cent of mean was 19.13 per cent.

4.2.3.9. Number of seeds per pod

In F_5 generation of cross H 10, the PCV was 9.75 per cent and GCV was 9.35 per cent. The heritability for this character was 90.00 per cent. Genetic advance for this character was 2.87. Genetic advance expressed as per cent of mean was 18.08 per cent.

In F_5 generation of cross H 11, the PCV was 8.94 per cent and GCV was 8.37 per cent. The heritability for this character was 87.81 per cent. Genetic advance for this character was 2.53. Genetic advance expressed as per cent of mean was 16.12 per cent.

4.2.3.10. Hundred seed weight (g)

In F_5 generation of cross H 10, the PCV was 13.78 per cent and GCV was 11.60 per cent. The heritability for this character was 85.80 per cent. Genetic advance

for this character was 3.18. Genetic advance expressed as per cent of mean was 24.34 per cent.

In F_5 generation of cross H 11, the PCV was 13.15 per cent and GCV was 12.27 per cent. The heritability for this character was 87.11 per cent. Genetic advance for this character was 3.39. Genetic advance expressed as per cent of mean was 23.60 per cent.

4.2.3.11. Grain yield per plant (g)

In F_5 generation of cross H 10, the PCV was 15.18 per cent and GCV was 11.88 per cent. The heritability for this character was 75.66 per cent. Genetic advance for this character was 15.43. Genetic advance expressed as per cent of mean was 23.65 per cent.

In F_5 generation of cross H 11, the PCV was 14.84 per cent and GCV was 13.22 per cent. The heritability for this character was 79.35 per cent. Genetic advance for this character was 17.57. Genetic advance expressed as per cent of mean was 24.26 per cent.

4.2.3.12. Protein content (%)

In F_5 generation of cross H 10, the PCV was 4.38 per cent and GCV was 2.27 per cent. The heritability for this character was 27.93 per cent. Genetic advance for this character was 0.60. Genetic advance expressed as per cent of mean was 2.52 per cent.

In F_5 generation of cross H 11, the PCV was 4.52 per cent and GCV was 2.65 per cent. The heritability for this character was 34.42 per cent. Genetic advance for this character was 0.78. Genetic advance expressed as per cent of mean was 3.21 per cent.

Table 4.21. Genetic parameters of F_5 generation of cross H10

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H^2	GA	GAM (%)
Plant height	848.58	386.29	462.29	17.20	9.75	45.52	27.32	16.12
No. of branches	0.42	0.28	0.14	19.04	13.93	66.67	0.89	26.15
Days to first flowering	16.03	0.00	18.36	6.74	0.00	0.00	0.00	0.00
Days to first harvest	13.33	0.00	17.60	4.64	0.00	0.00	0.00	0.00
Days to last harvest	24.03	17.11	6.92	4.03	3.40	71.20	7.19	5.91
No. of pods/plant	3.08	1.35	1.73	5.67	3.65	43.83	1.58	5.11
Length of pod	8.55	7.26	1.29	13.61	11.57	84.91	5.11	23.78
Pod weight	0.24	0.17	0.07	21.17	16.76	70.83	0.71	31.08
No. of seeds / pod	2.40	2.16	0.24	9.75	9.35	90.00	2.87	18.08
Test weight	3.24	2.78	0.46	13.78	11.60	85.80	3.18	24.34
Grain yield/ plant	97.99	74.14	23.85	15.18	11.88	75.66	15.43	23.65
Protein content	1.11	0.31	0.80	4.38	2.27	27.93	0.60	2.52

Table 4.22. Genetic parameters of F_5 generation of cross H11

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H^2	GA	GAM (%)
Plant height	1404.37	942.08	462.29	18.60	15.23	67.08	51.79	25.70
No. of branches	0.72	0.19	0.14	22.40	11.47	26.39	0.46	12.15
Days to first flowering	19.90	1.54	18.36	7.51	2.09	7.74	0.71	1.19
Days to first harvest	15.05	0.00	17.60	4.93	0.00	0.00	0.00	0.00
Days to last harvest	26.68	19.76	6.92	4.25	2.16	74.06	7.89	6.48
No. of pods/plant	7.88	6.15	1.73	8.84	7.81	78.05	4.52	14.22
Length of pod	7.00	5.71	1.29	11.37	10.27	81.57	4.45	19.13
Pod weight	0.29	0.22	0.07	21.87	19.06	75.86	0.84	34.30
No. of seeds / pod	1.97	1.73	0.24	8.94	8.37	87.81	2.53	16.12
Test weight	3.57	3.11	0.46	13.15	12.27	87.11	3.39	23.60
Grain yield/ plant	115.50	91.65	23.85	14.84	13.22	79.35	17.57	24.26
Protein	1.22	0.42	0.80	4.52	2.65	34.42	0.78	3.21

4.2.4. Correlation studies

4.2.4.1. Correlations between quantitative characters in F_5 generation of cross H 10 of cowpea

Correlation analysis among quantitative characters in F5 generation of cross H 10 showed that grain yield was positively correlated with plant height (0.419), number of branches per plant (0.313), number of pods per plant (0.485), length of pod (0.526) pod weight(0.680), number of seeds / pod (0.438)and test weight(0.642). Grain yield was found negatively correlated with days to first flowering and days to first harvest. Grain yield showed non-significant positive correlation with seed protein content.

Positive and significant correlation was found between plant heights with number of branches per plant (0.296), days to last harvest (0.333), pod length (0.696), single pod weight (0.458), and hundred seed weight (0.726). It showed significant negative correlation with number of seeds per pod (-0.339).

Number of branches per plant showed non- significant and negative correlation with days to first flowering (-0.146), days to first harvest (-0.143) and days to last harvest. Also it exhibits significant positive correlation with number of pods per plant (0.234), single pod weight (0.291), pod length (0.252) and hundred seed weight (0.251).

Days to first flowering showed significant and positive correlation with days to first harvest (0.850) and days to last harvest (0.327). It showed significant negative correlation with plant height, days to first flowering, number of pods per plant, single pod weight, number of seeds per plant and seed protein content.

Days to first harvest showed significant positive correlation with days to last harvest (0.378). It exhibits significant negative correlation with seeds per pod (-0.246).

Days to last harvest showed significant positive correlation with pod length (0.365), pod weight (0.201) and hundred seed weight (0.337). It exhibits significant negative correlation with pods per plant (-0.186) and seeds per pod (-0.299).

Pods per plant gave significant positive correlation with single pod weight (0.185) and number of seeds per plant (0.328).

There was significant positive correlation between pod length and single pod weight (0.700), number of seeds per plant (0.618), hundred seed weight (0.854) and seed protein content (0.698). It also showed significant negative correlation with seeds per pod (-0.236).

Pod weight exhibited significant positive correlation with hundred seed weight (0.669) and seed protein content (0.586).

Number of seeds per pod showed significant negative correlation with hundred seed weight (-0.311). Hundred seed weight showed significant positive correlation with protein content (0.614).

4.2.4.2. Correlations between quantitative characters in F_5 generation of cross H 11 of cowpea

Correlation analysis among quantitative characters in F5 generation of cross H 11 showed that grain yield was significantly and positively correlated with plant height (0.496), number of branches per plant (0.291), number of pods per plant (0. 570), length of pod (0. 505) pod weight(0.393), number of seeds / pod (0. 402)and test weight(0. 474). Grain yield was found negatively correlated with days to first flowering and days to first harvest.

Significant and positive relation was observed between plant height with number of branches per plant (0.172), number of pods per plant (0.528), pod length (0.196). It showed significant negative correlation with days to first flowering (-0.248) and days to first harvest (-0.239).

Number of branches per plant showed significant and negative correlation with days to first flowering (-0.342) and days to last harvest (-0.324). Days to first flowering exhibits significant positive correlation with number of pods per plant (0.452) and seeds per pod (0.216).

Days to first flowering showed significant and positive correlation with days to first harvest (0.930) and days to last harvest (0.424). It showed significant negative correlation with number of pods per plant and number of seeds per pod.

Days to first harvest showed significant positive correlation with days to last harvest (0.457). It showed significant negative correlation with pod weight and number of seeds per pod.

Pods per plant gave significant positive correlation with number of seeds per pod (0.377) and negative correlation with hundred seed weight (-0.249).

There was significant positive correlation between pod length and single pod weight (0.524), hundred seed weight (0.803) and negative correlation with number of seeds per pod (-0.238).

Pod weight exhibited significant positive correlation with number of seeds per pod (0.238), hundred seed weight (0.337) and grain yield per plant (0.393).

Number of seeds per pod showed significant negative correlation with hundred seed weight (-0.448).

Table 4.23. Correlation of F_5 generation of cross H10

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.296**	0.055	0.071	0.333**	0.076	0.696**	0.458**	-0.339**	0.726**	0.419**	0.596**
X2		1	-0.146	-0.143	-0.019	0.234**	0.252**	0.291**	0.020	0.251**	0.313**	0.219
X3			1	0.850**	0.327**	-0.087	0.080	0.024	-0.112	0.073	-0.068	-0.460*
X4				1	0.378**	-0.090	0.055	-0.026	-0.246**	0.066	-0.159*	-0.111
X5					1	-0.186*	0.365**	0.201*	-0.299**	0.337**	0.028	0.340
X6						1	-0.097	0.185*	0.328**	-0.008	0.485**	-0.055
X7							1	0.700**	-0.236**	0.854**	0.526**	0.698**
X8								1	0.057	0.669**	0.680**	0.586**
X9									1	-0.311**	0.438**	-0.227
X10										1	0.642**	0.614**
X11											1	0.342
X12												1

Table 4.24. Correlation of F_5 generation of cross H11

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	0.172*	-0.248**	-0.239**	0.054	0.528**	0.196*	0.032	0.125	0.140	0.496**
X2		1	-0.342**	-0.324**	-0.063	0.452**	-0.024	0.042	0.216*	-0.133	0.291**
X3			1	0.930**	0.424**	-0.408**	-0.013	-0.096	-0.267**	0.124	-0.301**
X4				1	0.457**	-0.384**	-0.038	-0.178*	-0.319**	0.100	-0.335**
X5					1	-0.152	0.335**	-0.180*	-0.321**	0.474**	0.157
X6						1	-0.148	-0.086	0.377**	-0.249**	0.570**
X7							1	0.524**	-0.238**	0.803**	0.505**
X8								1	0.238**	0.337**	0.393**
X9									1	-0.448**	0.402**
X10										1	0.474**
X11											1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

X1 – Plant height (cm)
X2 – Number of branches per plant
X3 – Days to first flowering
X4 – Days to first harvest
X5 – Days to last harvest
X6 – Number of pods per plant
X7 – Pod length (cm)
X8 – Single pod weight (g)
X9 – Number of seeds per plant
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

4.2.5. Path analysis in F_5 generation

4.2.5.1. Path analysis in F_5 generation of cross H10

Path analysis with direct and indirect effect of various quantitative traits on grain yield was done using unreplicated data from F_5 generation of cowpea cross and the results are presented in table 4.25 and 4.26. The residual effect contribution on grain yield was 0.05415 in analysis with cross H10.

4.2.5.1 1. Direct effect on grain yield

High positive direct effect on grain yield was given by number of seeds per pod (0.5727) and hundred seed weight (0.8357). Moderate direct effect was given by number of pods per plant on grain yield. Negligible positive direct effect was given by plant height and number of branches. Low positive direct effect on grain yield was given by pod weight. Low negative direct effect was given by pod length on grain yield. Negligible negative direct effect was given by number of branches, days to first flowering, days to first harvest and days to last harvest on grain yield.

4.2.5.1 2. Indirect effects on grain yield

Plant height

High positive indirect effect was exerted by hundred seed weight (0.607) through plant height on grain yield. Negligible, positive, indirect effect was exerted by plant height through number of branches, pods per plant (0.02) and pod weight (0.047)towards grain yield. Low negative indirect was given by seeds per pod. Negligible indirect effect was given by plant height through the other characters.

Number of branches per plant

Moderate and positive, indirect effect was exerted by number of branches per plant through hundred seed weight (0.209) towards grain yield. Negligible indirect effect was shown by other characters through number of branches per plant to grain yield.

Days to first flowering

Negligible indirect effect was shown by all characters through days to first flowering to grain yield.

Days to first harvest

Low and negative, indirect effect was exerted by days to first harvest through seeds per pod (-0.141) towards grain yield. Negligible indirect effect was shown by other characters through days to first harvest towards grain yield.

Days to last harvest

Moderate indirect positive effect was exerted by hundred seed weight to grain yield. Low indirect negative effect was exerted by seeds per pod on grain yield. Negligible indirect effect was shown by other characters through days to last harvest towards grain yield.

Number of pods per plant

Low, positive indirect effect was exerted by number of pods per plant through seeds per pod(0.187) towards grain yield. Negligible indirect effect was shown by other characters through number of pods per plant towards grain yield.

Pod length

High, positive indirect effect was exerted by pod length through hundred seed weight (0. 713) towards grain yield. Low negative indirect effect was given by seeds per pod towards grain yield. Negligible indirect effect was exerted by pod length through other characters towards grain yield.

Single pod weight

High, positive and indirect effect was exerted by single pod weight through hundred seed weight (0.559) towards grain yield. Negligible indirect effect was exerted by single pod weight through other characters towards grain yield.

Number of seeds per pod

Moderate negative and indirect effect was exerted by number of seeds per pod through hundred seed weight (-0.259) towards grain yield. Negligible and indirect effect was exerted by number of seeds per pod through other characters under study.

Hundred seed weight

Low negative indirect effect was exerted by seeds per pod towards grain yield. Negligible and indirect effect was exerted by hundred seed weight through other characters under study.

Path analysis in F_5 generation of cross H11

Path analysis with direct and indirect effect of various quantitative traits on grain yield was done using unreplicated data from F_5 generation of cowpea cross and the results are presented in table.4.26. The residual effect contribution on grain yield was 0.02547in analysis with cross H11.

Direct effect on grain yield

High positive direct effect on grain yield was given by number of pods per plant (0.550) number of seeds per pod (0.566) and hundred seed weight (0.801). Negligible direct effect was given other characters on grain yield.

Indirect effects on grain yield

Plant height

Moderate positive indirect effect was exerted by number of pods per plant (0.290) through plant height on grain yield. Low positive indirect effect was given by hundred seed weight (0.111). Negligible indirect effect was given by plant height through the other characters.

Number of branches per plant

Moderate and positive, indirect effect was exerted by number of branches per plant through number of pods per plant (0.249) towards grain yield. Low positive indirect effect was given by number of seeds per pod on grain yield whereas low negative effect was given by hundred seed weight. Negligible indirect effect was shown by other characters through number of branches per plant to grain yield.

Days to first flowering

Negligible indirect effect was shown by all characters through days to first flowering to grain yield except through number of seeds per pod which gave low negative indirect effect.

Days to first harvest

Moderate and negative, indirect effect was exerted by days to first harvest through pods per plant (-0.211) towards grain yield and low negative effect was given through number of seeds per pod. Negligible indirect effect was shown by other characters through days to first harvest towards grain yield.

Days to last harvest

High indirect positive effect was exerted by hundred seed weight to grain yield. Low indirect negative effect was exerted by seeds per pod on grain yield. Negligible indirect effect was shown by other characters through days to last harvest towards grain yield.

Number of pods per plant

Moderate, positive indirect effect was exerted by number of pods per plant through seeds per pod(0.213) towards grain yield. Low negative indirect effect was given by hundred seed weight. Negligible indirect effect was shown by other characters through number of pods per plant towards grain yield.

Pod length

High, positive indirect effect was exerted by pod length through hundred seed weight (0. 643) towards grain yield. Low negative indirect effect was given by seeds per pod towards grain yield. Negligible indirect effect was exerted by pod length through other characters towards grain yield.

Single pod weight

Moderate, positive and indirect effect was exerted by single pod weight through hundred seed weight (0.271) towards grain yield. Low positive indirect effect was exerted by seeds per pod on grain yield. Negligible indirect effect was exerted by single pod weight through other characters towards grain yield.

Number of seeds per pod

Moderate positive and indirect effect was exerted by number of seeds per pod through number of pods per plant (0.207) towards grain yield. High negative indirect effect was exerted by hundred seed weight (-0.358). Negligible and indirect effect was exerted by number of seeds per pod through other characters under study.

Hundred seed weight

Moderate negative indirect effect was given through seeds per pod. Low negative indirect effect was exerted by pods per plant towards grain yield. Negligible and indirect effect was exerted by hundred seed weight through other characters under study.

Table 4.25. Path analysis in F_5 generation of H10

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	r_{xy}
X1	**0.01329**	0.00519	-0.00251	-0.00014	-0.00154	0.02005	-0.07645	0.04792	-0.19391	0.60701	0.596**
X2	0.00393	**0.01757**	0.00036	0.00501	0.00009	0.06206	-0.02767	0.03040	0.01164	0.20949	0.219
X3	0.00073	-0.00256	**-0.00249**	-0.02984	-0.00152	-0.02297	-0.00880	0.00254	-0.06434	0.06110	-0.460*
X4	0.00095	-0.00250	-0.00211	**-0.03512**	-0.00175	-0.02383	-0.00605	-0.00275	-0.14075	0.05530	-0.111
X5	0.00442	-0.00033	-0.00081	-0.01326	**-0.00464**	-0.04922	-0.04010	0.02100	-0.17110	0.28172	0.340
X6	0.00101	0.00412	0.00022	0.00316	0.00086	**0.26478**	0.01062	0.01938	0.18760	-0.00655	-0.055
X7	0.00926	0.00443	-0.00020	-0.00194	-0.00169	-0.02563	**-0.10977**	0.07320	-0.13532	0.71371	0.698**
X8	0.00609	0.00511	-0.00006	0.00092	-0.00093	0.04906	-0.07683	**0.10459**	0.03299	0.55946	0.586**
X9	-0.00450	0.00036	0.00028	0.00863	0.00139	0.08673	0.02593	0.00602	**0.57275**	-0.25976	-0.227
X10	0.00965	0.00440	-0.00018	-0.00232	-0.00156	-0.00208	-0.09374	0.07001	-0.17801	**0.83578**	0.614**

Residual are 0.05415

X1 – Plant height (cm)
X2 – Number of branches per plant
X3 – Days to first flowering
X4 – Days to first harvest
X5 – Days to last harvest
X6 – Number of pods per plant
X7 – Pod length (cm)
X8 – Single pod weight (g)
X9 – Number of seeds per plant
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

Table 4.26. Path analysis in F_5 generation of H11

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	r_{xy}
X1	**-0.00454**	0.00319	0.00936	-0.00071	0.00215	0.29085	0.01240	0.00029	0.07089	0.11184	0.496**
X2	-0.00078	**0.01859**	0.01292	-0.00097	-0.00248	0.24905	-0.00152	0.00025	0.12221	-0.10614	0.291**
X3	0.00112	-0.00635	**-0.03781**	0.00277	0.01671	-0.22443	-0.00081	-0.00055	-0.15116	0.09903	-0.301**
X4	0.00108	-0.00603	-0.03518	**0.00298**	0.01800	-0.21126	-0.00241	-0.00101	-0.18075	0.07967	-0.335**
X5	-0.00025	-0.00117	-0.01604	0.00136	**0.03939**	-0.08382	0.02117	-0.00097	-0.18168	0.37923	0.157
X6	-0.00240	0.00841	0.01541	-0.00114	-0.00600	**0.55049**	-0.00934	-0.00047	0.21366	-0.19900	0.570**
X7	-0.00089	-0.00045	0.00049	-0.00011	0.01321	-0.08147	**0.06314**	0.00293	-0.13477	0.64295	0.505**
X8	-0.00024	0.00083	0.00372	-0.00054	-0.00685	-0.04675	0.03332	**0.00555**	0.13535	0.27113	0.393**
X9	-0.00057	0.00401	0.01009	-0.00095	-0.01263	0.20755	-0.01501	0.00133	**0.56670**	-0.35861	0.402**
X10	-0.00063	-0.00246	-0.00468	0.00030	0.01866	-0.13682	0.05070	0.00188	-0.25382	**0.80067**	0.474**

Residual are 0.02547

r_{xy}- phenotypic correlation

4.2.6. Selection criteria

The criteria was developed such that it was superior to the parent Anaswara. Based on the segregation pattern observed, the plants were grouped into two different categories - one with medium long pods and small seeds closely packed within the pod and the other type with long fleshy pods and bold seeds. Hence, separate selection criteria was developed for both the types comprising of characters like number of pods, number of seeds per pod, pod length, hundred seed weight, grain yield and protein content.

a) Family average greater than Anaswara for grain yield

Type 1

No. of pods - 35

No. of seeds/ pod – 16

Pod length –20 cm

Hundred seed weight-11.5g

Grain yield - 85g/plant

Protein – 22%

Type 2

No. of pods - 30

No. of seeds/ pod -15

Pod length-24 cm

Hundred seed weight-14g

Grain yield - 90g/plant

Protein – 22%

Based on these set criteria, five individual plants from cross H10 and 17 plants from cross H11 were selected. The features of the selected plants are given in the table 4.27 and 4.28.

Table 4.27. Features of individual plants selected and advanced to F_6 generation of cross H 10

Plant	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod	Pod weight	No. of seeds / pod	Test weight	Grain yield	Protein content
H-10-71-16-1-9-15	240.00	7.00	55.00	73.00	115.00	33.00	27.30	3.65	17.60	17.52	102.50	24.03
H-10-69.5-3-18-12	184.00	4.00	54.00	73.00	114.00	36.00	21.50	3.12	18.50	14.80	98.56	22.50
H-10-71.16-1-15-10	262.00	4.00	55.00	73.00	123.00	36.00	26.20	3.80	17.50	16.90	99.56	25.90
H-10-69.7-2-16-15	190.00	4.00	54.00	73.00	123.00	32.00	27.60	3.89	18.20	16.20	94.60	25.40
H-10-69.7-2-14-10	185.00	4.00	55.00	74.00	124.00	30.00	28.00	3.80	18.50	14.10	90.60	24.80

Table 4.28. Features of individual plants selected and advanced to F_6 generation of cross H 11

Plant	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod	Pod weight	No. of seeds / pod	Test weight	Grain yield	Protein content
H-11-10.34-1-16-11	220.00	3.00	55.00	73.00	135.00	35.00	27.00	2.95	15.50	17.44	91.88	25.40
H-11-2.20-3-14-13	295.00	5.00	53.00	73.00	126.00	38.00	26.50	2.30	15.60	16.02	96.44	23.70
H-11-2.20-3-14-16	290.00	6.00	53.00	73.00	124.00	38.00	26.66	2.28	15.75	16.27	98.40	24.80
H-11-2.20-3-14-7	181.00	4.00	65.00	84.00	130.00	32.00	24.10	1.68	16.80	15.80	90.10	23.80
H-11-3.9-1-1-11	251.00	4.00	54.00	78.00	118.00	38.00	20.50	1.97	16.30	12.63	85.80	26.10
H-11-3.9-1-1-12	210.00	4.00	53.00	73.00	15.00	40.00	20.60	2.20	17.60	11.86	85.20	23.40
H-11-3.9-1-1-18	260.00	4.00	52.00	73.00	114.00	40.00	21.10	2.34	18.10	12.12	90.10	26.10
H-11-3.9-1-1-19	261.00	4.00	53.00	73.00	114.00	40.00	21.20	2.32	18.20	11.34	85.55	23.80
H-11-10.34-1-18-16	265.00	5.00	54.00	73.00	123.00	34.00	27.60	2.99	18.20	14.38	90.98	24.50
H-11-10.34-1-18-17	260.00	5.00	52.00	73.00	121.00	36.00	26.30	2.00	15.90	14.90	90.50	24.70
H-11-34-16-1-15-13	210.00	3.00	57.00	73.00	116.00	34.00	26.80	3.40	18.00	16.30	99.75	23.70
H-11-36.5-3-15-1	210.00	4.00	56.00	73.00	115.00	32.00	27.00	3.80	16.00	17.30	90.57	23.80
H-11-36.5-3-15-2	250.00	5.00	53.00	73.00	115.00	35.00	26.70	3.89	17.10	16.80	100.54	24.10
H-11-36.5-3-15-16	260.00	5.00	52.00	73.00	115.00	33.00	26.40	3.67	16.80	15.20	90.26	23.50
H-11-3.9-1-7-13	201.00	5.00	57.00	73.00	120.00	34.00	22.00	3.19	18.00	14.80	90.28	23.80
H-11-49.7-1-8-10	165.00	3.00	62.00	80.00	120.00	31.00	28.30	4.73	17.60	17.40	94.50	25.30
H-11-49.7-1-8-16	235.00	5.00	57.00	74.00	124.00	33.00	28.40	3.81	18.10	17.60	106.10	25.40

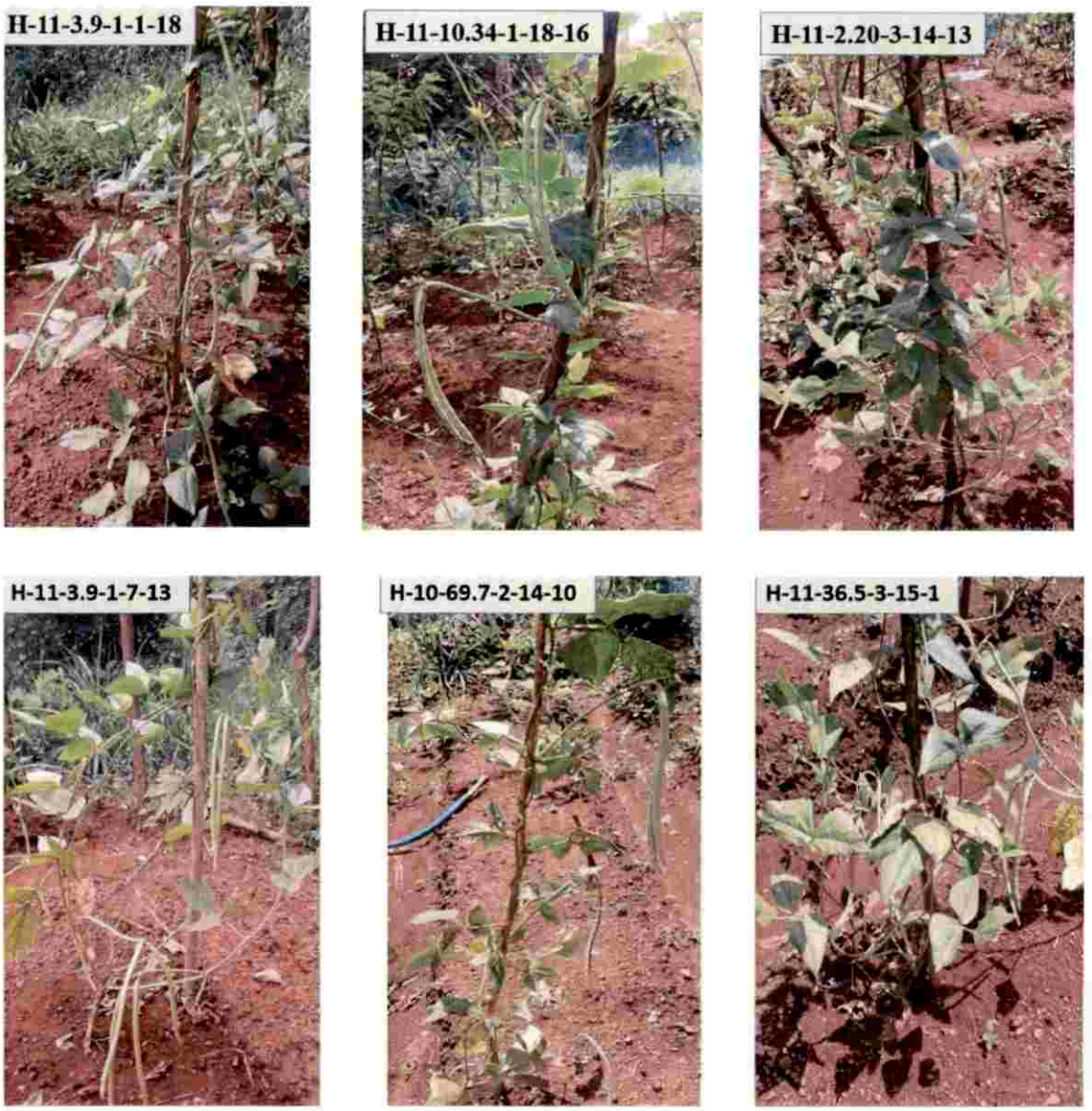

Plate 5. Plants selected from F_5 generation

4.3. Experiment 3: Evaluation of F_6 generation

4.3.1. Estimation of means and variance

The mean and variance of each character for the F_6 generation of H 10 and H 11 crosses are estimated and are presented in tables 4.29 and 4.30. The salient conclusions from the estimates are given below.

4. 3. 1. 1. Plant height (cm)

The mean value for plant height in F_6 generation of cross H10 was 99.16 cm which is less than of the parent Anaswara (118.83 cm). The values ranged from 57cm cm to 225cm with variance of 951.239.

Similarly in F_6 generation of cross H11 mean value of plant height was 104.45 cm which is less than of the parent Anaswara. The values ranged from 40 to 240cm with variance of 1791.858.

4. 3. 1. 2. Number of branches per plant

The mean value for number of branches per plant in F_6 generation of cross H10 was 2.86 which is less than that of the parent Anaswara (3.17). The values ranged from 1 to 6 with variance of 1.551.

Similarly in F_6 generation of cross H11 mean value of number of branches per plant was 3.041 which is higher than that of the parent Anaswara. The values ranged from 1 to 6 with variance of 1.933.

Comparing between H10 andH11 families, it showed that they perform similar in number of branches.

4. 3. 1. 3. Days of first flowering

The mean value for days to first flowering in F_6 generation of cross H10 was 60.7 which is less than of the parent Anaswara (63.5). In the F_6 population of H11, days to first flowering was 61.64. Both the population do not differ with respect to the mean

value for first days to flowering. Days to first flowering ranged from 46 to 66 days in H10 and 46 to 68 days in H11.

The variance for days to first flowering was higher for H10 segregants (27.84) than H11 segregants (21.65).

4. 3. 1. 4. Days to first harvest

In F_6 generation of cross H10, the days taken for first harvest ranged from 65 to 85 days. The average days taken for first harvest was 79 in F_6 population of cross H 10 whereas it was 79.74 in H11 cross. In H11 segregants the days to first harvest ranges between 59 to 89 days. Anaswara took 83.5 days for first harvest.

When both the F_6 population of cross H 10 and H 11 were considered for variability, H 11 cross showed high variability for days taken for first harvest with a value of 22.79.

4. 3. 1. 5. Days to last harvest

In F_6 generation of cross H10, the days taken to last harvest ranged from 104 to 115 days. The average value for days to last harvest was 109.56. In F_6 generation of cross H11, the range for days of last harvest was 99 to 122 days with an average of 110.406 days. . The last harvest for Anaswara was 111.17 days.

The high variance of 13.248 was observed in cross H 11 than H10 for days to last harvest in F_6 population.

4. 3. 1. 6. Number of pods per plant

Number of pods per plant in F_6 generation of cross H10 ranged from 25 to 37, with an average of 29.22, whereas in cross H11 it ranged from 24 to 44, with mean value was 32.659. Anaswara exhibited 28.83 number of pods per plant.

The high variance (29.291) for number of pods per plant was observed in F_6 population of cross H 11 compared to H10.

4. 3. 1. 7. Pod length (cm)

In F_6 generation of cross H10, the length of the pod ranged from 17 to 28cm, with mean value of 23.958cm. In cross H11 pod length ranged from 15 to 30 cm with average value of 23.01 cm. The pod length of Anaswara was 25.35 cm.

Comparing variances between two populations, H 11 population exhibited higher variance (12.437) for pod length than H 10 (10.312) population in F_6 generation.

4. 3. 1. 8. Pod weight (g)

In F_6 generation of cross H10, the pod weight ranged from 1.8 to 4.6 g, with an average weight of 3.151g. In H 11 population, pod weight ranged from 1.59 to 4.65g with mean value of 3.143g. Pod weight of Anaswara was 3.29g.

The variability was high in H 10 cross (0.49) when compared to H 11 (0.428) cross in F_6 generation.

4. 3. 1. 9. Number of seeds per pod

In F_6 population of cross H10, the number of seeds per pod ranged from 14 to 17 with mean value of 15.382. In cross H11 population it ranged from 12 to 19 with average number value of 15.238. Anaswara exhibited 15.23 seeds per pod.

Cross H 11 (1.476) showed the high variability than H 10 cross (1.46) for number of seeds per pod in F_6 population.

4. 3. 1. 10. Hundred seed weight (g)

The weight for hundred seeds in F_6 generation of cross H10 ranged from 11.2 to 20.5 g with average value of 16.445 g. In cross H 11 population, the hundred seed weight ranged from 11.3 to 21.8 g with an average of 16.175 g. Hundred seed weight of Anaswara was 17.62g.

The cross H 11 (7.01) showed higher variance than that of H 10 (6.624) cross in F_6 population.

4. 3. 1. 11. Grain yield per plant (g)

In cross H 10, the value for grain yield per plant ranged from 46.4 to 113.5 g in F_6 generation. The average grain yield was 74.729g. In F_6 generation of cross H 11, the range for grain yield per plant was 56.28 to 152.6 g with an average grain yield of 80.069 g. Anaswara gave a yield of 80.90g per plant.

The cross H 10 (249.34) showed higher variability than that of H 11 cross (220.889) in F_6 population.

4. 3. 1. 12. Protein content (%)

The protein content in seeds ranged from 21.87 to 26.1 per cent in F_6 population of cross H10, with average of 23.534 per cent. In F_6 population of cross H 11, the protein content ranged from 20.53 to 26.5 per cent, with average protein content of 23.91 per cent. The protein content of Anaswara seed was 23.65 per cent.

The cross H 10 (3.089) showed higher variability for protein content than cross H 11 (2.004) in F_6 population.

Table 4.29. Variability parameters in F_6 generation of cross H10

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F_6 generation for quantitative characters												
P_1	118.83	3.17	63.50	83.50	111.17	28.83	25.35	3.29	15.23	17.62	80.90	23.65
F_6	99.16	2.86	60.70	79.00	109.56	29.22	23.96	3.15	15.38	16.45	74.73	23.53
Variance of parents and F_6 generation for quantitative characters in cowpea												
P_1	923.61	0.88	8.27	5.91	6.15	8.15	0.63	0.11	1.34	0.26	216.44	0.55
F_6	951.24	1.55	27.85	20.12	6.46	8.34	10.312	0.49	1.46	6.63	249.35	3.09
Range of F_6 generation for quantitative characters in cowpea												
Min	57	1	46	65	104	25	17	1.80	14	11.20	46.40	21.87
Max	225	6	66	85	115	37	28	4.60	17	20.50	113.50	26.10
Range	168	5	20	20	11	12	11	2.80	3	9.30	67.10	4.230

Table 4.30. Variability parameters in F_6 generation of cross H11

Population	Plant height (cm)	No. of branches /plant	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods /plant	Pod length (cm)	Pod weight (g)	No. of seeds /pod	100 seed weight (g)	Grain yield /plant (g)	Protein content (%)
Mean of F_6 generation for quantitative characters												
P_1	118.83	3.17	63.50	83.50	111.17	28.83	25.35	3.29	15.23	17.62	80.90	23.65
F_6	104.45	3.04	61.64	79.75	110.41	32.66	23.01	3.14	15.24	16.18	80.07	23.91
Variance of parents and F_6 generation for quantitative characters in cowpea												
P_1	923.61	0.88	8.27	5.91	6.15	8.15	0.63	0.11	1.34	0.26	216.44	0.55
F_6	1791.86	1.93	21.65	22.79	13.25	21.29	12.44	0.43	1.48	7.01	220.89	2.00
Range of F_6 generation for quantitative characters in cowpea												
Min	40	1	46	59	99	24	15	1.59	12	11.30	56.28	20.53
Max	240	6	68	89	122	44	30	4.65	19	21.80	152.60	26.50
Range	200	5	22	30	23	20	15	3.06	7	10.50	96.32	5.97

4.3.2. Average and variances of family

4.3.2. a. Estimation of mean and variance of families

The mean and variances for the 12 characters within each family of both crosses are worked out to find the variability within family and is presented in the tables 4.31 and 4.32.

4.3.2. 1. Plant height

Comparing the mean value of plant height between families, H-11-2-20-3-14-16 exhibited the highest value (146.20 cm) while the lowest value was 69.60cm (H11-36.5-3-15-16). Plant height of Anaswara was 118.83 cm.

Variance among family ranged between 174 (H-10-71.16-1-15-10) and 2407.39 (H-10-69.5-3-18-12). Variance of Anaswara was 923.61.

4.3.2. 2. Number of branches per plant

Comparing the mean value of number of branches per plant between families, H-11-3.9-1-7-13 exhibited the highest value (4.21) while lowest value was 1.25. Mean value for Anaswara was 3.17.

Variance among family ranged between 0.25 (H-11-36.5-3-15-1) and 3.10 (H-11-3.9-1-1-11). Variance of Anaswara was 0.88.

4.3.2. 3. Days to first flowering

Comparing the mean value of days to first flowering between families, H-11-2-20-3-14-13 exhibited the highest value (65.75) while the lowest value was 57.21. Mean value for Anaswara was 63.50.

Variance among family ranged between 0.7 (H-11-49.7-1-8-16) and 61.57 (H-10-71.16-1-15-10). Variance of Anaswara was 8.27.

4.3.2. 4. Days to first harvest

Comparing the mean value of days to first harvest between families, H-11-2-20-3-14-13 exhibited the highest value (83.75) while the lowest value was 74.78 (H11-3.9-1-7-13). Mean value for Anaswara was 83.50.

Variance among family ranged between 2.11 and 36.64. Variance of Anaswara was 5.91.

4.3.2. 5. Days to last harvest

Comparing the mean value of days to last harvest between families, H-11-34-16-1-15-13 exhibited the highest value (112.61) while the lowest value was 106.71. Mean value for Anaswara was 111.17.

Variance among family ranged between 1.01 and 35.41. Variance of Anaswara was 6.15.

4.3.2. 6. Number of pods per plant

Comparing the mean value of number of pods per plant between families, H-11-3.9-1-7-13 exhibited the highest value (39.85) while the lowest value was 25.75. Mean value for Anaswara was 28.83.

Variance among family ranged between 1.88 and 14.69. Variance of Anaswara was 8.15.

4.3.2. 7. Pod length

Comparing the mean value of number of pod length between families, H-11-36.5-3-15-1 exhibited the highest value (26.11) while the lowest value was 17.65. Mean value for Anaswara was 25.35.

Variance among family ranged between 0.18 and 3.94. Variance of Anaswara was 0.63.

4.3.2. 8. Pod weight

Comparing the mean value of single pod weight between families, H-10-34-1-18-16 exhibited the highest value (4.01) while the lowest value was 1.98. Mean value for Anaswara was 3.29.

Variance within family ranged between 0.01 and 0.48. Variance of Anaswara was 0.11.

4.3.2. 9. Number of seeds per pod

Comparing the mean value of number of seeds per pod between families, H-11-3.9-1-7-13 exhibited the highest value (16.55) while the lowest value was 13.48. Mean value for Anaswara was 15.23.

Variance among family ranged between 0.03 and 2.53. Variance of Anaswara was 1.34.

4.3.2. 10. Test weight

Comparing the mean value of test weight between families, H11-10.34-1-18-16 exhibited the highest value (19.40) while the lowest value was 12.07. Mean value for Anaswara was 17.62.

Variance among family ranged between 0.13 and 1.99. Variance of Anaswara was 0.26.

4.3.2. 11. Grain yield per plant

Comparing the mean value of grain yield per plant between families, H-11-49.7-1-8-10 exhibited the highest value (102.49) while the lowest value was 51.72. Mean value for Anaswara was 80.90.

Variance among family ranged between 9.16 and 390.43. Variance of Anaswara was 216.44.

4.3.2. 12. Seed protein content

Comparing the mean value of seed protein content between families, H-11-36.5-3-15-1 exhibited the highest value (26.50) while the lowest value was 20.53. Mean value for Anaswara was 23.65.

Variance among family ranged between 0.18 and 1.81. Variance of Anaswara was 0.55.

Table 4.31. Mean value of families of cross H10

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weigh t	Grain yield/ plant	Protein content
H10-69.5-3-18-12	108.81	2.36	63.45	81.63	111.27	27.72	18.27	2.08	15.21	12.07	51.72	22.68
H10-71.16-1-15-10	89.90	3.10	58.70	76.80	108.90	30.10	25.70	3.38	15.35	17.68	82.31	23.40
H10-71-16-1-9-15	105.91	3.33	57.16	76.41	109.16	31.58	25.58	3.66	15.31	18.48	88.95	23.88
H10-69.7-2-16-15	98.62	2.88	61.50	78.50	110.13	28.25	25.58	3.54	15.41	18.15	79.30	21.87
H10-69.7-2-14-10	89.11	2.55	63.55	82.11	108.22	27.77	25.35	3.15	15.68	16.18	71.38	24.80
Anaswara	118.83	3.17	63.50	83.50	111.17	28.83	25.35	3.29	15.23	17.62	80.90	23.65

Table 4.32. Mean value of families of cross H11

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H11-2-20-3-14-13	77.25	1.25	65.75	83.75	112.37	25.75	25.05	3.28	14.76	17.75	69.60	23.80
H11-34-16-1-15-13	125.15	3.00	63.84	81.76	112.61	28.61	23.69	3.27	13.48	18.42	71.34	24.60
H11-2-20-3-14-16	146.20	3.13	61.20	80.40	110.46	30.20	25.62	3.61	15.34	18.34	87.42	24.10
H11--36.5-3-15-2	125.00	2.11	63.11	82.44	110.11	28.77	25.11	3.15	14.96	15.86	65.61	23.40
H11-3.9-1-1-19	73.28	2.00	62.85	79.00	109.57	34.28	17.65	1.98	14.71	12.27	63.40	24.40
H11-49.7-1-8-10	137.57	3.85	57.35	77.42	106.71	36.07	25.64	3.78	15.57	18.29	102.49	23.84

H11-3.9-1-1-11	78.76	3.46	60.76	77.84	109.30	37.15	18.72	2.35	15.84	12.19	73.79	24.60
H11-36.5-3-15-1	98.88	3.33	61.88	79.22	110.33	28.88	26.11	3.43	16.05	17.70	82.37	26.50
H11-10.34-1-16-11	123.88	3.55	60.33	78.88	109.66	31.10	25.61	3.39	15.92	17.32	86.66	25.00
H11-36.5-3-15-16	69.60	2.80	63.10	79.90	109.70	30.30	24.98	3.22	14.47	17.76	78.00	22.53
H11-49.7-1-8-16	88.40	2.40	64.20	83.00	108.40	32.40	25.58	3.70	15.16	17.46	85.90	25.50
H11-3.9-1-1-12	88.25	2.58	61.83	78.75	111.33	34.50	17.58	2.47	14.91	12.91	67.38	24.21
H11-3.9-1-1-18	93.55	3.00	62.89	81.77	111.22	38.11	18.06	2.35	15.40	12.79	77.02	20.53
H11-10.34-1-18-16	126.66	3.33	63.33	80.00	111.33	35.00	26.16	4.01	15.83	19.40	87.71	25.71
H11-2-20-3-14-7	107.50	3.50	63.70	81.70	113.40	31.80	25.42	3.82	15.10	18.44	86.94	23.40
H11-3.9-1-7-13	85.71	4.21	57.21	74.78	110.42	39.85	19.21	2.52	16.55	12.90	85.00	22.18
H11-10.34-1-18-17	93.00	2.14	60.85	80.71	110.28	29.42	24.85	3.66	14.80	18.42	81.28	24.60
Anaswara	118.83	3.17	63.50	83.50	111.17	28.83	25.35	3.29	15.23	17.62	80.90	23.65

Table 4.33.Variance of families of cross H10

	Plant height	**No. of branches**	**Days to first flowering**	**Days to first harvest**	**Days to last harvest**	**No. of pods/plant**	**Length of pod (cm)**	**Pod weight**	**No. of seeds / pod**	**Test weight**	**Grain yield/ plant**	**Protein content**
H10-69.5-3-18-12	2407.36	1.25	7.87	11.85	7.42	3.62	0.82	0.03	0.41	0.33	9.16	1.10
H10-71.16-1-15-10	174.10	2.10	61.57	28.62	3.66	1.88	1.34	0.48	1.05	0.20	55.91	0.52
H10-71-16-1-9-15	853.17	1.88	17.97	19.90	6.15	10.63	1.90	0.09	0.47	0.75	144.67	5.34
H10-69.7-2-16-15	569.41	0.41	20.00	11.43	5.84	8.21	0.89	0.14	0.85	1.41	93.02	1.20
H10-69.7-2-14-10	532.11	1.78	5.28	2.11	5.44	6.94	0.18	0.01	0.26	0.24	36.28	0.80

Anaswara	923.61	0.88	8.27	5.91	6.15	8.15	0.63	0.11	1.34	0.26	216.44	0.55

Table 4.34 Variance of families of cross H11

	Plant height	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/plant	Length of pod (cm)	Pod weight	No. of seeds / pod	Test weight	Grain yield/ plant	Protein content
H11-2-20-3-14-13	286.21	0.50	0.50	3.36	7.70	2.21	0.18	0.03	0.19	0.20	23.52	0.56
H11-34-16-1-15-13	1605.14	1.00	7.47	10.53	6.76	9.59	1.06	0.11	0.75	1.46	97.87	0.82
H11-2-20-3-14-16	2353.74	1.55	29.46	29.69	35.41	14.69	0.67	0.09	0.75	0.56	171.48	0.18
H11--36.5-3-15-2	1650.00	1.11	6.11	3.78	2.11	6.69	0.57	0.02	0.36	0.25	71.90	0.64
H11-3.9-1-1-19	277.90	1.33	19.48	25.00	5.29	0.90	2.71	0.03	2.52	0.21	35.02	0.87
H11-49.7-1-8-10	2294.42	2.75	25.48	33.34	10.84	7.76	3.94	0.18	1.96	1.26	390.43	1.48
H11-3.9-1-1-11	294.86	3.10	32.86	27.47	9.23	5.47	2.57	0.05	1.47	0.36	86.35	0.50
H11-36.5-3-15-1	1135.86	0.25	12.36	10.69	4.50	6.11	1.86	0.03	0.61	0.78	82.68	1.12
H11-10.34-1-16-11	1723.61	2.28	47.25	13.36	6.25	6.61	2.61	0.06	0.30	1.34	124.51	2.00
H11-36.5-3-15-16	411.16	1.51	14.32	15.88	11.79	2.90	0.53	0.11	0.42	0.58	18.17	0.82
H11-49.7-1-8-16	2010.30	0.80	0.70	5.00	8.80	2.30	0.34	0.09	0.03	0.19	11.25	0.62
H11-3.9-1-1-12	578.02	1.72	12.15	11.11	4.42	4.27	2.08	0.13	1.54	0.84	84.60	1.21
H11-3.9-1-1-18	3112.28	2.25	5.86	20.94	16.44	10.11	2.17	0.25	2.06	0.72	316.26	0.56
H11-10.34-1-18-16	1706.67	1.87	1.87	3.20	1.07	8.00	0.83	0.19	0.25	0.13	76.22	0.85
H11-2-20-3-14-7	613.17	1.39	6.01	18.90	4.27	7.16	0.93	0.12	0.52	0.20	92.30	0.65

H11-3.9-1-7-13	1192.84	0.95	24.80	36.64	27.03	5.67	3.72	0.16	1.36	0.54	133.75	1.81
H11-10.34-1-18-17	426.00	0.48	27.81	25.90	9.57	2.62	0.48	0.17	0.74	1.99	86.56	0.24
Anaswara	923.61	0.88	8.27	5.91	6.15	8.15	0.63	0.11	1.34	0.26	216.44	0.55

4.3.3. Genetic variability studies in F_6 generation

The genetic parameters like PCV, GCV, heritability, genetic advance are calculated from F_6 generation of two crosses and is given in table4.35 and 4.36.

4.3.3. 1. Plant height (cm)

In F_6 generation of cross H 10, the PCV was 31.10 per cent and GCV was 5.3 per cent. The heritability for this character was 2.90 per cent. Genetic advance for this character was 1.85. Genetic advance expressed as per cent of mean was 1.86 per cent.

In F_6 generation of cross H 11, the PCV was 40.53 per cent and GCV was 28.21 per cent. The heritability for this character was 48.45 per cent. Genetic advance for this character was 42.25. Genetic advance expressed as per cent of mean was 40.45 per cent.

4.3.3. 2. Number of branches per plant

In F_6 generation of cross H 10, the PCV was 43.55 per cent and GCV was 28.64 per cent. The heritability for this character was 43.26 per cent. Genetic advance for this character was 1.11. Genetic advance expressed as per cent of mean was 38.82 per cent.

In F_6 generation of cross H 11, the PCV was 45.72 per cent and GCV was 33.73 per cent. The heritability for this character was 54.47 per cent. Genetic advance for this character was 1.56. Genetic advance expressed as per cent of mean was 51.29 per cent.

4.3.3. 3. Days to first flowering

In F_6 generation of cross H 10, the PCV was 8.69 per cent and GCV was 7.28 per cent. The heritability for this character was 70.30 per cent. Genetic advance for this character was 7.64. Genetic advance expressed as per cent of mean was 12.59 per cent.

In F_6 generation of cross H 11, the PCV was 7.55 per cent and GCV was 5.93 per cent. The heritability for this character was 61.80 per cent. Genetic advance for this character was 5.93. Genetic advance expressed as per cent of mean was 9.60 per cent.

4.3.3. 4. Days to first harvest

In F_6 generation of cross H 10, the PCV was 5.68 per cent and GCV was 4.77 per cent. The heritability for this character was 70.62 per cent. Genetic advance for this character was 6.53. Genetic advance expressed as per cent of mean was 8.26 per cent.

In F_6 generation of cross H 11, the PCV was 5.99 per cent and GCV was 5.15 per cent. The heritability for this character was 74.07 per cent. Genetic advance for this character was 7.28. Genetic advance expressed as per cent of mean was 9.13 per cent.

4.3.3. 5. Days to last harvest

In F_6 generation of cross H 10, the PCV was 2.32 per cent and GCV was 0.50 per cent. The heritability for this character was 4.73 per cent. Genetic advance for this character was 0.25. Genetic advance expressed as per cent of mean was 0.23 per cent.

In F_6 generation of cross H 11, the PCV was 3.30 per cent and GCV was 2.28 per cent. The heritability for this character was 47.84 per cent. Genetic advance for this character was 3.59. Genetic advance expressed as per cent of mean was 3.24 per cent.

4.3.3. 6. Number of pods per plant

In F_6 generation of cross H 10, the PCV was 9.88 per cent and GCV was 1.48 per cent. The heritability for this character was 2.25 per cent. Genetic advance for this character was 0.13. Genetic advance expressed as per cent of mean was 0.46 per cent.

In F_6 generation of cross H 11, the PCV was 14.13 per cent and GCV was 11.10 per cent. The heritability for this character was 61.72 per cent. Genetic advance for this character was 5.86. Genetic advance expressed as per cent of mean was 17.96 per cent.

4.3.3. 7. Pod length (cm)

In F_6 generation of cross H 10, the PCV was 13.40 per cent and GCV was 12.98 per cent. The heritability for this character was 93.89 per cent. Genetic advance for this character was 6.21. Genetic advance expressed as per cent of mean was 25.92 per cent.

In F_6 generation of cross H 11, the PCV was 15.32 per cent and GCV was 14.93 per cent. The heritability for this character was 94.93 per cent. Genetic advance for this character was 6.89. Genetic advance expressed as per cent of mean was 29.98 per cent.

4.3.3. 8. Single pod weight (g)

In F_6 generation of cross H 10, the PCV was 22.21 per cent and GCV was 19.56 per cent. The heritability for this character was 77.55 per cent. Genetic advance for this character was 1.11. Genetic advance expressed as per cent of mean was 35.49 per cent.

In F_6 generation of cross H 11, the PCV was 20.81 per cent and GCV was 17.94 per cent. The heritability for this character was 74.30 per cent. Genetic advance for this character was 1.00. Genetic advance expressed as per cent of mean was 31.84 per cent.

4.3.3. 9. Number of seeds per pod

In F_6 generation of cross H 10, the PCV was 4.921 per cent and GCV was 2.25 per cent. The heritability for this character was 8.22 per cent. Genetic advance for this character was 0.13. Genetic advance expressed as per cent of mean was 0.83 per cent.

In F_6 generation of cross H 11, the PCV was 7.97 per cent and GCV was 2.42 per cent. The heritability for this character was 9.21 per cent. Genetic advance for this character was 0.23. Genetic advance expressed as per cent of mean was 1.51 per cent.

4.3.3. 10. Hundred seed weight (g)

In F_6 generation of cross H 10, the PCV was 13.78 per cent and GCV was 12.26 per cent. The heritability for this character was 79.32 per cent. Genetic advance for this character was 2.94. Genetic advance expressed as per cent of mean was 16.34 per cent.

In F_6 generation of cross H 11, the PCV was 13.15 per cent and GCV was 11.85 per cent. The heritability for this character was 79.69 per cent. Genetic advance for this character was 2.29. Genetic advance expressed as per cent of mean was 14.63 per cent.

4.3.3. 11. Grain yield per plant (g)

In F_6 generation of cross H 10, the PCV was 15.65 per cent and GCV was 15.34 per cent. The heritability for this character was 96.07 per cent. Genetic advance for this character was 5.09. Genetic advance expressed as per cent of mean was 30.98 per cent.

In F_6 generation of cross H 11, the PCV was 16.37 per cent and GCV was 16.06 per cent. The heritability for this character was 96.29 per cent. Genetic advance for this character was 5.25. Genetic advance expressed as per cent of mean was 32.47 per cent.

4.3.3. 12. Protein content (%)

In F_6 generation of cross H 10, the PCV was 7.47 per cent and GCV was 6.77 per cent. The heritability for this character was 82.19 per cent. Genetic advance for this character was 2.97. Genetic advance expressed as per cent of mean was 12.64 per cent.

In F_6 generation of cross H 11, the PCV was 5.92 per cent and GCV was 5.04 per cent. The heritability for this character was 72.55 per cent. Genetic advance for this character was 2.12. Genetic advance expressed as per cent of mean was 8.85 per cent.

Table 4.35. Genetic parameters of F_6 generation of cross H10

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H^2	GA	GAM (%)
Plant height	951.24	27.63	923.61	31.10	5.30	2.90	1.85	1.86
No. of branches	1.55	0.67	0.88	43.55	28.64	43.26	1.11	38.82
Days to first flowering	27.85	19.58	8.27	8.69	7.28	70.30	7.64	12.59
Days to first harvest	20.12	14.21	5.91	5.68	4.77	70.62	6.53	8.26
Days to last harvest	6.46	0.31	6.15	2.32	0.50	4.73	0.25	0.23
No. of pods/plant	8.34	0.19	8.15	9.88	1.48	2.25	0.13	0.46
Length of pod	10.31	9.68	0.63	13.40	12.98	93.89	6.21	25.92
Pod weight	0.49	0.38	0.11	22.21	19.56	77.55	1.11	35.49
No. of seeds / pod	1.46	0.12	1.34	4.92	2.25	8.22	0.13	0.83
Test weight	6.62	6.36	0.26	15.65	15.34	96.07	5.09	30.98
Grain yield/ plant	249.35	11.99	216.44	21.13	4.63	4.81	1.56	2.09
Protein	3.09	2.54	0.55	7.47	6.77	82.19	2.97	12.64

Table 4.36. Genetic parameters of F_6 generation of cross H11

Characters	Phenotypic variance	Genotypic variance	Environmental variance	PCV (%)	GCV (%)	H2	GA	GAM (%)
Plant height	1791.86	868.25	923.61	40.53	28.21	48.45	42.25	40.45
No. of branches	1.93	1.05	0.88	45.72	33.73	54.47	1.56	51.29
Days to first flowering	21.65	13.38	8.27	7.55	5.93	61.80	5.93	9.60
Days to first harvest	22.79	16.88	5.91	5.99	5.15	74.07	7.28	9.13
Days to last harvest	13.25	6.34	6.15	3.30	2.28	47.84	3.59	3.24
No. of pods/plant	21.29	13.14	8.15	14.13	11.10	61.72	5.86	17.96
Length of pod	12.44	11.81	0.63	15.33	14.93	94.93	6.90	29.98
Pod weight	0.43	0.32	0.11	20.81	17.94	74.30	1.00	31.84
No. of seeds / pod	1.48	0.14	1.34	7.97	2.42	9.21	0.23	1.51
Test weight	7.01	6.75	0.26	16.37	16.06	96.29	5.25	32.47
Grain yield/ plant	220.89	4.45	216.44	18.56	2.63	2.01	0.62	0.77
Protein	2.00	1.45	0.55	5.92	5.04	72.55	2.12	8.85

4.3.4. Selection criteria

Using the same set of traits in the selection criteria, five superior plants are selected. The selection criteria is given below.

a) Family average greater than Anaswara for grain yield

Type 1
No. of pods - 40
No. of seeds/ pod – 16
Pod length- 21 cm
Hundred seed weight- 14.5g
Grain yield - 105g/plant
Protein – 20%

Type 2
No. of pods - 35
No. of seeds/ pod -16
Pod length-26cm
Hundred seed weight- 17.5g
Grain yield - 110g/plant
Protein – 21%

Based on the above mentioned criteria, total five individual plants are selected, one from cross H10 and four from cross H11.

Green pod weight at vegetable harvest stage and crude fibre in pod husk at green tender stage were estimated in the selected plants and compared to parent anaswara. The green pod weight in dual purpose type was near to 11.00 g, whereas of grain type it was around 6.70g. Pod husk fibre content also ranged from 30.80 to 37.80 per cent. The features of the selected plants are given in the table 4.37 and 4.38.

Table 4.37. Features of plants selected in F_6 generation

Plant	Plant height(cm)	No. of branches	Days to first flowering	Days to first harvest	Days to last harvest	No. of pods/ plant	Length of pod (cm)	Pod weight (g)	No. of seeds / pod	Test weight (g)	Grain yield (g)	Protein content (%)	Green pod weight (g)	Pod husk crude fibre (g)
Type 1														
H11-3.9-1-7-13-7	150	5	59	78	120	43	22	3.17	18	14.50	105.00	23.40	6.72	35.10
H11-3.9-1-1-18-13	180	4	65	85	105	43	21	3.27	19	14.80	120.82	20.53	6.80	37.80
Type 2														
H11-49.7-1-8-10-15	204	6	50	71	112	42	28	3.92	18	20.23	152.60	25.50	11.90	31.44
H10-71-16-1-9-15-12	162	4	57	74	112	37	27	4.07	16	19.20	113.50	21.87	11.75	32.52
H11-2-20-3-14-16-12	169	3	53	71	102	37	26	3.85	17	17.68	112.50	24.40	11.30	30.80
Anaswara	115	3.16	63.50	83.50	111	28.83	25.35	3.28	15.35	17.61	80.27	23.65	10.80	36.93

4.3.5. Organoleptic evaluation of green cowpea pods of selected plants

Sensory evaluation for tender vegetable cowpea from selected plants along with parent Anaswara was carried out. Organoleptic parameters namely appearance, texture, colour, taste and overall acceptability were evaluated by 15 panel members using nine-point hedonic scale. The nine point hedonic scale was converted into rank scores and analysis done by Kendall's coefficient of concordance. The rank obtained is given in the table 4.38.

Table 4.38. Ranks obtained for cowpea genotypes

Plant	Appearance	Texture	Colour	Taste	Overall acceptability
H11-3.9-1-7-13-7	3.97	3.57	3.77	3.57	3.50
H11-3.9-1-1-18-13	2.73	2.77	2.43	2.90	2.67
H11-49.7-1-8-10-15	3.23	3.67	3.17	2.80	3.30
H11-2-20-3-14-16-12	4.50	4.23	4.40	4.43	4.77
H10-71-16-1-9-15-12	3.40	3.73	3.70	3.73	3.37
Anaswara	3.17	3.03	3.53	3.57	3.40

4.3.6. Analysis of variance between families

Analysis of variance was performed on the 12 characters to compare between different families in F_6 generation. The mean sum of squares, F value and critical difference (CD) for each characters are given in the table 4.39.

Table 4.39. ANOVA table

	MSS	F value	CD
Plant height	1494.305	2.702	38.825
No. of branches	1.175	1.627	Nil
Days to first flowering	17.212	1.961	4.891
Days to first harvest	47.350	5.595	4.803
Days to last harvest	143.035	0.947	Nil
No. of pods/plant	44.372	13.572	2.985
Length of pod (cm)	32.497	63.016	1.186
Pod weight	1.010	16.117	0.413
No. of seeds / pod	1.287	2.799	1.120
Test weight	44436.742	1.007	Nil
Grain yield/ plant	466.714	6.079	14.467

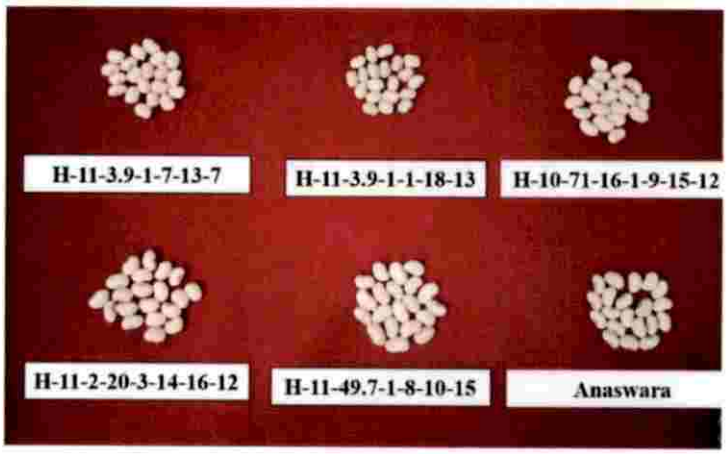

Plate 6. Seeds of selected plants

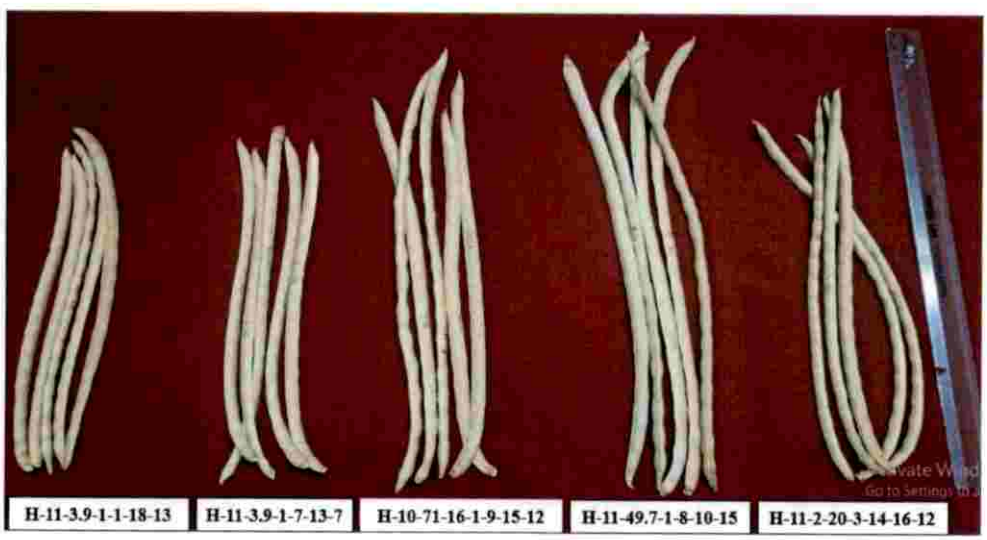

Plate 7. Pods of selected plants

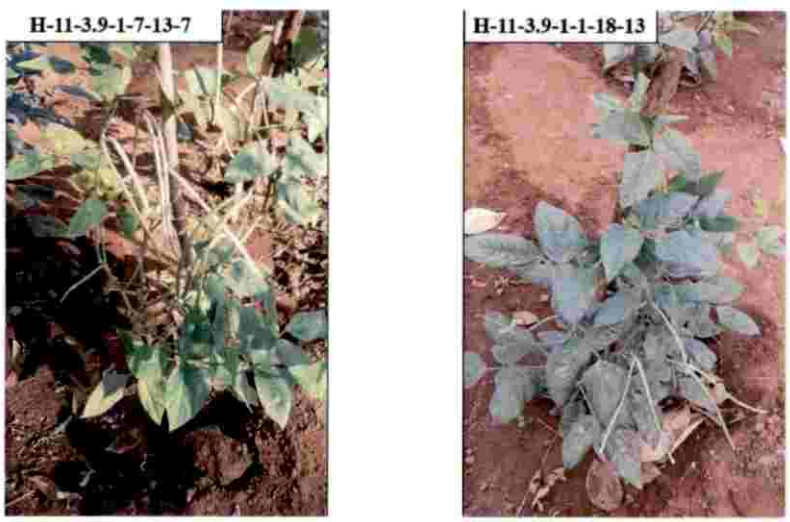

Plate 8. Type 1 plants selected

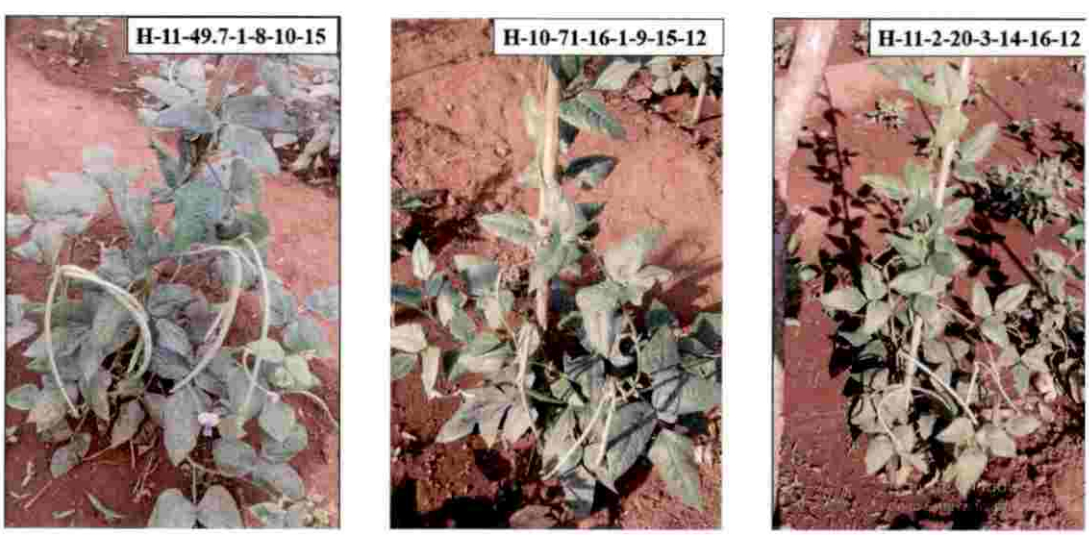

Plate 9. Type 2 plants selected

5. DISCUSSION

The present study entitled 'Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield' was conducted with an objective of selecting the best lines from F_4 and F_5 generations and develop stable F_6 populations with high grain yield and protein content. The study was performed in three experiments *viz.* 1) Evaluation of F_4 generation; 2) Evaluation of F_5 generation and 3) Evaluation of F_6 generation.

Variability parameters were worked out in three generations of the two crosses. Also variance and means within each family in F_4, F_5 and F_6 generations were estimated. Correlation and path analysis was worked out in F_4 and F_5 generations of the two crosses, which was not attempted in F_6 generation as similar results were given by the two generations. In F_6 generation, only analysis of variance was done to find the difference between families. After evaluating three generations, five superior plants were identified in F_6 generation. Organoleptic evaluation of tender green cowpea was done in selected plants from F_6 generation to assess the cooking quality of the pods as vegetable. The results pertaining to the study are discussed in this chapter under the following sections such that a comparison can be made between the segregating generations with respect to various characters.

5.1. Estimation of variability parameters in segregating generations
5.2. Estimation of family averages and variances
5.3. Estimation of genetic parameters in segregating generations
5.4. Correlation studies in segregating generations
5.5. Path analysis in segregating generations
5.6. Analysis of variance between families in F_6 generation
5.7. Organoleptic evaluation of tender green cowpea of selected plants

5.1. Estimation of variability parameters in segregating generations

Mean, range, and variance are simple measures used for analysing variability in the genetic material. The findings on estimation of mean, range, and variance of

the twelve characters studied in the experiment in F_4, F_5 and F_6 generations of crosses H10 and H11 are discussed below.

5.1.1. Mean value of characters

Analysing the mean values of characters in F_4 generation, it can be concluded that both the H10 and H11 families did not differ significantly. The mean value for yield in F_4 generation was less than that of parent Anaswara, but exhibited high variance and wide range providing scope for selecting superior plants. Similar was the case with other traits *viz*., number of pods per plant, pod length, pod weight, number of seeds per pod, hundred seed weight and seed protein content. It was noted that upper range for grain yield was more than double of the mean value. Millawithanachchi *et al.* (2015) reported mean values for plant height and pod length in F_4 generation were higher than of both the parents (CP 19 x Waruni) but mean value for grain yield was lower than of parents. Dinakar *et al.* (2018) also reported that the mean values for most of the characters viz., plant height, number of secondary branches per plant, number of pods per plant, number of seeds per pod, seed yield per plant and green fodder yield per plant in F_2 populations of cowpea crosses MFC-09-12 × PGCP12 and MFC-08-14 × PL-3 were lower than both the parents. Another report by Sathish *et al.* (2017) also recorded similar results that mean performance of F_2 populations was lower compared to their parents for most of the characters viz., plant height, number of secondary branches per plant, number of pods per plant, number of seeds per pod, seed yield per plant and green fodder yield per plant in cowpea.

In F_5 generation, mean value for yield was lower in H10, but higher in H11 as compared to Anaswara. For all other characters the mean values were comparable to that of Anaswara, with adequate variance. Millawithanachchi *et al.* (2015) reported mean values for seed yield per plant, plant height, number of pods per plant, length of pod in F_5generation were higher than of both the parents (CP 20 x CP 22).

In F_6 generation, mean values were comparable to Anaswara, with increased mean value for number of pods per plant in both crosses. Plant height, days to

flowering and harvest showed reduced mean value than Anaswara as selection was attempted to select shorter plants with earliness. Millawithanachchi *et al.* (2015) reported that in F_6 generation of cross CP 20 x CP 22 mean value for seed yield per plant was lower than the parents.

Comparing between the three generations, the mean values of plant height, number of branches per plant, number of pods per plant, hundred seed weight and grain yield were reduced in F_5 and F_6 generation as compared to F_4 generation in both crosses H10 and H11.This decrease can be due to the environmental effect, as F_5 generation was raised during high rainfall period, where pod set and pod filling were reduced. Ajetomobi and Abiodun (2010) reported negative correlation coefficient between rainfall and cowpea yield and suggested that flooding is not a conducive environment for cowpea production.On the contrary, the mean values of characters like days to flowering, first harvest and last harvest, pod length, pod weight, and number of seeds per pod increased from F_4 to F_6 generation. The increase in plant height, days to flowering, first harvest and last harvest from F_4 to F_5 generation can be attributed to the environmental influence as F_5 generation was raised during high rainfall period. This becomes clear from the similar performance of parent Anaswara. Lomeling *et al.* (2016) reported that soil moisture above 23 per cent, 52 DAP (especially during pod setting) induced an excess water stress that enhanced further vegetative growth and therefore delayed flowering and pod setting.

Similar pattern of expression of characters was reported by Millawithanachchi *et al.* (2015) in different segregating generations, where mean seed yield per plant was recorded to be 15g, 11.5g and 8.6g per plant in F_4, F_5 and F_6 generations, respectively, of the cross CP 20 x CP 22 during pedigree selection. They also reported that number of pods per plant and hundred seed weight also exhibited similar decreasing pattern over generations. On the other hand, average pod length and seeds per plant showed increasing pattern from F_4 to F_6 generation. The pods per plant and hundred seed weight recorded significant intergeneration correlations and they suggested the use of these characters for selection in segregating generations.

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5.1.2. Variance for characters

Considering variances for each character in F_4 generation, high variability existed for characters like number of pods per plant, pod length, number of seeds per pod, hundred seed weight and grain yield, which indicated that further selection is effective to improve the grain yield along with desirable traits. Number of branches per plant, days to first flowering, days to first harvest, and days to last harvest exhibited limited variance and range was also narrow, indicating there is less scope for selection for these characters. In F_4 generation, variance was more in H10 families compared to H11 families for all the characters except plant height. High amount of variability was observed for the fifteen quantitative and qualitative characters under studied in F_2 generation of cowpea crosses MFC-09-12 x BL-2 and UPC-622 × EC-4216 (Kumar *et al.*, 2017).

In F_5 generation, variability was higher in H11 family for most of the characters except pod length and number of seeds per pod. As compared to F_4 generation variance value has reduced for grain yield per plant, seed protein content, hundred seed weight, number of seeds per pod, pod weight, pod length, number of branches per plant and number of pods per plant in F_5 generation of both H10 and H11 crosses. This result can be attributed to selection pressure imposed on these traits. But plant height exhibited a marked deviation from this and exhibited a high value of variances. This can be due to environmental effect and indicates significance of stability of the segregating material under different condition. Also days to first flowering exhibited high value of variance, indicating influence of environment.

In F_6 generation, the variance for most of the characters is similar to that of Anaswara, indicating that the material has attained homozygous condition. The obtained variance was due to the environmental effect. Hundred seed weight and pod length were deviating from this trend, giving considerable variance than Anaswara. This can be due to selection imposed with two different criteria for grain type and

dual purpose type. Also high variance was recorded for number of pods per plant in F_6 generation of cross H11, which can also be attributed to environment.

5.2. Estimation of family averages and variances

Mean value and variances for each of the twelve characters were estimated from each families in F_4, F_5 and F_6 generations and the results are discussed below.

Analysing the variance values within families in F_4 generation indicated that there is limited variance within families for characters like number of branches per plant, days to first flowering, days to first harvest, days to last harvest, pod weight and hundred seed weight. But there are some families which exhibited high variance for these traits like H-10-1-1-1, which gave variance value of 9.19 for hundred seed weight. For other characters like grain yield per plant, number of pods per plant, length of pod and plant height exhibited considerable variation within families indicating the scope of selection from their subsequent segregating generations.

Considering mean values within families, it is noted that three families from H10 and three families from H11 exhibited more average grain yield than parent Anaswara. Seven families from H10 and six from H11 gave more test weight than parent Anaswara. Three families from H10 and five from H11 showed more number of seeds per pod than Anaswara. Seed protein content was found to be almost uniform between families. Only two families from H10 exhibited higher mean single pod weight than Anaswara. Three from each H10 and H11 showed more length of pod than that of Anaswara. Three families from H10 and two from H11 showed more number of pods per plant than Anaswara. Eight from H10 and nine from H11 showed more number of branches per plant as compared to Anaswara. Analysis of means and variances within families in F_4clearly demonstratedthe need for further selection in subsequent generation to select superior ones and forward them to make stable (homozygous).

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In F_5 generation, variance within family was more than or on par with that of Anaswara for most of the characters except plant height. The variance within family had reduced compared to F_4 generation, suggesting one more generation would make it uniform. Considering the mean values for characters within families in F_5 generation of the two crosses revealed that higher mean value was obtained for most of the families for grain yield, number of branches, number of pods, number of seeds per pod as compared to Anaswara. On the other hand lower mean values were observed in most families for plant height, days to flowering, days to harvest and days to last harvest with few exceptions. Some of the families exhibited lower mean values for pod length, pod weight and hundred seed weight, indicating its use as grain type cowpea. This clearly demonstrates that selection resulted in positive shift in the characters such as grain yield, number of branches, number of pods, and number of seeds per pod.

Analysing variance values in F_6 generation families, variance within most of the families were comparable to that of Anaswara for number of branches, number of pods per plant, length of pod, pod weight, number of seeds per pod, test weight, grain yield and seed protein content. This indicates that families are homogeneous and do not segregate further. Considering mean values within family, it was observed that most of the families exhibited higher mean values than parent Anaswara for characters like number of branches, number of pods per plant, pod length, pod weight, number of seeds per pod, test weight and protein content. Plant height, days to first flowering, days to first harvest and days to last harvest exhibited lower mean value than Anaswara similar to F_5 generation and recorded higher variance than Anaswara.

So in general the pedigree selection done in F_4 and F_5 generation resulted in positive shift for characters like grain yield, number of branches, number of pods, number of seeds per pod. Also selection resulted in negative shift for characters like days to first flowering, days to first harvest and days to last harvest. Also sufficient homozygosity has been achieved in F_6 generation.

5.3. Estimation of genetic parameters in segregating generations

Variability is the basis of any selection programme. For selection to be effective there should be sufficient variability that can be transferred to the next generation. The total variability can be partitioned into heritable and non-heritable components *viz*., phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). The degree to which variability could be transferred from parent to progenies is decided by heritability of the character. Heritability determines the response to selection. Genetic advance is a measure of genetic gain under selection, which is the improvement in mean genotypic value of selected plants over parental population.

Sivasubramanian and Madhavamenon (1973) classified PCV and GCV as follows:

Low : < 10 per cent

Moderate : 10-20 per cent

High : > 20 per cent

According to Johnson (1955) heritability is classified as follows:

Low : < 30 per cent

Moderate : 30-60 per cent

High : > 60 per cent

Johnson (1955) classified genetic advance as per cent of mean as follows:

Low : < 10 per cent

Moderate : 10-20 per cent

High : > 20 per cent

High heritability coupled with high genetic advance indicates additive gene effect and thus selection for character will be effective. High heritability accompanied by low genetic advance is an indicative of non- additive gene action and selection will not be rewarding. Low heritability along with high genetic advance

indicates additive gene action and selection may be effective. Low heritability with low genetic advance clearly indicates inefficiency of selection for the character.

Genetic analysis in F_4 generation of the two crosses H10 and H11 clearly demonstrated that there is sufficient variance for most of the characters. PCV was highest for grain yield in both the crosses, followed by single pod weight. In cross H10, high PCV was given by length of pod, pod weight and grain yield per plant, while corresponding GCV was moderate except for grain yield. In cross H11, high PCV was exhibited by plant height, pod weight and grain yield, but GCV was low for plant height and pod weight. These values indicate scope of selection for grain yield and for character like pod weight, number of seeds per pod and test weight. Similar to this Kalaiyarasi and Palanisamy (2000) reported moderate PCV for plant height, pod length, and seed yield per plant in F_4 generation of cowpea crosses. Dinesh *et al.* (2017) reported moderate PCV for plant height, number of pods per plant, number of branches, number of seeds per pod and seed yield per plant in F_3 generation of cowpea crosses.

Moderate PCV was given by plant height, number of branches, number of pods per plant, number of seeds per pod and hundred seed weight in H10, but GCV for plant height, number of branches and number of pods per plant was low. In cross H11, moderate PCV was given by number of branches, length of pod, number of seeds per pod and hundred seed weight, but GCV was low for number of branches and length of pod.

Low PCV and GCV was recorded for days to first flowering, days to first harvest, days to last harvest and seed protein content in both crosses H10 and H11. In H11, number of pods per plant also recorded low PCV and GCV. Similar to this, Nair *et al.* (2018) reported low GCV for days to first flowering. In F_3 generation of vegetable cowpea cross, Subbiah *et al.* (2013) reported low PCV and GCV for plant height and number of branches.

In the present study, in F_4 generation, high heritability coupled with high genetic advance was given by test weight and grain yield per plant in both the

crosses, so selection for these characters is effective. Number of pods per plant gave high heritability accompanied by moderate genetic advance indicating scope for selection for this character. Millawithanachchi *et al.* (2015) reported 44 per cent narrow sense heritability for 100 seed weight from F_4 to F_5.They also reported that narrow sense heritability of the number of pods per plant was high for crosses (CP 19 x Waruni) and (CP 20 x CP 22*)*, respectively, between the F_4 and F_5 generations. Sarutayophat and Nualsri (2010) also reported a narrow sense heritability of 18.43 per cent and 12.93 per cent for number of pods per plant in F_4 population of two yardlong bean crosses.

Number of seeds per pod gave moderate heritability with moderate genetic advance in both the crosses, suggesting the use of this character for selection. In cross H10, moderate heritability with moderate and high genetic advance was given by length of pod and pod weight respectively, indicating scope for improvement of these characters. Sarutayophat and Nualsri (2010) reported that narrow sense heritability for pod length was 39.13 per cent and 0.01 per cent in F_4 population of two yardlong bean crosses VU 162 × VU 189 and VU 162 × VU 171 respectively. Moreover, narrow sense heritability for pod weight was 18.48 per cent and 7.88 per cent, respectively for two cowpea crosses.

From genetic studies of F_4 generation, it can be concluded that number of pods per plant, number of seeds per pod, length of pod, pod weight, test weight and grain yield per plant can be improved by selection. All other characters such as plant height, number of branches, days to first flowering, days to first harvest, days to last harvest and seed protein content exhibited low genetic advance pointing that selection for these characters will be ineffective.

In F_5 generation of cross H10, GCV was moderate for number of branches, pod length, pod weight, hundred seed weight and grain yield and was low for all other characters. In cross H11, moderate GCV was shown by plant height, number of branches, pod length, hundred seed weight and grain yield.

High heritability coupled with high genetic advance as per cent of means was exhibited by number of branches, pod length, pod weight, test weight and grain yield in F_5 generation of cross H10, suggesting the scope for improvement of these characters. High heritability with moderate GAM was given by number of seeds per pod in cross H10. Dinesh *et al.* (2017) reported high heritability coupled with high genetic advance as per cent of mean (GAM) for plant height (67.13% and 21.78%) in F_3 generation of cowpea cross. Moderate heritability and genetic advance as per cent of mean was observed for number pods per plant (49.14% and 16.49 %). While low heritability and genetic advance was recorded for number of branches (19.66% and 6.08%), number seeds per pod (14.31% and 3.72 %), 100 seed weight (25.61% and 5.11%) and seed yield per plant (17.30% and 3.96 %).

Similar trend was observed in cross H11 also. In cross H11, plant height, pod weight, test weight and grain yield exhibited high heritability with high GAM. High heritability with moderate GAM was given by number of pods per plant, length of pod and number of seeds per pod. The results suggest that there is scope for improvement grain yield along with pods per plant, length of pod, number of seeds per pod, pod weight and hundred seed weight, but selection for seed protein content will be non- rewarding. Santos and Boiteux (2013) has reported 34.1 per cent in F_6 generation of cowpea crosses, by selection in segregating generations.

In F_6 generation, low GCV was given by all the characters except number of branches, length of pod, pod weight and test weight in cross H10. In H11, low and moderate GCV was given by plant height, number of branches, pods per plant, length of pod, pod weight and test weight, indicating reduced variation in F_6 generation. High heritability with high genetic advance was given by test weight, pod weight and length of pod in both crosses H10 and H11. This observation was due to selection imposed with two different criteria and therefore two types of plants were included in the H10 and H11 families. It can be concluded that selection can be made with respect to these characters in F_6 generation.

5.4. Correlation studies in segregating generations

Correlation analysis provides information about yield components and thus aids in formulating selection criteria for improvement of dependant traits like yield. Correlation measures the mutual relationship between two or more variables. Correlation coefficient is a statistical measure used to find out degree and direction of relationship between two or more variables. Genetic improvement in dependant trait can be achieved by applying strong selection pressure to character which is correlated with the dependant character.

Phenotypic correlation studies in F_4 and F_5 generation of the two crosses clearly indicate that grain yield was positively correlated with plant height, number of branches per plant, number of pods per plant, length of pod, pod weight, number of seeds per pod and test weight. In F_4 generation, the highest positive phenotypic correlation on grain yield was given by number of seeds/pod followed by pod weight, length of pod, number of pods per plant, test weight, plant height and number of branches respectively. On the other hand in F_5generation, highest positive correlation was given by pod weight followed by test weight, length of pod, number of pods per plant, number of seeds per pod, plant height, number of branches per plant respectively on grain yield. According to Aliou and Makinde (2016) seeds per pod and pods per plants were the most significantly correlated traits (r=0.95, 0.89) with grain yield in cowpea. The present result is similar to that reported by Palve *et al.* (2018) in F_5 generation of cowpea cross wherein the characters like number of pods per plant, number of pods per cluster, primary branches per plant, number of clusters per plant, pod length, pod diameter, average pod weight and leaf area had highly significant positive correlation with pod yield per plot both at genotypic and phenotypic level.

There was non-significant positive correlation between grain yield and seed protein content in the present study. This is contradictory to the reports by Oluwatosin (1996) that yield showed a strong negative correlation with protein

content (-0.81). Santos and Boiteux (2013) suggested that selection for high protein and mineral content does not affect grain yield.

Number of seeds per pod showed significant negative correlation with hundred seed weight in F_5 generation but positive relation was given in F_5 generation of cross H10. The negative correlation is in concordance with the report that seed size had negative correlation with seeds/pod, but high correlation exists between seeds/pod and grain yield (Aliou and Makinde, 2016).

Grain yield was found negatively correlated with days to first flowering, days to first harvest and days to last harvest. This is in contradiction to reports by Walle *et al.* (2018) where genotypic path coefficient analysis revealed that days to flowering and days to maturity had relatively high positive direct effect on seed yield. Sarvamangala *et al.* (2012) reported that days to maturity has negative direct effect on seed yield. Days to first flowering had high negative correlation with yield in yard long bean (Panicker, 2000).

In general, the results suggest that characters such as plant height, number of branches per plant, number of pods per plant, length of pod, pod weight, number of seeds per pod and test weight, which exhibited positive correlation with grain yield can be utilised in selection criteria for grain improvement provided they exhibit high heritability and genetic advance. Improvement of these characters will simultaneously bring about increased yield. Further path analysis will provide us better understanding about how these characters are correlated to yield, through direct effect or indirect effects.

5.5. Path analysis in segregating generations

Path analysis partitions the correlation coefficients between characters into direct and indirect effect and thereby giving a cause effect relationship between the dependant and independent characters. Yield being a complex trait is affected by many traits and path analysis can give clear idea of cause effect relationship of yield

and other traits. As per Lenka and Mishra (1973), the direct and indirect effects were grouped into:

>1.00 - Very high

0.30 – 0.99 - High

0.20 – 0.29 - Medium

0.10 – 0.19 - Low

0.09 – 0.00 - Negligible

Path coefficient analysis in F_4 and F_5 generation of both crosses H10 and H11 revealed that high positive direct effect on grain yield was given by pods per plant, number of seeds per pod and hundred seed weight. The results clearly demonstrated that these characters were the most yield contributing character to grain yield in segregating generations of cowpea. Further, it can be seen that other characters have negligible direct effect on grain yield in the F_4 and F_5 generations of the two crosses, indicating that they need not be considered for selection for yield.

This is in agreement with the reports of Dinesh *et al.* (2017) wherein path coefficient analysis in F_3 segregating population showed that number pods per plant, number seeds per pod and 100 seed weight had maximum direct effect on seed yield per plant. Also, Bhardu and Navale (2011) reported that the number of pods per plant recorded highest magnitude of direct effects on seed yield per plant followed by test weight, biomass at harvest and number of branches per plant. Similarly, Singh and Mehndiratta (1970) recorded that number of pods/plant, number of grains/pod and 100-grain weight have a large direct effect on grain yield. On contrast to this, Lokesh and Murthy (2019) observed that pod length recorded highest magnitude of direct effects on seed yield per plant followed by secondary branches per plant and plant height.

In the present study, it was noted that correlation of these characters with grain yield was high and almost equal to the direct effect on grain yield which indicate true association between the traits, so selection through these characters are effective for improving grain yield. Simultaneous selection through number of pods per plant, number of seeds per pod and hundred seed weight can be done in segregating generations of cowpea for improving yield.

For other traits like plant height, number of branches per plant, pod length, single pod weight which showed highly significant correlation with yield, but path coefficient analysis revealed negligible direct effect with yield. This confirmed that indirect effects are the cause for high correlation, and selection for these characters alone will be unfruitful. Hence the factors that indirectly contribute to grain yield have to be considered simultaneously. Here it is evident that indirect effect is mainly through hundred grain weight and seeds per pod.

In total, number of pods per plant, number of seeds per pod and hundred seed weight can be used simultaneously in selection criteria for grain yield in segregating generations of cowpea for improving grain yield.

5.6. Analysis of variance between families in F_6 generation

Analysis of variance was performed on the twelve characters to compare between different families in F_6 generation. The results indicate that families differed between each other with respect to plant height, days to first flowering, days to first harvest, number of pods per plant, length of pod, pod weight, number of seeds per pod and grain yield per plant. Families did not differ in number of branches, days to harvest and hundred seed weight.

All the five selected plants differed significantly from parent Anaswara in plant height, days to first flowering, number of pods per plant, number of seeds per pod and grain yield. Selection was attempted to develop cultures suitable for grain purpose and dual purpose by using separate selection criteria that distinguished them with respect to pod length, hundred seed weight and grain yield. The type 1 plants

differed significantly from each other in days to first flowering, days to first harvest, grain yield and protein content. Among the type 2 plants, H11-49.7-1-8-10-15 differed significantly from the other two plants in plant height, days to first flowering, number of pods per plant and grain yield.

5.7. Organoleptic evaluation of tender green cowpea of selected plants

The green pods from selected plants from F_6 generation were subjected to sensory evaluation to find their suitability to be used for vegetable purpose. Umaharan *et al.* (1997) conducted a preliminary study of consumer preferences for pod characteristics in vegetable cowpea, which showed a general preference for greener, longer, fleshier pods that are less seedy. Manju (2006) reported that the overall acceptability ranged from 2.00 to 3.60 in vegetable types and from 2.40 to 3.60 in dual purpose and grain types, with only slight difference among accessions. Organoleptic evaluation was performed in five selected plants along with check parent Anaswara and nine-point hedonic scale was used to score the genotypes. Ranks were given from these scores for the parameters appearance, texture, colour, taste and overall acceptability. Two genotypes *viz*., H11-2-20-3-14-16-12 and H11-3.9-1-1-18-13 exhibited the maximum and minimum score respectively for each parameters. Among the five genotypes, the grain type plant H11-3.9-1-1-18-13 recorded lower score than Anaswara in all the parameters. This suggests that identified type 1 plant, H11-3.9-1-1-18-13 is not suitable for vegetable purpose, but the other type 1 plant, H11-3.9-1-7-13-7 can be used for vegetable purpose as well. The score for overall acceptability of three of the five selected plants were higher than that of Anaswara, which can be utilised as dual purpose type.

6. SUMMARY

The present study entitled 'Development of stabilised population of cowpea segregants (*Vigna unguiculata* (L.) Walp.) with high protein content and grain yield' was conducted with an objective of selecting the best lines from F_4 and F_5 generations and develop stable F_6 populations with high grain yield and protein content. The study was performed in three experiments *viz.* 1) Evaluation of F_4 generation; 2) Evaluation of F_5 generation and 3) Evaluation of F_6 generation. The findings can be summarised as follows.

6.1. F_4 generation

The results from F_4 generation can be summarised as follows.

6.1.1. Variability and genetic parameters

- The F_4 generation of both the crosses exhibited lower mean value for most of the characters as compared to parent Anaswara. Higher mean value was observed for days to first flowering, first harvest, last harvest, number of branches and seed protein content.
- There was moderate to high variance and range.
- High GCV was recorded for grain yield per plant. GCV was moderate for length of pod, no. of seeds per pod, and hundred seed weight.
- High heritability coupled with moderate to high genetic advance was recorded for number of pods per plant, number of seeds per pod, hundred seed weight and grain yield.

6.1.2. Correlation studies

- Grain yield was positively correlated with plant height, number of branches per plant, number of pods per plant, length of pod, pod weight, number of seeds / pod and test weight.
- No correlation was recorded between grain yield and seed protein content.

6.1.3. Path analysis

High positive direct effect on grain yield was recorded by pods per plant, number of seeds per pod and hundred seed weight. Other characters did record negligible direct effect.

6.1.4. Selection criteria

Selection criteria was developed including the characters such as pods per plant, number of seeds per pod and hundred seed weight along with grain yield and protein content.

6.2. F_5 generation

The results of F_5 generation can be summarised as follows.

6.2.1. Variability and genetic parameters

- Mean values for number of branches, number of pods per plant, number of seeds per pod and protein content were higher than Anaswara.
- There was sufficient variance and range, narrow than F_4 generation.
- Moderate GCV was recorded for number of branches, length of pod, pod weight, test weight and grain yield per plant.
- High heritability with high genetic advance was recorded for number of pods per plant, length of pod, pod weight, number of seeds per pod, hundred seed weight and grain yield.

6.2.2. Correlation studies

- Grain yield was positively correlated with plant height, number of branches per plant, number of pods per plant, length of pod, pod weight, number of seeds / pod and test weight.
- No correlation was recorded between grain yield and seed protein content.

6.2.3. Path analysis

High positive direct effect on grain yield was recorded by pods per plant, number of seeds per pod and hundred seed weight. Other characters recorded negligible direct effect on grain yield.

6.2.4. Separate selection criteria

Separate selection criteria was developed for two categories of cowpea. The criteria included number of pods, number of seeds per pod, pod length, hundred seed weight, grain yield and protein content.

6.3. F_6 generation

The results from F_6 generation can be summarised as follows.

6.3.1. Variability and genetic parameters

- Higher mean value was recorded for number of pods per plant. Lower mean value was recorded for plant height, days to first flowering, days to first harvest, days to last harvest, pod length and hundred seed weight.
- Moderate GCV was recorded for length of pod, pod weight and hundred seed weight.
- High heritability with high genetic advance was recorded for length of pod, pod weight and hundred seed weight.
- Separate selection criteria was developed for two categories of cowpea. The criteria included number of pods, number of seeds per pod, pod length, hundred seed weight, grain yield and protein content.

To summarise, there was positive gain in grain yield, hundred seed weight, and pod weight. Seed protein content did not exhibit much gain, the family average of selected lines were on par with Anaswara. There was negative shift in days to first flowering, days to first harvest and days to last harvest as compared to Anaswara. Five superior lines identified with high yield and moderate seed protein, can be used as dual purpose. The identified lines are H11-3.9-1-7-13-7, H11-3.9-1-1-18-13, H11-49.7-1-8-10-15, H10-71-16-1-9-15-12, and H11-2-20-3-14-16-12. Identified plants can be evaluated in replicated yield trials and tested for stability over locations and seasons.

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DEVELOPMENT OF STABILISED POPULATION OF COWPEA SEGREGANTS (*Vigna unguiculata* (L.) Walp.) WITH HIGH PROTEIN CONTENT AND GRAIN YIELD

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important pulse crop providing good source of protein and often referred to as poor man's meat. It is a versatile crop, of which seeds are utilised as pulse, green pods as vegetable, leaves as forage and helps in restoring soil fertility. Many reports have indicated protein content of more than 30 per cent in certain cowpea genotypes, but at the cost of yield. Hence, the present study was proposed to develop cultures with high grain yield and protein content.

The present study was conducted at Department of Plant Breeding and Genetics, College of Horticulture during 2017-2019. Twenty three lines with high yield and protein content in the F_3 generation of two cowpea crosses H10 (Anaswara X PKB 3) and H11 (Anaswara X PKB 4) identified in previous studies formed the working material. These lines were evaluated in F_4, F_5 and F_6 generations and pedigree selection was performed to select superior plants. Observations were recorded on 12 characters *viz.* plant height, number of branches, days to first flowering, days to first harvest, days to last harvest, number of pods per plant, length of pod, pod weight, number of seeds per pod, hundred seed weight, grain yield per plant and protein content.

The F_4 generation of both the crosses exhibited lower mean value for most of the characters than the parent Anaswara, but recorded moderate to high variance and range. Higher mean value was observed for days to first flowering, first harvest, last harvest, number of branches and protein content. Genetic parameters indicated that GCV was moderate for length of pod, number of seeds per pod, and hundred seed weight and high for grain yield per plant. High heritability coupled with moderate to high genetic advance was recorded for number of pods per plant, number of seeds per pod, hundred seed weight, and grain yield.

Correlation studies in F_4 generation revealed that grain yield was positively correlated with plant height, number of branches per plant, number of pods per plant, length of pod, pod weight, number of seeds per pod and test weight. There was non-

significant correlation between grain yield and seed protein content. Further path analysis confirmed that high positive direct effect on grain yield was given by pods per plant, number of seeds per pod and hundred seed weight. Based on these observations, characters like number of pods per plant, hundred seed weight and number of seeds per pod were simultaneously included along with grain yield for setting selection criteria to select superior individual plants. Based on these set criteria, 13 individual plants from cross H10 and 10 plants from cross H11 were selected and forwarded to F_5 generation.

In F_5 generation, mean values for number of branches, number of pods per plant, number of seeds per pod and protein content were higher than that of Anaswara with sufficient variance and range. GCV was moderate for number of branches, length of pod, pod weight, hundred seed weight and grain yield per plant. High heritability with moderate to high genetic advance was recorded for number of pods per plant, length of pod, pod weight, number of seeds per pod, hundred seed weight and grain yield. Based on the segregation pattern observed, the plants were grouped into two different categories - one with medium long pods and small seeds closely packed within the pod and the other type with long fleshy pods and bold seeds. Hence, separate selection criteria was developed for both the types comprising of characters like number of pods, number of seeds per pod, pod length, hundred seed weight, grain yield and protein content. Based on these set criteria, five individual plants from cross H10 (one type 1 and four type 2) and 17 plants from cross H11 (five type 1 and twelve type 2) were selected and forwarded to F_6 generation.

In F_6 generation, mean value was higher than Anaswara for number of pods per plant but lower for plant height, days to first flowering, days to first harvest, days to last harvest, pod length and hundred seed weight. For other characters, mean value was comparable to Anaswara. Moderate GCV value was recorded for length of pod, pod weight and hundred seed weight. High heritability with high genetic advance was recorded for length of pod, pod weight and hundred seed weight. Separate

selection criteria was developed for the two categories of plants and total five individual plants were selected, one from cross H10 and four from cross H11.

The selected plants from F_6 generation were subjected to organoleptic evaluation to find its suitability to be used for vegetable purpose. Three plants of type 2 and one plant from type 1 were found promising. The identified lines, H11-3.9-1-7-13-7, H11-3.9-1-1-18-13, H11-49.7-1-8-10-15, H10-71-16-1-9-15-12, and H11-2-20-3-14-16-12 can be evaluated in replicated yield trials and tested for stability over locations and seasons.