Pedigree breeding in early segregating generations of cowpea

(*Vigna unguiculata* (L.) Walp)

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By

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DECLARATION

I hereby declare that this thesis entitled **"Pedigree breeding in early segregating generations of cowpea (Vigna unguiculata (L.) Walp)"** is a bonafide record of research done by me during the course of research and that 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.

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INTRODUCTION

1. Introduction

Pulses represent an essential component of agricultural food crops consumed and considered as an important crop to meet food and nutritional security for both farmers and consumers. Legumes possess the second largest group of higher plants, second in agricultural importance, next to grasses. In true sense, pulses complement cereal crop, in dietary terms, as a source of protein and minerals while in agronomical terms, it serves as rotation crop with cereals, supplying nitrogen to the cereal crop and reduces the activity of soil pathogens.

Pulses play a diverse and essential role in the agricultural system and in dietary plan of poor people. It serves as an ideal crop for achieving the developmental goals of reducing hunger and poverty. It enhances human health and nutrition and improves ecosystem resilience. Poor farmers across the developing world depend on pulses to sustain their life and to enhance their standard of living.

In several countries of tropics and sub-tropics, especially, in Asia, Africa, Central and South America, cowpea (*Vigna unguiculata* L. Walp) serve as an important food legume. For rural groups, cowpea plays an essential role in enrichment of their daily diet, mainly as a grain (pulses) and green pods (vegetables) and also serves as a nutritional fodder for livestock (Ajeigbe *et al.*, 2008). In general, cowpea seeds contains 23.4 per cent protein, 60.3 per cent carbohydrates and 1.8 per cent fat. It also provides considerable amount of vitamins and phosphorus (Venkatesan *et al.*, 2003). The protein availability in cowpea seeds and green pods is almost double/ triple the amount of available cereal protein, as it considered as economic source of protein (20-25 %) in major parts of India and South East Asia (Salimath *et al.*, 2007; Pandey, 2007; Hazra *et al.*, 2006). Cowpea is often referred as "poor man's meat", because of its high nutritional quality and protein content. The lysine-poor cereals are complimented with lysine-rich cowpea, in the diet. Apart from pulses, cowpea also serves as vegetable fodder.

Every part of a plant in cowpea consumed are nutritious, rich in protein, minerals and vitamins (vitamin B). USA developed varieties of cowpea with a "persistent-green" grain, being a versatile product for frozen vegetable applications (Ehlers *et al.*, 2002). In Africa and others parts of developing world, cowpea plays

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a crucial role, where it is served as an essential source of dietary protein that compliments staple low protein cereals and tuber crops nutritionally and produces' additional income for farmers and traders (Langyintuo *et al.,* 2003).

The crop is adaptable for various climatic and soil conditions, such as hot and humid, arid to semi-arid climate and acidic to neutral soils, respectively. It is capable of restoring soil fertility by nitrogen fixation of root nodules and therefore serve as an important part of sustainable farming system. Compared to other crop species, cowpea has considerable adaptation to high temperature and drought (Hall *et al.*, 2002; Hall, 2004).

The existing cultivars of cowpea shows lower productivity, less response to high dose of fertilizers, non-sustainability of the various farming systems, high duration, susceptible to major pest and diseases which causes economical damage and very poor harvest indices. The average grain yield of cowpea especially, in developing areas is still low and no single variety is adaptable for all growing conditions. Hence, exploiting genetic variability is an essential method, to overcome the complex nature of cowpea breeding and to identify an elite high yielding genotype (Shanko *et al.*, 2014).

Grain yield is a complex polygenic character, which is highly dependent on several other yield contributing traits and highly influenced by environmental factors. In order to increase the yield, a breeder should have a knowledge on choice of character for selection, available variation existing in genotypes/germplasms, the direct and indirect effects of the component characters contributing to the yield. Genetic variability and heritability are the two most important aspects considered for the success of any breeding programme. Heritable diversity in a crop species is essential for crop improvement. Based on the information of heritability, a breeder can formulate the criteria for selection to hasten the crop improvement (Johnson *et al.*, 1955).

Crossing genetically diverse parents results in maximum heterosis and provides maximum chance of identifying transgressive segregants. However, little information is available about the genetic variability in segregating generations and nutritional quality of cowpea genotypes in India. Thus, to achieve genetic improvement in cowpea, genotypes with high yield and nutritional quality should

be identified. Keeping all the facts in view, the present investigation has been undertaken with the following objective:

Pedigree selection from F_2 and F_3 generations of hybrids of cowpea for high grain yield coupled with high protein content.

REVIEW OF LITERATURE

2. Review of literature

The review of literature related to the study on "Pedigree breeding in early segregating generations of cowpea (*Vigna unguiculata* (L.) Walp)" is classified under the following headings

1. Studies on variability in cowpea
2. Heritability and genetic advance in cowpea
3. Correlation studies in cowpea
4. Path coefficient analysis in cowpea

2. 1. Variability in cowpea

Selection and variability form the basis for any breeding programme. Range is the simplest form to indicate the variability present in a population. Variance is another statistical measure used for finding out the variability present in a population. The knowledge about the variability present in a population will help us to design the breeding programme.

A study on variability parameters of two F_2 populations (V16 × S488 and V37 × S488) of cowpea showed that maximum range was observed for the trait plant height and minimum range was for number of branches per plant in both the F_2 populations. In the F_2 population of the cross V16 × S488 the phenotypic coefficient of variation was maximum for pod weight and genotypic coefficient of variation was maximum for number of pods per plant. In the cross V37 × S488, the total seed weight had maximum PCV and pod length showed maximum GCV. Considering these results, selection in cross V37 × S488 should emphasized based on the number of pods per plant, length of the pod and total seed weight whereas, in the cross V16 × S488 the selection should be based on number of branches per plant and 100 seed weight (Rangaiah, 1997).

Salimath *et al.* (2007) evaluated F_2 and F_3 population of two crosses of cowpea (KM-1 x Goa local and C-152 x Goa local). They observed that the mean performance of segregating progenies of both crosses were same in F_2 and F_3 generations with respect to yield per plant and its related characters. However, the magnitude of GCV and PCV were low in F_3 generation than F_2 generation.

Vural and Karasu (2007) observed significant differences among cowpea varieties for seed yield, biological yield and crop cycle. Kurer *et al.* (2010) hybridized two genetically distant parents belonging to determinate (V-1188) and indeterminate group (Goa local) and advanced to F_2 and F_3 generations. They observed that magnitude of variability was more in F_2 than in F_3 generation.

In order to create variability in cowpea, Moalafi *et al.* (2010) hybridized 55 exotic 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.

Santos *et al.* (2012) evaluated the total seed protein content in two crosses of cowpea (IT97K-1042-3 × BRS Tapaihum) and (IT97K-1042-3 × Canapu). They have observed individual plants having protein content up to 34.1 per cent in the F_2 population of the cross IT97K-1042-3 × Canapu. The study also suggested that an improved line with high protein content could be developed from the segregating generation by a standard breeding method.

Vavilapalli *et al.* (2013) studied genetic variability for different characters in 22 diverse genotypes of bush cowpea. The estimation of variance indicated that the prevalence of sufficient genetic variation among the genotypes for all the characters studied. They also observed high PCV and GCV for pod weight, plant height and pod length.

Shanko *et al.* (2014) observed high PCV and GCV for the traits like number of pods per plant, test weight and grain yield per plant in cowpea and suggested selection is effective through these characters.

According to a study by Santos *et al.* (2014), estimation of variance showed the existence of genetic variability among the genotypes for all the characters evaluated except for hundred seed weight. They also reported that phenotypic coefficients of variation were greater than genotypic coefficients of variation for all the character, which indicated that all the characters interacted with the environment to a greater degree.

Khan *et al.* (2015) carried out a genetic variability study with a set of 196 cowpea genotypes. The genotypes exhibited considerable amount of genetic variation for all the characters indicating the scope for selection of suitable basic material for further improvement. The estimates of PCV and GCV were high for number of pods per plant, pod length, plant height, number of branches per plant, test weight and seed yield per plant.

Khanpara *et al.* (2015) evaluated sixty diverse genotypes of vegetable cowpea for genetic variability. Significant differences among the genotypes for all the 12 characters studied were observed on estimation of variance. Green pod yield per plant exhibited highest range of variation, followed by pod weight, number of pods per plant and plant height. Green pod yield per plant, number of pods per plant, pod length and number of seeds per pod showed higher values of PCV than GCV indicating interaction of the genotypes with the environment. More or less equal value of PCV and GCV observed in the remaining characters indicated that these characters were less influenced by the environment.

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

Adetiloye *et al.* (2017) studied the morphological characters to evaluate the diversity in 20 cowpea accessions. Based on genotypic and phenotypic variances and genotypic coefficients of variation 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. 2. Heritability and genetic advance in cowpea

Heritability and genetic advance are the indicators of effectiveness of selection in a population. Heritability is determined by the genotypic and phenotypic variability present in the population while, genetic advance indicate how much improvement is possible through selection.

According to Rangaiah (1997), based on his studies on variability parameters of two F_2 populations (V16 × S488 and V37 × S488) of cowpea reported that heritability for number of pods per plant and pod weight were low. However, the cross V16 × S488 showed high genetic advance owing to high variability for pods per plant and pod weight.

In order to find out the effectiveness of selection in different generations of cowpea, Aremu (2011) conducted a study. He used two crosses of cowpea *viz.*, I7B × IAR 48 W and I7B × Danilla, for comparing the response of direct and indirect selection of plants for yield and yield contributing traits. The traits showing high values of heritability and genetic advance in the early segregating F_2 and F_3 generations were selected. They have observed that selection in the early segregating generations was reliable.

Vavilapalli *et al.* (2013) studied heritability and genetic advance for different characters in 22 diverse genotypes of bush cowpea. They observed high heritability coupled with high genetic advance for plant height, number of branches, pod length, pod girth, pod weight, pods per plant and yield per plant.

High heritability and genetic advance was observed in cowpea for number of pods per plant, test weight and grain yield per plant by Shanko *et al.* (2014). They suggested that selection for these traits will be effective for the improvement of the crop.

Santhos *et al.* (2014) observed moderate to high heritability for the characters days to flowering, green pod length, number of beans per pod, number of pods per plant and hundred seed weight. They also reported low value of heritability and the high value of the phenotypic coefficient of variation for grain yield indicating that direct selection based solely on yield will not be effective.

Higher heritability and genetic advance was observed for height of the plant, length of the pod, number of branches per plant, number of pods per plant, total seeds per pod, 100 seed weight and grain yield per plant (Khan *et al.*, 2015). This indicated that direct selection for these characters are suited for cowpea improvement.

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Khanpara *et al.* (2015) observed high heritability along with high genetic advance for green pod yield per plant, plant height, pod length, pod width, number of seeds per pod, number of pods per plant, pod weight, number of pods per cluster and hundred fresh seed weight in cowpea.

According to Sarath and Joseph (2017), grain yield per plant recorded high heritability and genetic advance while protein content recorded high heritability but low genetic advance.

Based on heritability and genetic advance obtained during the evaluation of 20 cowpea accessions, Adetiloye *et al.* (2017) concluded that yield improvement in cowpea can be achieved by improving number of main branches, pod numbers, pods per plant, pods per peduncle and seeds per pod.

2. 3. Correlation studies

Yield is a polygenic character governed by many genes and affected by other factors. Correlation studies imparts a better understanding of yield related factors, which in turn helps the plant breeder to adopt selection criteria. The degree and direction of association between two or more characters are measured statistically using correlation coefficient. The analysis on correlation also helps in determining the component characters on which selection can be practised for genetic improvement on yield (Singh and Narayanan, 1993). Generally, the character yield shows low heritability as it is controlled by polygenes. However, it may be positively correlated with characters showing high heritability. In such conditions, selection can be enforced to correlated traits with high heritability as representing characters in the early segregating generations.

Sumathi (2004) reported that number of pods per plant, pod length, hundred seed weight, number of cluster per plant and number of seeds per pod had positive significant correlation with grain yield per plant. It was also observed that plant height and pod filling index had negative significant correlation on grain yield.

The grain yield per plant recorded high positive and significant correlation with number of clusters per plant, number of pods per plant, hundred seed weight and harvest index (Lesly, 2005).

Biradar *et al.* (2007) reported that number of pods per plant was the most important character as it showed high and positive correlation with grain yield per plant. According to them seeds per plant and seed weight showed a positive and significant correlation with seed yield. The study also emphasised selection based on number of pods per plant and grain yield per plant in segregating generations of cowpea will be more effective in isolating promising breeding lines.

A general observation of data on correlation studies in F_2 population showed number of clusters per plant, number of pods per plant, length of the pod, pods per cluster and hundred seed weight had a significant correlation on grain yield per plant in segregating progenies of cowpea (Kurer, 2007).

Plant height, hundred seed weight and pods per cluster showed no significant correlation on grain yield per plant in F_2 and F_3 generations of cowpea (Ananda, 2012). In the study, pod length and number of pods per plant exhibited a significant association with grain yield per plant in progenies of F_2 and F_3 generations.

Grain yield per plant showed a higher positive significant correlation with clusters per plant and number of pods per plant. Protein content had a moderate positive significant relation with grain yield per plant (Throat and Gadewar, 2013).

High and positive significant correlation of pod yield per plant was observed with number of pods per plant, number of pods per cluster and pod weight (Singh, 2013). He suggested that these characters could serve as major components for the improvement of yield per plant.

Based on the studies conducted on the correlation of characters in cowpea Santhos *et al.* (2014) reported high positive correlations between the character pairs; days to flowering and days to maturity, days to maturity and pod weight, days to maturity and number of beans per pod, pod weight and number of beans per pod, green pod length and pod weight and number of pods per plant and grain yield. The character days to maturity and number of beans per pod showed negative correlation with grain yield.

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A study by Sharma *et al.* (2017) on correlation of various characters in F_2 generation of cowpea revealed that number of pods per plant, pod length and pod weight had significant and positive correlation with yield.

According to Silva *et al.* (2016), grain yield per plant showed a significant positive correlation with number of pods per plant in segregating generation.

Hundred seed weight and number of pods per plant showed positive direct effect on grain yield in cowpea and these characters are mainly controlled by additive gene action (Edakkalathur, 2016).

Patel *et al.* (2016) carried out correlation study on 32 diverse genotypes of cowpea for different traits. Correlation analysis between green pod yield per plant and other eleven quantitative characters showed that green pod yield per plant was highly significant and positively correlated with pod length and sugar content.

According to Sarath and Joseph (2017), number of seeds per pod had positive correlation with protein content, days to flowering and number of pods per plant. They also observed that grain yield per plant had negative correlation with protein content.

Correlation analysis for morphological traits in 20 cowpea accessions proved that yield improvement in cowpea could be achieved by improving the correlated traits *viz.*, number of main branches, pod numbers, pods per plant, pods per peduncle and seeds per pod (Adetiloye *et al.*, 2017).

2. 4. Path coefficient analysis

Path coefficient analysis allows the grouping of correlation coefficients into direct and indirect effects. It provides a more rational association of the characters and helps in determining the yielding components.

Grain yield showed a highest positive direct effect through number of pods per plant and lowest direct effect through pod length. The indirect effect for pod length was maximum through pod yield. The direct effect of grain yield through pod yield were almost equal to genotypic correlation between pod yield and grain yield (Neema and Palanisamy, 2001).

Grain yield per plant had positive direct effects through days to flowering and days to maturity. However, there was negative indirect effects observed through number of clusters per plant, pods per plant and pod filling index, resulting in negative non-significant relation with grain yield per plant (Sumathi, 2004).

Grain yield per plant showed highest positive direct effect through harvest index followed by number of pods per plant, number of seeds per pod and hundred seed weight. Plant height and days to flowering showed low positive direct effect on grain yield. Negative direct effect was showed by days to flower termination, days to physiological maturity and pod length on grain yield per plant (Lesly, 2005).

Number of pods per plant exhibited the highest positive direct effect on grain yield of cowpea followed by length of the pod, number of seeds per pod and hundred seed weight. Negative direct effect was shown by plant height, number of branches per plant, number of clusters and pods per clusters on grain yield of cowpea in F_2 and F_3 generations (Kurer, 2007).

Highest, positive direct effect was exhibited by number of cluster per plant towards grain yield per plant in F_2 and F_3 generations of cowpea cross C152 x IC-202778. Plant height showed negative direct effect on grain yield per plant in both the populations (Ananda, 2012).

The total pod yield showed highest direct effect through pod yield per plant followed by length of the pod. Days to 50 per cent flowering, pod weight and number of seeds per pod showed lowest positive direct effect towards total pod yield. Plant height, hundred seed weight, days to first harvest, number of pods per plant, pod width, number of primary branches and number of pods per cluster showed negative direct effects on yield. Indirect positive effects were manifested by plant height, number of pods per plant, number of pods per cluster and pod length towards pod yield (Singh, 2013).

As per the studies by Santos *et al.* (2014), green pod length was the trait that showed the greatest direct positive effect on grain yield in cowpea. Direct effect of number of pods per plant on grain yield was negative. However, number of pods per plant exhibited positive indirect effect through other traits especially through

number of seeds per plant. Days to maturity and days to flowering also showed positive direct effect on grain yield. However, indirect effects of days to flowering on grain yield through other characters were negligible. Number of beans per pod showed direct negative effect with grain yield.

On path analysis in F_2 generation of cowpea showed that pod yield had maximum positive direct effect through number of pods per cluster, days to first harvest, pod weight and days taken for pod development (Sharma *et al.*, 2015).

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

Hundred seed weight and number of pods per plant showed positive direct effect on grain yield in cowpea and these characters were mainly controlled by additive gene action (Edakkalathur, 2016).

Path analysis studies in cowpea showed that number of seeds per pod exhibited high positive direct effect on grain yield. Protein content exerted negative indirect effect through number of seeds per pod towards grain yield (Sarath and Joseph, 2017).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Pedigree breeding in early segregating generations of cowpea (*Vigna unguiculata* (L.) Walp)" was carried out during March 2016 – April 2017 at the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur. The main objective of the study was to select the best lines from F_2 and F_3 generations showing high yield and protein content. The study was conducted as two experiments

1) Evaluation of F_2 generation
2) Evaluation of F_3 generation

3. 1. Experimental site

The experimental site is 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. The annual rainfall was 1751.60 mm. The mean of maximum and minimum temperature was 30.17° C and 22.54° C respectively, during the growing season. The detailed data on weather during the growing season is given as Appendix-1.

3. 2. Experimental material

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. 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). The choice on these crosses were made because Anaswara is a high yielding variety of Kerala with moderate protein content, whereas, PKB 3 and PKB 4 are the varieties with high yield and protein content. In the present study, F_2 and F_3 generations of these two crosses were evaluated for yield and protein content. The features of the hybrids H 10 and H 11 are furnished in Table 1.

Table 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

3. 3. Experimental design

Experiment I: Evaluation of F_2 generation

The experimental material consisted of three parents (Anaswara, PKB 3 and PKB 4) and F_2 population of cross H 10 (Anaswara x PKB 3) and cross H 11 (Anaswara x PKB 4). Two hundred seeds of each F_1 population, along with their parents were sown in the experimental field of Plant Breeding and Genetics on 13-06-2016. The plot size was 100 m^2. The row-to-row distance was 60 cm and the plant-to-plant distance was 30 cm (Plate 1). 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), in order to raise a successful crop (Plate 3).

3. 4. Observations recorded

The observations in the field were recorded for all two hundred plants in each cross (Anaswara x PKB 3 and Anaswara x PKB 4) and twenty plants of parents. Observations were recorded as below:

3. 4. 1. Growth parameters

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

The height of individual plant was measured in centimetres (cm) from base

of the plant to the tip of main stem at maturity.

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

The total number of branches for each individual plant was counted and recorded at the time of harvest.

3. 4. 1. 3. Days to first flowering

The number of days taken from sowing date to the day on which first flower opened in individual plant was recorded.

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

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

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

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

3. 4. 2. Yield parameters

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

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

3. 4. 2. 2. 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 centimetres (cm).

3. 4. 2. 3. Number of seeds per pod

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

3. 4. 2. 4. Pod weight (g)

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

3. 4. 2. 5. Hundred seed weight (g)

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

3. 4. 2. 6. Grain yield per plant (g)

The weight of total seeds of each plant was recorded in grams at the time of harvest.

3. 4. 3. Biochemical traits

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

The protein content of seeds for each individual plant is estimated by Lowry's method (Sadasivam and Manickam, 1991). A detailed procedure is given below as flow chart

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 tartrate

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

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

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

Preparation of sample

500 mg of cowpea seeds were powdered using pestle and mortar

↓

10 ml of distilled water was added to the powdered sample

↓

The sample was centrifuged at 5000 rpm for 10 mins

↓

The supernatant was collected without disturbing the pellet

↓

The collected supernatant was used as sample

Preparation of standards

Five standards at a concentration of 0.04, 0.08, 0.12, 0.16, 0.20 mg ml^{-1} was prepared from bovine serum albumin

Analysis of protein content

0.2 ml of sample along with standards were taken in test tubes and

a blank was prepared with 1 ml of distilled water

↓

5 ml of reagent C was added to each test tube

↓

The test tubes were kept for 10 minutes incubation

↓

0.5 ml of reagent D was added to each test tube

↓

The test tubes were kept in dark for half an hour

↓

Development of blue colour is seen (except in blank)

↓

Optical density (OD) value was read out using spectrophotometer at 660 nm

Calculation

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.

$$\frac{OD\ of\ test}{OD\ of\ standard}\ x\ Concentration\ of\ the\ standard = X\ mg$$

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Plate 1. Evaluation of F_2 generation

Plate 2. Evaluation of F_3 generation

Plate 3. Field view of Experiment I

Plate 4. Field view of Experiment II

The protein content of the samples was estimated in mg ml^{-1} and expressed as percentage.

3. 5. Experiment II: Evaluation of F_3 generation

The experimental material consisted of F_3 population along with its three parents (Anaswara, PKB 3 and PKB 4). Twenty seeds of selected lines from F_2 population were sown in the experimental field along with twenty plants of their parents on 02-12-2016. The plot size was 200 m^2. The row-to-row distance and plant to plant, distance was 60 cm, respectively (Plate 2). All the operations for raising the crop was followed according to the recommended package of practices of KAU, 2011 (Plate 4).

3. 5. 1. Selection criteria for genotypes

From the two crosses (H 10 and H 11), totally twenty three lines were selected based on number of pods, total grain yield and protein content. Eight lines from the H 10 (Anaswara x PKB 3) population (Table 2) and fifteen lines from the H 11 (Anaswara x PKB 4) population were selected (Table 3). The criteria was

No. of pods : > 45

Grain yield : > 145 g / plant

Protein content : > 28 %

3. 6. Observations recorded

Same as experiment 1

3. 7. Statistical analysis

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

3. 7. 1. Estimation of mean and variance

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

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Table 2. Features of individual plants selected and advanced to F_3 generation of cross H 10

Plant no.	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)	Single 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. Features of individual plants selected and advanced to F_3 generation of cross H 11

Plant no.	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)	Single 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

3. 7. 1. 1. Mean

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

3. 7. 1. 2. 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

3. 7. 1. 3. Range

Difference between the maximum and minimum values in a data set.

3. 7. 2. 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).

3. 7. 2. 1. Phenotypic variance

For calculating the phenotypic variance, the individual observations made for each trait on F_2 and F_3 populations are used.

Phenotypic variance (σ_p^2) = Var. F_2

Where,

Var. F_2 = Variance in F_2 population

3. 7. 2. 2. Environmental variance

The environmental variance derived from the average of parents

$$\text{Environmental variance } (\sigma_e^2) = \frac{Var.p1 + Var.p2}{2}$$

Where,

Var. P_1 = Variance in parent 1

Var. P_2 = Variance in parent 2

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3. 7. 2. 3. Genotypic variance

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

Where,

σ_p^2 = Phenotypic variance

σ_e^2 = Environmental variance

3. 7. 2. 4. Genotypic and phenotypic coefficient of variation

According to the formula given by Burton and Devane (1953), the phenotypic and genotypic coefficient of variance 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

3. 7. 2. 5. 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

3. 7. 2. 6. Genetic advance

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

Genetic advance (GA) = I σ_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

3. 7. 2. 7. Genetic advance expressed as percentage over mean (GAM)

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

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. 7. 2. 8. Correlation analysis

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

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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. 7. 2. 9. 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.

$$P_{o1} + P_{o2}\, r_{12} + \text{----------} + P_{op}\, r_{1p} = r_{o1}$$

$$P_{o1} + r_{12} + P_{o2} + \text{----------} + P_{op}\, r_{2p} = r_{o2}$$

$$P_{o1} + r_{1p} + P_{o2}\, r_{2p} + \text{---------} + P_{op} = r_{op}$$

Where,

P_{o1}, P_{o2}, ---------- Pop = Direct path coefficients of variable 1, 2 ..... P on the dependent variables.

r_{12}, r_{13} ---------- r 1p -------- 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:

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

$P^2 oP)$.

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RESULTS

4. Results

The result obtained from the study on the quantitative characters in two inter-varietal crosses (H 10 and H 11) of cowpea are presented in this chapter. The data obtained for the different characters under study were subjected to statistical analysis to find out mean, variance, genetic components, correlations and path coefficients. The results are presented under the following headings

1. Estimation of means and variance
2. Genetic variability studies
3. Correlation studies
4. Path coefficient analysis

4. 1. Experiment I: Evaluation of F_2 generation

4. 1. 1. Estimation of means and variance

The mean and variance of each character for the F_2 generation of H 10 and H 11 crosses are presented in Table 4 and 5 respectively and described below

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

In cross H 10, Anaswara (P_1) (344.34 cm) was taller than PKB 3 (P_2) (40.47 cm). Based on the variance estimated, the parent Anaswara exhibited higher magnitude of variability (1856.55) than parent PKB 3 (12.33). The height of the plants in F_2 generation ranged from 210.50 cm to 516.20 cm. The mean height of cross H 10 in F_2 generation was 357.42 cm.

In cross H 11, Anaswara (P_1) (344.34 cm) was taller than PKB 4 (P_2) (131.46 cm). Based on the variance estimated, the parent Anaswara exhibited higher magnitude of variability (1856.55) than parent PKB 4 (147.05). The height of the plants in F_2 generation ranged from 230.60 cm to 523.60 cm. The mean height of the cross H 11 in F_2 generation was 354.16 cm.

Based on the variance estimated for plant height, higher variability was found in F_2 generation of cross H 10 (3264.84).

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

In cross H 10, higher number of branches per plant was observed in PKB 3 (P_2) (5.95) than that of Anaswara (P_1) (5.80). The range for branches per plant was 3.00 to 8.00 in F_2 generation. The mean value for number of branches per plant was 4.97.

In cross H 11, the higher number of branches per plant was observed in Anaswara (P_1) (5.80) than that of PKB 4 (P_2) (5.10). In the F_2 generation, the number of branches per plant ranged from 3.00 to 8.00. The mean value was 4.96.

Based on variance estimated for number of branches per plant, the higher variability for number of branches per plant was observed in F_2 generation of cross H 10 (1.35).

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

In cross H 10, the days taken for first flowering was higher in Anaswara (P_1) (57.55) than PKB 3 (P_2) (40.00). In the F_2 progenies, days to first flowering ranged from 50.00 to 80.00 days, with an average period of 65.31.

In H 11 cross, PKB 4 (P_2) (58.10) showed higher period for first flowering than that of Anaswara (P_1) (57.55). The range for days of first flowering was 48.00 to 79.00 days with a mean value of 63.71 in F_2 generation.

Based on the variance estimated, higher variability was observed in F_2 generation of cross H 10 (47.39) for days taken for first flowering.

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

In cross H 10, the number of days taken for first harvest was higher for parent Anaswara (P_1) (79.00) than PKB 3 (P_2) (64.05). In F_2 generation, the days taken for first harvest ranged from 68.00 to 99.00 days. The average days taken for first harvest was 84.78 in F_2 population.

In cross H 11, Anaswara (P_1) (79.00) showed higher value for days to first harvest than that of PKB 4 (P_2) (76.85). The range for days to first harvest in F_2 population was 63.00 to 99.00 days. The average days taken for first harvest was 82.26.

When both the F_2 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 51.98.

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

In the cross H 10, parent Anaswara (P_1) (129.35) showed higher value for days to last harvest than that of PKB 3 (P_2) (95.70). In F_2 generation, the days taken to last harvest ranged from 102.00 to 178.00 days. The average value for days to last harvest was 141.37.

In cross H 11, parent Anaswara (P_1) (129.35) had higher value for days to last harvest than that of PKB 4 (P_2) (121.50). In F_2 generation, the range for days to last harvest was 112.00 to 150.00 days with an average of 128.64.

The high variance of 297.49 was observed in cross H 10 for days to last harvest in F_2 population.

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

In cross H 10, number of pods per plant was higher in Anaswara (P_1) (40.60) than PKB 3 (P_2) (20.95). Number of pods per plant in F_2 generation ranged from 24.00 to 52.00. The average number of pods per plant was 37.70.

In cross H 11, number of pods per plant was higher in parent PKB 4 (P_2) (41.20) than Anaswara (P_1) (40.60). Number of pods per plant in F_2 generation ranged from 22.00 to 53.00. The mean value for number of pods per plant was 37.90.

The high variability (43.91) for number of pods per plant was observed in F_2 population of cross H 11.

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

In cross H 10, the mean of the pod length was higher in the case of Anaswara (P_1) (23.66 cm) than PKB 3 (P_2) (15.16 cm). In F_2 generation, the length of the pod ranged from 14.00 cm to 31.40 cm. The mean value for pod length was 23.67 cm.

In cross H 11, the higher mean for pod length was shown by Anaswara (P_1) (23.66 cm) than that of PKB 4 (P_2) (22.87 cm). The value for pod length in F_2

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generation ranged from 14.00 cm to 30.30 cm. The average value exhibited for pod length was 23.48 cm.

H 10 population exhibited higher variance (14.63) for pod length than H 11 (10.28) population in F_2 generation.

4. 1. 1. 8. Single pod weight (g)

In cross H 10, Anaswara (P_1) (3.81 g) showed higher magnitude towards pod weight when compared to PKB 3 (P_2) (3.10 g). In F_2 generation, the pod weight ranged from 2.86 g to 4.74 g. The average weight of the single pod was 3.62 g.

In H 11 cross, Anaswara (P_1) (3.81 g) showed higher value compared to PKB 4 (P_2) (3.77 g) for single pod weight. The range was 2.55 g to 5.97 g for pod weight in F_2 generation. The mean value for pod weight was 4.23 g.

The variability was high in H 11 cross (0.43) when compared to H 10 (0.28) cross in F_2 generation.

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

In cross H 10, the average value for number of seeds per pod was higher in Anaswara (P_1) (17.17) than PKB 3 (P_2) (12.62). In F_2 population, the number of seeds per pod ranged from 7.60 to 22.60. The mean value for seeds per pod was 15.94.

In cross H 11, the average value for number of seeds per pod was maximum in Anaswara (P_1) (17.17) than PKB 4 (P_2) (16.61). Number of seeds per pod ranged from 15.00 to 23.20 in F_2 population. The average number seeds per pod was 18.79.

The cross H 10 (5.74) showed higher variance than that of H 11 (4.17) cross in F_2 population.

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

In cross H 10, high value for hundred seed weight (21.41 g) was exhibited in Anaswara (P_1) than PKB 3 (P_2) (13.08 g). The weight for hundred seeds ranged from 10.42 to 30.81 g. The average weight for hundred seeds was 19.75 g in F_2 population.

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In cross H 11, the highest mean for hundred seed weight was recorded in Anaswara (P_1) (21.41 g) than PKB 4 (P_2) (20.09 g). The hundred seed weight ranged from 18.13 g to 25.96 g in F_2 population with an average hundred seed weight of 21.95 g.

Cross H 10 (13.04) showed high variability than H 11 cross (3.56) for hundred seed weight in F_2 population.

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

In cross H 10, the parent Anaswara (P_1) (137.80 g) recorded higher mean than the parent PKB 3 (P_2) (25.36 g) for grain yield per plant. The value for grain yield per plant ranged from 110.06 g to 197.69 g in F_2 generation. The average grain yield was 157.88 g.

In cross H 11, the maximum grain yield per plant was recorded in PKB 4 (P_2) (140.99 g) when compared to Anaswara (P_1) (137.80 g). In F_2 population, the range for grain yield per plant was 128.75 g to 161.88 g with an average grain yield of 143.39 g.

The cross H 10 (211.82) showed higher variability for grain yield per plant than that of H 11 cross (53.16) in F_2 population.

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

The protein content in seeds was higher in PKB 3 (P_2) (25.89) than that of Anaswara (P_1) (24.19). The protein content in seeds ranged from 15.10 per cent to 30.30 per cent in F_2 population. The average protein content in seeds was 23.75 per cent.

In cross H 11, PKB 4 (P_2) (26.57) showed high protein content than Anaswara (P_1) (24.19). In F_2 population of H 11, the protein content ranged from 18 per cent to 30.1 per cent. The average protein content recorded was 23.95 per cent.

The cross H 10 (9.34) showed higher variability for protein content than cross H 11 (8.48) in F_2 population.

Table 4. Mean performance of parents and F_2 generation of cross H 10 (Anaswara x PKB 3) for quantitative characters in cowpea

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)	Single pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
P_1	344.34	5.80	57.55	79.00	129.35	40.60	23.66	3.81	17.17	21.41	137.80	24.19
P_2	40.47	5.95	40.00	64.05	95.70	20.95	15.16	3.10	12.62	13.08	25.36	25.89
F_2	357.42	4.97	65.31	84.78	141.31	37.70	23.67	3.62	15.94	19.75	157.88	23.75
Variance of parents and F_2 generation for quantitative characters in cowpea												
P_1	1856.55	0.36	3.65	13.70	95.13	4.34	5.70	0.25	3.55	1.13	70.96	3.13
P_2	12.33	0.65	3.90	11.65	5.21	3.15	3.31	0.30	2.78	0.92	1.35	2.71
F_2	3264.84	1.35	47.39	49.56	297.49	33.56	14.63	0.28	5.74	13.04	211.82	9.34
Range of F_2 generation for quantitative characters in cowpea												
Min	210.50	3.00	50.00	68.00	102.00	24.00	14.00	2.86	7.60	10.42	110.06	15.10
Max	516.20	8.00	80.00	99.00	178.00	52.00	31.40	4.74	22.60	30.81	197.69	30.30

Table 5. Mean performance of parents and F_2 generation of cross H 11 (Anaswara x PKB 4) for quantitative characters in cowpea

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)	Single pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
P_1	344.34	5.80	57.55	79.00	129.35	40.60	23.66	3.81	17.17	21.41	137.80	24.19
P_2	131.46	5.10	58.10	76.85	121.50	41.20	22.87	3.77	16.61	20.09	140.99	26.57
F_2	354.16	4.96	63.71	82.26	128.64	37.90	23.48	4.23	18.79	21.95	143.39	23.95
Variance of parents and F_2 generation for quantitative characters in cowpea												
P_1	1856.55	0.36	3.65	13.70	95.13	4.34	6.01	0.25	3.55	1.13	70.96	3.13
P_2	147.05	0.29	6.69	12.33	20.45	11.36	3.61	0.17	3.73	1.59	29.25	1.91
F_2	2681.41	0.90	44.38	51.98	94.16	43.91	10.28	0.43	4.17	3.56	53.16	8.48
Range of F_2 generation for quantitative characters in cowpea												
Min	230.60	3.00	48.00	63.00	112.00	22.00	14.00	2.55	15.00	18.13	128.75	18.00
Max	523.60	8.00	79.00	99.00	150.00	53.00	30.30	5.97	23.20	25.96	161.88	30.10

P_1 = Parent 1, P_2 = Parent 2

4. 1. 2. Genetic variability studies

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_2 population of cross H 10 and H 11 and are presented in Table 6 and 7, respectively.

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

In F_2 generation of cross H 10, the PCV was 15.99 and GCV was 13.51. The heritability for this character was 71.38 per cent. Genetic advance for this character was 84.02. Genetic advance expressed as per cent of mean was 23.51.

In F_2 generation of cross H 11, the PCV was 14.62 and GCV was 11.57. The heritability for this character was 62.64 per cent. Genetic advance for this character was 66.82. Genetic advance expressed as per cent of mean was 18.87.

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

In F_2 generation of cross H 10, the PCV was 23.34 and GCV was 18.47. The heritability for this character was 62.63 per cent. Genetic advance for this character was 1.50. Genetic advance expressed as per cent of mean was 30.18.

In F_2 generation of cross H 11, the PCV was 19.13 and GCV was 15.29. The heritability for this character was 63.96 per cent. Genetic advance for this character was 1.25. Genetic advance expressed as per cent of mean was 25.20.

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

In F_2 generation of cross H 10, the PCV was 10.54 and GCV was 10.11. The heritability for this character was 92.04 per cent. Genetic advance for this character was 13.05. Genetic advance expressed as per cent of mean was 19.98.

In F_2 generation of cross H 11, the PCV was 10.46 and GCV was 9.83. The heritability for this character was 88.35 per cent. Genetic advance for this character was 12.12. Genetic advance expressed as per cent of mean was 19.02.

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

In F_2 generation of cross H 10, the PCV was 8.30 and GCV was 7.16. The heritability for this character was 74.43 per cent. Genetic advance for this character was 10.79. Genetic advance expressed as per cent of mean was 12.73.

In F_2 generation of cross H 11, the PCV was 8.76 and GCV was 7.59. The heritability for this character was 74.96 per cent. Genetic advance for this character was 11.13. Genetic advance expressed as per cent of mean was 13.53.

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

In F_2 generation of cross H 10, the PCV was 12.21 and GCV was 11.13. The heritability for this character was 83.14 per cent. Genetic advance for this character was 29.54. Genetic advance expressed as per cent of mean was 20.90.

In F_2 generation of cross H 11, the PCV was 7.54 and GCV was 4.69. The heritability for this character was 38.63 per cent. Genetic advance for this character was 7.72. Genetic advance expressed as per cent of mean was 6.00.

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

In F_2 generation of cross H 10, the PCV was 15.37 and GCV was 14.48. The heritability for this character was 88.84 per cent. Genetic advance for this character was 10.60. Genetic advance expressed as per cent of mean was 28.12.

In F_2 generation of cross H 11, the PCV was 17.49 and GCV was 15.84. The heritability for this character was 82.12 per cent. Genetic advance for this character was 11.21. Genetic advance expressed as per cent of mean was 29.58.

4. 1. 2 .7. Pod length (cm)

In F_2 generation of cross H 10, the PCV was 16.16 and GCV was 13.44. The heritability for this character was 69.18 per cent. Genetic advance for this character was 5.45. Genetic advance expressed as per cent of mean was 23.02.

In F_2 generation of cross H 11, the PCV was 13.65 and GCV was 10.10. The heritability for this character was 54.67 per cent. Genetic advance for this character was 3.61. Genetic advance expressed as per cent mean of was 15.37.

4. 1. 2. 8. Single pod weight (g)

In F_2 generation of cross H 10, the PCV was 14.53 and GCV was 0.90. The heritability for this character was 0.38 per cent. Genetic advance for this character was 0.01. Genetic advance expressed as per cent of mean was 0.28.

In F_2 generation of cross H 11, the PCV was 15.58 and GCV was 11.21. The heritability for this character was 51.77 per cent. Genetic advance for this character was 0.70. Genetic advance expressed as per cent of mean was 16.55.

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

In F_2 generation of cross H 10, the PCV was 15.03 and GCV was 10.06. The heritability for this character was 44.82 per cent. Genetic advance for this character was 2.21. Genetic advance expressed as per cent of mean was 13.86.

In F_2 generation of cross H 11, the PCV was 10.87 and GCV was 3.86. The heritability for this character was 12.62 per cent. Genetic advance for this character was 0.53. Genetic advance expressed as per cent of mean was 2.82.

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

In F_2 generation of cross H 10, the PCV was 18.28 and GCV was 17.55. The heritability for this character was 92.14 per cent. Genetic advance for this character was 6.85. Genetic advance expressed as per cent of mean was 34.68.

In F_2 generation of cross H 11, the PCV was 8.60 and GCV was 6.76. The heritability for this character was 61.87 per cent. Genetic advance for this character was 2.41. Genetic advance expressed as per cent of mean was 10.98.

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

In F_2 generation of cross H 10, the PCV was 9.22 and GCV was 8.39. The heritability for this character was 82.93 per cent. Genetic advance for this character was 24.86. Genetic advance expressed as per cent of mean was 15.75.

In F_2 generation of cross H 11, the PCV was 5.08 and GCV was 1.22. The heritability for this character was 5.76 per cent. Genetic advance for this character was 0.86. Genetic advance expressed as per cent of mean was 0.60.

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Table 6. Estimation of genetic variability components for quantitative characters in F_2 generation of cowpea cross H 10 (Anaswara x PKB 3)

Characters	Mean	PCV	GCV	h^2 (%)	GA	GAM (%)
Plant height (cm)	357.42	15.99	13.51	71.38	84.02	23.51
Number of branches /plant	4.97	23.34	18.47	62.63	1.50	30.18
Days to first flowering	65.31	10.54	10.11	92.04	13.05	19.98
Days to first harvest	84.78	8.30	7.16	74.43	10.79	12.73
Days to last harvest	141.31	12.21	11.13	83.14	29.54	20.90
No. of pods /plant	37.70	15.37	14.48	88.84	10.60	28.12
Pod length (cm)	23.67	16.16	13.44	69.18	5.45	23.02
Single pod weight (g)	3.62	14.53	0.90	0.38	0.01	0.28
No. of seeds /pod	15.94	15.03	10.06	44.82	2.21	13.86
100-seed weight (g)	19.75	18.28	17.55	92.14	6.85	34.68
Grain yield /plant (g)	157.88	9.22	8.39	82.93	24.86	15.75
Protein content (%)	23.75	12.87	10.67	68.72	4.33	18.23

Table 7. Estimation of genetic variability components for quantitative characters in F_2 generation of cowpea cross H 11 (Anaswara x PKB 4)

Characters	Mean	PCV	GCV	h^2 (%)	GA	GAM (%)
Plant height (cm)	354.16	14.62	11.57	62.64	66.82	18.87
Number of branches /plant	4.96	19.13	15.29	63.96	1.25	25.20
Days to first flowering	63.71	10.46	9.83	88.35	12.12	19.02
Days to first harvest	82.26	8.76	7.59	74.96	11.13	13.53
Days to last harvest	128.64	7.54	4.69	38.63	7.72	6.00
No. of pods /plant	37.90	17.49	15.84	82.12	11.21	29.58
Pod length (cm)	23.48	13.65	10.10	54.67	3.61	15.37
Single pod weight (g)	4.23	15.58	11.21	51.77	0.70	16.55
No. of seeds /pod	18.79	10.87	3.86	12.62	0.53	2.82
100-seed weight (g)	21.95	8.60	6.76	61.87	2.41	10.98
Grain yield /plant (g)	143.39	5.08	1.22	5.76	0.86	0.60
Protein content (%)	23.95	12.16	10.19	70.25	4.21	17.58

PCV : Phenotypic coefficient variation
GCV : Genotypic coefficient variation
GA : Genetic advance
GAM : Genetic advance as per cent of mean
h^2 : Heritability per cent

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

In F_2 generation of cross H 10, the PCV was 12.87 and GCV was 10.67. The heritability for this character was 68.72 per cent. Genetic advance for this character was 4.33. Genetic advance expressed as per cent of mean was 18.23.

In F_2 generation of cross H 11, the PCV was 12.16 and GCV was 10.19. The heritability for this character was 70.25 per cent. Genetic advance for this character was 4.21. Genetic advance expressed as per cent of mean was 17.00.

4. 1. 3. Correlation studies

Selection for particular character is known to bring about correlated response in certain different characters (Falconer, 1960). The genetic variability of various traits is important for selecting a genotype in breeding programme, to progress for next generation. Grain yield is the most essential and complex trait in majority of the crop species. Grain yield of a crop can be improved by indirect selection through other easily detectable characters. However, this needs a better understanding about the relationship of various attributes of grain yield and their possible relationship among themselves. The phenotypic correlations of grain yield with other quantitative characters in F_2 population of cross H 10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) are given in Table 8 and 9, respectively.

4. 1. 3. 1. Correlation between quantitative characters in cross H 10 of cowpea

A correlation matrix between quantitative characters of cross H 10 showed a significant and positive relation between plant height with number of branches per plant (0.055), single pod weight (0.073) and protein content (0.016). Days to first flowering showed significant and positive correlation with days to first harvest (0.914) and single pod weight (0.223). Days to first harvest showed significant and positive correlation with days to last harvest (0.213). Days to last harvest showed significant and positive correlation with pod length (0.018). Number of pods per plant showed significant and positive correlation with hundred seed weight (0.050). Single pod weight showed significant and positive correlation with hundred seed weight (0.299) and grain yield per plant (0.063).

There was also significant and negative correlation observed between plant height with days to first harvest (-0.157). Days to first flowering showed significant

and negative correlation with protein content (-0.167). Days to first harvest showed significant and negative correlation with pod length (-0.033), number of seeds per pod (-0.079) and grain yield per plant (-0.031). Days to last harvest showed significant and negative correlation with single pod weight (-0.195), grain yield per plant (-0.055) and protein content (-0.049). Single pod weight showed significant and negative correlation with protein content (-0.249).

4. 1. 3. 2. Correlation between quantitative characters in cross H 11 of cowpea

A correlation matrix between quantitative characters of cross H 11 showed a significant and positive relation between plant height with number of branches per plant (0.268) and hundred seed weight (0.035). Number of branches per plant showed significant and positive correlation with number of seeds per pod (0.109). Days to first flowering showed significant and positive correlation with days to first harvest (0.843) and single pod weight (0.016). Days to last harvest showed significant and positive correlation with hundred seed weight (0.151) and grain yield per plant (0.004). Number of pods per plant showed significant and positive correlation with pod length (0.247), grain yield per plant (0.518) and protein content (0.372). A significant and positive correlation was showed by pod length with hundred seed weight (0.230).

There was also significant and negative correlation observed between plant height with number of pods per plant (-0.066). Number of branches per plant showed significant and negative correlation with days to last harvest (-0.153). Days to first flowering showed significant and negative correlation with protein content (-0.011). Days to first harvest showed significant and negative correlation with pod length (-0.120) and grain yield per plant (-0.139). Days to last harvest showed significant and negative correlation with number of pods per plant (-0.249) and pod length (-0.142). Number of pods per plant showed significant and negative correlation with single pod weight (-0.045).

Table 8. Correlation between quantitative characters of cowpea in F_2 generation of cross H 10 (Anaswara x PKB 3)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.055**	-0.125	-0.157*	0.010	-0.010	0.027	0.073*	-0.036	-0.053	-0.062	0.016*
X2		1	-0.017	-0.009	0.101	0.191	0.044	-0.231	-0.099	-0.133	0.080	0.177
X3			1	0.914**	0.175	-0.020	-0.002	0.223**	-0.020	0.093	0.011	-0.167**
X4				1	0.213*	-0.033	-0.033**	0.196	-0.079*	0.043	-0.031**	-0.131
X5					1	0.053	0.018*	-0.195**	-0.221	-0.253	-0.055*	-0.049**
X6						1	0.103	-0.167	-0.018	0.050**	0.268	0.192
X7							1	0.037	0.247	0.094	-0.051	0.178
X8								1	0.317	0.299**	0.063**	-0.249**
X9									1	0.382	0.286	-0.042
X10										1	0.079	-0.142
X11											1	-0.129
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 pod
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

Table 9. Correlation between quantitative characters of cowpea in F_2 generation of cross H 11 (Anaswara x PKB 4)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.268**	0.103	0.128	0.024	-0.066**	0.061	-0.011	0.055	0.035**	-0.059	-0.062
X2		1	-0.056	-0.040	-0.153**	0.030	0.231	-0.060	0.109**	-0.002	-0.006	0.108
X3			1	0.843**	0.221	-0.202	-0.065	0.016**	-0.023	0.087	-0.060	-0.011**
X4				1	0.127	-0.237	-0.120**	-0.025	-0.008	0.065	-0.139**	-0.102
X5					1	-0.249*	-0.142**	0.105	-0.017	0.151*	0.004**	-0.164
X6						1	0.247**	-0.045**	0.014	-0.031	0.518**	0.372**
X7							1	0.0237	0.159	0.230**	0.169	0.275
X8								1	0.178	0.753	0.217	0.076
X9									1	0.144	0.012	0.110
X10										1	0.250	0.082
X11											1	0.226
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 pod
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

4. 1. 4. Path coefficient analysis for grain yield

Grain yield is a complex trait directly and indirectly influenced by other traits. Hence, the direct and indirect effect of different traits on grain yield was partitioned by path analysis. The estimates of direct and indirect effects of the quantitative characters on grain yield in F_2 population are shown in Table 10.

The residual effect contribution on grain yield was 0.268. 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

4. 1. 4. 1. Direct effect on grain yield

High, positive direct effect showed by plant height (0.440), days to first harvest (0.409) and number of seeds per pod (0.374) on grain yield. Pod length (0.277) and hundred seed weight (0.202) showed a moderate, positive direct effect. High and negative, direct effect was showed by number of pods per plant (-0.593). Moderate and negative, direct effect showed by days to last harvest (-0.200) and single pod weight (-0.242). Protein content (-0.114) showed low and negative, direct effect. Number of branches per plant (-0.048) and days to first flowering (-0.039) showed a negligible and negative, direct effect on grain yield.

4. 1. 4. 2. Indirect effects on grain yield

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

Low, positive, indirect effect was exerted by plant height through number of pods per plant (0.181), single pod weight (0.123) and hundred seed weight (0.101) towards grain yield. Negligible and positive, indirect effect was exerted by plant height through number of branches per plant (0.031) and days to last harvest (0.035). Low, negative and indirect effect was exerted by plant height through pod length (-0.136) and number of seeds per pod (-0.158). Negligible and negative,

indirect effect was exerted by plant height through days to first flowering (-0.075), days to first harvest (-0.062) and protein content (-0.031) towards grain yield.

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

Negligible and positive, indirect effect was exerted by number of branches per plant through days to last harvest (0.013), pod length (0.015), number of seeds per pod (0.013), hundred seed weight (0.003) and protein content (0.003) towards grain yield. Negligible and negative, indirect effect was exerted by number of branches per plant through days to first flowering (-0.001), days to first harvest (-0.002), number of pods per plant (-0.021) and single pod weight (-0.001) towards grain yield.

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

Negligible and positive, indirect effect was exerted by days to first flowering through plant height (0.067), number of pods per plant (0.063) and single pod weight (0.071). High, negative and indirect effect showed through days to first harvest (-0.338). Negligible and negative, indirect effect was exerted by days to first flowering through number of branches per plant (-0.008), days to last harvest (-0.055), pod length (-0.063), hundred seed weight (-0.016) and protein content (-0.067). Days to first flowering had no indirect effect on grain yield through number of seeds per pod (0.000).

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

High and positive, indirect effect was exerted by days to first harvest through days to first flowering (0.351) towards grain yield. Low, positive indirect effect was exerted by days to first harvest through pod length (0.131) towards grain yield. Negligible, positive indirect effect was exerted by days to first harvest through number of branches per plant (0.016), number of seeds per pod (0.069), hundred seed weight (0.078) and protein content (0.012) towards grain yield. Low, negative indirect effect was exerted by days to first harvest through number of pods per plant (-0.102) and single pod weight (-0.131). Negligible and negative, indirect effect was exerted by days to first harvest through plant height (-0.057) and days to first harvest (-0.029) towards grain yield.

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

Low and positive, indirect effect was exerted by days to last harvest through hundred seed weight (0.100) towards grain yield. Negligible, positive and indirect effect was exerted by days to last harvest through number of branches per plant (0.054), days to first harvest (0.014), number of pods per plant (0.052), pod length (0.002), single pod weight (0.026), number of seeds per pod (0.016) and protein content (0.002) towards grain yield. Negligible and negative, indirect effect was exerted by days to last harvest through plant height (-0.016) and days to first harvest (-0.028) towards grain yield.

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

Moderate, positive and indirect effect was exerted by number of pods per plant through pod length (0.237) towards grain yield. Low, positive and indirect effect was exerted by number of pods per plant through days to first harvest (0.148), days to last harvest (0.154) and number of seeds per pod (0.113). Negligible, positive indirect effect was exerted by number of pods per plant through days to first flowering (0.095) and hundred seed weight (0.089) towards grain yield. High and negative, indirect effect was exerted by number of pods per plant through single pod weight (-0.415). Moderate, negative indirect effect was exerted by number of pods per plant through plant height (-0.243) and number of branches per plant (-0.261). Number of pods per plant had no indirect effect on yield per plant through protein content (0.000) towards grain yield.

4. 1. 2. 2. 7. Pod length (cm)

Moderate, positive indirect effect was exerted by pod length through number of seeds per pod (0.205) towards grain yield. Negligible, positive and indirect effect was exerted by pod length through days to first flowering (0.044), days to first harvest (0.088) and protein content (0.017). Low, negative indirect effect was exerted by pod length through number of pods per plant (-0.110) and single pod weight (-0.122) towards grain yield. Negligible, negative and indirect effect was exerted by pod length through plant height (-0.086), number of branches per plant (-0.088), days to last harvest (0.003) and hundred seed weight (-0.033) towards grain yield.

4. 1. 2. 2. 8. Single pod weight (g)

Low, positive and indirect effect was exerted by single pod weight through number of pod length (0.106) towards grain yield. Negligible, positive and indirect effect was exerted by single pod weight through days to first flowering (0.043), days to first harvest (0.077), days to last harvest (0.031), number of seeds per pod (0.024) and protein content (0.029) towards grain yield. Low, negative and indirect effect was exerted by single pod weight through number of pods per plant (-0.169) towards grain yield. Negligible, negative and indirect effect was exerted by single pod weight through plant height (-0.067) and number of branches per plant (-0.007) towards grain yield. Single pod weight had no indirect effect on grain yield through hundred seed weight (0.000).

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

Low, positive indirect effect was exerted by number of seeds per pod through plant height (0.134) and number of branches per plant (0.101) towards grain yield. Negligible, positive and indirect effect was exerted by single pod weight through days to last harvest (0.030), number of pods per plant (0.071), single pod weight (0.037) and hundred seed weight (0.041) towards grain yield. Moderate, negative and indirect effect was exerted by single pod weight through pod length (-0.277). Negligible, negative and indirect effect was exerted by single pod weight through days to first harvest (-0.063). Number of seeds per pod had no indirect effect through days to first flowering (0.000) and protein content (0.000) towards grain yield.

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

Low, positive and indirect effect was exerted by hundred seed weight through days to last harvest (0.101) towards grain yield. Negligible, positive and indirect effect was exerted by hundred seed weight through number of branches per plant (0.014), number of pods per plant (0.030), pod length (0.024), number of seeds per pod (0.022) and protein content (0.069) towards grain yield. Negligible, negative and indirect effect was exerted by hundred seed weight through plant height (-0.046), days to first flowering (-0.008) and days to first harvest (-0.038) towards grain yield. Hundred seed weight had no indirect effect through single pod weight (0.00) towards grain yield.

Table 10. Path analysis with direct and indirect effects on grain yield of F_2 population in cowpea

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	**0.440**	-0.003	0.067	-0.057	-0.016	-0.243	-0.086	-0.067	0.134	-0.046	0.008
X2	0.031	**-0.048**	-0.008	0.016	0.054	-0.261	-0.088	-0.007	0.101	0.014	0.007
X3	-0.075	-0.001	**-0.039**	0.351	-0.028	0.095	0.044	0.043	0.000	-0.008	-0.019
X4	-0.062	-0.002	-0.338	**0.409**	0.014	0.148	0.088	0.077	-0.063	-0.038	-0.003
X5	0.035	0.013	-0.055	-0.029	**-0.200**	0.154	-0.003	0.031	0.030	0.101	0.001
X6	0.181	-0.021	0.063	-0.102	0.052	**-0.593**	-0.110	-0.169	0.071	0.030	0.000
X7	-0.136	0.015	-0.063	0.131	0.002	0.237	**0.277**	0.106	-0.277	0.024	-0.007
X8	0.123	-0.001	0.071	-0.131	0.026	-0.415	-0.122	**-0.242**	0.037	0.000	0.014
X9	-0.158	0.013	0.000	0.069	0.016	0.113	0.205	0.024	**0.374**	0.022	0.000
X10	0.101	0.003	-0.016	0.078	0.100	0.089	-0.033	0.000	0.041	**0.202**	0.039
X11	-0.031	0.003	-0.067	0.012	0.002	0.000	0.017	0.029	0.000	0.069	**-0.114**

Residual effect = 0.268

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 pod
X10 – Hundred seed weight (g)
X11 – Protein content (%)

4. 1. 2. 2. 11. Protein content (%)

Negligible and positive, indirect effect was exerted by protein content through plant height (0.008), number of branches per plant (0.007), days to last harvest (0.001), single pod weight (0.014) and hundred seed weight (0.039) towards grain yield. Negligible and negative, indirect effect was exerted by protein content through days to first flowering (-0.019), days to first harvest (-0.003) and pod length (-0.007) towards grain yield. Protein content had no indirect effect through number of pods per plant and number of seeds per pod (0.000) on grain yield.

4. 2. Experiment II: Evaluation of F_3 generation

4. 2. 1. Estimation of means and variance

The mean and variance of each character for the F_3 generation of cross H 10 and cross H 11 are presented in Table 11 and 12, respectively and described below.

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

In cross H 10, Anaswara (P_1) (285.10 cm) was taller than PKB 3 (P_2) (31.16 cm). Based on the variance estimated, the parent Anaswara exhibited higher magnitude of variability (883.11). The height of the plants in F_3 generation ranged from 215.20 cm to 449.80 cm. The mean height of cross H 10 in F_3 generation was 327.87 cm.

In cross H 11, Anaswara (P_1) (285.10 cm) was taller than PKB 4 (P_2) (130.61 cm). Based on the variance estimated, the parent Anaswara exhibited higher magnitude of variability (883.11). The height of the plants in F_2 generation ranged from 236.90 cm to 437.50 cm. The mean height of the cross H 11 in F_3 generation was 339.56 cm.

Based on the variance estimated for plant height, higher variability was observed in F_3 generation of cross H 10 (2211.68).

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

In cross H 10, higher number of branches per plant was observed in PKB 3 (P_2) (5.20) than that of Anaswara (P_1) (4.40). The range for number of branches

per plant was 3.00 to 6.00 in F_3 generation. The mean value for number of branches per plant is 4.78.

In cross H 11, the higher number of branches per plant was observed in PKB 4 (P_2) (4.50) than Anaswara (P_1) (4.40). In the F_3 generation, the number of branches per plant ranged from 4.00 to 7.00. The mean value for number of branches per plant was 4.79.

Based on variance estimated for number of branches per plant, the maximum variability for branches per plant was observed in F_3 generation of cross H 10 (0.50).

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

In cross H 10, the days taken for first flowering was higher in Anaswara (P_1) (54.30) than PKB 3 (P_2) (40.70). In the F_3 progenies, days to first flowering ranged from 49.00 to 76.00 days, with an average period of 59.50.

In cross H 11, PKB 4 (P_2) (57.10) showed higher period for first flowering than that of Anaswara (P_1) (54.30). The range for days of first flowering was 50.00 to 75.00 days with a mean value of 63.18 in F_3 generation.

Based on the variance estimated higher variability was observed in F_3 generation of cross H 10 (29.59) for days taken for first flowering.

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

In cross H 10, the number of days taken for first harvest was higher for parent Anaswara (P_1) (73.40) than PKB 3 (P_2) (57.90). In F_3 generation, the days taken for first harvest ranged from 69.00 to 104.00 days. The average days taken for first harvest was 84.06 in F_3 population.

In cross H 11, PKB 4 (P_2) (75.40) showed higher value for days to first harvest than Anaswara (P_1) (73.40). The range for days to first harvest in F_3 population was 73.00 to 102.00 days. The average days taken for first harvest was 86.74.

When both the F_3 population of cross H 10 and H 11 are considered for variability, H 10 cross showed maximum variability for days taken for first harvest with a value of 38.66.

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

In the cross H 10, parent Anaswara (P_1) (126.60) showed higher value for days to last harvest than that of PKB 3 (P_2) (94.70). In F_3 generation, the days taken to last harvest ranged from 119.00 to 149.00 days. The average value for days to last harvest was 135.26.

In cross H 11, parent Anaswara (P_1) (126.60) had higher value for days to last harvest than that of PKB 4 (P_2) (126.20). In F_3 generation, the range for days of last harvest was 120.00 to 149.00 days with an average of 139.83.

The high variance of 63.07 was observed in cross H 10 for days to last harvest in F_3 population.

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

In cross H 10, number of pods per plant was higher in Anaswara (P_1) (41.00) than PKB 3 (P_2) (21.30). Number of pods per plant in F_3 generation ranged from 34.00 to 48.00. The average number of pods per plant was 41.30.

In cross H 11, number of pods per plant was higher in parent PKB 4 (P_2) (41.00) than Anaswara (P_1) (37.50). Number of pods per plant in F_3 generation ranged from 5.00 to 51.00. The mean value for number of pods per plant was 40.93.

The high variability (19.81) for number of pods per plant was observed in F_3 population of cross H 11.

4. 2. 1. 7. Pod length (cm)

In cross H 10, the mean of the pod length was higher in the case of Anaswara (P_1) (23.65 cm) than PKB 3 (P_2) (13.80 cm). In F_3 generation, the length of the pod ranged from 14.80 cm to 29.80 cm. The mean value for pod length was 23.32 cm.

In cross H 11, the higher mean for pod length was shown by Anaswara (P_1) (23.65 cm) than that of PKB 4 (P_2) (23.52 cm). The value for pod length in F_3 generation ranged from 15.50 cm to 28.60 cm. The average value exhibited for pod length was 23.19 cm.

H 10 population exhibited higher variance (8.81) for pod length than H 11 (6.42) population in F_3 generation.

4. 2. 1. 8. Single pod weight (g)

In cross H 10, Anaswara (P_1) (3.48 g) showed higher magnitude towards pod weight when compared to PKB 3 (P_2) (2.29 g). In F_3 generation, the pod weight ranged from 4.96 g to 3.05 g. The average weight of the pod was 3.90 g.

In H 11 cross, Anaswara (P_1) (3.48 g) showed higher value compared to PKB 4 (P_2) (3.32 g) for pod weight. The range was 3.01 g to 5.96 g for pod weight in F_3 generation. The mean value for pod weight was 3.87 g.

The variability was high in H 11 cross (0.33) when compared to H 10 (0.31) cross in F_3 generation.

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

In cross H 10, the average value for number of seeds per pod was higher in Anaswara (P_1) (15.02) than PKB 3 (P_2) (13.06). In F_3 population, the number of seeds per pod ranged from 9.50 to 22.00. The mean value for number of seeds per pod was 15.88.

In cross H 11, the average value for number of seeds per pod was higher in PKB 4 (P_2) (15.67) than Anaswara (P_1) (15.02). Number of seeds per pod ranged from 11.30 to 20.70 in F_3 population. The average number seeds per pod was 14.85.

The cross H 10 (5.70) showed higher variance than that of H 11 (2.85) cross in F_3 population.

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

In cross H 10, highest value for hundred seed weight was exhibited in Anaswara (P_1) (20.62 g) than PKB 3 (P_2) (12.84 g). The weight for hundred seeds ranged from 16.97 g to 25.97 g. The average weight for hundred seeds was 21.53 g in F_3 population.

In cross H 11, the highest mean for hundred seed weight was recorded in Anaswara (P_1) (20.62 g) than PKB 4 (P_2) (20.48 g). The hundred seed weight ranged from 15.61 g to 27.65 g in F_3 population with an average hundred seed weight of 21.44 g.

Cross H 11 (4.01) showed the highest variability than cross H 10 (3.56) for hundred seed weight in F_3 population.

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

In cross H 10, the parent Anaswara (P_1) (139.86 g) recorded higher mean than the parent PKB 3 (P_2) (26.45 g) grain yield per plant. The value for grain yield per plant ranged from 120.19 g to 192.84 g in F_3 generation. The average grain yield was 145.96 g.

In cross H 11, the higher grain yield per plant was recorded in Anaswara (P_1) (139.87 g) when compared to PKB 4 (P_2) (137.98 g). In F_3 population, the range for grain yield per plant was 123.15 g to 189.70 g with an average grain yield of 147.32 g.

The cross H 11 (213.84) showed higher variability than that of H 11 cross (153.95) in F_3 population.

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

The protein content in seeds was higher in PKB 3 (P_2) (22.37) than that of Anaswara (P_1) (22.36). The protein content in seeds ranged from 20.10 per cent to 27.60 per cent in F_3 population. The average protein content in seeds was 24.16 per cent.

In cross H 11 PKB 4 (P_2) (23.01) showed highest protein content than Anaswara (P_1) (22.36). In F_3 population of H 11, the protein content ranged from 21.00 per cent to 27.90 per cent. The average protein content recorded was 24.15 per cent.

The cross H 10 (3.50) showed higher variability for protein content than cross H 11 (3.10) in F_3 population.

Table 11. Mean performance of parents and F_3 generation of cross H 10 (Anaswara x PKB 3) for quantitative characters in cowpea

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 (%)
P_1	285.10	4.40	54.30	73.40	126.60	41.00	23.65	3.48	15.02	20.62	139.86	22.36
P_2	31.16	5.20	40.70	57.90	94.70	21.30	13.80	2.29	13.06	12.84	26.45	22.37
F_3	327.87	4.78	59.50	84.06	135.23	41.30	23.32	3.90	15.88	21.53	145.96	24.16
Variance of parents and F_3 generation for quantitative characters in cowpea												
P_1	883.11	0.44	3.21	4.04	18.44	6.00	1.70	0.05	1.28	0.36	5.92	0.60
P_2	7.66	0.36	8.81	11.29	7.41	4.41	2.21	0.04	1.81	1.49	0.88	1.42
F_3	2211.68	0.50	29.59	38.66	63.07	11.52	8.81	0.31	5.70	3.56	213.84	3.50
Range of F_3 generation for quantitative characters in cowpea												
Min	215.20	3.00	49.00	69.00	119.00	34.00	14.80	3.05	9.50	16.97	120.19	20.10
Max	449.80	6.00	76.00	104.00	149.00	48.00	29.80	4.96	22.00	25.97	192.84	27.60

Table 12. Mean performance of parents and F_3 generation of cross H 11 (Anaswara x PKB 4) for quantitative characters in cowpea

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 (%)
P_1	285.10	4.40	54.30	73.40	126.60	41.00	23.65	3.48	15.02	20.62	139.86	22.36
P_2	130.61	4.50	57.10	75.40	126.20	37.5	23.52	3.32	15.67	20.48	137.98	23.01
F_3	339.56	4.79	63.18	86.74	139.83	40.93	23.19	3.87	14.85	21.44	147.32	24.15
Variance of parents and F_3 generation for quantitative characters in cowpea												
P_1	883.11	0.44	3.21	4.04	18.44	6.00	1.70	0.05	1.28	0.36	5.92	0.60
P_2	32.71	0.25	7.49	20.04	13.76	5.45	1.21	0.11	1.61	0.46	4.62	1.20
F_3	1681.82	0.39	25.28	33.33	42.24	19.81	6.42	0.33	2.85	4.01	153.95	3.10
Range of F_3 generation for quantitative characters in cowpea												
Min	236.90	4.00	50.00	73.00	120.00	5.00	15.50	3.01	11.30	15.61	123.15	21.00
Max	437.50	7.00	75.00	102.00	149.00	51.00	28.60	5.96	20.70	27.65	189.70	27.90

P_1 = Parent 1, P_2 = Parent 2

4. 2. 2. Genetic variability studies

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 cross H 10 and H 11 of cowpea in F_3 population and presented in Table 13 and 14, respectively.

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

In F_3 generation of cross H 10, the PCV was 14.34 and GCV was 12.82. The heritability for this character was 79.86 per cent. Genetic advance for this character was 77.37. Genetic advance expressed as per cent of mean was 23.59.

In F_3 generation of cross H 11, the PCV was 12.08 and GCV was 10.30. The heritability for this character was 72.77 per cent. Genetic advance for this character was 61.48. Genetic advance expressed as per cent of mean was 18.11.

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

In F_3 generation of cross H 10, the PCV was 14.80 and GCV was 6.60. The heritability for this character was 19.90 per cent. Genetic advance for this character was 0.29. Genetic advance expressed as per cent of mean was 6.07.

In F_3 generation of cross H 11, the PCV was 13.04 and GCV was 4.46. The heritability for this character was 11.68 per cent. Genetic advance for this character was 0.15. Genetic advance expressed as per cent of mean was 3.14.

4. 2. 2. 3. Days to first flowering

In F_3 generation of cross H 10, the PCV was 9.14 and GCV was 8.16. The heritability for this character was 79.69 per cent. Genetic advance for this character was 8.93. Genetic advance expressed as per cent of mean was 15.01.

In F_3 generation of cross H 11, the PCV was 7.96 and GCV was 7.07. The heritability for this character was 78.84 per cent. Genetic advance for this character was 8.17. Genetic advance expressed as per cent of mean was 12.92.

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

In F_3 generation of cross H 10, the PCV was 7.40 and GCV was 6.62. The heritability for this character was 80.17 per cent. Genetic advance for this character was 10.27. Genetic advance expressed as per cent of mean was 12.22.

In F_3 generation of cross H 11, the PCV was 6.66 and GCV was 5.32. The heritability for this character was 63.87 per cent. Genetic advance for this character was 7.59. Genetic advance expressed as per cent of mean was 8.76.

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

In F_3 generation of cross H 10, the PCV was 5.87 and GCV was 5.24. The heritability for this character was 79.51 per cent. Genetic advance for this character was 13.01. Genetic advance expressed as per cent of mean was 9.62.

In F_3 generation of cross H 11, the PCV was 4.65 and GCV was 3.66. The heritability for this character was 61.89 per cent. Genetic advance for this character was 8.29. Genetic advance expressed as per cent of mean was 5.93.

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

In F_3 generation of cross H 10, the PCV was 8.22 and GCV was 6.09. The heritability for this character was 54.83 per cent. Genetic advance for this character was 8.33. Genetic advance expressed as per cent of mean was 9.28.

In F_3 generation of cross H 11, the PCV was 10.87 and GCV was 9.17. The heritability for this character was 71.09 per cent. Genetic advance for this character was 6.52. Genetic advance expressed as per cent of mean was 15.92.

4. 2. 2 .7. Pod length (cm)

In F_3 generation of cross H 10, the PCV was 12.72 and GCV was 11.22. The heritability for this character was 77.81 per cent. Genetic advance for this character was 4.76. Genetic advance expressed as per cent of mean was 20.39.

In F_3 generation of cross H 11, the PCV was 10.93 and GCV was 9.61. The heritability for this character was 77.29 per cent. Genetic advance for this character was 4.03. Genetic advance expressed as per cent mean of was 17.40.

4. 2. 2. 8. Single pod weight (g)

In F_3 generation of cross H 10, the PCV was 14.16 and GCV was 13.06. The heritability for this character was 85.01 per cent. Genetic advance for this character was 0.99. Genetic advance expressed as per cent of mean was 24.80.

In F_3 generation of cross H 11, the PCV was 14.77 and GCV was 12.89. The heritability for this character was 76.19 per cent. Genetic advance for this character was 0.90. Genetic advance expressed as per cent of mean was 23.19.

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

In F_3 generation of cross H 10, the PCV was 15.03 and GCV was 12.83. The heritability for this character was 72.81 per cent. Genetic advance for this character was 3.58. Genetic advance expressed as per cent of mean was 22.54.

In F_3 generation of cross H 11, the PCV was 11.37 and GCV was 7.98. The heritability for this character was 49.24 per cent. Genetic advance for this character was 1.71. Genetic advance expressed as per cent of mean was 11.53.

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

In F_3 generation of cross H 10, the PCV was 8.76 and GCV was 7.53. The heritability for this character was 73.91 per cent. Genetic advance for this character was 2.87. Genetic advance expressed as per cent of mean was 13.34.

In F_3 generation of cross H 11, the PCV was 9.34 and GCV was 8.85. The heritability for this character was 89.77 per cent. Genetic advance for this character was 3.70. Genetic advance expressed as per cent of mean was 17.27.

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

In F_3 generation of cross H 10, the PCV was 10.02 and GCV was 9.94. The heritability for this character was 98.41 per cent. Genetic advance for this character was 29.64. Genetic advance expressed as per cent of mean was 20.31.

In F_3 generation of cross H 11, the PCV was 8.42 and GCV was 8.28. The heritability for this character was 96.58 per cent. Genetic advance for this character was 24.68. Genetic advance expressed as per cent of mean was 16.76.

Table 13. Estimation of genetic variability components for quantitative characters in F_3 generation of cowpea cross H 10 (Anaswara x PKB 3)

Characters	Mean	PCV	GCV	h^2 (%)	GA	GAM (%)
Plant height (cm)	327.87	14.34	12.82	79.86	77.37	23.59
Number of branches /plant	4.77	14.80	6.60	19.90	0.29	6.07
Days to first flowering	59.50	9.14	8.16	79.69	8.93	15.01
Days to first harvest	84.06	7.40	6.62	80.17	10.27	12.22
Days to last harvest	135.23	5.87	5.24	79.51	13.01	9.62
No. of pods /plant	41.30	8.22	6.09	54.83	8.33	9.28
Pod length (cm)	23.32	12.72	11.22	77.81	4.76	20.39
Single pod weight (g)	3.90	14.16	13.06	85.01	0.99	24.80
No. of seeds /pod	15.88	15.03	12.83	72.81	3.58	22.54
100-seed weight (g)	21.53	8.76	7.53	73.91	2.87	13.34
Grain yield /plant (g)	145.96	10.02	9.94	98.41	29.64	20.31
Protein content (%)	24.16	7.75	6.54	71.20	2.75	11.36

Table 14. Estimation of genetic variability components for quantitative characters in F_3 generation of cowpea cross H 11 (Anaswara x PKB 4)

Characters	Mean	PCV	GCV	h^2 (%)	GA	GAM (%)
Plant height (cm)	339.56	12.08	10.30	72.77	61.48	18.11
Number of branches /plant	4.79	13.04	4.46	11.68	0.15	3.14
Days to first flowering	63.18	7.96	7.07	78.84	8.17	12.92
Days to first harvest	86.74	6.66	5.32	63.87	7.59	8.76
Days to last harvest	139.83	4.65	3.66	61.89	8.29	5.93
No. of pods /plant	40.93	10.87	9.17	71.09	6.52	15.92
Pod length (cm)	23.19	10.93	9.61	77.29	4.03	17.40
Single pod weight (g)	3.87	14.77	12.89	76.19	0.90	23.19
No. of seeds /pod	14.85	11.37	7.98	49.24	1.71	11.53
100-seed weight (g)	21.44	9.34	8.85	89.77	3.70	17.27
Grain yield /plant (g)	147.32	8.42	8.28	96.58	24.68	16.76
Protein content (%)	24.15	7.29	9.14	70.93	2.57	10.65

PCV : Phenotypic coefficient variation

GCV : Genotypic coefficient variation

GA : Genetic advance

GAM : Genetic advance as per cent of mean

h^2 : Heritability per cent

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

In F_3 generation of cross H 10, the PCV was 7.75 and GCV was 6.54. The heritability for this character was 71.20 per cent. Genetic advance for this character was 2.75. Genetic advance expressed as per cent of mean was 11.36.

In F_3 generation of cross H 11, the PCV was 7.29 and GCV was 9.14. The heritability for this character was 70.93 per cent. Genetic advance for this character was 2.57. Genetic advance expressed as per cent of mean was 10.65.

4. 2. 3. Correlation studies

The phenotypic correlations of seed yield with other quantitative characters in F_3 population of cross H10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) are given in Table 15 and 16, respectively.

4. 2. 3. 1. Correlation between quantitative characters in cross H 10 of cowpea

A correlation matrix between quantitative characters of cross H 10 showed a significant and positive relation between plant height with number of branches per plant (0.170), days to first harvest (0.282) and protein content (0.095). Number of branches showed positive and significant correlation with number of seeds per pod (0.059). Days to first flowering showed significant and positive correlation with days to first harvest (0.724). Days to first harvest showed significant and positive correlation with days to last harvest (0.213), pod length (0.068) and number of seeds per pod (0.003). Days to last harvest showed significant and positive correlation with pod length (0.038) and grain yield per plant (0.063).

There was also significant and negative correlation observed between plant height showed significant and negative correlation with number of pods per plant (-0.081), single pod weight (-0.052) and hundred seed weight (-0.096). Number of branches per plant showed significant and negative correlation with days to last harvest (-0.068). Days to first flowering showed significant and negative correlation with single pod weight (-0.052) and protein content (-0.076). Days to first harvest showed significant and negative correlation with grain yield per plant (-0.105).

Table 15. Correlation between quantitative characters of cowpea in F_3 generation of cross H 10 (Anaswara x PKB 3)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.170*	0.145	0.282**	0.133	-0.081*	-0.043	-0.052**	-0.079	-0.096*	-0.101	0.095**
X2		1	0.074	0.015	-0.068*	-0.032	0.139	0.075	0.059*	0.065	-0.117	-0.021
X3			1	0.724**	0.163	-0.055	-0.001	-0.052**	-0.099	0.046	0.046	-0.076**
X4				1	0.123**	0.071	0.068**	-0.037	0.003**	0.007	-0.105**	-0.089
X5					1	-0.067	0.038*	-0.069	-0.128	0.061	0.063*	0.025
X6						1	0.099	-0.011	0.055	0.197	0.131	-0.304
X7							1	0.299	0.473	0.306	0.081	0.036
X8								1	0.475	0.248	0.012	0.050
X9									1	0.194	-0.025	0.055
X10										1	0.134	-0.074
X11											1	-0.123
X12												1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.05 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 pod
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

Table 16. Correlation between quantitative characters of cowpea in F_3 generation of cross H 11 (Anaswara x PKB 4)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	0.682**	-0.024	0.009	0.059	-0.010**	-0.019	0.049	0.066	0.025**	0.119	-0.027
X2		1	0.042	0.084	0.004**	-0.066	-0.032	-0.009	0.018**	0.019	0.085	-0.006
X3			1	0.856**	0.012	-0.083	0.045	0.106	0.030	-0.109	-0.110	0.016
X4				1	-0.007	-0.054	0.011**	0.054	-0.032	-0.121	-0.065**	0.070
X5					1	-0.045	-0.028	-0.105	-0.041	-0.023	0.055	-0.058
X6						1	-0.051	-0.083	-0.030	-0.051	0.032	-0.012
X7							1	0.550	0.537	0.078	-0.070	0.028
X8								1	0.528	0.060	-0.091	0.004
X9									1	0.033	-0.012	0.065
X10										1	0.032	-0.050*
X11											1	-0.038
X12												1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.05 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 pod
X10 – Hundred seed weight (g)
X11 – Grain yield per plant (g)
X12 – Protein content (%)

4. 2. 3. 2. Correlation between quantitative characters in cross H 11 of cowpea

A correlation matrix between quantitative characters of cross H 11 showed a significant and positive relation between plant height with number of branches per plant (0.682) and hundred seed weight (0.025). Number of branches per plant showed significant and positive correlation with days to last harvest (0.004) and number of seeds per pod (0.018). Days to first flowering showed significant and positive correlation with days to first harvest (0.856). Days to first harvest showed significant and positive correlation with pod length (0.011).

There was also significant and negative correlation observed between plant height with number of pods per plant (-0.010). Days to first harvest showed significant and negative correlation with grain yield per plant (-0.065). Grain yield per plant showed significant and negative correlation with single protein content (-0.050).

4. 2. 4. Path coefficient analysis for grain yield

The estimates of direct and indirect effects of the quantitative characters on grain yield in F_3 population are shown in Table 17 and described below

The residual effect contribution on grain yield was 0.395.

4. 2. 4. 1. Direct effect on grain yield

Very high, positive direct effect showed by days to first flowering (1.152) on grain yield. High, positive direct effect showed by single pod weight (0.839) grain yield. Plant height (0.281) showed a moderate, positive direct effect. Number of pods per plant (0.169) showed low, positive direct effect on grain yield. Very high and negative, direct effect was showed by days to first harvest (-1.507) on grain yield. High and negative, direct effect was showed by days to last flowering (-0.835) and pod length (-0.591). Moderate and negative, direct effect showed by number of branches per plant (-0.206) and protein content (-0.251). Hundred seed weight (-0.164) showed low and negative, direct effect. Number of seeds per pod (-0.068) showed a negligible and negative, direct effect on grain yield.

4. 2. 4. 2. Indirect effects on grain yield

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

Low, positive, indirect effect was exerted by plant height through number of branches per plant (0.157) and days to last harvest (0.107) towards grain yield. Negligible and positive, indirect effect was exerted by plant height through days to first flowering (0.042), days to first harvest (0.067), number of pods per plant (0.042), single pod weight (0.028) and protein content (0.053) towards grain yield. Low, negative and indirect effect was exerted by plant height through hundred seed weight (-0.149). Negligible and negative, indirect effect was exerted by plant height through pod length (-0.003) and number of seeds per plant (-0.025) towards grain yield.

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

Negligible and positive, indirect effect was exerted by number of branches per plant through days to first flowering (0.025), number of pods per plant (0.043), pod length (0.027), single pod weight (0.010), number of seeds per pod (0.004) and hundred seed weight (0.035) towards grain yield. Low and negative, indirect effect was exerted by number of branches per plant through plant height (-0.115). Negligible and negative, indirect effect was exerted by number of branches per plant through days to first flowering (-0.027), days to first harvest (-0.014) and protein content (-0.006) towards grain yield.

4. 2. 2. 2. 3. Days to first flowering

Very high and positive, indirect effect was exerted by days to first flowering through days to first harvest (1.083) towards grain yield. High and positive, indirect effect was exerted by days to first flowering through protein content (0.426). Moderate and positive, indirect effect was exerted by days to first flowering through days to last harvest (0.276) towards grain yield. Low and positive, indirect effect was exerted by days to first flowering through plant height (0.173) and single pod weight (0.161) towards grain yield. Moderate, negative and indirect effect was exerted by days to first flowering through number of pods per plant (-0.276), pod length (-0.299), number of seeds per pod (-0.207) and hundred seed weight (-0.265)

towards grain yield. Low and negative, indirect effect was exerted by days to first flowering through number of branches per plant (-0.138) towards grain yield.

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

High and positive, indirect effect was exerted by days to first harvest through pod length (0.407) and hundred seed weight (0.497) towards grain yield. Moderate, positive indirect effect was exerted by days to first harvest through number of pods per plant (0.286) and number of seeds per pod (0.211) towards grain yield. Very high, negative indirect effect was exerted by days to first harvest through days to first flowering (-1.416) towards grain yield. High, negative indirect effect was exerted by days to first harvest through plant height (-0.362) and protein content (-0.467) towards grain yield. Low, negative indirect effect was exerted by days to first harvest through number of branches per plant (-0.105). Moderate and negative, indirect effect was exerted by days to first harvest through days to last harvest (-0.211) and single pod weight (-0.241) towards grain yield.

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

Moderate and positive, indirect effect was exerted by days to last harvest through number of seeds per pod (0.209) towards grain yield. Moderate, negative indirect effect was exerted by days to last harvest through days to last harvest (-0.200). High, negative indirect effect was exerted by days to last harvest through plant height (-0.317) and single pod weight (-0.418) towards grain yield. Moderate, negative indirect effect was exerted by days to last harvest through days to first flowering (-0.200). Low, negative indirect effect was exerted by days to last harvest through number of branches per plant (-0.109), days to first harvest (-0.117) and pod length (-0.109) towards grain yield. Negligible and negative, indirect effect was exerted by days to last harvest through number of pods per plant (-0.050) and protein content (-0.100) towards grain yield. Days to first harvest had no indirect effect on grain yield through hundred seed weight (0.000).

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

Negligible, positive indirect effect was exerted by number of pods per plant through plant height (0.025), days to last harvest (0.010), pod length (0.042) and number of seeds per pod (0.049) towards grain yield. Negligible, negative indirect

effect was exerted by number of pods per plant through number of branches per plant (-0.035), days to first flowering (-0.040) days to first harvest (-0.032), hundred seed weight (-0.022) and protein content (-0.029) towards grain yield. Number of pods per plant had no indirect effect on grain yield through single pod weight (0.000).

4. 2. 2. 2. 7. Pod length (cm)

Low, positive indirect effect was exerted by pod length through days to first flowering (0.154), days to first harvest (0.159) and protein content (0.142) towards grain yield. Negligible, positive and indirect effect was exerted by pod length through plant height (0.006), number of branches per plant (0.077) towards grain yield. High, negative indirect effect was exerted by pod length through number of seeds per pod (-0.384). Moderate, negative indirect effect was exerted by pod length through single pod weight (-0.259) and hundred seed weight (-0.213) towards grain yield. Low, negative indirect effect was exerted by pod length through number of pods per plant (-0.148). Negligible, negative and indirect effect was exerted by pod length through days to last harvest (-0.077) towards grain yield.

4. 2. 2. 2. 8. Single pod weight (g)

High, positive and indirect effect was exerted by single pod weight through days to last harvest (0.419) and pod length (0.369) towards grain yield. Moderate, positive and indirect effect was exerted by single pod weight through number of seeds per pod (0.252) and hundred seed weight (0.227) towards grain yield. Low, positive and indirect effect was exerted by single pod weight through days to first flowering (0.117), days to first harvest (0.134) and protein content (0.185) towards grain yield. Negligible, positive and indirect effect was exerted by single pod weight through plant height (0.084) towards grain yield. Negligible, negative and indirect effect was exerted by single pod weight through number of branches per plant (-0.042) towards grain yield. Single pod weight had no indirect effect on grain yield through number of pods per (0.000).

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

Negligible, positive and indirect effect was exerted by number of seeds per podthrough plant height (0.006), number of branches per plant (0.001), days to first

harvest (0.012), days to first harvest (0.009), days to last harvest (0.017), number of pods per plant (0.019) and protein content (0.009). Negligible, negative and indirect effect was exerted by number of seeds per pod through pod length (-0.044), single pod weight (-0.021) and hundred seed weight (-0.018).

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

Negligible, positive and indirect effect was exerted by hundred seed weight through plant height (0.087), number of branches per plant (0.028), days to first flowering (0.038), days to first harvest (0.054), number of pods per plant (0.021) and protein content (0.008) towards grain yield. Negligible, negative and indirect effect was exerted by hundred seed weight through pod length (-0.059), single pod weight (-0.044) and number of seeds per pod (-0.044) towards grain yield. Hundred seed weight had no indirect effect through days to last harvest on grain yield (0.00).

4. 2. 2. 2. 11. Protein content (%)

Negligible and positive, indirect effect was exerted by protein content through number of pods per plant (0.043), pod length (0.060), number of seeds per pod (0.033) and hundred seed weight (0.013) towards grain yield. Negligible and negative, indirect effect was exerted by protein content through plant height (-0.048), number of branches per plant (-0.007), days to first flowering (-0.093), days to first harvest (-0.078), days to first harvest (-0.030) and single pod weight (-0.055) towards grain yield.

Table 17. Path analysis with direct and indirect effects on grain yield of F_3 population in cowpea

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	**0.281**	-0.115	0.173	-0.362	-0.317	0.025	0.006	0.084	0.006	0.087	-0.048
X2	0.157	**-0.206**	-0.138	-0.105	-0.109	-0.035	0.077	-0.042	0.001	0.028	-0.007
X3	0.042	0.025	**1.152**	-1.416	-0.200	-0.040	0.154	0.117	0.012	0.038	-0.093
X4	0.067	-0.014	1.083	**-1.507**	-0.117	-0.032	0.159	0.134	0.009	0.054	-0.078
X5	0.107	-0.027	0.276	-0.211	**-0.835**	0.010	-0.077	0.419	0.017	0.000	-0.030
X6	0.042	0.043	-0.276	0.286	-0.050	**0.169**	-0.148	0.000	0.019	0.021	0.043
X7	-0.003	0.027	-0.299	0.407	-0.109	0.042	**-0.591**	0.369	-0.044	-0.059	0.060
X8	0.028	0.010	0.161	-0.241	-0.418	0.000	-0.259	**0.839**	-0.021	-0.044	-0.055
X9	-0.025	0.004	-0.207	0.211	0.209	0.049	-0.384	0.252	**-0.068**	-0.044	0.033
X10	-0.149	0.035	-0.265	0.497	0.000	-0.022	-0.213	0.227	-0.018	**-0.164**	0.013
X11	0.053	-0.006	0.426	-0.467	-0.100	-0.029	0.142	0.185	0.009	0.008	**-0.251**

Residual effect = 0.395

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 pod
X10 – Hundred seed weight (g)
X11 – Protein content (%)

DISCUSSION

5. Discussion

Cowpea is an important, quick growing legume, well adapted to wide range of climate and can be grown on all types of soils. In India, the crop is mainly grown both in kharif and spring summer season. It is an early, multiseasonal and multipurpose crop. Seeds of cowpea are good source of protein, containing around 23 per cent. Varieties with protein content more than 27 per cent has been reported (Sarath and Joseph, 2017). Grain yield in cowpea is also found to be highly variable. In order to develope successful breeding programme to improve the yield potentials of cowpea, the nutritional quality of the grains also should be an important concern. This will enable the breeder to operate efficient selection and subsequently develop appropriate breeding strategies to solve the problems of poor yield as well as to improve the nutritive quality of the crop (Animasaun, 2015)

Silva *et al.* (2016) initiated a breeding programme to develope breeding lines with high yield and protein content. They have developed four promising lines with high yield of 1050 kg /ha and high protein content of 27 per cent. This indicates that there is possibility of blending high yield and protein content in cowpea.

Obisesan (1992) evaluated the effectiveness of two breeding procedures *viz.*, pedigree selection and single seed descent selection in crosses of cowpea. He found that both techniques have been viable in creating superior genotype for yield and number of pods. However, the pedigree selection delivered superior transgressive segregates, whereas, single seed descent selection permitted a more rapid improvement in generation than pedigree selection.

Present study is an attempt to identify cowpea lines with high grain yield and high protein content from F_2 and F_3 generations of two hybrids of cowpea. Selection of best lines related to high yield and other associated characters in segregating generation pave a way for the development of new variety with high performance over the selected parents.

The results obtained from the present study are discussed under following headings

5. 1. Estimation of means and variance

5. 2. Genetic variability studies

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5. 3. Correlation studies

5. 4. Path coefficient analysis

5. 1. Estimation of means and variance

Mean and variance are the primary statistics used for analyzing the genetic variability of the quantitative traits. Both mean and variance are vital components for choosing populations to be used as source of breeding lines: The findings on estimation of means and variance on twelve quantitative characters of cowpea under study is discussed below.

Mean value of each trait were estimated by dividing the total values with corresponding number of observations. Mean is often used for phenotypic characterization of a group of individuals. Choosing breeding populations with a high mean performance is a direct approach to improve the population.

In cross H 10, the mean performance of parent Anaswara was higher than PKB 3, for all the characters under study except for number of branches per plant and protein content in both F_2 and F_3 generations.

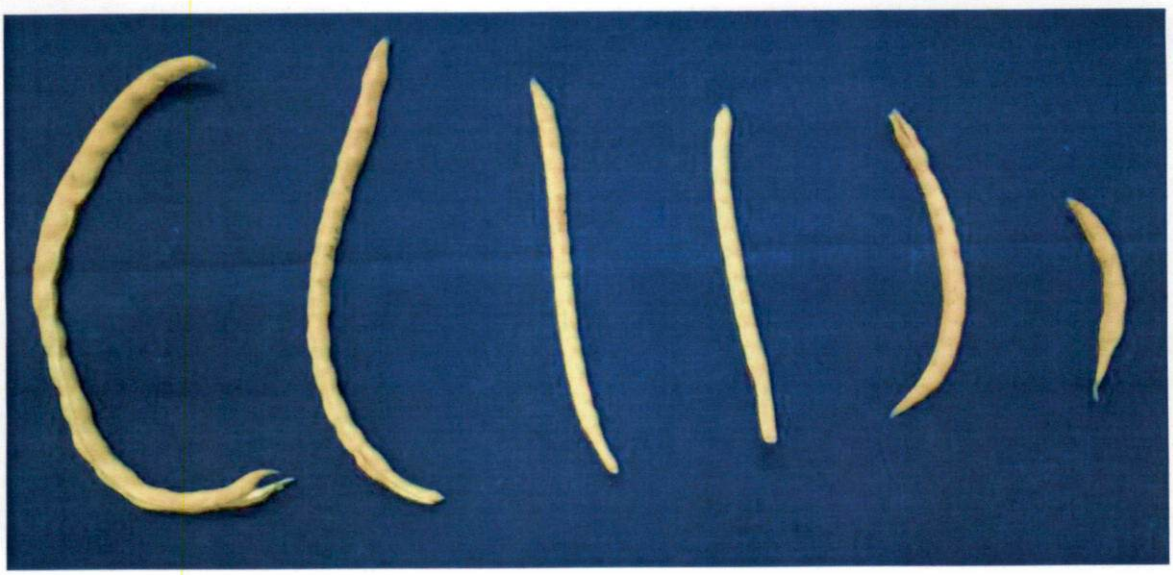
In the case of cross H 11, the mean performance of parent Anaswara was higher than PKB 4 for characters other than, days to first flowering (58.10), number of pods per plant (41.20), grain yield per plant (143.81 g) and protein content (26.57 %) in F_2 generation. Whereas, in F_3 generation PKB 4 showed higher value for number of branches per plant (4.50), days to first flowering (57.10), days to first harvest (75.40), number of seeds per pod (15.67) and protein content (23.01), than parent Anaswara.

Maximum range in F_2 generation in the present study was observed for plant height in both the crosses and the minimum range was for branches per plant. Rangaiah (1997) also observed maximum range for plant height and minimum range for number of branches per plant in two F_2 populations during his experiment.

In cross H 10, the F_2 generation showed high mean performance for all the characters except for number of pods per plant, single pod weight and protein content, when compared to F_3 generation.

Plate 5. Variability in pod length in F_2 generation

Plate 6. Variability in pod length in F_3 generation



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In the case of cross H 11, the F_2 generation showed high mean performance for all the characters except for days to first harvest, days to last harvest, number of pods per plant, grain yield per plant and protein content, when compared to F_3 generation.

Salimath *et al.* (2007) based on their observations on F_2 and F_3 population of two crosses of cowpea reported that the mean performance of segregating progenies of both crosses were same in F_2 and F_3 generation with respect to yield per plant and its related characters. However, as per the present study the mean performance of F_2 population was higher for most of the characters compared to F_3 population. The transgressive segregants observed in the F_2 population might have helped in increasing the mean value of the traits. Increased mean value of the F_3 population for protein content in both the H 10 and H 11 families and yield in H 11 family, can be explained as the result of selection of lines with high protein and yield in the F_2 generation

Variance is used to find out the deviation of the individual observations around the mean. A character with high variance depicts high variability for that particular character. Based on the estimation of variance in F_2 generation of cross H 10, parent Anaswara exhibited higher variability than PKB 3 for all the characters except for number of branches per plant and single pod weight. Similarly, in F_2 generation of cross H 11, parent Anaswara exhibited higher variability than PKB 4 for all the characters except for days to first flowering, number of pods per plant and hundred seed weight. On estimation of variance in F_3 generation of cross H 10, parent PKB 3 showed higher variability than Anaswara for characters such as days to first flowering, days to first harvest, pod length, number of seeds per pod and hundred seed weight.

In F_3 generation of cross H 11, parent PKB 4 showed higher variability than Anaswara for characters such as days to first flowering, days to first harvest, single pod weight, number of seeds per pod, hundred seed weight and protein content.

For all the characters studied, F_2 and F_3 generations of cross H 10 and H 11 showed more variance than the parents. Reduction in the variance was observed in the F_3 generations of both the crosses compared to F_2 generations except for days to first harvest, number of pods per plant, and pod weight. This indicate that

maximum variability was present in the F_2 generation. One generation of selfing might have resulted in reduction of variability in the F_3 generation.

Kurer *et al.* (2010) developed F_2 and F_3 generation of two genetically distant parents belonging to determinate (V-1188) and indeterminate (Goa local) group by hybridization. They observed that magnitude of variability was more in F_2 than in F_3 generation.

5. 2. Genetic variability studies

The information on the estimates of variability with respect to yield and its heritable components of the breeding material is the basics to draw selection criteria. In this specific circumstance, it is important to partition the total variability into heritable and non-heritable components *viz.*, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). Furthermore, understanding these parameters are important to compute heritability and genetic advance for various quantitative traits, which enable the breeder to satisfy the breeding objective.

Coefficient of variation is an independent unit of measurement and is more reliable. The degree of variability measured by PCV and GCV additionally gives information with respect to relative measure of variation in various populations. The degree to which variability could be transferred from parent to progenies would recommend how far the heritable variation has close bearing on response to selection. PCV and GCV, heritability and genetic advance as per cent of mean were classified by different authors as below.

Sivasubramanian and Menon (1973) classified PCV and GCV as follows

Low : < 10 per cent

Moderate : 10-20 per cent

High : > 20 per cent

Johnson (1955) classified heritability 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

Salimath *et al.* (2007) observed that the magnitude of GCV and PCV were low in F_3 generation than F_2 generation, based on their observation on F_2 and F_3 population of two crosses of cowpea.

Rangaiah (1997) based on their studies on segregating generations of two crosses observed that the total seed weight had maximum PCV and pod length showed maximum GCV. Based on mean value and variance in the population they suggested different traits to be considered for selection in each cross. For selection in cross V37 × S488, he suggested to consider the traits such as number of pods per plant, length of the pod and total seed weight while, in the cross V16 × S488, the selection should be based on number of branches per plant and 100 seed weight. This indicates that depending on the genetic parameters of traits observed in each generation for each segregating population the selection criteria should be modified. Accordingly, the selection criteria in the present study should be to select for number of branches in H 10 F_2 families and number of pods per plant in H 11 F_2 families. In the F_3 families, selection can be done for pod length, pod weight and number of seeds per pod in H 10 family and number of pod per plant in H 11 family, this will hold good if the objective of the breeding programme is to improve all the traits under consideration. However, the objective of the present study was to identify lines with high yield and protein content, hence, selection criteria was modified accordingly.

The genetic parameters for each character are discussed below in detail;

5. 2. 1. Plant height (cm)

Moderate PCV, GCV, high heritability and high GAM was observed for the F_2 families of H 10 while moderate PCV, GCV, GAM and high heritability was observed for the F_2 families of H 11 for plant height. Higher values of PCV and

GCV were showed by F_2 generation in both the crosses than F_3 generation. F_3 family of H 10 showed moderate PCV, GCV and high heritability and GAM. In case of F_3 family of H 11 moderate PCV, GCV, GAM and high heritability were observed. Thaware *et al.* (1991) also reported similar results with respect to components of variance in F_2 and F_3 population of cowpea hybrids. High values of GCV, heritability and genetic advance indicate that selection will be effective to improve plant height in the population. The high values of these parameters in F_2 population indicate the presence of high variability. Selfing followed by selection in the F_2 generation might have resulted in the reduction of variability leading to lesser values for plant height in F_3 generation.

5. 2. 2. Number of branches per plant

Higher values of PCV, GCV heritability and genetic advance as per cent of mean were recorded for number of branches per plant in F_2 generation of both crosses than F_3 generation. F_2 family of H 10 had high PCV, moderate GCV, and high heritability and GAM, while the F_2 family of H 11 had moderate PCV and GCV and high heritability and GAM. This indicates the presence of high variability in F_2 generation and chance of improvement of number of branches per plant by selection. In F_3 population of both the crosses had moderate PCV and low GCV, heritability and GAM indicating the reduction in variability in F_3 population and lesser chance of improving the trait by selection. Tharware *et al.* (1991), Mehta and Zaveri (1999) and Kurer (2007) also reported similar results in F_2 and F_3 generations of cowpea. Selfing followed by selection in F_2 generation might have reduced the variability for number of branches per plant in the F_3 generation.

5. 2. 3. Days to first flowering

Earliness in any crop is an added advantage especially when the crop is grown under stress situation. Hence, selection of early lines can be attempted when high variability is present in the population. F_2 generation of both crosses exhibited higher GCV, PCV, heritability and GAM for days to first flowering than F_3 generation of both crosses. F_2 generation of cross H 10 had moderate PCV, GCV, and GAM with high heritability while F_2 population of H 11 showed moderate PCV and GAM with low GCV and high heritability. This indicate the possibility of improving the trait by selection. Santhos *et al.* (2014) also observed moderate to

high heritability for days to flowering. In the F_3 generation low PCV, GCV, high heritability and moderate GAM was observed in both the crosses indicating reduction in variability.

5. 2. 4. Days to first harvest

Higher PCV and GCV values for days to first harvest were observed for F_2 generation of both crosses than F_3 generation. The heritability and genetic advance as per cent of mean were high in F_2 generation compared to F_3 generation except for cross H 10 of F_3 generation, where it showed high heritability (80.17 %) than F_2 generation (74.43 %). Low PCV, GCV, high heritability and moderate GAM was observed in F_2 and F_3 families indicating lesser variability in the population and selection will not be effective to improve the trait.

5. 2. 5. Days to last harvest

Higher phenotypic and genotypic coefficient of variations were recorded in F_2 population of both crosses than F_3 generation. Moderate PCV and GCV combined with high heritability and GAM was observed for F_2 family of H 10, while F_2 family of H 11 showed low PCV, GCV, GAM and moderate heritability. This indicate that selection will be effective in H 10 F_2 families and ineffective in H 11 F_2 family for this trait. In F_3 families of both the crosses had low PCV, GCV, GAM and moderate heritability indicating lesser variability of the populations and ineffectiveness of selection to improve the trait.

5. 2. 6. Number of pods per plant

The F_2 generation showed higher values for GCV, PCV, heritability and GAM compared with F_3 generation. Number of pods is an important character which is directly associated with grain yield, thus the trait should show a high heritable nature for improvement by simple selection. In the present study F_2 families of both the crosses showed moderate PCV, GCV and high heritability and GAM indicating the scope of improvement through selection. F_3 family of H 10 had low PCV, GCV, GAM and high heritability indicating lesser variability and ineffectiveness of selection. While, H 11 F_3 family had Low GCV, moderate PCV, GAM and high heritability indicating selection may be effective to improve the

trait. Earlier works by Gowda *et al.* (1991), Selvi *et al.* (1994), Mathur (1995) and Kurer (2007) also recorded high heritability for number of pods per plant.

5. 2. 7. Pod length (cm)

Higher PCV and GCV values for pod length were observed for F_2 generation of both crosses than F_3 generation. Moderate PCV, GCV and high heritability and GAM was observed in H 10 F_2 family while moderate PCV, GCV, heritability and GAM was observed in H 11 F_2 family indicating selection may be effective in H 10 F_2 family. In H 10 F_3 family moderate PCV, GCV and high heritability and GAM was observed indicating selection would be effective to improve the trait. H 11 F_3 family had moderate PCV and GAM, low GCV and high heritability.

5. 2. 8. Single pod weight (g)

Single pod weight exhibited higher PCV values in F_2 generation of both crosses than F_3 generation. GCV values, heritability and genetic advance as per cent of mean was higher in F_3 generation when compared to F_2 generation indicating presence of more variability in F_3 generation. Moderate PCV and low GCV, heritability and GAM observed in H 10 F_2 families shows ineffectiveness of selection to improve the trait. However, moderate effects of PCV, GCV, heritability and GAM indicate that selection may be effective in this population. Both F_3 families indicated effectiveness of selection with medium values of PCV and GCV and high value for heritability and GAM.

5. 2. 9. Number of seeds per pod

The F_3 generation showed high values for GCV, PCV, heritability and genetic advance as per cent of mean than F_2 generation for number of seeds per pod. F_2 family of H 10 showed moderate PCV, GCV, heritability and GAM and family H 11 exhibited low PCV, GCV and GAM with moderate heritability. This indicates less variability and ineffectiveness of selection in F_2 family of H 10 to improve number of seeds per pod. However, in F_3 family of H 10 showed moderate PCV, GCV and high heritability and GAM indicating chance of improvement through selection. H 11 F_3 family showed moderate PCV, heritability, GAM and low GCV.

5. 2. 10. Hundred seed weight (g)

Hundred seed weight showed high value for PCV, GCV, heritability and genetic advance as per cent of mean in F_2 generation of cross H 10. Backiyarani and Nadarajan (1996), Selvam *et al.* (2000) and Kurer (2007) recorded the similar results. Moderate PCV, GCV and high heriability and GAM was seen in H 10 F_2 family, while low PCV, GCV, high heritability and moderate GAM in H 11 F_2 family indicating selection may be effective to improve hundred seed weight in these populations. In the case of cross H 11, F_3 generation showed higher values of PCV, GCV, heritability per cent and genetic advance over mean than F_2 generation In both F_3 families low PCV, GCV, high heritability and moderate GAM was observed indicating selection may be effective to improve the trait.

5. 2. 11. Grain yield per plant (g)

Improvement in yield is the ultimate goal of any breeding programme. Yield is a complex character, which is controlled by several genes and highly influenced by environment. A comparison of GCV, PCV, heritability per cent and genetic advance over mean showed high values in F_3 generation than F_2 generation. Low PCV, GCV and high heritability and GAM was observed in F_2 family of H 10 while in F_2 family of H 11 all these parameters were low indicating low variability and ineffectiveness of selection for yield in H 11 family. However, the F_3 family of H 10 had moderate PCV, low GCV and high heritability and GAM, while F_3 family of H 11 had low PCV, GCV, high heritability and moderate GAM indicating scope of improvement through selection in F_3 generation.

5. 2. 12. Protein content (%)

High PCV, GCV and genetic advance over mean for protein content were observed for F_2 generation of both crosses than F_3 generation. High value for heritability were shown by F_3 generation than F_2 generation in both crosses. Moderate PCV and GCV with high heritability and GAM was observed in both F_2 families for protein content indicating variability and chance of improvement through selection. In the F_3 families low PCV, GCV high heritability and moderate GAM was observed indicating chance of improvement through selection.

Fig 1. PCV and GCV in F_2 family of H 10 (Anaswara x PKB 3)

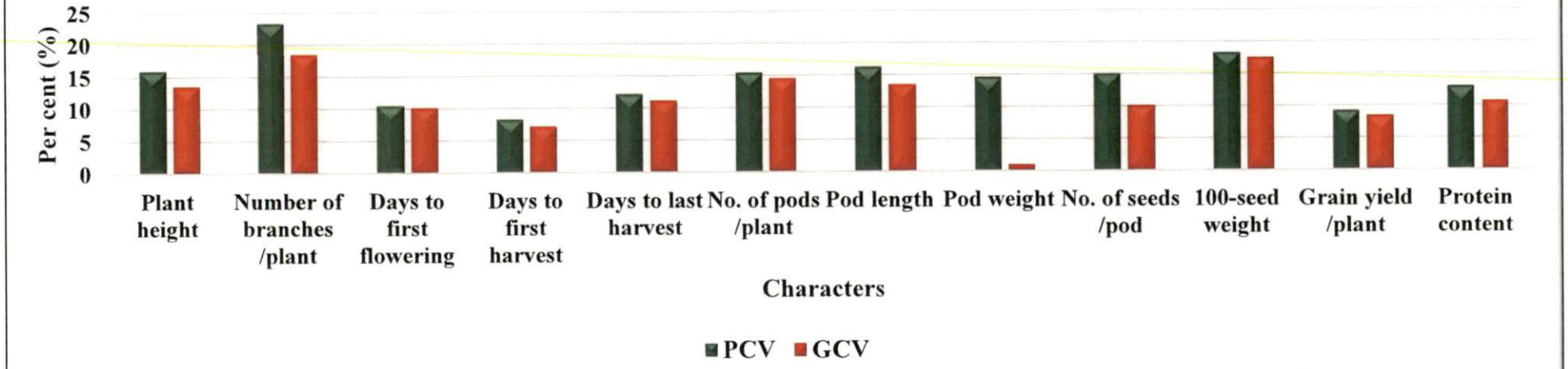


Fig 2. PCV and GCV in F_2 family of H 11 (Anaswara x PKB 4)

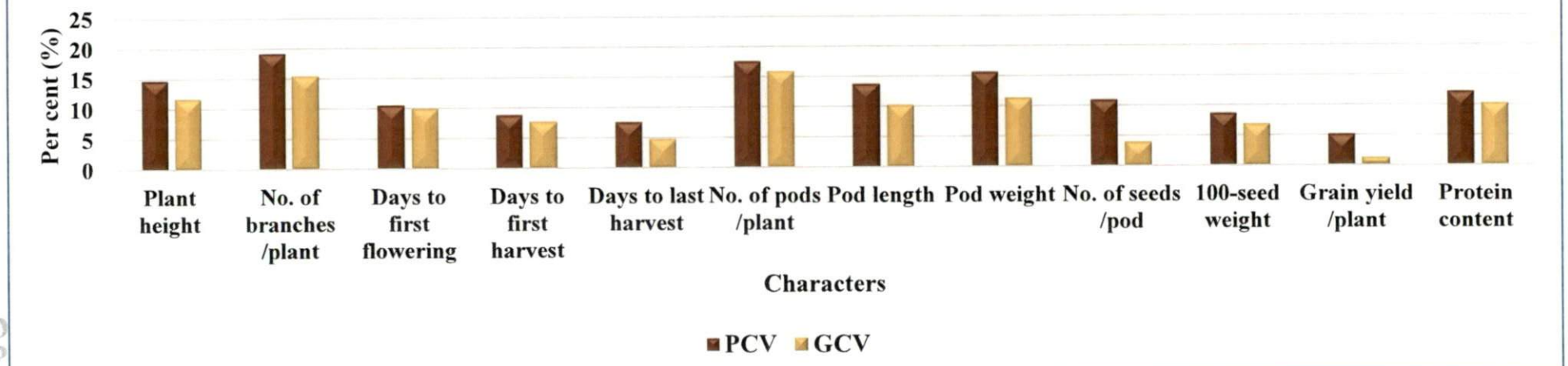


Fig 3. Heritability per cent of F_2 families (H 10 and H 11)

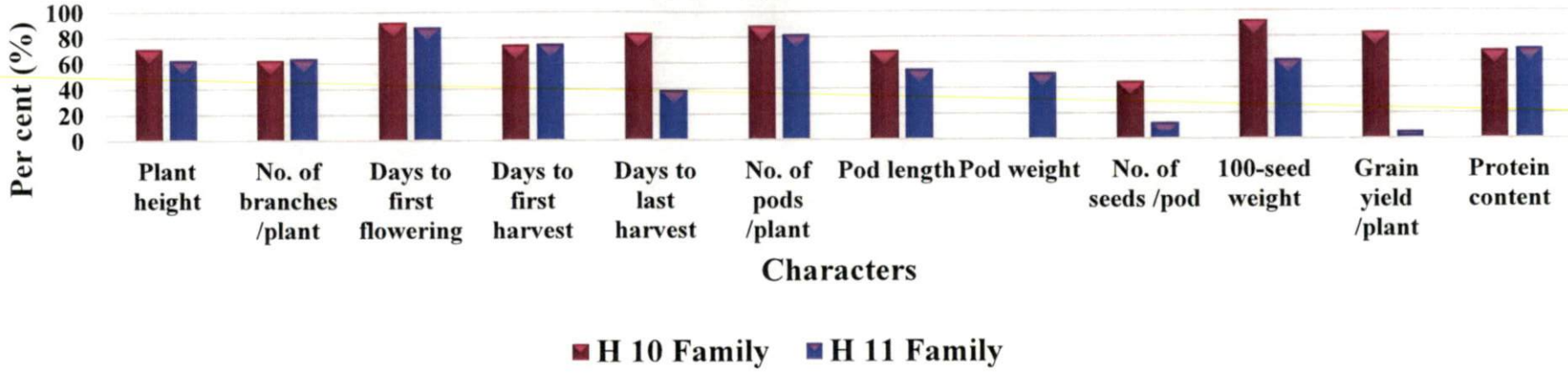


Fig 4. Genetic advance as per cent of mean of F_2 families (H 10 and H 11)

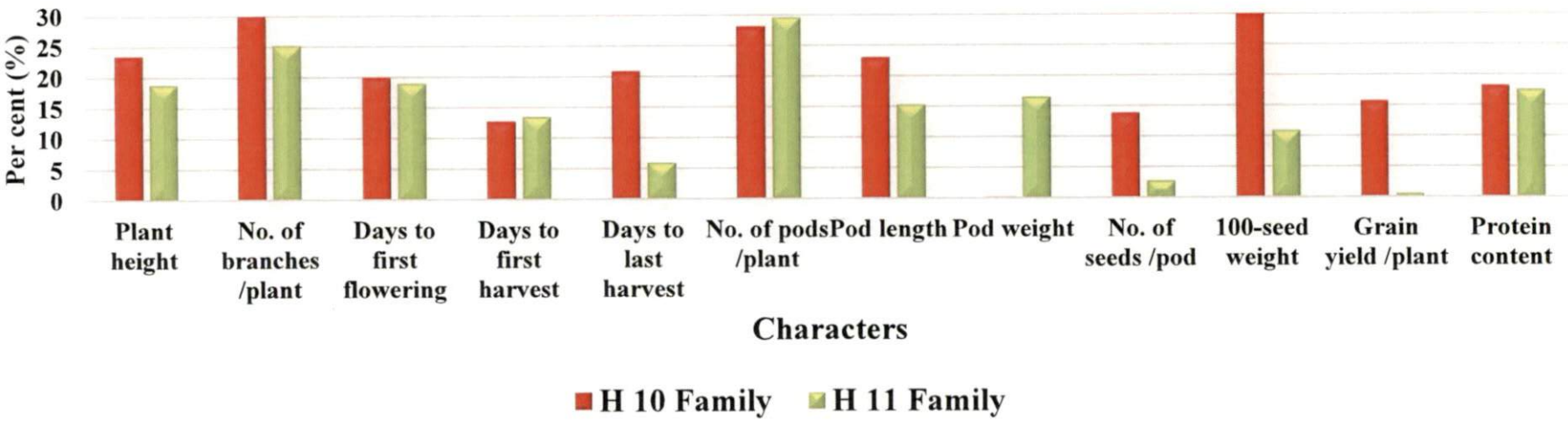


Fig 5. PCV and GCV in F_3 family of H 10 (Anaswara x PKB 3)

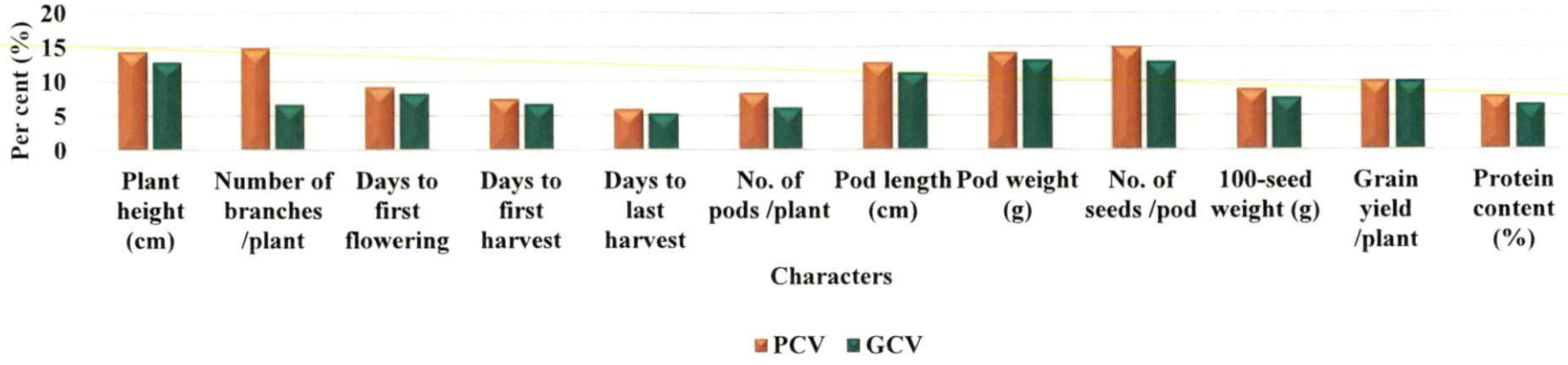


Fig 6. PCV and GCV in F_3 family of H 11 (Anaswara x PKB 4)

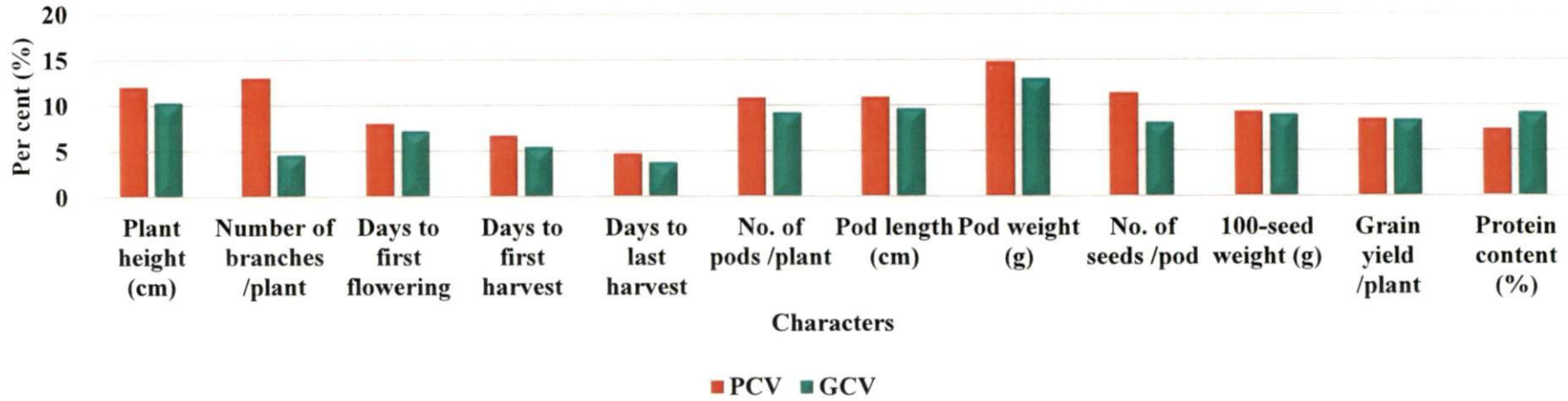


Fig 7. Heritability per cent of F_3 families (H 10 and H 11)

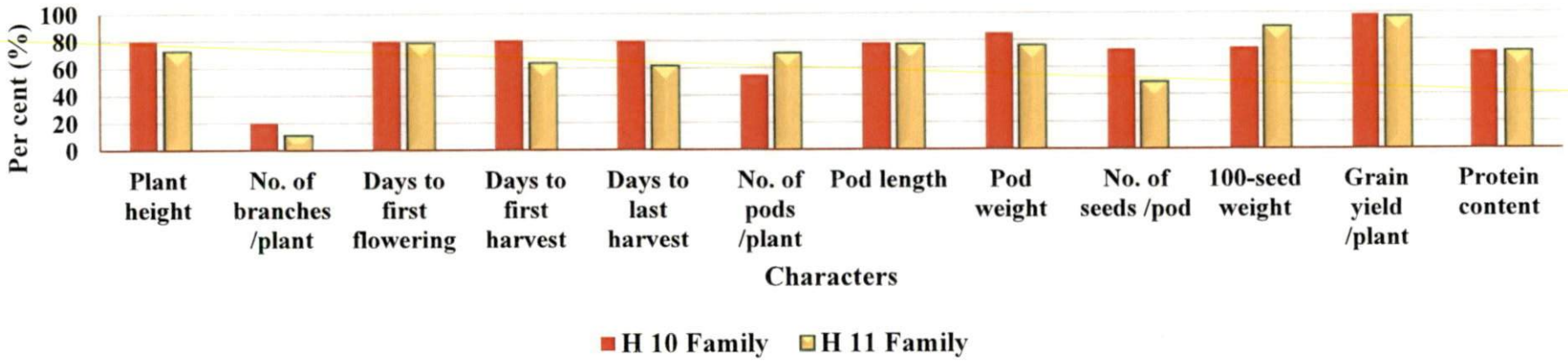
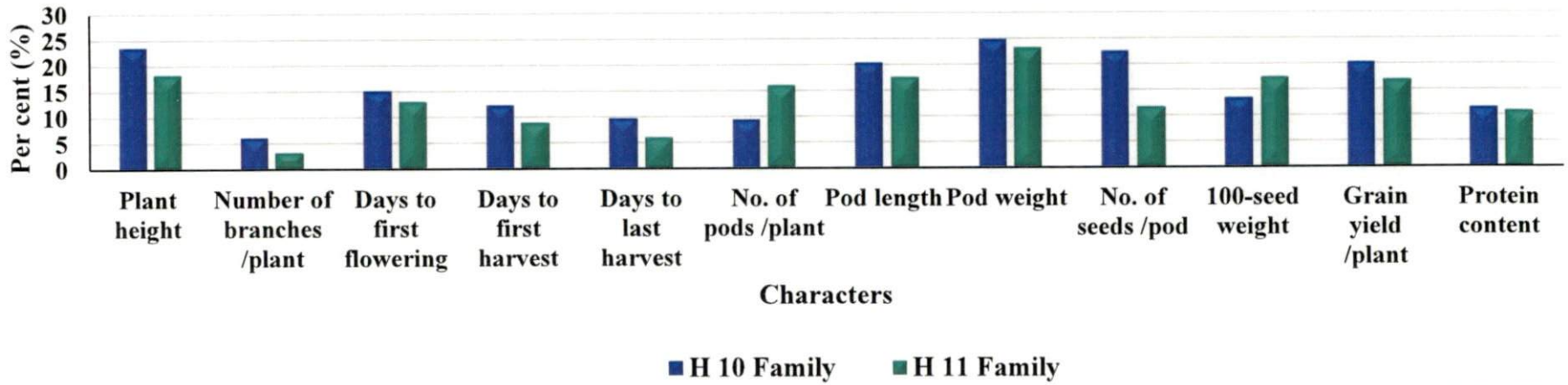


Fig 8. Genetic advance as per cent of mean of characters of F_3 families (H 10 and H 11)



In general, the magnitude for genotypic coefficient of variation was low as compared to phenotypic coefficient of variation for all the twelve quantitative characters of cowpea irrespective of crosses and generation (fig 1, fig 2, fig 5 and fig 6). This indicates variability in the population is not only due to genetic causes but also due to environmental effects. On heritability estimation, almost all the characters showed a high heritability per cent, irrespective of crosses and generations (fig 3, fig 4, fig 7 and fig 8).

5. 3. Correlation studies

In the event of where two positive characters are related, determination for one character will consequently be adequate for the other. Correspondingly, when a character is related with another undesirable character, there would be the requirement for breaking such relationship through repeated back crossing with intermittent parent. Grafius (1959) reported that yield by itself has no genes as such but controlled through its components. Therefore, correlation analysis is the statistical way which helps the breeder to frame the selection strategy effectively for grain yield, a highly complex character in which breeder is interested.

5. 3. 1. Correlation of seed yield per plant to other traits

The study on correlation of different component traits in segregating generation of cowpea showed that single pod weight (0.063) in F_2 family of H 10 showed a significant and positive relation with grain yield per plant. In F_2 family of H 11, days to last harvest (0.004) and number of pods per plant (0.518) showed a significant positive correlation with grain yield per plant. In F_3 generation of cross H 10, days to last harvest had a significant correlation with grain yield per plant (0.063). The correlation of days to last harvest with yield shows that extended duration of crop growth will be increasing the total yield from a plant. Correlation of number of pods per plant to yield indicate that indirect selection can be attempted to increase the yield in cowpea in F_2 families of H 11.

5. 3. 2. Correlation of plant height to number of branches per plant

Plant height showed a significant positive correlation with number of branches per plant in both the crosses of F_2 and F_3 generations indicating development of more branches when the plant become taller.

5. 3. 3. Correlation of days to first flowering to days to first harvest

Significant positive correlation was observed for days to first flowering to days to first harvest in both the crosses of F_2 and F_3 generations. When the plants are early to flower it is natural to harvest it early.

5. 4. Path coefficient analysis

Path coefficient analysis additionally provide a knowledge on inter relationship of different characters on grain yield. In cowpea, grain yield is an intricate character impacted by number of inter related component characters. The inter dependence of the component traits among themselves frequently impact their direct association with grain yield. Accordingly, database on correlation coefficient becomes not trustworthy. Path analysis gives a more sensible inter relationship of traits with grain yield. Various studies in cowpea showed that number of pods per plant had the maximum positive direct effect on grain yield Chikkadevaiah, (1985); Siddique and Gupta, (1992); Sawant, (1994); Singh *et al*, (1998) and Hadapad, (2001)

Lenka and Mishra (1973) classified path coefficient as:

0.00 - 0.09 : Negligible

0.10 - 0.19 : Low

0.20 - 0.29 : Moderate

0.30 – 1.00 : High

> 1 : Very high

In the present experiment with segregating generations of cowpea the path analysis showed that plant height had high (0.440) to moderate (0.281) positive direct effect on grain yield in both F_2 and F_3 populations. In F_2 generation, days to first flowering showed a high (0.409) positive direct effect on grain yield followed by a moderate, positive direct effect by pod length (0.277) and hundred seed weight (0.202). In case of F_3 generation, days to first flowering showed very high (1.152) positive direct effect on grain yield. Single pod weight showed a high (0.839)

positive direct effect on grain yield followed by number of pods per plant with low (0.169) direct positive effect on grain yield. The traits which showing very high, high or moderate direct or indirect effect on seed yield, should be considered for selection to improve the yield.

Santos *et al.* (2014) studied path analysis of yield components in cowpea and revealed that the variable of days to flowering showed high direct effect on grain yield. They also reported that variables of days to last harvest, pod length and pod weight showed a direct effect on grain yield. According to Neema and Palanisamy (2001) number of pods per plant showed highest positive direct effect on grain yield and lowest direct effect was by pod length. The indirect effect for pod length was maximum through pod yield. Direct effect of grain yield through pod yield were almost equal to genotypic correlation between pod yield and grain yield. Sumathi (2004) suggested that grain yield per plant had positive, direct effects through days to flowering and days to maturity. However, there was negative indirect effects observed through number of clusters per plant, pods per plant and pod filling index, resulting in negative non-significant relation with grain yield per plant.

Based on the objective of combining yield and protein content selection criteria was fixed as grain yield of more than 160 g and protein content more than 25 per cent. Nine lines from both F_3 families were selected and to be forward to F_4 generation. The features of the selected lines from the F_3 generations are furnished in Table 18 and Table 19.

The present study indicate that combining grain yield and protein content in cowpea is practically possible. Hence, the identified lines will be forwarded to later generations with pedigree selection for evaluation (Plate 7).

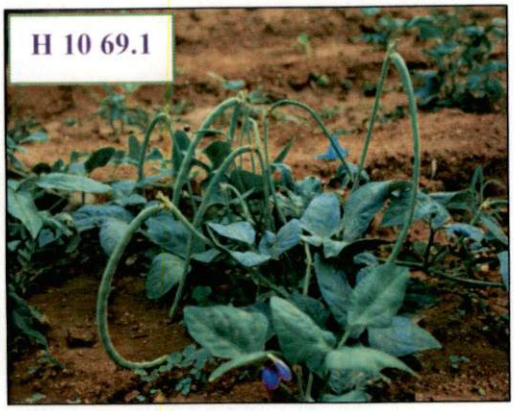
Table 18. Features of individual plants selected and to be advanced to F_4 generation of cross H 10

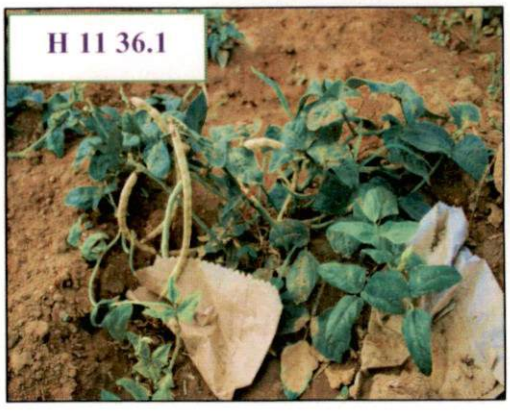
Plant no.	Plant height (cm)	No. of branch /plant	Days to first flowering	Days to first harvest	Days to last harvest	Number of pods /plant	Pod length (cm)	Single pod weight (g)	No. of seeds /pod	100-seed weight (g)	Grain yield /plant (g)	Protein content (%)
H 10 1.4	238.10	5.00	52.00	76.00	124.00	39.00	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
H 10 71.16	315.60	4.00	65.00	91.00	140.00	45.00	20.50	3.84	14.70	19.40	165.94	26.30

Table 19. Features of individual plants selected and to be advanced to F_4 generation of cross H 11

Plant no.	Plant height (cm)	No. of branch /plant	Days to first flowering	Days to first harvest	Days to last harvest	Number of pods /plant	Pod length (cm)	Single 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

Plate 7. Promising lines to be forwarded to F_4 generation





SUMMARY

6. Summary

The present study on "Pedigree breeding in early segregating generations of cowpea (*Vigna unguiculata* (L.) Walp)" was conducted as two experiments in the Department of Plant Breeding And Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara in the year 2015 - 2017. The research programme was to evaluate the segregating progenies of two hybrid families viz., H 10 (Anaswara x PKB 3) and H 11 (Anaswara x PKB 4) in F_2 and F_3 generations. The salient features of the study are summarized below.

Estimation of means and variance

- The segregating generations showed high mean performance over parents for all the characters studied, except for number of branches per plant and protein content, irrespective of crosses and generations.
- In general, the segregating populations showed high variance for almost all characters studied. This shows high level of variability in the segregating generation.
- Comparing, the F_2 and F_3 generation, the variability was high in F_2 generation and gradually, decreased in F_3 generation. This may be due to the selection pressure given in F_2 generation.
- Similarly, the range for all the characters in the segregating populations were high, indicating more variability within the population.

Genetic variability studies

- On estimation of phenotypic coefficient variation (PCV) and genotypic coefficient variation (GCV) for all the characters under study, they showed moderate to low effects, irrespective of crosses and generations.
- Considering, grain yield per plant and protein content, PCV and GCV effects were low for both the crosses, in both generations, except in F_2 family of H 10, which exhibited a moderate PCV effect.
- In general, the PCV effects was more than GCV effects, which depicts there is high environmental influence over the characters studied.
- On heritability estimation, almost all the characters showed a high heritability per cent, irrespective of crosses and generations.

- High heritability coupled with high genetic advance as per cent of mean was observed for grain yield per plant and protein content in both the crosses. Hence, selection based on such characters will be highly effective.
- Based on the genetic parameter estimation, a selection criteria had framed to select best lines to forward to F_3. By this, eight lines from H 10 family and fifteen lines from H 11 family were selected and forwarded to F_3 generation.

Correlation studies

- In F_2 generation of H 10 family, single pod weight showed significant and positive correlation with hundred seed weight and grain yield per plant.
- Days to first flowering, days to first harvest and number of seeds per pod had a negative correlation with grain yield per plant and protein content.
- In F_2 generation of H 11 family, days to last harvest and number of pods per plant showed significant and positive correlation with grain yield per plant.
- Days to first harvest showed significant negative correlation with grain yield per plant and days to first flowering with protein content.
- There was no significant positive correlation with the characters towards grain yield, in the F_3 generation of both the crosses.
- Significant and negative correlation, showed by days to first harvest with grain yield per plant and days to first flowering with protein content in family H 10. Whereas, in family H 11 days to first flowering showed negative correlation with grain yield per plant and grain yield per plant with protein content.

Path coefficient analysis

- In F_2 generation, plant height, days to first harvest and pod length showed a positive direct effect on grain yield. Negative direct effect showed by protein content towards grain yield.
- In F_3 generation, days to first flowering showed high positive direct effect followed by single pod weight, plant height and number of pods per plant. Very high negative direct effect showed by days to first harvest towards grain yield.

- From the F_3 generation, nine lines from H 10 family and nine lines from H 11 family were found to be superior and shall be forwarded to next generations for evaluation.

Appendix

Appendix-1: Monthly meteorological data for the year 2016 of Kerala Agricultural University, Vellanikkara

Month	Rainfall (mm)	Relative humidity (%)	Temperature	
	2016	2016	2016	
			Maximum	Minimum
January	23.8	56	33.2	23.0
February	11.4	57	35.3	23.6
March	00.0	67	36.3	25.6
April	25.8	71	35.8	26.3
May	269.4	78	34.0	24.2
June	654.7	89	29.8	21.6
July	393.0	86	29.9	21.6
August	183.5	83	30.4	23.3
September	86.0	82	30.3	23.6
October	37.3	81	31.5	22.7
November	13.8	68	33.0	22.2
December	52.9	68	32.4	22.3
Total	1751.60 mm			

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Pedigree breeding in early segregating generations of cowpea

(*Vigna unguiculata* (L.) Walp)

Abstract of the thesis

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Abstract

Pulses represent an essential component of agricultural food crops and considered as an important crop to meet food and nutritional security. They complement cereal crops in terms of dietary requirement as a source of protein and minerals. In several countries of the tropics and sub-tropics, cowpea serves as an important food legume. It plays an essential role in enrichment of daily diet, mainly as a grain and green pods. In general, cowpea seeds contain 23.4 per cent protein, 60.3 per cent carbohydrates and 1.8 per cent fat. It also provides considerable amount of vitamins and phosphorus. The protein availability in cowpea seeds and green pods is almost double/ triple the amount of available cereal protein.

The average grain yield of cowpea is still low and no single variety is adaptable for all growing conditions. Exploiting genetic variability is an essential method, to overcome the complex nature of cowpea breeding and to identify an elite high yielding genotype. Selection of best lines with high yield and other associated characters, in segregating generations paves a way to develop new varieties. The present study aimed to evaluate the F_2 and F_3 generations for high yield and protein content in two crosses (H 10 and H 11), involving Anaswara, PKB 3 and PKB 4 as parents.

In general, the F_2 families of both the crosses showed high mean performance and variance over the parents. Grain yield showed very low phenotypic coefficient variation (PCV) and genotypic coefficient variation (GCV). All other characters showed a moderate PCV and GCV values in segregating generation expect for days to first flowering, days to first harvest and days to last harvest.

Most of the characters showed high heritability (h^2) in F_2 generation. In F_2, the lowest value for h^2 was observed for single pod weight in H 10 family and for grain yield in H 11 family. Similarly, High genetic advance over mean (GAM) was exhibited by 100-seed weight in H 10 family and number of pods per plant in H 11 family. Selection based on characters with high h^2 and high GAM will be highly effective.

In F_2 generation of H 10 family, single pod weight showed significant and positive correlation with hundred seed weight and grain yield per plant. Days to first harvest and days to last harvest had a significant negative correlation with grain yield per plant. Days to first flowering, days to last harvest and single pod weight had significant negative correlation with protein content. In F_2 generation of H 11 family, days to last harvest and number of pods per plant showed significant and positive correlation with grain yield per plant. Number of pods per plant showed a significant positive correlation with protein content. Days to first harvest showed significant negative correlation with grain yield per plant and days to first flowering with protein content. On path analysis, plant height, days to first harvest, pod length and hundred seed weight showed a positive direct effect on grain yield. Negative direct effect was exerted by protein content towards grain yield.

A selection criteria was fixed based on number of pods per plant, grain yield per plant and protein content for selecting best lines to be forwarded to F_3 generations. Eight lines from F_2's of H 10 family and fifteen lines from F_2's of H 11 family were identified to be the best and forwarded to next generation.

F_3 family of both H 10 and H 11 followed a general trend for mean, variance, GCV, PCV, h^2 and GAM. Mean and variance were high for most of the characters and GCV and PCV values were moderate except for days to first flowering, days to first harvest, days to last harvest, 100-seed weight and grain yield, where it was low. F_3 families showed high heritability and moderate GAM, for most of the characters.

In F_3 generation of cross H 10, days to last harvest had significant positive correlation with grain yield per plant. There was no significant positive correlation with the characters towards grain yield, in the F_3 generation of cross H 11. Significant and negative correlation, showed by days to first harvest with grain yield per plant and days to first flowering with protein content in family H 10. Whereas, in family H 11 hundred seed weight showed significant negative correlation with protein content. On path analysis, days to first flowering showed very high positive direct effect followed by single pod weight, plant height and

number of pods per plant. Very high negative direct effect showed by days to first harvest through days to first flowering towards grain yield.

Nine lines each from F_3's of H 10 and H 11 with high yield and protein content was selected and shall be forwarded for next generation evaluation.