GENETIC DIVERGENCE STUDIES IN CLUSTER BEAN
(*Cyamopsis tetragonoloba* (L) Taub.)

By

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(2016-12-001)

THESIS

Submitted in partial fulfilment of the

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2018

DECLRATION

I hereby declare that the thesis entitled **"Genetic divergence studies in cluster bean (*Cyamopsis tetragonoloba* (L) Taub.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled **"Genetic divergence studies in cluster bean (*Cyamopsis tetragonoloba* (L) Taub."** is a record of research work done independently by **Ms.Remzeena A.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of **Ms.Remzeena A.**, a candidate for the degree of **Master of Science in Horticulture**, with major field in **Vegetable Science**, agree that the thesis entitled **"Genetic divergence studies in cluster bean"** may be submitted by **Ms. Remzeena A.** in partial fulfilment of the requirement for the degree.

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EXTERNAL EXAMINER

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Remzeena A

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Introduction

1.INTRODUCTION

Agriculture all over the world have been hard hit by the impacts of climate change like flood, drought, erratic rainfall, heat and cold waves. Countries like India are more vulnerable in view of the dependence of majority of population on agriculture, excessive pressure on natural resources and poor mitigation strategies (Maheshwari *et al.*, 2015). Suitable adaptation and mitigation strategies including use of climate resilient crops and cultivars for different regions are of paramount importance to cope with these aberrant weather conditions.

Leguminous crops are well known for their resilience, adaptation and tolerance to adverse conditions and they can come up well even in poor soils with less management practices (Gangadhara, 2013). Cluster bean (*Cyamopsis tetragonoloba* (L) Taub.) is an important leguminous crop belonging to the family Fabaceae (2n = 14). It is a hardy and drought tolerant crop extremely suitable for warm tropical regions. Its extensive tap root system imparts drought tolerance. It can serve as fodder and green manure crop, can enrich the soil by fixing atmospheric nitrogen (50-60 kg/ha) and add organic matter to the soil.

Cluster bean is widely exploited as an industrial crop because of its seed which contains galactomannan rich endosperm (Sharma *et al.*, 2014). The guar gum extracted from the seeds of cluster bean is found to have large-scale application in textile, paper, pharmaceutical and petroleum industries. India, share 80% of total world production. India produces 2.46 million tonnes from an area of 5.15 million hectares.It is mainly exported to USA, Germany, Netherlands, Italy, Japan etc..

In south India, it is mainly consumed as a vegetable. The pods are rich in nutrients like protein, vitamin A, vitamin C, calcium and iron (Kumar and Singh, 2002). 100g of edible pods contain 10.8g of carbohydrates, 3.2 g of protein and 0.4g fat. Even though it has great potential as a vegetable and industrial crop, it is not very popular in Kerala because no promising variety has been released suitable to Kerala condition. As climate change is posing threat to the food and nutritional security of the state, this is a crop, which has great scope in future,

Wide variability is observed for cluster bean all over India. Very limited number of studies has been conducted to explore the variability in the germplasm of cluster bean. Genetic improvement for quantitative traits depends upon the nature and amount of variability present in the genetic stock and the extent to which the desirable traits are heritable. Knowledge on variability, components of variance such as genotypic coefficient of variation, phenotypic coefficient of variation and heritability help in designing crop improvement program and choice of parental genotypes. Estimation of genetic divergence in any germplasm is very important in hybridization program. Hybrids with high heterosis can be developed by crossing between genotypes belonging to clusters of diverse origin. Hence, the present study was undertaken with the following objective.

1. To evaluate the performance of cluster bean genotypes for yield and quality.
2. To study the variability and correlation for yield and yield attributing characters.

Review of literature

2. REVIEW OF LITERATURE

Crop improvement work in vegetable type cluster bean is rather scanty. However, many workers have reported studies on genetic diversity, genotypic and phenotypic variability, heritability and correlation. The literature available on above aspects are reviewed and presented here under the following heads

1. Genetic variability, heritability and genetic advance
2. Correlation and path coefficient
3. Genetic divergence

2.1. Genetic variability, heritability and genetic advance:

Mitra *et al.* (2000) evaluated 234 genotypes of cluster bean. They observed that number of pods per plant showed maximum variability and divergence

In a study conducted among 30 genotypes of cowpea, Eswaran *et al.* (2006), observed high heritability and high genetic advance for plant height at initiation of flowering, 50% flowering and maturation.

Anandhi and Ommen (2007) reported high variability for all characters except number of seeds per pod and days to 50% flowering in 29 genotypes of cluster bean. Number of pods per plant, number of clusters per plant, pod length, pod weight and pod yield exhibited high heritability and genetic advance.

Buttar *et al.* (2008) observed high genotypic coefficient of variation (GCV) and heritability for seed yield per plant, biological yield, number of branches and plant height in 42 genotypes of cluster bean.

Prakash *et al.* (2008) observed high estimates of variation for number of pods per plant, harvest index, seed yield per plant, number of branches per plant and number of clusters per plant. High heritability coupled with high genetic advance were observed for characters such as number of pods per plant, seed yield per plant, number of branches per plant, harvest index, number of clusters per plant, plant height, number of pods per cluster and days to maturity.

Goud (2010) reported that characters like plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, vegetable pod yield, pod weight, dry pod weight and dry pod yield have high phenotypic coefficient of variation and genotypic coefficient of variation. In the same study, plant height, number of branches per plant, days to flower initiation, number of clusters per plant, number of pods per cluster, pod length, pod breadth, days to harvestable maturity, vegetable pod yield, dry pod weight, 100 seed weight, seed yield, protein content and gum content showed high heritability coupled with high GAM.

Pathak *et al.* (2011), observed significant difference between genotypes for all characters. Phenotypic coefficient of variation (PCV) was slightly higher than genotypic coefficient of variation (GCV). PCV and GCV were highest for number of primary branches followed by seed yield. High heritability was reported for number of pods per plant, endosperm (%), days to 50% flowering and number of primary branches.

In 31 genotypes of cluster bean, Shabarish *et al.* (2012), observed maximum variability for number of branches, plant height, clusters per plant, pod length and pod yield per plant. High heritability coupled with high genetic gain was observed for pod yield per plant, number of pods per plant, days to 50% flowering, number of branches and plant height. High heritability with low genetic advance was shown for pods per cluster, number of seeds per pod and pod width.

Girish *et al.* (2013) observed significant differences between genotypes for all characters except number of branches at 45 days after sowing (DAS), stem girth and 100 seed weight. The GCV and PCV were high for stem girth, dry pod yield per plot, seed yield per plant and gum content. High heritability coupled with high genetic advance were observed for plant spread in north –south (N-S) direction at 90 DAS, leaf area index, protein content and gum content.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and they reported high GCV and PCV for number of branches per plant, number of clusters per plant, number of pods per cluster, fresh pod yield, dry pod yield, 100 seed weight and gum content. High heritability coupled with high genetic advance was observed for plant height, number of branches per plant, number of pods per cluster, number of clusters per plant , pod length, fresh pod yield per plant, dry pod yield, 100 seed weight, days taken to maturity, crude protein and gum content. High heritability with low genetic advance was reported for days to maturity.

Malaghan *et al.* (2013) conducted a study on 67 cluster bean genotypes and they observed that there were significant differences for all characters. Maximum variability was observed for number of branches at 90 DAS, 10 fresh pod weight and number of dry pods per plant. High heritability combined with high genetic advance were observed for number of branches at 90 DAS, pod length and 10 fresh pod weight.

Bhatkodle *et al.* (2014) reported that phenotypic variance was higher than genotypic variance for most of the important traits in 24 vegetable type cluster beans and high heritability coupled with high genetic gain were observed for number of leaves, branches, and pods per plant, clusters per plant, pod length and yield per plant.

Kapoor (2014) reported significant variation for all characters in 66 genotypes of cluster bean. High heritability and high genetic advance were recorded for number of leaves per plant, number of branches, dry matter yield and green fodder yield. PCV was higher than GCV suggesting the influence of environment. High GCV and PCV were observed for leaf weight, number of leaves per plant, number of branches per plant, stem girth and dry matter yield.

Verma *et al.* (2014) observed large variability and high heritability and genetic advance for plant height, number of secondary branches per plant, number of pods per inflorescence, number of inflorescence per plant, mean pod weight, number of pods per plant, 100 seed weight and pod yield/ha in dolichos bean.

Kumar and Ram (2015) reported a large variability for pod yield (q/ha) and pod yield /plant (g) among 30 genotypes of cluster bean. Coefficient of variation was minimum for number of branches/plant and maximum for pod width. High heritability and high genetic advance were found for number of clusters/plant, number of pods per plant, pod yield/plant, plant height, days to maturity, number of pods per plant, number of clusters per plant and pod yield and heritability was lower for pod width, days taken for first flowering, days taken for 50% flowering and germination.

Kumar *et al.* (2015) observed wide variability for characters such as plant height, pod yield per plant, number of pods per plant, number of clusters/plant, pod yield and number of pods/cluster in cluster bean. High genotypic and phenotypic variance were also reported for days to maturity and germination percentage. Heritability and genetic advance were high for number of pods/cluster and number of clusters/ plant, heritability was lowest for pod width. Number of pods/cluster, number of clusters/plant, number of reproductive branches per plant, plant height and pod yield showed high GCV and PCV.

Vir and Singh (2015) observed high degree of genetic variability during summer and *kharif* for seed yield/plant, 100 – seed weight, number of seeds/pod, number of pods/plant, number of pod clusters per plant, number of branches per plant, number of clusters per plant, plant height, number of days to 50% flowering and number of days to maturity in 44 accessions of cluster bean and moderate to high heritability coupled with moderate to high genetic advance were observed for all these characters.

Inamdar *et al.* (2015) evaluated 37 genotypes of pole type dolichos bean, they observed green pod yield/plant, pod yield/plot, pod yield/ha, average weight of 10 pods and number of pods per vine have high GCV and these characters also shows high heritability, genetic advance and genetic advance as percentage of mean.

Jukanti *et al.* (2015) reported high heritability (> 85%) coupled with high genetic advance (>30%) for yield per plant, pods per cluster and clusters on main branch in cluster bean.

Manivannan *et al.* (2015) observed considerable level of variability for different traits among 42 genotypes of cluster bean. Largest variation was observed for days to maturity, plant height, pods per plant and cluster per plant.

Chandran *et al.* (2015) reported high PCV, GCV and high heritability for all-important traits except days to 50% flowering and number of seeds per pod in 90 genotypes of dolichos bean.

In a study, Devi *et al.* (2015), observed wide variability for characters such as days to flowering, days to first picking, average pod weight, pod length, pod/plant, plant height and pod yield/plant. Pod yield/plant and pods/plant have high PCV and GCV.

Boghara *et al.* (2016) evaluated 31 genotypes of cluster bean and observed considerable amount of variability for different morphological traits coupled with high heritability (51%).

Patil *et al.* (2016) reported high variability for all important characters except pod length and pod diameter. High heritability coupled with high genetic advance were observed for number of primary branches/plant, pod length, number of pod clusters, average weight of 50 pods, pod yield/plant, pod yield/plot, pod yield /ha and plant height.

Among the 43 genotypes of cluster bean collected from different parts of the country, Santhosha *et al.* (2017), estimated high amount of variation for number of branches at 45 and 90 days after sowing, number of pods per cluster, number of clusters per plant, number of pods per plant, vegetable pod yield per plant, weight of 10 pods, gum content and vegetable pod yield per plot. High heritability and high genetic advance were observed for number of branches at 45 days after sowing, plant height at 90 days after sowing, stem girth, plant spread, number of pods per cluster, number of clusters per plant, number of pods per plant, pod length, vegetable pod yield per plant, vegetable pod yield per plot, 100 seed weight, seed yield per plant, endosperm gum content and protein content.

Kumar *et al.* (2017) evaluated 30 cluster bean genotypes and observed that PCV was higher than GCV in all characters indicating higher influence of environment and high genetic advance were observed for plant height.

Reddy *et al.* (2017) reported significant variation among 51 genotypes of cluster bean for growth, yield and quality parameters. Number of pods was higher in IC 200680 and IC 34344. Pod yield was highest in IC 103295 and IC 34344. Protein content was highest in IC 28287 and IC 28795. The fibre content was higher in IC 28795 (9.03%) and IC 34344 (8.60%).

Goudar *et al.* (2017) found that number of vegetable pods, number of clusters per plant and pod yield exhibited maximum variability in 18 genotypes of cluster bean. Number of pods per plant, number of clusters per plant, pod yield and days to first flowering showed high heritability and high genetic gain.

In 24 genotypes of pea, Gautam *et al.* (2017), reported highest PCV and GCV for plant height and weight of seeds per pod. It was medium for number of pods per plant, number of branches per plant and pod yield. Characters like days to pod initiation, number of pods and pod yield showed high heritability and genetic advance.

2.2.1. Correlation

Mitra *et al.* (2000) reported that number of pods per plant have significant and positive correlation with yield in cluster bean.

Eswaran *et al.* (2007) observed that seed yield per plant have significant and highest positive correlation with dry matter production and harvest index in cowpea. Mishra *et al.* (2009) observed positive, significant correlation of characters such as branches/ plant, inflorescence per plant, green pods/plant, green pod length, green pod weight, pod girth and protein content of green pod with green pod yield in yard long bean.

Singh *et al.* (2009) reported that pod yield showed significant, positive genotypic and phenotypic correlation with number of pods per plant, pod length and number of seeds per pod in cluster bean.

Goud (2010) observed that there is a significant, positive correlation between number of pods per cluster, days to flower initiation, vegetable pod yield, number of pods per plant and seed yield in cluster bean.

Pathak *et al.* (2011) reported significant, positive correlation of seed yield per plant with number of pods per plant, number of seeds per pod, number of secondary branches, plant height and number of primary branches in cluster bean.

Girish *et al.* (2012) found that the green pod yield in cluster bean have significant and positive correlation with number of clusters per plant, plant height, plant spread, stem girth, number of pods per cluster, cluster length and pod length. Seed protein exhibited significant, positive correlation with pod width at genotypic level. Gum content has significant, negative correlation with plant height.

According to Mahalingam *et al.* (2013) pod weight, percentage fruit set, number of flowers/ cluster and number of pods/plant have positive and significant correlation with yield in dolichos bean.

Kapoor (2014) observed positive, significant genotypic and phenotypic correlation of green fodder yield with plant height, leaf length, leaf weight, number of leaves per plant and dry matter yield.

Verma *et al.* (2014) evaluated 34 genotypes of pole type french bean. They observed that all the characters viz., pod width and days to 50% flowering were positively correlated with pod yield/plant except vitamin C.

Vir and Singh (2014) reported that in cow pea, pod yield is positively and significantly correlated with number of seeds/pod, number of pods/plant, number of pods/cluster, number of clusters/plant and days to 50% flowering.

Rai and Dharmatti (2014) observed high positive phenotypic and genotypic correlation of pod yield/hectare with number of pods/plant, plant height, number of pod clusters/plant and pod yield/plant in cluster bean.

Chandran *et al.* (2015) evaluated 90 genotypes of dolichos bean, and reported that the green pod yield is positively and significantly correlated with branches per plant, green pods/plant, green pods per branch, green pod length, green pod weight and seeds per pod.

Devi *et al.* (2015) reported positive, significant correlation of pod yield with days to flowering, average pod weight, branches/plant, pods/plant and plant height in french bean.

Manivannan *et al.* (2015) reported that single plant yield was significantly and positively correlated with primary branches per plant, secondary branches per plant, and clusters per plant, pods per cluster and pods per plant. However, pod length was significantly and negatively correlated with single plant yield.

Vir and Singh (2015) observed number of seeds per pod, number of pods per plant, number of pods per cluster, number of clusters per plant, days to 50% flowering and days to maturity had significant and positive correlation with seed yield per plant in cluster bean.

Jain *et al.* (2015) recorded a positive, significant correlation between seed yield and biological yield in soybean.

Hemavathy *et al.* (2015) recorded that number of clusters per plant, number of pods/plant, 100 seed weight and number of seeds per pod have positive correlation with seed yield in mungbean.

Chatale (2015) reported that yield/plot have positive significant correlation with number of primary branches, weight of 50 pods, number of pods/cluster, negative and significant correlation with days to 50% flowering, days to first harvest and duration of crop in cluster bean.

Bhartiya *et al.* (2016) evaluated 22 genotypes of soybean, they observed highly significant positive phenotypic and genotypic correlation of dry matter, 100 seed weight and number of pods/plant with yield.

According to Panchabhaiya *et al.* (2016), days to 50% flowering, seed yield/plant, number of pods/plant, plant height, number of pod clusters/plant, number of pods/cluster, number of seeds/pod, pod length and pod weight showed significant and positive correlation with pod yield in french bean.

Choudary *et al.* (2016) found that traits like pod yield/ha, seed yield, plant height at 60 days, days to flowering, days to first picking, days to last picking, weight of 10 pods, number of green pods/plant, pod length, pericarp thickness, moisture percentage and seed yield/plant at genotypic and phenotypic level is positively correlated with green pod yield/plant in lab lab bean.

Lakshmanan and Vahab (2016) found that pod weight, pod length, pod girth, pods per plant , number of pod clusters per plant, plant height, shelf life and 100 seed weight is weight is significantly and positively correlated with vegetable pod yield in a study conducted in 100 genotypes of cluster bean.

In a study with 24 genotypes of peas, Gautam *et al.* (2016) observed number of pods per plant, number of branches per plant and days to 50% flowering are significantly and positively correlated to yield.

Muthuselvi *et al.* (2017) estimated the correlation between fourteen biometric and two quality parameter with yield contributing characters in 50 genotypes of cluster bean. They observed that genotypic correlation was higher than those of their respective phenotypic correlation coefficient for majority of the characters. Dry pod yield per plant showed significant positive correlation with plant height, days taken to first flowering, number of pods per cluster, fresh pod yield, seed yield per plant and 100 seed weight.

Kanwar *et al.* (2017) evaluated 28 genotypes of french bean. They observed seed yield/plant is positively and significantly correlated with all important traits except pod width at both phenotypic and genotypic level.

2.2.2. Path coefficient

Narayankutty *et al.* (2005) evaluated 63 accessions of cowpea and they reported highest positive correlation of number of pods/plant with yield.

Buttar *et al.* (2008) reported that path coefficient analysis of 42 genotypes of cluster bean revealed that number of seeds per pod and number of pods/plant have the highest direct effect on seed yield.

Goud (2010) revealed that days to flower initiation and number of pods per plant are the major traits to be considered for the improvement of seed yield in cluster bean.

Pathak *et al.* (2011) observed that number of pods per plant, endosperm, number of secondary branches and days to 50 % flowering had direct and positive effect on gum content, whereas plant height had maximum negative direct effect on gum content. Number of primary branches, number of secondary branches, number of pods per plant and seed yield per plant had indirect negative effect and 100 seed weight had indirect positive effect on the gum content.

According to Singh *et al.* (2011), number of pods/plant, pod length, pod width and seed width have direct positive effect on yield whereas days to first flowering have direct negative effect in dolichos bean.

Girish *et al.* (2012) observed that traits like dry pod yield, green pod yield/plot, dry pod yield /plot have high direct effect on green pod yield in cluster bean.

Kapoor (2014) reported that yield contributing traits like plant height, leaf length, leaf weight, number of leaves per plant, dry matter yield have direct effect on green fodder yield in cluster bean.

According to Rai and Dharmatti (2014) pod yield/plant had strong positive association and direct positive effect on pod yield/hectare. Pods per cluster, pod breadth, pods per cluster have indirect positive effect on pod yield/hectare in french bean.

After the evaluation of 90 genotypes of dolichos bean, Chandran *et al.* (2015), observed that green pod weight, green pods/ branch, green pods per plant and branches/plant have maximum direct effect on green pod yield.

Devi *et al.* (2015) found number of branches/plant, pods/plant and average pod weight had maximum direct effect on pod yield in french bean.

Jain *et al.* (2015) reported that in soybean the seed yield was directly and indirectly influenced by number of pods/plant, biological yield and 100 seed weight.

Hemavathy *et al.* (2015) reported that the yield components pods per plant, number of pods/cluster, number of clusters per plant and 100 seed weight is having highest direct effect on yield in urd bean.

Raturi *et al.* (2015) observed that in mungbean maximum direct effect on yield is shown by components such as number of pods per plant followed by plant height and 1000 seed weight.

Chatale (2015) observed that pod length, number of pods/cluster, days to first flowering and plant height have direct positive effect on yield

Bhartiya *et al.* (2016) reported that the components influencing yield in soyabean is dry matter content, days to maturity and 100 seed weight.

Dehal *et al.* (2016) found that in chick pea, biological yield and harvest index have highest direct effect on yield, but primary branches and pods per plant had negligible direct effect , however their indirect effect through biological yield and harvest index

Panchabhaiya *et al.* (2016) reported highest direct positive effect on yield was imparted by traits like number of pods/plant and pod weight in French bean.

. Katoch *et al.* (2016) found that components like pods/plant and pod length had highest positive direct effect on yield in garden peas.

Lakshmanan and Vahab (2016) observed that highest direct effect on yield was imparted by characters like pod length, plant height, number of clusters and number of pods/plant.

Number of pods per plant, days to flowering, pod weight and pod length had maximum direct positive effect on yield in peas (Gautam *et al.*, 2016).

Kunwar *et al.* (2017) reported that highest direct positive effect on seed yield /plant was shown by pod length which is followed by number of seeds/pod, number of pods/plant, days to 50% flowering, number of branches/plant, plant height at final harvest in french bean.

Yahaya and Ankrumah (2017) found that in soybean number of pods/plant had highest positive direct effect on grain yield. Maximum combined contribution to grain yield was from number of pods per plant and number of seeds per pod.

2.3. Genetic divergence

Mitra *et al.* (2000) grouped 231 genotypes of cluster bean into 12 clusters using non- hierarchical Euclidian analysis. Among the clusters, cluster genetic divergence was highest between cluster V and cluster IX, while cluster III and VIII had the least divergence.

Narayankutty *et al.* (2005) grouped 63 cowpea genotypes to 8 clusters. This clustering indicated that there is no association between geographical distribution and genetic divergence. Maximum divergence was contributed by pod weight, pod yield, pod/plant and pod length.

In genetic divergence study of 50 cluster bean genotypes Goud (2010), reported that 50 genotypes were grouped in 12 clusters and characters like number of branches per plant, gum content and dry pod yield contributed to the maximum divergence.

Singh *et al.* (2011) grouped seventy nine genotypes of dolichos bean into 7 clusters. Among the clusters, cluster I had maximum number of genotypes. Inter cluster distance was maximum between III and VII (10.820). Mean pod yield was maximum in cluster VII.

Verma *et al.* (2014) grouped 34 genotypes of pole type french bean to 5 clusters. The maximum diversity was contributed by the traits Vitamin C, dry matter content and number of pods per plant.

. Manivannan *et al.* (2015) observed that clustering of 42 cluster bean genotypes based on their morphological traits and grouped them into 4 main clusters and 6 sub clusters. Dendrogram based hierarchical clustering grouped them based on their morphological traits rather than geographic origin.

Malaghan *et al.* (2016) reported that 77 genotypes of cluster bean exhibited wide range of genetic divergence for 18 characters. Using D^2 techniques, they were grouped into seven clusters. Cluster II consisted of more number of genotypes and cluster VI showed maximum intracluster distance followed by cluster II. Inter cluster distance was maximum between cluster 6 and cluster 3 followed by cluster III and II. Therefore, the parents chosen from this clusters produce better recombinants.

Rupesh *et al.* (2016) studied genetic divergence in cow pea genotypes using Mahalanobis D^2 technique, they observed very little genetic divergence between genotypes. The genotypes were divided into V clusters. Maximum number of genotypes were there in cluster II. Intra cluster distance varied from 0.00 to 5.04. Maximum divergence was shown by cluster V followed by clusters II, III and IV. Largest inter cluster distance was between cluster I and cluster V. Cluster III showed maximum value for mean green pod yield followed by cluster IV.

After evaluation of the 18 genotypes, Gaudar *et al.* (2017), reported maximum intra cluster distance in cluster 1 and high inter cluster distance between cluster1 and cluster III.

Materials and Methods

3. MATERIALS AND METHODS

The experiment was conducted in the Department of Vegetable Science, College of Horticulture, Kerala Agricultural University, Vellanikkara during August to October 2017. The research field was located at an altitude of 22.5M above MSL, between 70° 32' N latitude and 76° 16' E longitude. The soil of the experimental site was laterite and the area has a warm humid tropical climate.

3.1. Experimental materials

The experimental material consisted of 30 different genotypes of cluster bean collected from NBPGR Regional Station, Jodhpur,Rajasthan. They are listed in Table.1.

Table.1. Source of cluster bean accessions used in the study

Sno.	Genotype	Source
1	CT-1	NBPGR, Jodhpur
2	CT-2	NBPGR, Jodhpur
3	CT-3	NBPGR, Jodhpur
4	CT-4	NBPGR, Jodhpur
5	CT-5	NBPGR, Jodhpur
6	CT-6	NBPGR, Jodhpur
7	CT-7	NBPGR, Jodhpur
8	CT-8	NBPGR, Jodhpur
9	CT-9	NBPGR, Jodhpur
10	CT-10	NBPGR, Jodhpur
11	CT-11	NBPGR, Jodhpur
12	CT-12	NBPGR, Jodhpur
13	CT-13	NBPGR, Jodhpur
14	CT-14	NBPGR, Jodhpur
15	CT-15	NBPGR, Jodhpur
16	CT-16	NBPGR, Jodhpur
17	CT-17	NBPGR, Jodhpur
18	CT-18	NBPGR, Jodhpur
19	CT-19	NBPGR, Jodhpur
20	CT-20	NBPGR, Jodhpur
21	CT-21	NBPGR, Jodhpur

22	CT-22	NBPGR, Jodhpur
23	CT-23	NBPGR, Jodhpur
24	CT-24	NBPGR, Jodhpur
25	CT-25	NBPGR, Jodhpur
26	CT-26	NBPGR, Jodhpur
27	CT-27	NBPGR, Jodhpur
28	CT-28	NBPGR, Jodhpur
29	CT-29	NBPGR, Jodhpur
30	CT-30	NBPGR, Jodhpur

3.2. Experimental methods

The experiment was laid out in randomized block design with 2 replications. The seeds were sown in plots of size 3 × 2.7 m^2 at a spacing of 60 × 45 cm. Each plot consist of 20 plants. All the crop management practices were performed as per Package of Practices Recommendations- Crops, KAU, (2016).

3.2.1. Collection of experimental data

Ten plants were selected randomly from each replication of all the treatments and tagged for recording biometrical characters. The observations were recorded on vegetative, floral, pod set and seed characters and the average values were calculated for further analysis.

3.2.2. Cataloguing of cluster bean genotypes

Thirty genotypes of cluster bean collected were catalogued based on NBPGR descriptor (2000) as shown in Table.2

Plate.1. General view of experimental field

Table.2. Descriptor of cluster bean

1.Vegetative characters		
1.1	Growth habit	Branched and non- branched
2. Floral characters		
2.1	Flower colour	White/ light purple/ purple/others
3. Pod characters		
3.1	Pod colour	Light green/ dark green
3.2	Pod pubescence	Glabrous/ pubescent/others
4. Seed Characters		
4.1	Seed colour	Light pink/Light grey/ Grey/ Dark grey/ White/ white purple/ purple/ Dark purple/ Pink/ Grey and light pink/others

3.3. Observations of growth and yield parameters

3.3.1. Plant height (cm)

Plant height was measured from base of the plant to the tip of main shoot after final harvest and expressed in centimeter.

3.3.2. Number of branches

Number of primary and secondary branches of ten random plants were recorded at cluster bearing stage.

3.3.3. Days to 50% flowering

Number of days taken from date of sowing to the flowering of 50% of plants in each accession were recorded.

3.3.4. Days to first fruit set

Number of days from sowing to the first fruit set was recorded.

3.3.5. Days to first harvest

Number of days from sowing to the date of first harvest of pods at vegetable maturity was recorded.

3.3.6. Number of pod clusters /plant

Number of pod clusters on main shoot and branches at full cluster bearing stage were recorded.

3.3.7. Number of pods/ cluster

Number of mature and effective pods in a single cluster were recorded.

3.3.8. Number of pods/ plant

Number of mature pods on main shoot and branches of ten random plants were recorded.

3.3.9. Pod length (cm)

Lengths of ten pods of each accession at vegetable maturity was measured.

3.3.10. Pod girth (cm)

Girth of ten random pods of each accession was measured at vegetable maturity.

3.3.11. Pod weight (g)

Weight of 10 pods from each accession were measured and expressed in gram.

3.3.12. Number of seeds/ pod

Number of seeds/ pod was counted from ten randomly selected pods in each accession.

3.3.13. Pod yield/ plant (g)

Pod yield/ plant at every harvest from ten plants in each accession were recorded.

3.3.14. Number of harvests

Number of harvest throughout the growing period of each genotype was recorded.

3.3.15. Flower colour

The observation on flower colour was recorded at full blossom stage of the plants and expressed as white/purple/ or others.

3.3.16. Pod colour

The observation on pod colour was recorded at fully mature stage of the pods.

3.3.17. Pod pubescence

The observation on pod pubescence was recorded at pod formation stage.

3.3.18. Seed colour

The observation on seed colour was recorded at full maturity stage of pods.

3.4. Qualitative parameters

Biochemical analysis for estimation of total carbohydrates, crude protein, crude fibre, vitamin C, iron, Calcium, and total phenols were done using standard procedures given below. Quality parameters were estimated as detailed by Sadasivum and Manickam (1996).

3.4.1. Total carbohydrate (mg/100g)

Total carbohydrates present in the dried samples of pods were estimated by anthrone method as detailed by Sadasivum and Manickam (1996).

Standard glucose stock: 100mg dissolved in 100ml water

Working standard: 10ml stock solution diluted to 100ml

100 mg of dried powdered sample w with 5ml of 2.5N HCl was taken in a boiling tube and kept in a boiling water bath for 3h. Neutralize the solution by adding solid sodium carbonate until the effervescence stops then made up the volume to 100ml and centrifuged. Collect the supernatant. Pipetted out 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard and 0.5ml of sample extract to a series of test tubes. Make the volume to 1ml in each test tubes by adding distilled water. To each test tube 4ml of anthrone reagent was added. The test tubes were then placed in a boiling water bath for eight minutes. Cooled rapidly and absorbance was read at 630nm. A standard graph was drawn by plotting concentration of the standards in X- axis and absorbance in Y- axis. From this graph the amount of carbohydrate present in the sample was calculated.

3.4.2. Crude protein (mg/100g)

Crude protein was estimated by Lowry's method as given by Sadasivum and Manickam (1996).

Reagent A: 2% Sodium carbonate in 0.1 N Sodium hydroxide,

Reagent B: 0.5% copper sulphate ($CuSO_4.5H_2O$) in 1% potassium sodium tartarate

Reagent C: Mix 50ml of Reagent A to 1.0 ml of Reagent B prior to use.

Reagent D: Folin –Ciocalteau Reagent

Stock Standard: 50 mg bovine serum albumin was dissolved in distilled water and made up the volume to 50ml in a standard flask.

Working standard: 10ml of this solution diluted to 50ml with distilled water in a standard flask.

Working standards of 0.2, 0.4, 0.6, 0.8 and 1.0ml were pipetted out in a series of test tubes. The cluster bean pod sample (0.5g) was ground well in a mortar with 5 to 10 ml of phosphate buffer. It was centrifuged and the supernatant was used for protein estimation. Sample extract (0.1ml) was pipetted out into another test tube. Then the volumes in each tube were made up to 1.0ml with distilled water. Tube with 1.0ml water served as blank.

To each test tube including blank, Reagent C (5.0ml) was added. It was mixed well. and allowed to stand for 10 minutes. To all test tubes, Reagent C (0.50ml) was added, mixed well and incubated at room temperature in dark for 30 minutes until blue colour was developed. Absorbance was read at 660nm in a spectrophotometer. A standard graph was drawn by plotting the concentrations of working standards and the sample on 'X' axis and absorbance on 'Y 'axis.

3.4.3. Crude fiber (%)

Crude fiber was estimated by acid alkali digestion method as suggested by Sadasivum and Manickam (1996).

Two gram of cluster bean pod was dried, defatted and boiled with 200ml of 1.25 per cent sulphuric acid for 30minutes. This was filtered through muslin cloth and washed with boiling water until the washings were no longer acidic and again boiled with 200ml of 1.25 per cent sodium hydroxide solution for thirty minutes and filtered through muslin cloth and washed with 25ml of 1.25 per cent sulphuric acid, 50ml water and 25ml of alcohol. The residue was transferred to a pre-weighed ashing dish (W_1) and dried at 130°C for 2 hours in hot air oven. The ashing dish was cooled in a dessicator and weighed (W_2). Then ignited in a muffle furnace at 600°C for 30 minutes and cooled in a desiccator and reweighed (W_3).

$$\% \text{ crude fibre in ground sample} = \frac{(W_2 - W_1) - (W_3 - W_1) \times 100}{\text{Weight of the sample}}$$

3.4.4. Vitamin C (mg/100g)

Vitamin C was estimated by volumetric method as suggested by Sadasivum and Manickam (1996).

Dye solution: 42mg sodium bicarbonate was dissolved in a small volume of distilled water and then 52mg of 2, 6 – dichlorophenol indophenol dye was dissolved in it and made up to 200ml.

Ascorbic acid stock standard: Dissolving 100mg ascorbic acid in 100ml of 4% oxalic acid. Working standard: 10ml of stock solution diluted to 100ml with 4% oxalic acid.

10ml of working standard was pipetted out into a conical flask and 10ml of 4% oxalic acid was added and titrated against 2,6, Dichlorophenol indophenol dye solution taken in a burette. End point was denoted by the appearance of pink colour that lasts for few seconds. The quantity of dye solution used is measured (V_1ml). Extract of fresh cluster bean pods (0.5g) was prepared using 4% oxalic acid and made up to 100ml and centrifuged. From this 5.0 ml of supernatant was pipetted out and 10ml of 4% oxalic acid was added and titrated against the dye and the volume of dye used was noted (V_2ml).

$$\text{Amount of ascorbic acid (mg/100g sample)} = \frac{0.5\text{mg} \times V_2\,\text{ml} \times 100\text{ml} \times 100}{V_1\,\text{ml} \times 5\text{ml} \times \text{wt. of the sample}}$$

3.4.5. Iron and Calcium (%)

Cluster bean pods were dried at 60° C in a hot air oven for 7- 9 days. The dried pods were powdered using a grinder. This powdered sample (0.2g) was used for digestion. The sample was digested in microwave digester by adding concentrated nitric acid.

Table.3. Methods used for analysis of iron and calcium

Iron	Digested in microwave and estimated by ICP -OES	Piper,1966
Calcium	Digested in microwave and estimated by ICP -OES	Piper ,1966

3.4.6. Total phenols (mg/100g)

Total phenol was estimated by the method suggested by Sadasivum and Manickam (1996).

Stock standard: 100mg of catechol dissolved in 100ml of water

Working standard: 10ml of stock solution diluted to 100ml

The sample extract was prepared by homogenizing 0.5g of fresh ground pods in 10 times volume of 80% ethanol and centrifuged at 10,000 rpm for 20min. The supernatant was saved and residue was re-extracted by adding five times the volume of 80% ethanol and supernatants obtained were pooled. It was evaporated to dryness. Then the dried residue was dissolved in a known volume of water (5ml).

Working standards of 0.2, 0.4, 0.6 0.8, 1.0 ml and sample extract 0.2ml were pipette out into a series of test tubes, in each test tube the volume was made up to 3.0ml with distilled water. To each test tube 0.5ml of Folin – Ciocalteau reagent was added followed by 2.0ml of 20% sodium carbonate. The test tubes were then placed in boiling water bath for one minute. Test tubes were cooled and absorbance was read at 650nm. A standard graph was drawn by plotting concentration of the standards on X- axis and absorbance on Y- axis. The amount of phenol present in the sample was calculated.

3.5. Incidence of pest and diseases

Pest and disease incidence on the plants during the entire growth period was recorded. It was expressed as percentage.

$$\text{Disease incidence/Pest incidence (\%)} = \frac{\text{Number of plants infected} \times 100}{\text{Total number of plants}}$$

3.6. Organoleptic evaluation

A panel of 15 judges were selected using triangle test (Jellineck, 1985) and organoleptic qualities were evaluated using 9 point hedonic scale.

The cooked pods were evaluated for their colour, appearance, flavor, taste, texture. Total score were given based on a method suggested by (Arunachalam, and Bandyopadhyay, 1984.).

3.7. Statistical methods

The data recorded on different parameters were subjected to statistical analysis for estimation of various genetic parameters. To find out degree of association between different characters and their contribution to the yield of pods. Parameters like phenotypic coefficient of variation, genotypic coefficient of variation, correlation coefficients, Heritability, Genetic advance, Genetic gain, Path coefficient etc. were found out.

I. Phenotypic, Genotypic and Environmental variances: The variance components were estimated using formula suggested by Burton (1992).

1. Phenotypic variance (Vp) = Vg + Ve

Where, (Vg) = Genotypic variance

(Ve) = Environmental variance

2. Genotypic variance (Vg) = (VT – VE)/N

Where, VT = Mean sum of squares of treatments

VE = Mean sum of squares due to error

N = Number of replication

3. Environmental variance (Ve) = VE

Where, VE = Mean sum of squares due to error

II. Phenotypic and genotypic coefficient of variation: The phenotypic and genotypic coefficients of variation were calculated by the formula given by Burton and Devane (1953).

1. Phenotypic coefficient of variation (PCV) = $(Vp^{1/2} / X \times 100)$

Where, Vp = phenotypic variance

X = Mean of the character under study

2. Genotypic coefficient of variation (GCV) = $(Vg^{1/2} / X \times 100)$

Where, Vg = genotypic variance

X = Mean of the character under study

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

1. $H = (Vg/Vp) \times 100$

Where, Vg = Genotypic variance

Vp = Phenotypic variance

IV. Expected genetic advance: The expected genetic advance is estimated by the formula given by Lush (1949) and Johnson *et al.* (1955) at five percent selection intensity using the constant K as 2.06 given by Allard (1960).

1. $GA = (Vg/Vp) \times K$

Where, Vg = Genotypic variance

Vp = Phenotypic

K = selection differential

V. Genetic gain (Genetic advance as percentage mean)

1. $GG = GA/\ X \times 100$

Where, GA = Genetic advance

X = mean of character under study

VI. Phenotypic, genotypic and environmental correlation coefficients: The phenotypic, genotypic and environmental covariance were estimated similarly as the variance were calculated. The covariance estimation was done according to the method given by Fisher (1954).

1. Phenotypic covariance between two characters 1 and 2

$(CoVp_{12}) = CoVg_{12} + CoVe_{12}$

$CoVg_{12}$ = Genotypic covariance between characters 1 and 2

$CoVe_{12}$ = Environmental covariance between 1 and 2

2. Genotypic covariance between two characters 1 and 2

$CoVg_{12} = (Mt_{12} - Me_{12}) / N$

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

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

N = Number of replication

VII. The phenotypic, genotypic and environmental correlation coefficients: The phenotypic, genotypic and environmental correlation coefficients between different characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955).

1. Phenotypic correlation coefficient between two characters

$(rp_{12}) = COVp_{12} / Vp_1 \ Vp_2$

$COVp_{12}$ = Phenotypic covariance between characters 1 and 2

Vp_1 = Phenotypic variance of character 1

Vp_2 = Phenotypic variance of character 2

2. Genotypic correlation coefficient between two characters

$(rg_{12}) = COVg_{12} / Vg_1 \ Vg_2$

$COVg_{12}$ = Genotypic covariance between characters 1 and 2

Vg_1 = Genotypic variance of character 1

Vg_2 = Genotypic variance of character 2

3. Environmental correlation coefficient between two characters 1 and 2

$(re_{12}) = COVe_{12}/ Ve_1Ve_2$

$COVe_{12}$ = Environmental covariance between characters 1 and 2

Ve_1 = Environmental variance of character 1

Ve_2 = Environmental variance of character

VIII. Path coefficient analysis: In the path coefficient analysis the correlation among cause and effect is divided into direct and indirect effects of causal factors on effect factors. The principle and techniques suggested by Wright (1921) and Li (1955) for cause and effect system were adopted for analysis using the formula given by Dewey and Lu (1959).

IX. Assessment of Genetic divergence and grouping of genotypes: The genetic distances among 30 genotypes were calculated by adopting Mahalanobis D^2 (Mahalanobis, 1928), Values between every pair of quantitative characters was estimated. Grouping of genotypes into different clusters were done by the method suggested by Tocher's method (Rao, 1952).

Results

4. RESULTS

The present study entitled " Genetic divergence studies in cluster bean" was carried out to evaluate the performance of different cluster bean accessions in the humid tropics of Kerala and to estimate the genetic variability, heritability, correlation between yield and its components and to find out the direct and indirect effects of different yield components on yield. The results of the experiment are presented below.

4.1. Cataloguing of cluster bean accessions

Thirty accessions of cluster bean were catalogued based on NBPGR, Minimal Descriptor for characterization and Evaluation of Agri-Horticultural Crops (2000). Morphological characters like growth habit, flower colour, pod colour, pod pubescence and seed colour were recorded and accessions were catalogued and are presented in Table 4.

The accessions collected for the study exhibited two growth patterns of branching and non-branching types. The non-branching types were CT-9, CT-15, CT-17 and CT-27. All others were branching types.

Flower colour was light purple for all accessions except CT-8, which had white flower. The pod colour varied from light green to dark green among the thirty accessions. None of the accessions produced pubescent pods. However, glabrous pods were produced by CT-3, CT-12, CT-28 and CT-29. Seed colour ranged from light pink (CT-1, CT-22) to dark grey (CT-10, CT-27) among the 30 accessions.

Table.4. Morphological characters of cluster bean accessions

Genotype	Growth habit	Flower colour	Pod colour	Pod pubescence	Seed colour
CT-1	Branched	Light purple	Dark green	Absent	Light pink
CT-2	Branched	Light purple	Dark green	Absent	Light grey
CT-3	Branched	Light purple	Light green	Glabrous	Grey
CT-4	Branched	Light purple	Dark green	Absent	Grey
CT-5	Branched	Light purple	Dark green	Absent	Grey
CT-6	Branched	Light purple	Dark green	Absent	Grey
CT-7	Branched	Light purple	Dark green	Absent	Grey
CT-8	Branched	White	Light green	Absent	Grey
CT-9	Non branched	Light purple	Dark green	Absent	Grey
CT-10	Branched	Light purple	Light green	Absent	Dark grey
CT-11	Branched	Light purple	Dark green	Absent	Grey
CT-12	Branched	Light purple	Light green	Glabrous	Grey
CT-13	Branched	Light purple	Dark green	Absent	Grey
CT-14	Branched	Light purple	Light green	Absent	Grey
CT-15	Non branched	Light purple	Dark green	Absent	Grey
CT-16	Branched	Light purple	Dark green	Absent	Grey
CT-17	Non branched	Light purple	Light green	Absent	Grey
CT-18	Branched	Light purple	Dark green	Absent	Light grey
CT-19	Branched	Light purple	Light green	Absent	Light grey
CT-20	Branched	Light purple	Light green	Absent	Grey
CT-21	Branched	Light purple	Dark green	Absent	Grey
CT-22	Branched	Light purple	Light green	Absent	Light pink
CT-23	Branched	Light purple	Dark green	Absent	Grey
CT-24	Branched	Light purple	Dark green	Absent	Grey
CT-25	Branched	Light purple	Dark green	Absent	Grey
CT-26	Branched	Light purple	Dark green	Absent	Grey
CT-27	Non branched	Light purple	Light green	Absent	Dark grey
CT-28	Branched	Light purple	Light green	Glabrous	Grey
CT-29	Branched	Light purple	Dark green	Glabrous	Grey
CT-30	Branched	Light purple	Dark green	Absent	Grey

Plate.2. Variability for growth habit

Plate. 3. Variability for flower colour

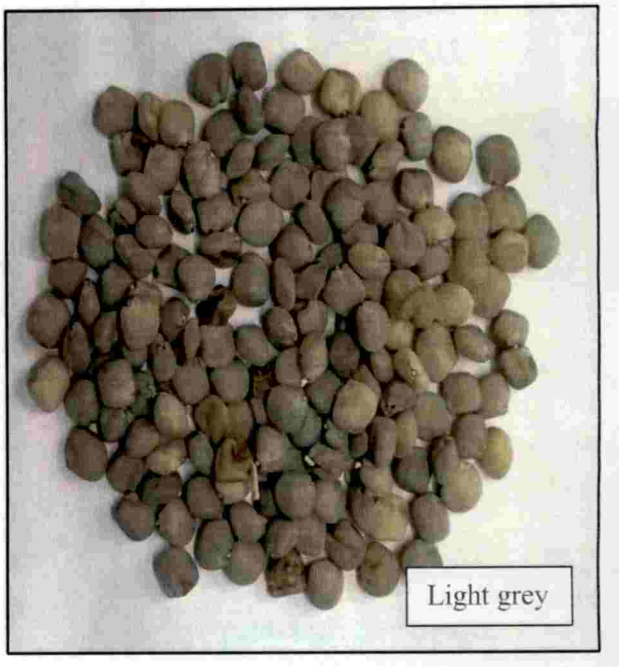

Plate.4. Variability for seed colour

4.2. Genetic variability in cluster bean

Analyses of variance for 21 characters were done using cluster bean accessions and the results showed that there were significant variations among cluster bean accessions for all the characters studied.

The mean performance of 30 accessions for 21 characters in terms of population mean, range, genotypic variance(GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation(PCV), broad sense heritability(h^2), genetic advance(GA), genetic advance as percentage of mean(GAM) were worked out to find out the extent to which observed variations are influenced by genetic factors and are presented in Table. 5 and Table.6.

4.2.1. Variability for morphological characters in cluster bean accessions.

4.2.1.1. Plant height

The plant height ranged from 109.12cm (CT-10) to 207.40cm (CT -15) with a general mean of 139.04cm. There was high GV (541.73) and PV (554.76) recorded respectively. There were moderate estimates for GCV (16.74), PCV (16.94), GA (47.36) and GAM (34.06) and high heritability (97.59 %) for plant height.

4.2.1.2. Number of branches

The number of branches in the cluster bean accessions ranged from 0.00(CT-9, CT-15, CT-17 and CT-27) to 19.20(CT -16, CT -18(19.10) with a mean of 12.73. The estimate of GV (25.79) and PV (26.38) were moderate so also GCV (40.35) and PCV (39.90). High heritability ((97.81%), GAM (81.29.) and low estimates for GA (10.35).

Table. 5. Performance of cluster bean accessions for growth and quality characters

	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	CT-1	131.90^{ijk}	17.45^{ab}	24.50^{cd}	26.50^{cd}	51.50^{a}	51.03^{bc}	5.88^{gh}	194.15^{gf}	6.15^{lmn}	0.71^{jk}	1.23^{mn}	8.70^{b}	242.66^{j}	5.00^{def}
2	CT-2	136.50^{fghi}	17.15^{ab}	24.50^{cd}	26.50^{cd}	48.50^{abc}	39.48^{fgh}	6.63^{efg}	150.25^{hk}	6.70^{def}	0.81^{efghi}	1.74^{e}	7.50^{b}	260.72^{ghij}	5.50^{cdef}
3	CT-3	113.70^{m}	13.80^{def}	30.00^{ab}	32.00^{ab}	45.00^{bc}	33.40^{hi}	8.25^{cde}	145.39jk	7.09^{c}	0.96^{bc}	1.93^{b}	7.50^{b}	283.25^{fg}	5.70^{cdef}
4	CT-4	119.80^{jkl}	16.40^{bc}	23.50^{d}	25.50^{d}	46.50^{bc}	44.00^{def}	6.63^{efg}	227.98^{ef}	6.48^{ghi}	0.68^{k}	1.10^{q}	7.40^{b}	248.72^{ij}	5.25^{cdef}
5	CT-5	125.20^{cd}	13.75^{def}	26.50^{bcd}	28.50^{bcd}	46.00^{bc}	34.90^{hi}	7.75^{def}	126.18^{lm}	6.55^{fgh}	0.72^{hijk}	1.33^{jk}	7.50^{b}	168.00^{nrs}	3.25^{g}
6	CT-6	148.70^{kl}	11.70^{fghi}	27.50^{bcd}	29.50^{bcd}	48.50^{abc}	36.65^{gh}	6.50^{fg}	167.39	6.34^{hijk}	0.84^{def}	1.16^{op}	7.90^{b}	192.60^{em}	4.15^{fg}
7	CT-7	123.90^{kl}	17.85^{ab}	33.00^{a}	35.00^{a}	47.00^{bc}	44.06^{def}	7.13^{defg}	131.82^{lml}	6.78^{de}	0.83^{def}	1.42^{fg}	8.10^{b}	188.88^{emn}	4.25^{efg}
8	CT-8	119.97^{lm}	9.30^{i}	27.00^{bcd}	29.00^{bcd}	51.50^{a}	35.30^{hi}	4.50^{h}	157.04^{hk}	6.87^{c}	0.69^{jk}	1.09^{qr}	7.60^{b}	167.29^{nrs}	4.15^{fg}
9	CT-9	154.25^{c}	0.00^{j}	24.50^{cd}	26.50^{cd}	44.50^{c}	15.25^{k}	12.88^{b}	120.21^{m}	7.08^{d}	0.79^{fghij}	1.33^{jk}	7.80^{b}	158.43^{rs}	3.25^{g}
10	CT-10	109.12^{n}	13.90^{def}	24.00^{d}	26.00^{d}	45.00^{bc}	34.93^{hi}	7.25^{defg}	141.60^{ijkl}	6.51^{fgh}	0.83^{def}	1.27^{e}	8.80^{b}	181.50^{emnr}	3.50^{g}
11	CT-11	125.34^{jkl}	13.30^{def}	24.00^{d}	26.00^{d}	49.00^{ab}	43.25^{def}	8.63^{cde}	257.88^{d}	5.79^{q}	0.72^{ijk}	1.31^{k}	8.70^{b}	335.25^{cd}	6.25^{cd}
12	CT-12	139.80^{fghi}	14.45^{cd}	22.50^{d}	24.50^{d}	46.00^{bc}	43.30^{def}	6.38^{fg}	146.87^{jk}	7.88^{b}	1.18^{a}	1.83^{d}	7.50^{b}	269.20^{ghi}	5.50^{cdef}
13	CT-13	131.60^{ijk}	12.15^{efghi}	25.00^{cd}	27.50^{cd}	45.00^{bc}	41.82^{efg}	8.25^{cde}	208.84^{f}	6.17^{lmn}	0.84^{def}	1.24^{m}	7.40^{b}	255.50^{hij}	5.15^{def}
14	CT-14	151.00^{cd}	17.90^{ab}	25.50^{bcd}	27.50^{bcd}	45.50^{bc}	49.50^{bcd}	8.50^{cde}	153.92^{hk}	6.42^{ghij}	0.86^{def}	1.21^{n}	8.70^{b}	184.17^{emn}	4.25^{efg}
15	CT-15	207.40^{a}	0.00^{j}	22.50^{d}	24.50^{d}	45.00^{bc}	23.50^{j}	19.13^{a}	189.24^{g}	6.46^{ghij}	0.86^{def}	1.06^{s}	8.80^{b}	198.91^{kl}	4.50^{efg}

1.Plant height (cm)
2.No. of branches
3.Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. No. of pod clusters/plant
7. No. of pods/cluster
8. No. of pods/plant
9. Pod length (cm)
10.Pod girth (cm)
11.Pod weight (g)
12.No. of seeds/pod
13. Pod yield/plant (g)
14. No. of harvests

Table.5. Contd..

	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	CT-16	143.14^{defg}	19.20^{a}	22.50^{d}	24.50^{d}	49.00^{ab}	44.45^{def}	8.75^{cde}	274.14^{cb}	6.29^{jkl}	0.69^{k}	1.25^{lm}	8.70^{b}	340.59^{c}	6.75^{bc}
17	CT-17	200.85^{a}	0.00^{j}	22.50^{d}	24.50^{d}	46.50^{bc}	29.50^{i}	19.25^{a}	187.38^{g}	6.83^{d}	0.92^{bcd}	1.33^{jk}	8.80^{b}	248.29^{ij}	5.25^{cdef}
18	CT-18	141.40^{efgh}	19.10^{a}	22.50^{d}	24.50^{d}	46.50^{bc}	54.26^{b}	9.50^{b}	286.07^{b}	6.08^{ef}	0.84^{def}	1.35^{j}	8.90^{b}	382.00^{b}	7.75^{ab}
19	CT-19	134.50^{hi}	10.75^{ghi}	22.50^{d}	25.00^{d}	46.50^{bc}	42.96^{ef}	7.88^{cdef}	197.72^{gf}	6.10^{nop}	0.73^{ghijk}	1.4^{gh}	7.40^{b}	278.93^{fg}	5.25^{cdef}
20	CT-20	143.56^{def}	15.10^{cd}	23.50^{d}	25.50^{d}	47.50^{bc}	48.56^{bcd}	8.25^{cde}	264.03^{cd}	6.35^{hijk}	0.72^{ghijk}	1.18^{o}	8.20^{b}	307.76^{de}	6.25^{cd}
21	CT-21	131.90^{ijk}	13.20^{def}	29.50^{cba}	31.50^{abc}	49.00^{ab}	62.21^{a}	7.25^{defg}	383.62^{a}	6.28^{klm}	0.71^{jk}	1.07^{rs}	8.90^{b}	412.83^{a}	8.25^{a}
22	CT-22	135.60^{ghi}	11.00^{ghi}	24.50^{ac}	26.50^{cd}	48.00^{abc}	52.07^{b}	7.25^{defg}	262.93^{cd}	6.05^{p}	0.69^{k}	1.14^{p}	7.90^{b}	296.50^{ef}	5.75^{cde}
23	CT-23	122.87^{l}	14.40^{cd}	24.50^{cd}	26.50^{cd}	46.00^{bc}	53.40^{b}	7.75^{def}	116.42^{m}	6.13^{mno}	0.76^{fghijk}	1.38^{i}	7.50^{b}	160.13^{rs}	3.25^{g}
24	CT-24	113.70^{m}	11.86^{efghi}	24.50^{cd}	26.50^{cd}	46.00^{bc}	45.39^{cde}	6.63^{efg}	128.29^{m}	6.01^{p}	0.87^{cde}	1.36^{ij}	8.50^{b}	170.91^{mnrs}	3.25^{g}
25	CT-25	135.05^{ghi}	17.19^{ab}	22.50^{d}	24.50^{d}	46.00^{bc}	49.29^{bcd}	7.88^{cdef}	192.31^{g}	6.62^{efg}	0.82^{efgh}	1.43^{f}	7.50^{b}	274.95^{fgh}	5.25^{cdef}
26	CT-26	134.60^{hi}	14.80^{cd}	25.00^{cd}	27.00^{cd}	47.50^{bc}	54.55^{b}	7.38^{defg}	282.64^{b}	6.33^{ijk}	0.85^{def}	1.14^{p}	7.90^{b}	320.85^{cd}	6.25^{cd}
27	CT-27	189.20^{b}	0.00^{j}	22.50^{d}	24.50^{d}	46.50^{bc}	20.35^{jk}	18.00^{a}	126.69^{ml}	6.50^{fghi}	0.78^{fghijk}	1.95^{b}	7.60^{b}	249.76^{ij}	4.75^{defg}
28	CT-28	149.60^{cd}	13.05^{def}	23.50^{d}	25.50^{d}	49.00^{ab}	52.38^{b}	8.25^{cde}	166.58^{b}	7.75^{b}	0.99^{b}	1.86^{bc}	8.90^{b}	311.81^{de}	6.25^{cd}
29	CT-29	132.50^{ij}	9.75^{hi}	25.00^{cd}	27.00^{cd}	46.00^{bc}	33.48^{hi}	7.75^{def}	61.33^{n}	11.80^{a}	1.10^{a}	2.46^{a}	9.10^{a}	148.27^{s}	3.25^{g}
30	CT-30	124.51^{jkl}	16.40^{bc}	23.50^{d}	25.50^{d}	46.00^{bc}	61.20^{a}	6.75^{efg}	162.94^{h}	6.60^{efg}	0.82^{efg}	1.31^{k}	6.50	218.57^{k}	4.25^{efg}
	CD (0.05)	7.47	1.55	4.05	4.02	3.45	5.28	1.41	4.05	0.19	0.087	0.024	0.66	21.06	1.35
	SE	3.66	0.76	1.98	2.43	1.69	2.58	0.68	7.10	0.09	0.04	0.012	0.32	10.30	0.66

1.Plant height (cm)
2.No. of branches
3.Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. No. of pod clusters/plant
7. No. of pods/cluster
8. No. of pods/plant
9. Pod length (cm)
10.Pod girth (cm)
11.Pod weight (g)
12.No. of seeds/pod
13. Pod yield/plant (g)
14. No. of harvests

Table.5. Contd..

	Genotypes	15	16	17	18	19	20	21
1	CT-1	8.33^{f}	4.58^{ab}	4.31^{n}	4.30^{ijk}	0.013^{abc}	0.486^{bcde}	6.26^{g}
2	CT-2	6.56^{mn}	5.43^{ab}	5.41^{ij}	6.40^{e}	0.013^{abc}	0.648^{abcd}	7.10^{d}
3	CT-3	9.37^{e}	3.43^{ab}	5.27^{jk}	4.40^{ijk}	0.017^{abc}	0.881^{abcd}	6.20^{g}
4	CT-4	8.22^{h}	5.62^{ab}	3.71^{o}	4.70^{i}	0.008^{bc}	0.415^{cde}	8.10^{d}
5	CT-5	9.53^{de}	4.34^{ab}	4.31^{n}	5.22^{h}	0.014^{abc}	0.594^{bcde}	8.20^{c}
6	CT-6	7.73^{i}	3.63^{ab}	5.06^{lm}	3.81^{m}	0.013^{bc}	0.767^{ab}	6.22^{f}
7	CT-7	8.25^{gh}	3.72^{ab}	4.93^{ij}	6.32^{d}	0.013^{bc}	0.796^{ab}	8.00^{c}
8	CT-8	6.63^{no}	3.37^{b}	5.17^{hi}	7.71^{cb}	0.014^{abc}	0.944^{abc}	9.10^{c}
9	CT-9	12.63^{a}	3.72^{ab}	6.17^{ef}	7.92^{b}	0.016^{abc}	0.481^{bcde}	6.23^{g}
10	CT-10	8.44^{gh}	5.44^{ab}	5.84^{g}	4.23^{ijk}	0.009^{bc}	0.507^{bcde}	5.77^{g}
11	CT-11	11.53^{b}	3.35^{b}	6.37^{e}	5.61^{fgh}	0.012^{bc}	0.613^{abcde}	7.60^{e}
12	CT-12	6.58^{no}	4.72^{ab}	6.13^{ef}	4.21^{lk}	0.047^{abc}	0.845^{abcde}	6.02^{g}
13	CT-13	7.32^{kl}	4.54^{ab}	6.74^{fg}	5.66^{fgh}	0.012^{abc}	0.568^{bcde}	8.13^{c}
14	CT-14	6.36^{no}	4.38^{ab}	4.64^{k}	3.97^{lm}	0.018^{ab}	0.932^{abc}	7.27^{f}
15	CT-15	6.31^{o}	3.31^{b}	6.67^{fg}	5.62^{fg}	0.012^{abc}	0.522^{bcde}	6.26^{g}

15.Total carbohydrates (mg/100g)

16.Crude protein (mg/100g)

17. Crude fibre (%)

18.Vitamin C (mg/100g)

19. Iron (%)

20. Calcium (%)

21. Total phenols (mg/100g)

52

Table.5. Contd..

	Genotypes	15	16	17	18	19	20	21
16	CT-16	10.55^{c}	6.63^{a}	7.06^{e}	3.23^{n}	0.008^{bc}	0.303^{e}	9.20^{b}
17	CT-17	10.34^{c}	4.23^{ab}	8.05^{d}	5.88^{e}	0.011^{abc}	0.384^{de}	9.30^{c}
18	CT-18	9.72^{d}	4.88^{ab}	7.13^{cd}	5.63^{efg}	0.014^{abc}	0.481^{bcde}	8.85^{c}
19	CT-19	6.35^{no}	3.43^{b}	7.37^{c}	5.67^{efg}	0.033^{ab}	0.707^{bcde}	7.90^{c}
20	CT-20	8.38^{fgh}	4.75^{ab}	4.13^{lm}	5.74^{ef}	0.011^{abc}	0.553^{bcde}	6.30^{g}
21	CT-21	8.63^{fg}	3.50^{b}	3.96^{mn}	4.22^{jk}	0.012^{abc}	0.713^{abcd}	8.20^{c}
22	CT-22	6.71^{m}	6.63^{a}	4.17^{lm}	5.76^{ef}	0.014^{abc}	0.822^{abcde}	7.87^{de}
23	CT-23	7.53^{jk}	5.38^{ab}	4.21^{l}	8.74^{a}	0.014^{abc}	0.670^{abcde}	9.78^{a}
24	CT-24	8.45^{fgh}	5.42^{ab}	6.33^{ef}	5.61^{fgh}	0.038^{a}	0.797^{bcde}	10.15^{b}
25	CT-25	6.84^{lm}	5.47^{ab}	5.87^{g}	6.33^{d}	0.014^{abc}	0.746^{bcde}	8.94^{d}
26	CT-26	8.15^{fgh}	3.76^{ab}	6.13^{hi}	5.27^{gh}	0.015^{abc}	0.638^{abcde}	7.90^{de}
27	CT-27	7.31^{ij}	4.71^{ab}	8.35^{a}	6.32^{d}	0.016^{abc}	0.636^{abcde}	8.12^{c}
28	CT-28	8.23^{gh}	5.76^{ab}	5.82^{g}	7.37^{dc}	0.017^{abc}	0.764^{bcde}	8.85^{b}
29	CT-29	9.32^{c}	4.48^{ab}	5.33^{h}	8.43^{a}	0.029^{ab}	1.04^{a}	7.95^{d}
30	CT-30	5.23^{p}	4.65^{ab}	7.75^{b}	4.32^{ij}	0.009^{c}	0.416^{cde}	7.84^{c}
	CD (0.05)	0.28	0.29	1.43	0.112	0.001	0.008	1.28
	SE	0.12	0.15	0.13	0.13	0.012	0.138	0.21

15.Total carbohydrates (mg/100g)

16.Crude protein (mg/100g)

17. Crude fibre (%)

18.Vitamin C (mg/100g)

19. Iron (%)

20. Calcium (%)

21. Total phenols (mg/100g)

Table.6. Estimates of components of variance, heritability and genetic advance over percentage of mean

Characters	Range	mean	GV	PV	GCV	PCV	h^2	GA	GAM
Plant height (cm)	109.12- 200.85	139.04	541.73	554.76	16.74	16.94	97.59	47.36	34.06
No. of branches	0.00 – 19.20	12.73	25.79	26.38	39.90	40.35	97.81	10.35	81.29
Days to 50% flowering	22.50 -33.00	24.77	4.34	8.27	8.41	11.61	52.47	3.11	12.55
Days to first fruit set	24.50 – 35.00	25.82	0.70	6.60	3.23	9.95	10.56	0.56	2.17
Days to first harvest	44.50 - 51.50	47.02	1.86	4.70	2.90	4.61	39.63	1.77	3.76
No of pod clusters/plant	15.25 - 62.21	42.48	123.97	130.58	26.21	26.90	94.90	22.34	52.59
No, of pods/cluster	4.50 – 19.25	8.76	13.31	13.78	41.64	42.37	96.55	7.38	84.27
No, of pods/plant	61.33 - 383.62	187.06	4628.58	4567.82	36.17	36.37	98.91	138.61	74.10
Pod length (cm)	5.79 – 11.80	6.69	1.14	1.15	15.96	16.02	99.28	2.19	32.76
Pod girth (cm)	0.68 -1.18	0.82	0.013	0.015	14.04	14.97	87.92	0.22	27.12
Pod weight (g)	1.06 – 2.46	1.39	0.10	0.10	23.21	23.23	99.87	0.68	47.79
No. of seeds/pod	6.5 – 9.1	8.07	0.39	0.49	7.76	8.72	79.29	1.15	14.24
Pod yield/plant (g)	148.27 – 412.83	248.57	4882.24	4987.00	28.11	28.41	97.87	142.39	57.29
No, of harvests	3.25 -8.25	5.01	1.63	2.06	25.45	28.66	78.84	2.33	46.54
Carbohydrates(mg/100g)	5.23 – 12.63	8.13	2.91	2.93	20.98	21.04	99.47	3.51	43.11
Crude protein (mg/100g)	3.31 – 6.63	4.57	0.89	0.91	20.66	20.92	97.50	1.92	42.03
Crude fibre (%)	3.71 – 8.35	5.99	1.69	1.71	21.75	21.85	99.06	2.67	44.58
Vitamin C (mg/100g)	3.23 – 8.43	5.61	1.97	1.98	25.02	25.12	99.18	2.88	51.32
Iron (%)	0.008 – 0.047	0.01	3.03	3.03	55.13	55. 12	99.80	0.01	113.54
Calcium (%)	0.30 – 1.04	0.62	0.037	0.037	31.15	31.11	99.87	0.40	64.08
Phenols (mg/100g)	5.77 – 10.15	7.69	2.05	2.10	18.65	18.86	97.82	2.92	38.00

2.1.3. Days to 50% flowering

Days to 50% flowering ranged from 22.50 (CT-12, CT- 15, CT- 16, CT-17, CT- 18, CT-19, CT-25, and CT- 27) to 33.00 (CT-7), with a mean of 24.77. Estimates of GV(4.34) and PV(8.27), GCV(8.41) and PCV(11.61) , GA(3.11) and GAM(12.55)were low. However, there was moderate heritability (52.47 %.) for the character.

4.2.1.4. Days to first fruit set

Days to first fruit set varied from 24.50 (CT-12, CT-15, CT- 16, CT-17, CT-18, CT-19,CT-25 and CT- 27) to 35.00(CT-7) with a mean of 25.82. There were very low estimates for GV(0.70), PV(6.60), GCV(3.23),PCV(9.95),GA(0.56), GAM(2.17) and heritability (10.56%).

4.2.1.5. Days to first harvest

Days to first harvest varied from 44.50 (CT-9) to 51.50(CT-1 and CT-8). Estimates of GV (1.86), PV(4.70), GCV(2.90), PCV(4.61), GA(1.77) and GAM(3.76) were very low. However, moderate heritability (39.63%) was recorded for the character.

4.2.1.6. Number of pod clusters/plant

Number of pod clusters per plant varied from15.25 (CT-9) to 62.21(CT -21) with a mean of 42.48. There were high estimates for GV (123.97), PV (130.58), moderate estimates for GCV (26.21), PCV (26.90), GA (22.34), GAM (52.59) and high heritability (94.90%).

4.2.1.7. Number of pods/cluster

Number of pods/cluster varied from 4.50 (CT-8) to 19.25 (CT-17) with a mean of 8.76. Estimates for GV (13.31), PV (13.78), and GA (7.38) were very low.

However, the character recorded moderate estimates for GCV (36.17), PCV (369.37) and high GAM (84.27) and heritability (96.55%).

4.2.1.8. Number of pods/plant

Number of pods/plant varied from 61.33(CT-29) to 383.62(CT- 21) with a mean of 187.06. The estimate of GV (4628.58) and PV (4567.82) were high. However, the same character showed moderate estimates for GCV (36.17), PCV (36.37) and high for GAM (74.10), GA (138.61) and heritability (98.91%).

4.2.1.9. Pod length

Pod length in cluster bean accessions varied from 5.79cm (CT-11) to 11.80cm (CT -29) with a mean of 6.69cm. The estimates for GV (1.14), PV (1.15) and GA (2.19) were very low; GCV (15.96), PCV (16.02) low; moderate GAM (32.76) and high heritability (99.28%) for pod length.

4.2.1.10. Pod girth

Pod girth varied from 0.68cm (CT-4) to 1.18cm (CT-12) with a general mean of 0.82cm. The character recorded very low estimates for GV (0.013), PV (0.015), GCV (14.04), PCV (14.97), and GA (0.22). However, there were moderate estimates for GAM (27.12) and high estimates for heritability (87.92%).

4.2.1.11. Pod weight

Pod weight varied from 1.06g (CT-15) to 2.46g (CT-29), with general mean of 1.39g. Pod weight recorded very low estimates for GV (0.10), PV (0.10), and GA (0.68), moderate estimates for GCV (23.21), PCV (23.23) and GAM (47.79). However, high estimate for heritability (99.87%) were recorded for pod weight.

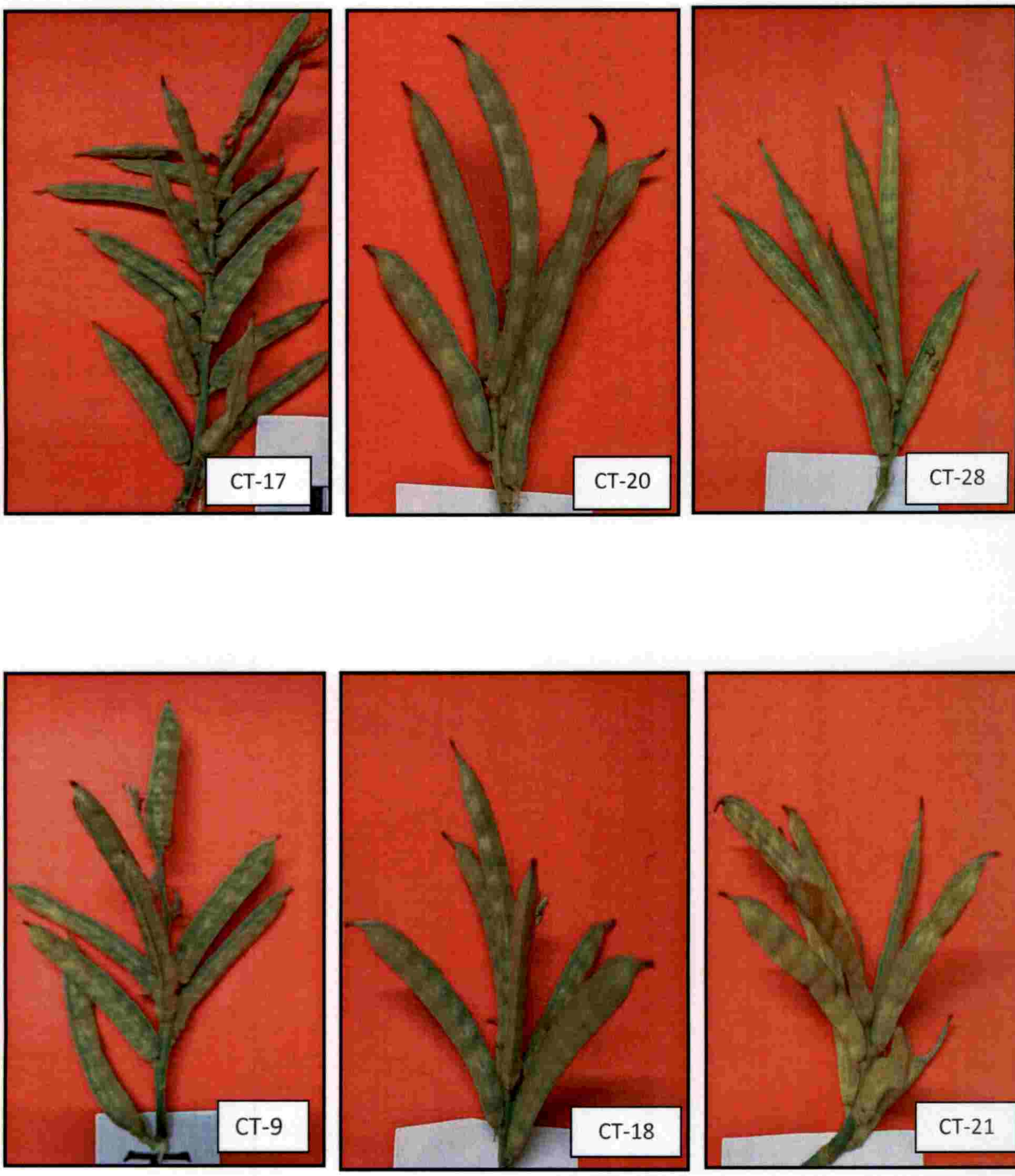

Plate.5. Variability in number of pods/cluster

4.2.1.12. Number of seeds /pod

Number of seeds/pod varied from 6.50(CT-30) to 9.10(CT- 29) with a general mean of 8.07. The character recorded very low estimates for GV (0.39), PV (0.49), GCV (7.76), PCV 8.72), GA (1.15), and GAM (14.24). High Heritability (79.29%) was recorded for number of seeds/pod.

4.2.1.13. Pod yield/plant

Pod yield/plant in cluster bean genotypes varied from 148.27g (CT-29) to 412.83g (CT-21) with a general mean of 248.57g. There were high estimates for GV (4882.24), PV (4987.00). However, this character recorded moderate GCV (28.11), PCV (28.41) and GAM (57.29). Estimates for heritability (97.87%), GA (142.39) for pod yield were found to be high.

4.2.1.14. Number of harvests

Number of harvests varied from 3.25(CT-5, CT-9, CT -23, CT-24 and CT-29) to 8.25(CT-21) with a general mean of 5.01. It was found that GV(1.63),PV(2.06) ,GCV(25.45), PCV(28.66) and GA(2.33) for the character were low. However, high heritability (78.84 %), and moderate GAM (46.54) were observed.

4.2.1.15. Total Carbohydrates

Total carbohydrates in the cluster bean accessions varied from 5.23mg/100g (CT-30) to 12.63mg/100g (CT-9) with a general mean of 8.13mg/100g. The estimates for GV (2.91),PV(2.93),GCV(20.98), PCV(21.04) and GA(3.51) were found low, however, high heritability (99.47 %) and moderate GAM (43.11.) were estimated for the character.

4.2.1.16. Crude protein

Crude protein in the cluster bean accessions varied between 3.31 mg/100g (CT- 15) to 6.63 mg/100g (CT-22, CT 16) with a general mean of 4.57mg/100g. The character exhibited very low estimates for GV (0.89), PV (0.91), GCV (20.66), PCV (20.92) and GA (1.92). However, crude protein showed high heritability (97.50%) and moderate GAM (42.03).

4.2.1.17. Crude fibre

Crude fiber in the cluster bean accessions varied from 3.71 %(CT-4) to 8.35 %(CT-27) with a general mean of 5.99%.The estimates for GV(1.69), PV(1.71), GCV(21.75),PCV(21.85), GA(2.67) were low for crude fibre, however, it showed, high heritability(99.06%) and moderate GAM(44.58).

4.2.1.18. Vitamin C

Vitamin C in the cluster bean accessions varied from 3.23 mg/100g (CT- 16) to 8.43 mg/100g (CT- 29) with a general mean of 5.61mg/100g. The character exhibited low estimates of GV (1.97), PV (1.98), GCV (25.02), PCV (25.12) and GA (2.88). However, heritability (99.18%) was high and GAM (51.32) was moderate.

4.2.1.19. Iron

Iron content in the accessions varied from 0.008 %(CT- 4) to 0.047 % (CT-12) with a general mean of 0.01%. Estimates for GV(3.03), PV(3.03), GA(0.01) were very low; GCV(55.13), PCV(55.12) were moderate; heritability(99.8%) and GAM(1 13.54) were high for the character .

4.2.1.20. Calcium

Calcium content in the accessions of cluster bean varied from 0.30% (CT-16) to 1.04% (CT-29) with a general mean of 0.62%. Very low estimates of GV(0.037),PV(0.037) ,GA(0.40) were exhibited for the character and moderate estimates of GCV(31.15),PCV(31.11) and GAM(64.08.) and high heritability (99.87%.) for the character.

4.2.1.21. Total phenols

Total phenols in cluster bean accessions varied from 5.77mg/100g (CT- 10) to 10.15mg/100g (CT- 24) with a general mean of 7.69 mg/100g. Estimates for GV (2.05), PV (2.10), GCV (18.65),PCV(18.86) and GA(2.92) were low. However, there was moderate GAM (38.00) and high heritability (97.82%).

4.3.0. Genotypic correlation

Genotypic correlations of various yield components with yield were estimated and presented in the Table.7. Plant height was significantly and positively correlated with number of pods/cluster, vitamin C and number of seeds/pod (rG = 0.91, 0.45 and 0.26) respectively and it was significantly, negatively correlated with number of branches, days to 50% flowering, days to first fruit set(rG = -,0.67, 0.46, 0.46) respectively.

Number of branches was significantly and positively correlated to days to first harvest , number of pod clusters/plant, number of pods/plant, number of harvests, total carbohydrates, crude fibre (rG=0.35, 0.75, 0.26, 0.31,0.33,0.35). It was significantly, negatively correlated to number of pods/ cluster, vitamin C, iron and calcium (rG = -0.76, -0.41,- 0.38and -0.53) respectively.

Table.7. Genotypic correlation among yield, growth and quality characters in cluster bean

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1**																				
2	-0.67**	1**																			
3	-0.46**	0.24	1**																		
4	-0.46**	0.23	0.98**	1**																	
5	-0.15	0.35**	0.11	0.10	1**																
6	-0.47	0.75**	0.09	0.09	0.40**	1**															
7	0.91**	-0.76**	-0.44**	-0.44**	-0.50**	-0.62**	1**														
8	0.02	0.26*	-0.07	-0.07	0.49**	0.53**	-0.07	1**													
9	0.02	-0.17	0.05	0.05	-0.20	-0.25	-0.03	-0.49**	1**												
10	0.15	-0.13	-0.03	-0.03	-0.55**	-0.17	0.12	-0.47**	0.69**	1**											
11	0.02	-0.09	-0.03	-0.03	-0.27*	-0.27*	0.06	-0.56**	0.76**	0.70**	1**										
12	0.26*	-0.08	-0.09	-0.11	0.26*	-0.02	0.24	0.24	0.21	0.19	0.02	1**									
13	0.04	0.31*	-0.16	-0.16	0.42**	0.49**	-0.03	0.86**	-0.30*	-0.16	-0.12	0.21	1**								
14	0.12	0.33*	-0.10	-0.09	0.39**	0.52**	0.00	0.89	-0.28*	-0.07	-0.13	0.28*	0.97**	1**							
15	0.02	-0.16	0.08	0.07	0.01	-0.32*	0.22	0.11	0.09	-0.07	0.07	0.47**	0.15	0.14	1**						
16	-0.13	0.35**	-0.52**	-0.54**	0.01	0.31*	-0.17	0.02	-0.03	-0.06	0.08	0.00	0.10	0.09	-0.12	1**					
17	0.45**	-0.41**	-0.62**	-0.61**	-0.37**	-0.28*	0.55**	-0.14	0.03	0.27*	0.26*	-0.02	0.08	0.03	-0.02	-0.10	1**				
18	0.08	-0.38**	-0.05	-0.05	-0.07	-0.25	0.15	-0.43**	0.42**	0.12	0.38**	-0.03	-0.34**	-0.37**	0.08	-0.03	0.11	1**			
19	-0.11	-0.53**	-0.51**	-0.50**	-0.59**	-0.22	-0.14	-0.97**	0.97**	0.98**	0.98**	0.18	-0.30*	0.16	-0.38**	-0.33**	0.62**	0.92**	1**		
20	-0.28*	-0.03	0.99**	0.98**	0.30*	-0.07	-0.40**	-0.47**	0.69**	0.39**	0.58**	0.17	-0.42**	-0.27*	-0.26*	-0.48**	-0.48**	0.46**	0.93**	1**	
21	-0.08	0.15	-0.06	-0.05	0.19	0.36**	-0.06	0.08	-0.097	-0.19	0.03	-0.04	0.14	0.10	-0.05	0.29*	0.17	0.31	0.42**	-0.09	1**

1.Plant height
2. No. of branches
3. Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. No. of clusters/plant
7. No. of pods/cluster
8. No. of pods/plant
9. Pod length
10. Pod girth
11. Pod weight
12. No. of seeds/pod
13. No. of harvests
14. Total carbohydrates
15. Crude protein
16. Crude fibre
17. Vitamin C
18. Iron
19.Calcium
20. Total phenol
21. pod yield/plant

* significant at 5% level
** significant at 1 and 5% level

Days to first fruit set was significantly and positively correlated to total phenols (rG = 0.98). It was significantly, negatively correlated to number of pods/cluster, crude fibre, vitamin C and calcium (rG = -0.44, -0.54, -0.61, -0.50) respectively.

Days to first harvest was significantly and positively correlated to number of pod clusters/plant, number of pods/plant, number of seeds/pod, number of harvests, total carbohydrates and total phenols (rG = 0.40,0.49,0.26, 0.42, 0.39 and 0.30) respectively. It was significantly negatively correlated to pods/cluster, pod girth, pod weight, vitamin C and calcium (rG = -0.50, -0.55, -0.27,-0.37 and -0.59 respectively).

Number of pod clusters/plant was significantly and positively correlated with number of pods/plant, number of harvests, total carbohydrates, crude fibre and pod yield per plant (rG = 0.53, 0.49, 0.52, 0.31and 0.36) respectively. It was significantly and negatively correlated with number of pods/cluster, pod weight, crude protein and vitamin C (rG = -0.62, -0.27, -0.32 and -0.28) respectively.

Number of pods/cluster was significantly and positively correlated with vitamin C (rG = 0.55) and it was significantly, negatively correlated with total phenol (rG = -0.40).

Number of pods/plant was significantly and positively correlated with number of harvests and total carbohydrates (rG = 0.86 and 0.89) respectively. It was significantly, negatively correlated with pod length, pod girth and pod weight, iron, calcium and total phenols (rG = -0.49, -0.47, -0.56,-0.43, 0.99and 0.47) respectively.

Pod length was positively and significantly correlated with pod girth, pod weight, iron, calcium and total phenols (rG = 0.69, 0.76, 0.42, 0.97and 0.69) respectively. It was significantly and negatively correlated with number of harvests and carbohydrates (-0.30 and -0.28) respectively.

Pod girth was significantly and positively correlated with pod weight, vitamin C, Calcium and total phenols (rG = 0.70, 0.27, 0.98 and 0.39) respectively. Pod weight was significantly, positively correlated with vitamin C, iron, calcium and total phenol (rG =0.26, 0.38, 0.98 and 0.58) respectively.

Number of seeds/pod was significantly and positively correlated with total carbohydrate and crude protein (rG = 0.28 and 0.47) respectively.

Number of harvests was significantly and positively correlated with total carbohydrates (rG = 0.97). It was significantly and negatively correlated with iron, calcium and total phenol content (rG = -0.34, - 0.30 and -0.42) respectively.

Total carbohydrate content was significantly and negatively correlated with iron and total phenol content (rG = -0.37 and -0.27) respectively. Crude protein and crude fibre content was significantly and negatively correlated with calcium and phenol content (rG = -0.38, -0.26) and ((rG = -0.33, -0.48) respectively. Vitamin C was significantly positively correlated with calcium (rG = 0.62) and it was negatively and significantly correlated with total phenol content (rG = -0.48). Iron content was significantly and positively correlated with calcium and total phenol content (rG = 0.92 and 0.46). Calcium content was significantly positively correlated with total phenol content and pod yield per plant (rG = 0.93 and 0.42).

Pod yield /plant was significantly and positively correlated with number of pod clusters/plant, crude fibre and calcium (rG= 0.36,0.29,0.42) respectively. Pod yield/plant showed negative association with plant height, days to 50% flowering, days to first fruit set, number of pods/cluster, pod length, pod girth, number of seeds/pod, crude protein (-0.08,-0.06,-0.05,-0.06,-0.97,-0.19,-0.04,-0.05) respectively.

Table.8. Phenotypic correlation among yield, growth and quality characters in cluster bean

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1**																				
2	-0.65**	1**																			
3	-0.35**	0.14	1**																		
4	-0.35**	0.14	0.99**	1**																	
5	-0.12	0.18	0.14	0.13	1**																
6	-0.46**	0.73**	0.04	0.04	0.29*	1**															
7	0.88**	-0.74**	-0.29*	-0.29*	-0.29*	-0.58**	1**														
8	0.01	0.26*	-0.06	-0.06	0.31*	0.52**	-0.06	1**													
9	0.01	-0.16	0.04	0.03	-0.11	-0.24	-0.02	-0.48**	1**												
10	0.14	-0.11	-0.04	-0.04	-0.30*	-0.14	0.09	-0.44**	0.65**	1**											
11	0.02	-0.09	-0.02	-0.03	-0.17	-0.26*	0.06	-0.56**	0.76**	0.66**	1**										
12	0.25	-0.06	0.01	-0.01	0.17	0.001	0.22	0.21	0.19	0.13	0.02	1**									
13	0.03	0.30*	-0.13	-0.12	0.27*	0.48**	-0.03	0.86**	-0.29*	-0.16	-0.12	0.19	1**								
14	0.1	0.30*	-0.10	-0.10	0.27*	0.44**	0.01	0.81**	-0.24	-0.14	-0.11	0.22	0.95**	1**							
15	0.03	-0.16	0.05	0.04	0.001	-0.31*	0.21	0.11	0.09	-0.07	0.07	0.41**	0.15	0.13	1**						
16	-0.13	0.34**	-0.37**	-0.38**	-0.03	0.28*	-0.16	0.02	-0.03	-0.05	0.08	0.02	0.10	0.07	-0.12	1**					
17	0.45**	-0.40**	-0.43**	-0.43**	-0.23	-0.28*	0.54**	-0.14	0.03	0.26*	0.26*	0.003	0.07	0.01	-0.02	-0.10	1**				
18	0.08	-0.37**	-0.03	-0.03	-0.05	-0.24	0.15	-0.42**	0.42**	0.11	0.38**	-0.02	-0.34**	-0.34**	0.08	-0.03	0.11	1**			
19	-0.001	-0.12	-0.06	-0.05	-0.15	-0.02	-0.04	-0.19	0.22	0.37**	0.33*	0.17	-0.06	-0.14	-0.08	-0.01	0.13	0.18	1**		
20	-0.18	0.02	0.46**	0.45**	-0.01	-0.006	-0.24	-0.26*	0.38**	0.31*	0.32*	0.01	-0.23	-0.25	-0.15	-0.29*	-0.26*	0.27*	0.32*	1**	
21	-0.09	0.15	-0.01	-0.004	0.15	0.34**	-0.05	0.08	-0.10	-0.19	0.03	-0.04	0.13	0.10	-0.05	0.28*	0.16	0.31*	0.04	-0.06	1**

1.Plant height
2. No. of branches
3. Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. No. of clusters/plant
7. No. of pods/cluster
8. No. of pods/plant
9. Pod length
10. Pod girth
11. Pod weight
12. No. of seeds/pod
13. No. of harvests
14. Total carbohydrates
15. Crude protein
16. Crude fibre
17. Vitamin C
18. Iron
19.Calcium
20. Total phenol
21. pod yield/plant

* significant at 5% level
** significant at 1 and 5% level

4.3.2. Phenotypic correlation

Phenotypic correlations of various yield components with yield were estimated and presented in Table.8. At phenotypic level, plant height was significantly and positively correlated with number of pods/cluster, vitamin C, (rP = 0.88 and 0.45) respectively and it was significantly, negatively correlated with number of branches ,days to 50% flowering, days to first fruit set, number of pod clusters/plant (rP = - 0.65, -0.35,-0.35 and -0.46) respectively.

Number of branches was significantly, positively correlated to number of pod clusters/plant, number of pods/plant, number of harvests, total carbohydrates, crude fibre (rP = 0.73,0.26,0.30, 0.30 and 0.34) respectively. It was significantly, negatively correlated to pods/ cluster, vitamin C and iron (rP = - 0.74,-0.40 and -0.37) respectively.

Days to 50% flowering was positively and significantly correlated to days to first fruit set (rP= 0.99) and total phenol (rP= 0.46). It was significantly and negatively correlated to number of pods/cluster, crude fibre and vitamin C (rP= -0.29, - 0.37 and -0.43) respectively.

Days to first fruit set was significantly and positively correlated to total phenols (rP = 0.45). It was significantly and negatively correlated to number of pods/cluster, crude fibre and vitamin C (rP = -0.29, -0.38, -0.43) respectively.

Days to first harvest was significantly and positively correlated to number of pod clusters /plant, number of pods/plant, number of harvests and total carbohydrates (rP = 0.29, 0.31 ,0.27, 0.27) respectively. It was significantly and negatively correlated to pods/cluster and pod girth (rP = -0.29 and -0.30).

Number of pod clusters/plant was significantly and positively correlated with number of pods/plant, number of harvests, total carbohydrates, crude fibre and pod yield per plant (rP = 0.52, 0.48, 0.44 0.28 and 0.34) respectively. It was significantly and negatively correlated with number of pods/cluster, pod weight, crude protein and vitamin C (rP = -0.58, -0.26, -0.31 and -0.28) respectively.

Number of pods/cluster was significantly and positively correlated with vitamin C (rP = 0.54).

Number of pods/plant was significantly and positively correlated with number of harvests, total carbohydrates (rP = 0.86 and 0.81) respectively. It was significantly, negatively correlated with pod length, pod girth, pod weight, iron and total phenols (rP = - 0.48, -0.44, -0.56.-0.42 and -0.26) respectively.

Pod length was positively and significantly correlated with pod girth, pod weight, iron, and total phenols (rP = 0.65, 0.76, 0.42 and 0.38 respectively). It was significantly, negatively correlated with number of harvests (rP= -0.29).

Pod girth was significantly, positively correlated with pod weight, vitamin C, Calcium and total phenol (rP = 0.66, 0.26, 0.37 and 0.31 respectively). Pod weight was significantly positively correlated with vitamin C, iron, calcium and total phenol (rP =0.26, 0.38, 0.33 and 0.32) respectively. Number of seeds/pod was significantly and positively correlated with crude protein (rP = 0.41).

Number of harvests was significantly and positively correlated with total carbohydrates (rP = 0.95). It was significantly negatively correlated with iron (rP = -0.34).

Total carbohydrates content was significantly and negatively correlated with iron content (rP = -0.34). No significant positive or negative association of crude protein and other morphological characters were observed. Crude fibre was found to have significant and positive association with pod yield/plant (0.28). Crude fibre and vitamin C content was significantly and negatively correlated with total phenol content (rP = -0.29 and 0.26) respectively. Iron content was found positively and significantly associated with pod yield/plant (0.31); Iron and calcium showed positive correlation with total phenol (rP = 0.27, 0.32) respectively. Total phenol showed negative association with pod yield/plant (-0.06).

Pod yield was significantly and positively correlated with number of pod clusters per plant, crude fibre and iron content (rP = 0.34, 0.28 and 0.31) respectively. It was also positively correlated with number of branches, days to first harvest, number of pods/plant, pod weight, number of harvests, total carbohydrates, vitamin C and iron. At phenotypic level, pod yield/plant showed negative association with plant height, days to 50% flowering, days to first fruit set, number of pods/cluster, pod length, pod girth, number of seeds/pod, crude protein and total phenols.

4.4. Path analysis

Dividing the correlation of yield and its component characters into direct and indirect effects help to identify the direct and indirect contribution of component characters to the yield. The results of path analysis are presented in Table 9.

4.4.1. Direct effects on yield

In the table, diagonal values represent the direct effect and values on both sides of diagonal represent indirect effects. The number of pods/plant had highest direct positive effect on yield (1.164) followed by pod weight (0.742), days to first fruit set (0.638), plant height (0.203), pod girth (0.110), number of branches (0.203) and number of seeds/pod (0.005).

It had the highest direct negative effect on days to 50% flowering (-0.703), followed by pod length (-0.400), number of pods/cluster (-0.271), number of pod clusters/plant (-0.118) and days to first harvest (-0.040).

Table. 9. Path coefficient analysis for pod yield and its component characters in cluster bean

	1	2	3	4	5	6	7	8	9	10	11	12
1	**0.203**	-0.049	0.323	-0.296	0.006	0.056	-0.247	0.018	-0.006	0.017	0.011	0.001
2	-0.137	**0.073**	-0.166	0.149	-0.014	-0.089	0.207	0.300	0.066	-0.014	-0.068	0.000
3	-0.093	0.017	**-0.703**	0.638	-0.005	-0.011	0.119	-0.079	-0.022	-0.003	-0.020	0.000
4	-0.094	0.017	-0.703	**0.638**	-0.004	-0.011	0.120	-0.076	-0.018	-0.004	-0.023	-0.001
5	-0.031	0.025	-0.080	0.064	**-0.040**	-0.047	0.135	0.573	0.081	-0.061	-0.199	0.001
6	-0.096	0.055	-0.064	0.059	-0.016	**-0.118**	0.167	0.622	0.100	-0.018	-0.197	0.000
7	0.185	-0.056	0.308	-0.283	0.020	0.073	**-0.271**	-0.080	0.010	0.013	0.047	0.001
8	0.003	0.019	0.048	-0.041	-0.020	-0.063	0.019	**1.164**	0.195	-0.052	-0.417	0.001
9	0.003	-0.012	-0.038	0.029	0.008	0.030	0.007	-0.566	**-0.400**	0.077	0.562	0.001
10	0.030	-0.009	0.017	-0.022	0.022	0.020	-0.031	-0.545	-0.279	**0.110**	0.522	0.001
11	0.003	-0.007	0.019	-0.020	0.011	0.031	-0.017	-0.655	-0.303	0.077	**0.742**	0.000
12	0.054	-0.006	0.065	-0.069	-0.010	0.002	-0.065	0.283	-0.083	0.020	0.015	**0.005**

Residual : 0.0132

Legends — **Negative direct effect** — **Positive direct effect** — **Positive indirect effect** — **Negative indirect effect**

1.Plant height(cm)
2.Number of branches
3.Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. Number of pod cluster/plant
7. Number of pods/cluster
8.Number of pods/plant
9. Pod length (cm)_
10. Pod girth (cm)
11. Pod weight (g)
12. Number of seeds/pod

4.2. Indirect effects on yield

Plant height had direct positive effect on yield (0.203) and indirect positive effect was noticed on yield through days to 50% flowering (0.323), number of pod clusters/plant (0.056) and number of pods/plant (0.018), pod girth (0.017) and pod weight (0.011).

Number of branches had direct positive effect (0.073) on yield. It had indirect positive effect on yield through days to first fruit set (0.149), number of pods/cluster (0.207), and number of pods/plant (0.300) and pod length (0.066).

Days to 50% flowering had direct negative effect on yield (-0.703) and indirect positive effect on yield through number of branches (0.017), days to first fruit set (0.638) and number of pods/cluster (0.119).

Days to first fruit set had direct positive effect (0.638) and indirect positive effect on yield through number of branches (0.017) and number of pods/cluster (0.120).

Days to first harvest had direct negative effect on yield (-0.040) and indirect positive effect on yield through number of branches(0.025), days to first fruit set (0.064), number of pods/cluster (0.135), number of pods/plant (0.573) and pod length (0.081).

Number of pod clusters/plant had direct negative effect on yield (-0.118) and indirect positive effect on yield through number of branches (0.055), days to first fruit set (0.059), number of pods/cluster (0.167), number of pods/plant (0.622) and pod length (0.100).

Number of pods/cluster had direct negative effect on yield (-0.271) and indirect positive effect on yield through plant height (0.185), days to 50% flowering (0.308), days to first harvest (0.020), number of pod clusters/plant (0.073), pod length (0.009), pod girth (0.013) and pod weight (0.047).

Number of pods/plant had direct positive effect on yield (1.164) and indirect positive effect on yield through plant height (0.003) number of branches (0.019), days to 50% flowering (0.048), pod length (0.195) and number of pods/cluster (0.019).

Pod length had direct negative effect on yield (-0.400) and indirect positive effect on yield through plant height (0.003), days to first fruit set (0.029), days to first harvest (0.008), number of clusters/plant (0.030), number of pods/plant (0.007), pod weight (0.562) and pod girth (0.077) .

Pod girth had direct positive effect on yield (0.110) and indirect positive effect on yield through plant height (0.030), days to 50% flowering (0.017), days to first harvest (0.022), pod clusters/plant (0.020) and pod weight (0.522).

Pod weight had direct positive effect on yield (0.742) and indirect positive effect through plant height (0.003), days to 50% flowering (0.019), days to first harvest (0.011), number of pod clusters/plant (0.031) and pod girth (0.077).

Number of seeds/pod had direct positive effect on yield (0.005) and indirect positive effect on yield through plant height (0.054), days to 50% flowering (0.065), number of pod clusters/plant (0.002), number of pods/plant (0.283), pod girth (0.020) and pod weight (0.015).

4.5. Genetic divergence

To study the genetic divergence among 30 accessions of cluster bean, they were evaluated based on 21 characters. The data obtained from evaluation was subjected to Mahalanobis D^2 analysis. Based on the results, the 30 accessions of cluster bean were grouped into 8 clusters using Tocher's method. The results of divergence studies are presented in Table 10, Table 11, and Table 12.

Table. 10. Cluster composition based on D^2 statistic in cluster bean

Cluster no.	No. of genotypes in each cluster	Genotypes
I	7	CT-2, CT-8, CT-13, CT-14, CT-23, CT-25 and CT-28
II	3	CT-15, CT-27 and CT-30
III	2	CT-9 and CT-11
IV	8	CT-1, CT-4, CT-5, CT-6, CT-7, CT-20, CT-21 and CT-26
V	3	CT-12, CT-19 and CT-24
VI	3	CT- 16, CT-17 and CT-18
VII	2	CT-3 andCT-22
VIII	2	CT-10 and CT-29

Table 11. Intra cluster and inter cluster D^2 values in cluster bean accessions

Cluster	I	II	III	IV	V	VI	VII	VIII
I	36290.07							
II	196034.64	84503.50						
III	421822.75	573525.69	18228.16					
IV	70197.41	304034. 34	265356.50	27981.42				
V	112519.11	209789.53	473070.25	184813.77	84403.53			
VI	260657.45	272487.59	112150.97	192457.70	295547.88	32795.28		
VII	106303.27	395070.47	361623.44	80451.53	207485.02	305375.94	200922.70	
VIII	139034.73	155648.45	253742.92	134305.69	167582.81	97180.41	228610.73	87722.69

4.5.1. Classification of cluster bean accessions

Thirty accessions of cluster bean were grouped into 8 clusters by using Trocher's method (Rao, 1952). The distribution pattern of genotypes into various clusters is shown in Table 10

Cluster IV had highest number of accessions (8) followed by cluster I (7) accessions. There were three accessions each in cluster II, V and VI. Clusters III, VII and VIII had two accessions each.

The accessions included in cluster I are CT-2, CT-8, CT-13, CT-14, CT-23, CT-25 and CT-28. Cluster II consisted of the accessions CT- 15, CT-27, CT-30. Cluster III consisted of the accessions CT-9 and CT-11. Cluster IV consisted of the accessions CT-1, CT-4, CT-5, CT-6, CT-7, CT-20, CT-21 and CT-26. Cluster V consisted of CT-12, CT-19 and CT-24. Cluster VI consisted of CT-16, CT-17 and CT-18. Cluster VI consist of CT-16, CT-17 and CT-18. Cluster VII consisted of CT-3 and CT-22. Cluster VIII consisted of CT-10 and CT-29.

Inter and intra cluster distance between 8 clusters are given in Table. 11. Intra cluster distance was maximum in cluster VII (D^2 = 200922.70). Intra cluster distance was minimum in cluster III (D^2 = 18228.16). Inter cluster distance was maximum between cluster III and II (D^2 = 573525.69). Inter cluster distance was minimum between cluster IV and I (D^2 = 70197.41).

4.5.2. Mean performance of characters in clusters

Cluster means of 21 characters of cluster bean accessions are presented in Table 12.

4.5.2.1. Plant height

The highest mean plant height was observed in cluster II (173.70) followed by cluster VI (161.80). The lowest mean plant height was observed in cluster VIII (120.80).

Table 12.Means of 21 characters for 8 clusters in cluster bean accessions

Characters / Clusters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
I	135.22	14.44	24.64	26.71	47.36	45.80	7.39	163.62	6.66	0.82	1.42	7.90	230.65	4.83	7.06	4.90	5.41	6.59	0.015	0.753	8.45
II	173.70	5.47	22.83	24.83	45.83	35.01	14.62	159.62	6.52	0.82	1.44	7.63	222.41	4.50	6.28	4.22	7.59	5.42	0.012	0.525	7.40
III	139.80	6.65	24.25	26.25	46.75	29.25	10.75	189.05	6.44	0.76	1.32	8.25	246.84	4.75	12.08	3.53	6.27	6.77	0.014	0.547	6.92
IV	132.45	15.03	26.63	28.63	47.94	46.99	7.09	222.22	6.41	0.76	1.20	8.07	260.28	5.33	8.40	4.24	4.57	4.95	0.012	0.620	7.40
V	129.33	12.35	23.17	25.33	47.17	43.88	6.96	157.62	6.66	0.93	1.53	7.80	239.68	4.66	7.13	4.52	6.61	5.16	0.039	0.783	8.02
VI	161.80	12.77	22.50	24.50	47.33	42.74	12.50	249.19	6.40	0.82	1.31	8.80	323.63	6.58	10.2	5.25	7.41	4.91	0.011	0.389	9.12
VII	124.65	12.40	27.25	29.25	46.50	42.74	7.75	204.16	6.57	0.83	1.53	7.70	289.87	5.72	8.04	5.03	4.72	5.08	0.016	0.852	7.04
VIII	120.81	11.83	24.50	26.50	45.50	34.20	7.50	101.46	9.16	0.97	1.87	8.95	164.89	3.38	8.87	4.96	5.58	6.33	0.019	0.773	6.86

1.Plant height
2. No. of branches
3. Days to 50% flowering
4. Days to first fruit set
5. Days to first harvest
6. No. of clusters/plant
7. No. of pods/cluster
8. No. of pods/plant
9. Pod length
10. Pod girth
11. Pod weight
12. No. of seeds/pod
13. Pod yield
14. No. of harvests
15. Total carbohydrates
16. Crude protein
17. Crude fibre
18. Vitamin C
19. Iron
20. Calcium
21. Total phenols

4.5.2.2. Number of branches

The highest mean number of branches was observed in cluster III (15.03) followed by cluster I (14.44). The lowest mean number of branches was observed in cluster II (5.47).

4.5.2.3. Days to 50% flowering

The highest mean number days to 50% flowering was observed in cluster VII (27.25) followed by cluster IV (26.63). The lowest mean number of days to 50% flowering was observed in cluster VI (22.50).

4.5.2.4. Days to first fruit set

The highest mean number of days to first fruit set was observed in cluster VII (29.25) followed by cluster IV (28.63). The lowest mean number of days to first fruit set was observed in cluster VI (24.50).

4.5.2.5. Days to first harvest

The highest mean number of days to first harvest was observed in cluster IV (47.94), followed by cluster I (47. 36). The lowest mean was observed in cluster VIII (45.50).

4.5.2.6. Number of pod clusters/plant

The highest mean for number of pod clusters/plant was observed in cluster IV (46.99), followed by cluster I (45. 80). The lowest mean number of pod clusters/plant was observed in cluster III (29.25).

4.5.2.7. Number of pods/cluster

The highest mean number of pods/cluster was observed in cluster II (14.62), followed by cluster VI (12.50). The lowest mean number of pods/cluster was observed in cluster V (6.96).

4.5.2.8. Number of pods/plant

The highest mean number of pods/plant was observed in cluster VI (249.19), followed by cluster IV (222.22). The lowest mean number of pods /plant was observed in cluster VIII (101.46).

4.5.2.9. Pod length

The highest mean pod length was observed in cluster VIII (9.16), followed by cluster I (6.67). The lowest mean pod length was observed in cluster VI (6.40).

4.5.2.10. Pod girth

The highest mean pod girth was observed in cluster VIII (0.97), followed by cluster V (0.93). The lowest mean pod girth was observed in cluster III and IV (0.76).

4.5.2.11. Pod weight

The highest mean pod weight was observed in cluster VIII (1.87), followed by cluster V and VII (1.53 each). The lowest mean pod weight was observed in cluster IV (1.20).

4.5.2.12. Number of seeds/pod

The highest mean number of seeds/pod was observed in cluster VIII (8.95), followed by cluster VI (8.80). The lowest mean number of seeds/pod was observed in cluster II (7.63).

4.5.2.13. Pod yield/pant

The highest mean pod yield/plant was observed in cluster VI (323.63), followed by cluster VII (289.87). The lowest mean pod yield /plant was observed in cluster VIII (164.89).

4.5.2.14. Number of harvests

The highest mean number of harvests were observed in cluster VI (6.58), followed by cluster VII (5.72). The lowest mean numbers of harvests were observed in cluster VIII (3.38).

4.5.2.15. Total carbohydrates

The highest mean for total carbohydrates was observed in cluster III (12.08), followed by cluster VI (10.20). The lowest mean was observed in cluster II (6.28).

4.5.2.16. Crude protein

The highest mean for crude protein was observed in cluster VI (5.25), followed by cluster VII (5.03). The lowest mean was observed in cluster III (3.53).

4.5.2.17. Crude fibre

The highest mean crude fibre was observed in cluster II (7.59), followed by cluster VI (7.41). The lowest mean was observed in cluster IV (4.57).

4.5.2.18. Vitamin C

The highest mean vitamin C was observed in cluster III (6.77), followed by cluster I (6.59). The lowest mean vitamin C was observed in cluster VI (4.91).

4.5.2.19. Iron

The highest mean iron content was observed in cluster V (0.039), followed by cluster VIII (0.019). The lowest mean was observed in cluster VI (0.011).

4.5.2.20. Calcium

The highest mean calcium content was observed in cluster VII (0.852), followed by cluster V (0.783). The lowest mean calcium was observed in cluster VI (0.389).

4.5.2.21. Total phenols

The highest mean total phenols was observed in cluster VI (9.12), followed by cluster I (8.45). The lowest mean total phenol was observed in cluster VIII (6.86).

4.6. Organoleptic evaluation

Organoleptic evaluation of cluster bean accessions were done to judge the sensory qualities based on scores of 9-point hedonic scale given by a panel of judges. The data were subjected to statistical analysis. Sensory characters like appearance, colour, flavor, taste, texture, were judged based on scores and ranks and the results are presented in the Table.13.

4.6.1. Appearance

Accession CT- 22 had the highest mean score, rank for appearance (8.13), (0.07), followed by CT 20 (8.04),(0.07). The accession, CT- 23 (5.16),(1.00) had the lowest mean value for appearance.

4.6.2. Colour

Accession CT -20 had the highest mean score, rank for colour (8.24),(0.07), followed by CT -22 (8.16),(0.11) and CT- 23 (5.20),(1.00) had the lowest mean value.

4.6.3. Flavour

Accession CT -20 had the highest mean score, rank for flavor (8.17),(0.08), followed by CT- 3 (7.84),(0.13)and CT -23 (5.27),(1.00) had the lowest score and rank mean value.

Table. 13. Sensory qualities of cluster bean accessions

Genotype	Appearance	Colour	Flavor	Taste	Texture	Total score
CT-1	7.76 (0.11)	7.69 (0.21)	7.76 (0.17)	7.76 (0.15)	7.78 (0.13)	0.76
CT-2	7.84 (0.07)	7.82 (0.14)	7.71 (0.21)	7.71 (0.15)	7.24 (0.33)	0.91
CT-3	7.82 (0.07)	7.98 (0.11)	7.84 (0.13)	7.96 (0.15)	7.88 (0.13)	0.58
CT-4	6.07 (0.82)	6.42 (0.79)	6.09 (0.88)	6.31 (0.75)	6.29 (0.83)	4.06
CT-5	6.67 (0.54)	6.64 (0.64)	6.40 (0.79)	6.56 (0.70)	6.22 (0.88)	3.54
CT-6	7.80 (0.71)	7.89 (0.11)	7.60 (0.25)	7.89 (0.15)	7.89 (0.13)	0.70
CT-7	7.11 (0.36)	8.07 (0.11)	6.87 (0.58)	7.18 (0.40)	6.53 (0.71)	2.16
CT-8	6.60 (0.61)	6.42 (0.79)	6.40 (0.79)	6.64 (0.60)	7.00 (0.46)	3.99
CT-9	7.62 (0.11)	8.00 (0.11)	7.42 (0.29)	7.80 (0.15)	7.42 (0.25)	0.91
CT-10	7.96 (0.07)	7.91 (0.11)	7.73 (0.21)	7.78 (0.15)	7.64 (0.17)	0.70
CT-11	6.76 (0.46)	6.93 (0.50)	6.82 (0.63)	7.04 (0.50)	7.09 (0.42)	2.51
CT-12	7.67 (0.11)	7.98 (0.11)	7.58 (0.25)	7.82 (0.15)	7.96 (0.08)	0.70
CT-13	5.73 (0.89)	7.13 (0.43)	6.49 (0.75)	5.64 (0.90)	5.89 (0.92)	3.74
CT-14	7.16 (0.32)	6.78 (0.57)	7.04 (0.50)	6.64 (0.60)	6.51 (0.71)	2.70
CT-15	7.95 (0.07)	7.89 (0.11)	7.45 (0.29)	7.57 (0.30)	7.74 (0.17)	0.94
CT-16	6.22 (0.71)	5.96 (0.89)	5.98 (0.88)	6.20 (0.75)	6.18 (0.88)	4.11
CT-17	6.16 (0.79)	6.51 (0.71)	6.04 (0.88)	6.24 (0.75)	6.38 (0.79)	3.91
CT-18	6.35 (0.68)	6.60 (0.68)	6.29 (0.88)	6.06 (0.85)	6.56 (0.71)	3.79
CT-19	7.09 (0.39)	7.16 (0.39)	7.24 (0.46)	7.07 (0.50)	7.42 (0.25)	1.99
CT-20	8.04 (0.07)	8.24 (0.07)	8.17 (0.08)	8.24 (0.10)	8.00 (0.08)	0.41
CT-21	7.02 (0.39)	7.09 (0.46)	7.00 (0.50)	7.76 (0.40)	6.84 (0.54)	2.30

CT-22	8.13 (0.07)	8.16 (0.11)	7.00 (0.50)	7.44 (0.30)	6.60 (0.67)	1.66
CT-23	5.16 (1.00)	5.20 (1.00)	5.27 (1.00)	4.78 (1.00)	4.87 (1.00)	6.00
CT-24	6.71 (0.50)	6.29 (0.82)	6.33 (0.83)	6.29 (0.75)	6.62 (0.67)	4.39
CT-25	6.40 (0.68)	6.18 (0.86)	6.13 (0.86)	6.18 (0.75)	6.51 (0.71)	3.87
CT-26	7.18 (0.29)	7.38 (0.29)	6.29 (0.88)	7.11 (0.40)	7.76 (0.17)	2.01
CT-27	6.76 (0.46)	6.98 (0.50)	6.80 (0.67)	6.51 (0.75)	6.80 (0.58)	2.96
CT-28	5.58 (0.96)	5.91 (0.93)	5.89 (0.92)	6.69 (0.60)	6.22 (0.88)	3.32
CT-29	7.29 (0.21)	7.67 (0.21)	7.31 (0.38)	7.11 (0.40)	7.60 (0.17)	1.37
CT-30	7.31 (0.14)	7.31 (0.32)	7.04 (0.50)	7.62 (0.25)	7.42 (0.25)	1.46

(Values in parenthesis indicate the ranking for the sensory qualities)

4.6.4. Taste

Accession CT -20 had the highest mean score, rank for taste (8.24),(0.10), followed by CT- 3 (7.96),(0.15) and CT- 23 (4.78),(1.00) had the lowest mean value.

4.6.5. Texture

Accession CT -20 had the highest mean score, rank for flavor (8.00),(0.08), followed by CT- 12 (7.96),(0.08) and CT -23 (4.87),(1.00) had the lowest mean score, rank.

Total score for all the sensory qualities were calculated and accessions having lowest statistical score were considered best. They were CT- 20 (0.41), CT 3 (0.58), CT-6 (0.70), CT-10 (0.70) and CT-12(0.70) in the order of preference.

4.7. Disease and pest incidence

In the later stages of crop growth, the plants were infected with powdery mildew and sucking pests like white fly, thrips and hoppers. The percentage incidence of diseases and pests are given in the Table 7. Percentage of plants infected with powdery mildew varied from 5.0%to 30.0 %. The lowest incidence of powdery mildew was noted in the accessions CT-8(5.00%) and CT-25(5.00%), and the percentage of plants infected by sucking pests like white fly and thrips varied from 5.0%to 20.0%. It was observed that accessions CT-14(5.0%), CT-27(5.0%), and CT-30(5.0%) showed very low incidence of white fly and thrips.

Table.14.Percentage disease and pest incidence of cluster bean accessions

Genotype	Powdery mildew (%)	Sucking pest incidence (%)
CT-1	15	10
CT-2	20	10
CT-3	15	20
CT-4	25	15
CT-5	15	15
CT-6	15	15
CT-7	20	20
CT-8	5	15
CT-9	20	10
CT-10	10	10
CT-11	25	10
CT-12	20	15
CT-13	30	15
CT-14	10	5
CT-15	15	10
CT-16	25	15
CT-17	20	15
CT-18	15	20
CT-19	30	10
CT-20	10	10
CT-21	10	10
CT-22	15	15
CT-23	20	15
CT-24	15	15
CT-25	5	10
CT-26	20	15
CT-27	10	5
CT-28	15	20
CT-29	15	20
CT-30	10	5

Plate. 6. High yielding cluster bean accessions

Discussion

5. DISCUSSION

Cluster bean is an important legume crop having industrial importance because of the gum extracted from its endosperm. It is a crop suitable for warm tropical regions. It come up well even in marginal soils and areas receiving scanty rainfall. The green pods are used as vegetable and plant is used as a cattle feed.

5.1. Genetic variability

Knowledge on genetic variability and divergence present in a crop is important for designing a successful crop improvement programme. The 30 genotypes of cluster bean showed significant difference among themselves for characters such as plant height, number of branches, days to 50% flowering, days to first fruit set, days to first harvest, number of clusters/plant, number of pods/cluster, number of pods/plant, pod length, pod weight, number of seeds/pod, pod yield/plant, number of harvests, total carbohydrates, crude protein, crude fiber, vitamin C, iron, calcium and total phenols.

Plant height was significantly different in 30 genotypes of cluster bean. GCV and PCV made similar contribution to the total variability in plant height. High heritability and high genetic gain indicated that this character could be improved through selection. Similar results were reported by Vir and Singh (2015); Boghara *et al*. (2016); Patil *et al.* (2016); Santhosha *et al*. (2017) in cluster bean.

Number of branches was significantly different in the 30 genotypes of cluster bean. High GCV, heritability and genetic gain were observed for number of branches which showed that variation in the character is due to genotype alone. High heritability coupled with high genetic gain were probably due to addictive gene action. These results were in confirmation with Anandhi and Ommen (2007); Bhatkodle *et al.* (2014), Vir and Singh (2015). Patil *et al.* (2016) Santhosha *et al.* (2017).

GCV, PCV and genetic gain were low for days to 50% flowering and days to first harvest. These characters were moderately heritable. Moderate heritability coupled with low genetic gain was due to non- addictive gene effect. Patil *et al.* (2016) also reported similar results. PCV, GCV, heritability and genetic gain were very low for days to fruit set indicating that variability is very low for this character.

There were significant difference among accessions for number of pod clusters/plant, number of pods/cluster and number of pods/plant. GCV and PCV for this character were almost similar, indicating that variation was due to genotype alone; high heritability coupled with high genetic gain observed for this characters were due to addictive gene effect and these can be improved through selection. This result was in corroboration with the results obtained by Muthuselvi and Shanthi (2013); Vir and Singh (2015); Kumar *et al.* (2015); Boghara *et al.* (2016) and Patil *et al.* ((2016).

Pod length, pod girth and pod weight were significantly different in 30 accessions and GCV,PCV, heritability and genetic gain were high for these characters, indicating that the variability was due to genotypic differences and genetic improvement is possible through selection. These results are in accordance with Muthuselvi and Shanthi (2013); Patil *et al.* (2016); Boghara *et al.* (2016); Santhosha *et al.* (2017).

Number of seeds/pod recorded low GCV, PCV and genetic gain, however it exhibited a high heritability and low genetic gain for this character indicated the presence of non-addictive gene effects. This is in accordance with the earlier report by (Anandhi and Sunny, 2006).

Pod yield/plant and number of harvests exhibited high GCV, PCV, heritability, genetic gains and genetic advance specifying that the variability is mainly due to genotypic differences. High heritability coupled with high genetic gain indicated the presence of addictive gene action and the trait can be improved through selection. Bhatkodle *et al*. (2014) observed similar results for pod yield in cluster bean.

All the quality characters like total carbohydrates, crude protein, crude fibre, vitamin C, iron, calcium and total phenols had almost similar GCV and PCV. They also recorded high heritability and genetic gain revealing that environment do not have any role in influencing these characters. High heritability combined with high genetic gain showed that these characters are controlled by addictive gene effects and genetic improvement is possible through selection

5.2. Correlation studies

Crop improvement programmes can be made more effective through knowledge of the interrelationship among yield and its component characters. Hence, knowledge of correlation and causation among yield and yield components is of paramount importance. Indirect improvement of a trait is possible by improving the trait of interest, if they are positively correlated.

In this study, yield was positively correlated with number of pod clusters/plant, number of branches, number of pods/plant, days to first harvest, pod weight and number of harvests. Genotypic correlation was higher or similar to phenotypic correlation coefficient for all these characters indicating that, the environment had lesser effects. Heritability for these characters were also high hence, when selection is done for these characters, it would simultaneously improve yield. This is in confirmation with the results of Anandhi and Sunny (2006); Lakshmanan and Vahab (2011);Boghara *et al*. (2016); Muthuselvi *et al*.(2017).

The pod yield was also positively associated with quality characters such as crude fibre, iron, calcium, total carbohydrates and crude protein. Hence, selection for the high yielding accessions would result in simultaneous improvement of quality characters.

Plant height was significantly, positively correlated with number of pods/cluster and Vitamin C, it did mean that when we select accessions with more plant height, it would also result in more number of pods/cluster and Vitamin C. Similar results on plant height and number of pods/cluster were reported by Manivannan *et al.* (2015) and Muthuselvi *et al.* (2017). However similar results on Vitamin C has not been reported so far. Plant height was negatively correlated with number of branches, days to 50% flowering, days to first fruit set, number of seeds/pod and total phenols. Therefore it can be inferred that, accessions with more height will be having less number of branches, will be early in flowering, fruit set, have less number of seeds/pod and total phenols. These results were in agreement with the findings of Manivannan *et al.* (2015) and Muthuselvi *et al.* (2017) for number of branches and days to 50% flowering. However similar results on days to first fruit set, number of seeds/pod and total phenols has not been reported so far.

Number of branches were significantly and positively correlated with days to first harvest, number of pod clusters /plant, number of pods/plant, number of harvests and crude fibre (%). Therefore it can be inferred that selection of accessions with more number of branches would also result in more number of pod clusters/plant, number of pods/plant, number of harvests and more yield and delayed harvest. It was inferred that accessions with more number of branches were late in harvest however, they were high yielders. These results were in agreement with Singh *et al.* (2009); Anandhi and Sunny (2006); Lakshmanan and Vahab (2011).

In addition in the present study it was found that more number of branches were positively associated with crude fibre. Cluster bean is considered as crop of industrial importance all over India because it is a source of guar gum. However, cluster bean is consumed as a vegetable in the southern part of India and presence of crude fibre is an important attribute valued in vegetables. From the present study, it was found that when we are selecting accession with more number of branches, they would be high yielding with more crude fibre. Similar results have not been reported so far.

Days to 50% flowering was significantly and positively correlated with days to first fruit set and total phenol. It was inferred that accessions with more days to 50% flowering recorded late fruit set and harvest, such accessions contained more total phenols. However days to 50% flowering was found to be negatively correlated with pod yield. Therefore it was inferred that accessions with early 50% flowering, where high yielders with more total phenols. Pods of such accessions will be more astringent. From the results of sensory evaluation it was found that these accessions with more total phenols recorded high total score (Table.13) hence, less acceptability. So days to 50% flowering can be used as a selection index for selecting cluster bean genotypes with less total phenols.

Days to 50% flowering was found significantly and negatively correlated with number of pods/cluster. Therefore it was inferred that accessions with more days to 50% flowering had less number of pods/cluster. Similar results were reported by Manivannan *et al.*, (2015). From the present study it was also found that days to 50% flowering had significant, negative correlation with crude fibre, vitamin C and calcium, it does mean that those accession with more days to 50% flowering have less crude fibre, vitamin C and calcium. Similar results has not been reported so far.

Days to first fruit set was significantly and positively correlated with total phenols. It was inferred that accessions with more number of days to fruit set will have more total phenols. Such accessions are more astringent and less preferred for consumption (Table.13). However, days to first fruit set was negatively and significantly correlated with number of pods/cluster, crude fibre, vitamin C and calcium. It was inferred that accessions which are late to set fruit had less number of pods/cluster, crude fibre, vitamin C and calcium. Similar results have not been reported so far.

Days to first harvest was positively and significantly correlated with number of pods/cluster, number of pods/plant, number of seeds/pod, number of harvests, total carbohydrates and total phenols. Therefore it can be inferred that those accessions which are late for first harvest have more number of pods/cluster, number of pods/plant, more number of harvests, consequently higher pod yield/plant. However, days to first harvest was also significantly, negatively correlated with crude fibre, vitamin C, iron and calcium. It does mean that those accessions which are late to harvest have less crude fibre, vitamin C, iron and calcium.

Number of pod clusters/plant was significantly, positively correlated with number of pods/plant, number of harvests and pod yield/plant. It was inferred that selection of accessions with more number of pod clusters/plant would also have more number of pods /plant, number of harvests and more yield. Hence, accessions with more number of pod clusters/plant would be high yielders .Similar findings were reported by Anandhi and Sunny (2006); Lakshmanan and Vahab (2011) ; Boghara *et al*. (2016) for number of pods/cluster and number of pods/plant.

In addition, number of pod clusters/plant was found positively associated with total carbohydrates and crude fibre. It does mean that accessions with more number of pod clusters/plant are high yielders with high amount of carbohydrates and crude fibre. However, it was significantly, negatively correlated to number of pods/cluster, pod weight, crude protein and vitamin C. Therefore, it was inferred that those accessions with more number of pod clusters/plant had low pod weight, crude protein, Vitamin C and number of pods/cluster.

Number of pods/cluster was significantly and positively correlated with vitamin C and negatively correlated to total phenols. Therefore, it was inferred that when we select for number of pods/cluster, it would also result in accessions with more vitamin C and less total phenols.

Number of pods/plant was significantly and positively correlated with number of harvests. It does mean that when number of pods/plant increases the number of harvest would also increase. However, it was negatively correlated with pod length hence, those accessions with more number of pods will have shorter pods .This finding is in agreement with Boghara *et al.*(2016). Number of pods/plant was also negatively associated with pod width, pod weight, Iron, calcium and total phenols. It was inferred that those accessions with more number of pods will have thinner pods with low pod weight, iron, calcium and total phenols.

Pod length was significantly and positively correlated with pod girth. It does mean that when pod length increases it would also result in an increase in pod girth. This result is similar to the findings of Lakshmanan and Vahab (2011); Kumar *et al.* (2015). Pod length was also positively correlated with pod weight, vitamin C, iron and calcium which, indicated that when pod length increases pod weight, vitamin C, iron and calcium also increases. Hence, when selection is done for longer pods, it would also improve pod weight, pod girth, vitamin C, iron and calcium.

In addition, it was significantly, negatively correlated with number of harvests and total carbohydrates. It does mean that when pod length increases number of pods decreases and therefore, less number of harvests and total carbohydrates.

Pod girth was significantly and positively correlated with pod weight. It was inferred that accessions having thicker pods would have more pod weight. This is in confirmation with the findings of Lakshmanan and Vahab (2011).

Pod weight was significantly and positively correlated with crude fibre, iron, calcium and vitamin C. It does mean that those accessions with higher pod weight have more crude fibre, iron, calcium and vitamin C.

Number of seeds/pod was significantly and positively correlated with total carbohydrates and crude protein. It does mean that those accessions with more number of seeds/pod have high amount of total carbohydrates and crude protein.

Number of harvests was significantly and positively correlated with total carbohydrates and negatively correlated with iron, calcium and total phenols. It is inferred that those accessions which are harvested frequently would have more total carbohydrates and less iron, calcium and total phenols.

5.3. Path coefficient analysis

Correlation alone cannot give a real picture of intercharacter association, so it becomes necessary to study the path coefficient analysis, which takes into account the cause effect relationship apart from the degree of relationship. Path analysis will indicate whether, the association of the yield related traits with yield is due to their direct effect, where direct selection can be made for improvement or is a consequence of their indirect effect via some other traits in such cases a breeder has to select the trait by considering the indirect effect.

. The residual effect was very low (0.0132), indicating that most of the variability present in the genotypes was explained with the traits under study. The yield contributing characters like number of pods/plant, had highest positive direct effect on yield followed by pod weight, number of days to first harvest, plant height, number of harvests and number of branches. Anandhi and Sunny (2006) and Lakshmanan and Vahab (2011), reported similar results.

Days to 50% flowering, number of pods/cluster and pod length showed negative direct effect on yield. Anandhi and sunny (2006) and Chatale (2015), also reported a negative direct effect of days to 50% flowering on pod yield. Other traits had only negligible positive and negative direct on pod yield.

Plant height had negative correlation with pod yield/plant and have high positive direct effect on pod yield/plant and it had positive indirect effect on pod yield through days to 50% flowering and number of clusters/plant. This is in conformity with the results obtained by Rai and Dharmatti (2014), where plant height exhibited direct effect and indirect effect through number of pod clusters/plant.

Number of branches had positive correlation with pod yield/plant and it had positive direct effect on pod yield. It also had positive indirect effect on yield through number of pods/ plant, number of pods/cluster and days to first fruit set.

Days to 50% flowering had negative correlation with pod yield/plant and it had negative direct effect on pod yield. It also had a positive indirect effect on yield through plant height, days to first fruit set and number of pods/cluster. This is in line with the findings of Chatale (2015), where days to 50% flowering exhibited negative direct effect and indirect positive effect through plant height.

Days to first harvest had positive correlation with pod yield/plant and had negligible negative direct effect on pod yield. It also had high positive indirect effect on yield through days to first fruit set, number of pods/cluster and number of pods/plant. Chaitanya *et al.* (2014) also observed similar result in dolichos bean.

Pod length had negative correlation with pod yield/plant and it had negative direct effect on pod yield and positive indirect effect through pod weight. Girish *et al.* (2012) observed a negative direct effect of pod length on yield in cluster bean.

Pod girth had negative correlation with pod yield/plant and it had positive direct effect on pod yield. It also had an indirect positive effect through pod weight. Singh *et al.* (2011) and Chaitanya *et al.* (2014) in dolichos bean. Verma *et al.* (2014) in french bean observed similar results for direct and indirect effects.

Number of pod clusters/plant had positive significant correlation with pod yield/plant and negligible negative direct effect on yield. Whereas, it has positive indirect effect through number of pods/plant. This is in accordance with the results obtained by Anandhi and Sunny (2006). Number of pods/cluster also had a negative direct effect on pod yield and indirect positive effect through plant height.

Number of seeds/pod had negative correlation with pod yield/plant and it had negligible positive direct effect on yield and it have an indirect positive effect through number of pods/plant. Lakshmanan and Vahab (2018) also observed negative direct effect of number of seeds/pod on pod yield.

Based on the above discussion, the characters like number of pods/plant, days to first fruit set, pod weight, plant height and number of branches can be considered as the major characters contributing towards pod yield and direct selection of genotypes based on this traits is useful for developing high yielding varieties.

5.4. Genetic Divergence

Mahalanobis D^2 analysis is one of the potent tool used for measuring genetic divergence (Mahalanobis, 1936). In breeding programmes it help to estimate the differentiation force at inter and intra cluster level. Through this it helps the breeders to choose genetically divergent parents for developing hybrids with more heterosis.

Thirty cluster bean accessions were grouped into 8 clusters based on the D^2 values. If the distance between the clusters is larger, the divergence between the accessions is more viz. versa.

Highest mean value for yield was shown by the cluster VI. This cluster also had higher mean values for number of pods/cluster, number of pods/plant and number of harvests. Most of the high yielding accessions were the members of this cluster.

Considering the quality traits, cluster VI was having comparatively higher mean values for total carbohydrates, crude protein, crude fibre, and total phenols than other clusters, and hence, qualitatively superior to other clusters. Accessions in cluster V was rich in iron and cluster VII was rich in calcium.

The clusters which are separated by greatest statistical distance exhibit the maximum divergence. Intra cluster distance was maximum in cluster VII and minimum in cluster III, hence greater heterogeneity exist in the former and greater homogeneity latter. Inter cluster distance was maximum between cluster III and II. Inter cluster distance is minimum between cluster IV and I. In a hybridization programme parents for crossing can be selected from this two clusters to obtain superior hybrids.

Summary

6. Summary

The present study was undertaken at the Department of Vegetable Science, college of Horticulture Vellanikkara during August- September, 2017. The accessions for the experiment was collected from NBPGR, Jodhpur. Thirty accessions were used in the study and they were sown in randomized block design with two replications to evaluate cluster bean genotypes for yield and quality.

The findings of the study are summarized below

Thirty accessions of cluster bean was catalogued based on NBPGR crop descriptor. Wide variability was observed for all the characters. Two types of growth habits were observed branching and non- branching. Among the 30 accessions all were branching types except four accessions (CT-9, CT-15, CT-17, CT-27), which were non- branching types. Accession CT-8 produced white flower colour whereas, all others produced light purple colour flower. Pod colour varied from light green to dark green. None of the accessions exhibited pubescent pods. Four accession produced glabrous pods (CT-3, CT-12, CT-28, CT-29). Seed colour also showed wide variability, such as light pink colour seeds (CT-1, CT-22), light grey (CT-2, CT-18, CT-19), Dark grey (CT-27, CT-10) all others had grey colour seeds.

There was significant difference among the thirty accessions for all the characters studied The accession CT-15 recorded highest plant height (207.40cm). Highest number of branches was observed in CT-16 (19.20).

. The earliest accessions with respect to days to 50% flowering, days to first fruit set were CT-12, CT-15,CT-16,CT-17,CT-18,CT-19, CT-25,CT-27.

Number of pod clusters/plant (62.21), number of pods/plant (383.62) and pod yield/plant was highest in CT-21 (412.83g) followed by CT18, CT-16, CT-26 and CT-20, whereas, number of pods/cluster was highest in CT-17 (19.25).

The extent of genetic variability present in the germplasm was studied based on phenotypic and genotypic coefficient of variation (GCV and PCV). High GCV and PCV was observed for number of branches, number of pod clusters/plant, number of pods/cluster, number of pods/plant, pod weight, pod yield/plant, number of harvests, total carbohydrates, crude protein, crude fibre, vitamin C, iron, calcium and total phenols. This confirms the presence of broad genetic base which will be useful for further selection.

Very high estimates of heritability coupled with high genetic advance over percent mean was observed for plant height, number of branches, number of pod clusters/plant, number of pods/cluster, number of pods/plant, pod length, pod girth, pod weight, pod yield/plant, number of harvests, total carbohydrates, crude protein, crude fibre, vitamin C, iron, calcium and total phenols. This indicates that these traits may be controlled by addictive genes and these can be improved through selection.

Pod yield/plant was positively correlated with number of branches, number of pod clusters/plant, number of pods/plant, days to first harvest, pod weight, number of harvests, iron, calcium, total carbohydrates, crude fibre and vitamin C. Since, these associated traits are in desirable direction, it indicated the simultaneous selection for these traits would be useful in improving the pod yield/plant.

Path coefficient analysis of yield and component characters revealed that number of pods/plant had maximum direct positive effect on pod yield followed by days to first fruit set, pod weight, plant height, number of harvests, crude fibre, number of branches and total carbohydrates. Hence, direct selection of accessions based on these traits would be useful for improving pod yield/plant. From the study, based on the above traits CT-16, CT-18, CT-20 and CT-21 were found good.

The thiry accessions were grouped into VIII clusters by using Mahalanobis D^2 analysis. Cluster IV had maximum number of accessions. (8) followed by cluster I (7) accessions. There were three accessions in Cluster II, V and VI. Cluster III, VII and VIII had two accessions each. The intra cluster distance was maximum in cluster VII. Inter cluster distance was maximum between III and II. In a hybridization program, parents can be selected from cluster II and Cluster III for developing hybrids with more heterosis.

In the present study, sensory qualities of all the thirty accessions were evaluated, CT-20, CT-3, CT-6, CT-10 & CT-12 were found having better sensory qualities. These accessions were having less total phenol content.

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Abstract

GENETIC DIVERGENCE STUDIES IN CLUSTER BEAN

(*Cyamopsis tetragonoloba* (L) Taub.)

By

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ABSTRACT

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DEPARTMENT OF VEGETABLE SCIENCE
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Genetic divergence studies in cluster bean (*Cyamopsis tetragonoloba* (L) Taub.)

ABSTRACT

Cluster bean (*Cyamopsis tetragonoloba* (L) Taub.) is a hardy drought tolerant crop in warm tropical and subtropical regions. In southern parts of India, the pods which are rich in vitamin A, vitamin C, iron and calcium are consumed as a vegetable. The *guar* gum extracted from the seeds of cluster bean is used in paper, textiles and pharmaceutical industries.

Genetic divergence studies help to determine the degree of variability present in a germplasm and to identify suitable genotypes for crop improvement. Eventhough wide variability is present in cluster bean, limited work has been done to exploit genetic resources to identify genotypes for vegetable purpose.

In this context, the present study was undertaken with the objectives of determining the variability and correlation between yield and yield components in cluster bean. Thirty accessions of cluster bean were collected from NBPGR, Jodhpur and evaluated for different morphological and quality characters. The experiment was conducted in the Department of Vegetable Science, College of Horticulture, Vellanikkara, during August – October 2017.

Thirty accessions were catalogued based on NBPGR crop descriptor. The accessions exhibited branching and non- branching growth habits. Except four accessions, all others were branching types. The non-branching types were CT-9, CT-15, CT-17 and CT-27. All accessions were having light purple flower except CT-8 which had white flower. Pods were dark green to light green in colour, without

pubescence and glabrous. Seed colour varied from light pink and light grey to dark grey.

Significant differences were observed among thirty accessions of cluster bean for all the characters studied. Genetic parameters like GCV, PCV, heritability, genetic advance and genetic gain were estimated to study extent of variability. The effectiveness of selection depends up on the magnitude of heritability of the trait. Characters like plant height, number of branches, number of pod clusters/plant, number of pods/cluster, number of pods/plant, pod length, pod girth, pod weight and pod yield/plant exhibited high GCV, PCV and heritability, indicating that these traits can be improved through selection.

Pod yield/plant was positively correlated with number of branches, number of pod clusters/plant, number of pods/plant, days to first harvest, pod weight, number of harvests, iron, calcium, total carbohydrates, crude fibre and vitamin C. Path coefficient analysis of yield and component characters revealed that number of pods/plant had maximum direct positive effect on pod yield followed by days to first fruit set, pod weight, plant height, number of harvests, number of branches, crude fibre and total carbohydrates. Hence, direct selection of accessions based on these traits would be useful for improving pod yield/plant. The genotypes CT-16, CT-18, CT-20 and CT-21 were found promising.

In the present study, CT-20, CT-3, CT-6, CT-10 & CT-12 were found having better sensory qualities.

Mahalanobis D^2 analysis grouped the thirty accessions to VIII clusters. Cluster IV had maximum number of accessions, (8) followed by cluster I (7) accessions. There were three accessions in Cluster II, V and VI. Cluster III, VII and VIII had two accessions each. Inter cluster distance was maximum between III and II. Hence, parents can be selected from cluster II and Cluster III for production of hybrids.

Appendix-I

Mean monthly weather data from January to December 2017

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Sunshine (hours)	Rainfall (mm)
January	34.1	22.9	53	7.6	0.0
February	35.6	23.2	51	8.7	0.0
March	36.1	24.7	67	7.4	0.0
April	35.6	25.9	69	6.5	0.6
May	34.4	24.9	73	5.7	5.4
June	30.4	23.6	86	2.0	21.3
July	30.7	22.9	84	2.9	12.4
August	30.0	23.4	87	3.1	15.4
September	31.4	23.0	84	4.2	13.8
October	31.5	22.4	82	4.9	5.9
November	32.9	21.8	73	6.4	1.9
December	32.5	21.1	63	7.3	0.0