

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

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

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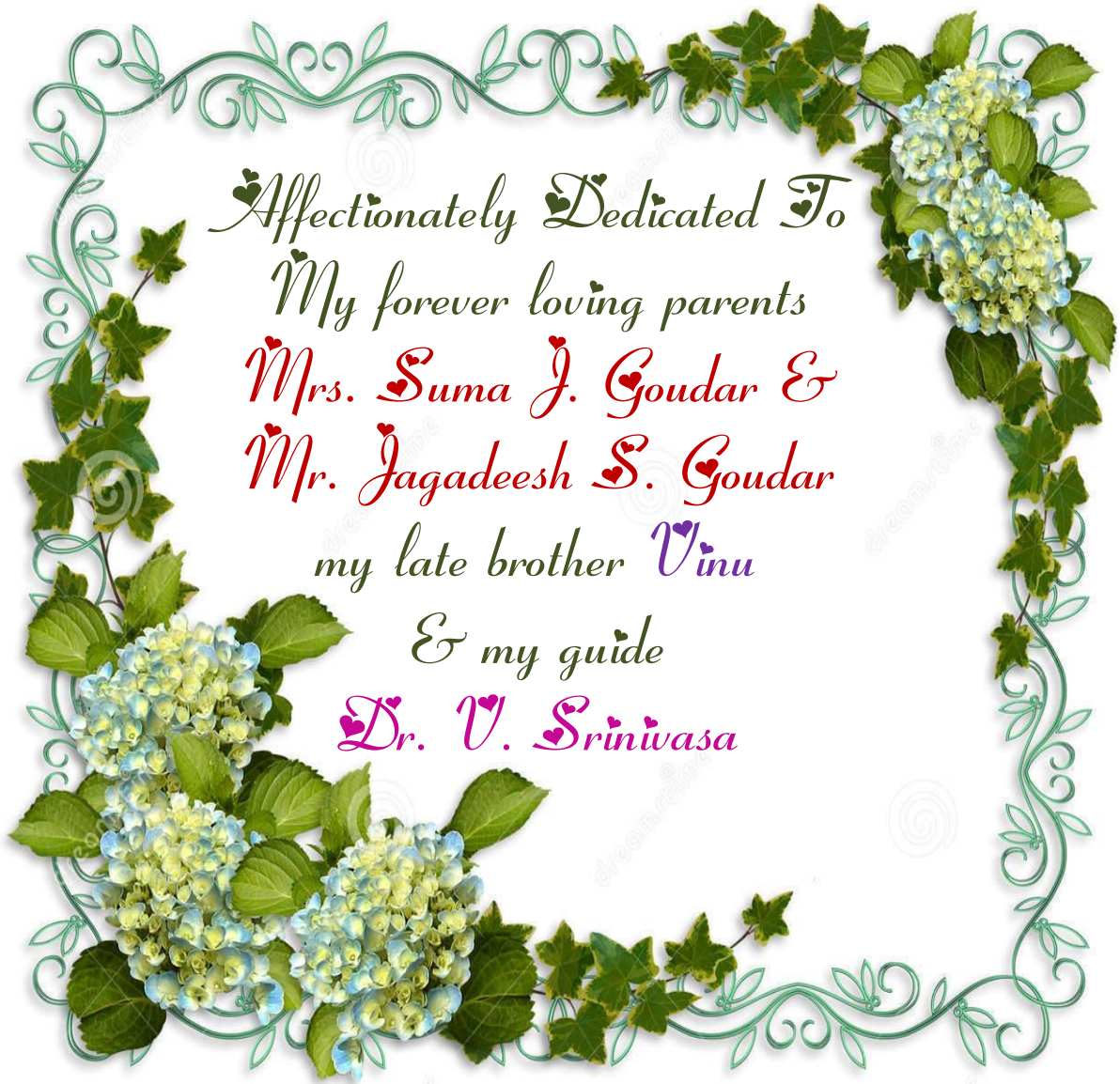
**VEGETABLE SCIENCE**

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**JUNE, 2015**



*Affectionately Dedicated To*

*My forever loving parents*

*Mrs. Suma J. Goudar &*

*Mr. Jagadeesh S. Goudar*

*my late brother Vinu*

*& my guide*


*Dr. V. Srinivasa*

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**CERTIFICATE**

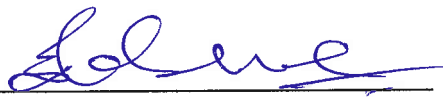
This is to certify that the thesis entitled “**GENETIC VARIABILITY STUDIES IN CLUSTER BEAN (*Cyamopsis tetragonoloba* L.)**” submitted in partial fulfilment of the requirement for the award of degree of **MASTER OF SCIENCE (Horticulture) in VEGETABLE SCIENCE** to the University of Agricultural and Horticultural Sciences, Shivamogga is a record of *bonafide* research work carried out by **Ms. REVATI GOUDAR**, ID No. **MH2TAC034** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or any other similar titles.


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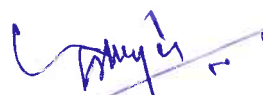
  
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 (R.J. Goudar)

**REVATI GOUDAR**


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

**REVATI GOUDAR (MH2TAC034)**

**ABSTRACT**

Cluster bean genotypes collected from different regions of Karnataka were evaluated in Randomized Complete Block Design with two replications to study the genetic variability, correlation, path analysis and genetic divergence at Department of vegetable science, College of Horticulture, Mudigere during summer season of 2014-15. Analysis of variance revealed that high significant difference among genotypes were observed for all characters taken for study. High heritability coupled with genetic advance over mean was observed for most of growth characters *viz.*, number of vegetable and dry pods per plant, number of clusters per plant and number of pods per cluster which indicated predominance of additive gene action for these traits. Correlation studies indicated positive association of pod yield per plant with pod yield per plot, number of dry pods per plant, dry pod yield per plant, seed yield per plant at both genotypic and phenotypic levels. Path analysis showed that yield per plant exhibited positive direct effect (0.934) and had strong positive association with yield per plot ( $r_G=0.999$ ) suggesting that these parameters may be considered as prime traits during selection to fetch higher yield. The genetic divergence studies using Mahalanobis  $D^2$  statistics grouped eighteen genotypes of cluster bean into three groups. The maximum intra cluster distance was observed in cluster I indicated that genotypes are having diverse genetic architecture. The intercluster distance was high between cluster I and III, this indicated wide range of variability among clusters. Dry pod yield per plant (29.41%) followed by number of dry pods per plant (24.18%) and seed yield per plant (16.99 %) contributed maximum towards genetic diversity.

**JUNE, 2015**  
**Department of Vegetable Science**  
**College of Horticulture, Mudigere**

  
**Dr. V. SRINIVASA**  
**(Major Advisor)**


ಚವಳಿಕಾಯಿಯ (ಸಯಮೋಪಸ್ ಟೇಟ್ರಾಗೋನಾಲೋಬ ಲಿ.) ವಂಶವಾಹಿ ರೂಪಗಳ  
ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನ

ರೇವತಿ ಗೌಡರ (ಎಂಎಚ್ ೨ಟಿಎಸಿ೦೩೪)

ಸಾರಾಂಶ

ಹದಿನೆಂಟು ಚವಳಿಕಾಯಿ ವಂಶವಾಹಿರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನವನ್ನು ೨೦೧೪-೧೫ರ ಬೇಸಿಗೆ ಕಾಲದ ಅವಧಿಯಲ್ಲಿ ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗ, ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ, ಮೂಡಿಗೆರೆಯಲ್ಲಿ ಎರಡು ಪ್ರತಿಕ್ಯತಿ ಜೊತೆಗೆ ಯಾಧ್ಯಚೈಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೌಲ್ಯ ಮಾಪನ ಮಾಡಲಾಯಿತು. ವ್ಯತ್ಯಾಸದ ವಿಶ್ಲೇಷಣೆಯು ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ ಅಧ್ಯಯನ ವಂಶವಾಹಿರೂಪಗಳ ನಡುವೆ ಹೆಚ್ಚು ಕಂಡು ಬಂದಿದೆ. ಅಧಿಕ ಅನುವಂಶಿಕತೆ ಜೊತೆಗೆ ಹೆಚ್ಚು ಅನುವಂಶಿಕ ಮುಂಗಡದ ಸರಾಸರಿಯು ಹಸಿ ಹಾಗೂ ಒಣ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡದ ಗೊಂಚಲುಗಲ ಸಂಖ್ಯೆ ಮತ್ತು ಪ್ರತಿ ಗೊಂಚಲಲ್ಲಿರುವ ಕಾಯಿಗಳ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಈ ಎಲ್ಲಾ ಗುಣಗಳು ಅಧಿಕ ಸಂಯೋಜನೆಯ ಅನುವಂಶಿಕ ಘಟಕದ ಪ್ರಮುಖ ಪಾತ್ರವನ್ನು ಸೂಚಿಸಿವೆ ಆದ್ದರಿಂದ ಈ ಮೇಲ್ಕಂಡ ಗುಣಗಳು ಆಯ್ಕೆಗೆ ಸೂಕ್ತವಾಗಿವೆ. ಪರಸ್ಪರ ಅಧ್ಯಯನದ ಮೂಲಕ ತಿಳಿದು ಬಂದಿರುವುದೇನೆಂದರೆ, ಗುಣಾತ್ಮಕ ಸಹಯೋಗವನ್ನು ಪ್ರತಿ ಗಿಡ ಹಾಗೂ ತಾಕಿನ ಇಳುವರಿ, ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಒಣ ಕಾಯಿಗಳ ಇಳುವರಿ ಹಾಗೂ ಪ್ರತಿ ಗಿಡದ ಬೀಜದ ಇಳುವರಿ ಈ ಗುಣಗಳನ್ನು ವಂಶನಾರ್ಥದ ಮತ್ತು ವಿಭಿನ್ನಾರ್ಥದ ಎರಡು ಮಟ್ಟದಲ್ಲಿ ಕಂಡುಕೊಳ್ಳಲಾಗಿದೆ. ಮಾರ್ಗ ಗುಣಾಂಕದ ಅಧ್ಯಯನ ಮೂಲಕ ತಿಳಿದು ಬಂದಿರುವುದೇನೆಂದರೆ, ಪ್ರತಿ ಗಿಡದ ಇಳುವರಿಯು ನೇರ ಸಕರಾತ್ಮಕ ಪರಿಣಾಮವನ್ನು ತಾಕಿನ ಇಳುವರಿ ಮೇಲೆ ಬೀರುವುದು ಕಂಡುಬಂದಿದೆ. ಮಹಾಲನೋಬಿಸ್ ಡಿ ವಿಶ್ಲೇಷಣೆಯ ಪ್ರಕಾರ ೧೮ ತಳಿಗಳನ್ನು ಒಟ್ಟು ೩ ಗುಂಪುಗಳಾಗಿ ವಿಂಗಡಣೆಗೊಂಡವು. ಪ್ರತಿ ಗಿಡದ ಕಾಯಿಗಳ ಇಳುವರಿಯ (೨೯.೪೧ ಶೇ) ಜೊತೆಗೆ ಪ್ರತಿ ಒಣ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ (೨೪.೧೮ ಶೇ) ಮತ್ತು ಬೀಜದ ಇಳುವರಿ (೧೬.೯೯ ಶೇ) ವಂಶವಾನಿಯಗಳ ನಡುವೆ ಒಟ್ಟು ಅನುವಂಶಿಕದ ವೈವಿಧ್ಯತೆಗೆ ಹೆಚ್ಚಿನ ಚದುರುಕೆಯನ್ನು ವ್ಯಕ್ತಪಡಿಸುತ್ತದೆ.

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ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗ  
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(ಮುಖ್ಯ ಸಲಹೆಗಾರರು)

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# **INTRODUCTION**

## I. INTRODUCTION

Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub] is an important under exploited leguminous vegetable crop belongs to family Fabaceae with diploid chromosome number of  $2n=14$ . It is commonly known as guar, chavli kayi, guari and khutti. India is considered as centre of origin for cluster bean. The genus *Cyamopsis* consists of three species, out of which *Cyamopsis tetragonoloba* is the only member of economic importance.

Cluster bean is a robust growing annual crop with long tap root and a well developed lateral root system. Stem is angled, leaves are trifoliolate, ovate, serrate and borne on long petioles. The white or pink coloured flowers are small in size, typically papilionaceous and are borne in axillary raceme. Androecium is monoadelphous. The pods are compressed, linear, erect, beaked and clustered with double ridge on dorsal side and single ridge below. Length of the pods is 4-10 cm in size. Seeds are 5 mm long, 5-12 numbers per pod and white to grey or black in colour (Pandey, 2008).

It is one of the most important and potential vegetable cum industrial crop grown for its tender pods and endospermic gum (30-35%). Tender pods are nutritionally rich in energy (16 Kcal), moisture (81g), protein (3.2 g), fat (1.4 g), carbohydrates (10.8 g), vitamin A (65.3 IU), vitamin C (49 mg), calcium (57 mg) and iron (4.5 mg) for every 100 g of edible portion (Kumar and Singh, 2002).

The tender pods are used as vegetable and in southern parts of India, they are dehydrated and stored for use. It serves as nutritious fodder for livestock and the seeds are also fed to cattle. Besides, the crop can be used for soil improvement. In agriculture, guar gum is used as water retainer, soil aggregate and anti-crusting agent (Singh *et al.*, 1985). In pharmaceutical industry, gum is used as insulinogenic, blood glucose, blood lipid and cholesterol lowering agent. The polysaccharide guran isolated and purified from the seed possesses a potential anti diabetic effect. Biscuits are prepared from guar is effective in decreasing the postprandial increase in blood glucose and in improving glycaemia content. The mucilaginous seed flour is valued as guar gum (galactomannan)

and this gum is used in textile, paper, cosmetic and oil industries throughout the world. In explosive industry, guar gum is used as a water remover in explosion, plasticity improver in semi- dynamite blasting and as gelling agent in water resistant explosives (Ambrozek *et al.*, 1988).

India is the leading producer of cluster bean followed by Pakistan, Sudan, USA, South Africa, Brazil, Malawi, Zaire and Australia. In India, cluster bean occupies an area of 2.20 million hectares with a production of 0.60 million tonnes. In North Indian states like Rajasthan, Haryana, Gujarat and Punjab, it is mainly cultivated for the production of the guar gum and forage whereas in South India, it is being mainly cultivated for vegetable purpose (Anon., 2009). In Karnataka, it is being grown for tender pods in an area of 3,405 hectares with annual production of 25,488 metric tonnes. The major cluster bean growing districts in Karnataka are Koppal, Belgaum, Bagalkot, Haveri and Dharwad. In Chikmagalur, it is cultivated in an area of 20 hectares with the production of 103 metric tonnes (Anon., 2012).

Considering the importance of cluster bean as vegetable and its adaptability to hill zone condition, there is a prime need for its improvement by adopting suitable breeding approaches. Development and identification of segregating suitable vegetable purpose varieties to specific agro-ecological conditions of hill zone of Karnataka is need of the hour. Hence, this calls for an evaluation of local cluster bean genotypes to know the presence of variability and divergence which is very important for crop improvement programme.

The phenotypic expression of the plant is mainly controlled by the genetic makeup of the plant and the environment under which the crop is grown. Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variations.

Improvement made in crop varieties is mainly concentrated on increasing yield and yield attributing characters. A study of correlation between different quantitative

characters provides an idea of association. It could be effectively exploited to formulate selection strategies for improving yield and quality. Correlation study does not reveal the direct and indirect contribution of individual character towards yield. In order to have clear picture of yield components for effective selection programme, it would be desirable to consider the relative magnitude of various characters contributing towards yield. The path coefficient technique developed by Wright (1921) helps in estimating the direct and indirect contribution of various components in building up the correlation towards yield. On the basis of these studies, the quantum importance of individual characters is marked to facilitate the selection programme in cluster bean.

Generally diverse genotypes is expected to give high hybrid vigour (Harington, 1940). Hence, it necessitates the study of genetic divergence among different genotypes for the identification of divergent parents for hybridization programme. The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be of most useful in proper planning of the breeding programme.  $D^2$  statistics developed by Mahalanobis (1928) provides a measure of magnitude for divergence between two genotypes under comparison. Grouping of genotypes based on  $D^2$  analysis will be useful in choosing suitable parental lines for heterosis breeding which inturn help the farmers to choose elite varieties.

Keeping these things in view and the above said facts, the present investigation on “Genetic variability studies in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub)” was undertaken with the following objectives

1. To determine the extent of genetic variability in cluster bean germplasm for growth and vegetable pod yield.
2. To assess the character association and path analysis among growth, vegetable pod yield and seed yield.
3. To study the genetic divergence among the yield and yield parameters.

# **REVIEW OF LITERATURE**

## **II. REVIEW OF LITERATURE**

Plant breeder is primarily concerned with the improvement of plant characters of both quantitative and qualitative nature. To achieve this, it is necessary to quantify the genetic variation available for various characters of economic importance and inter-relationship among them. In the present investigation, an attempt has been made to study genetic variability, heritability, divergence, character association and path coefficient analysis in cluster bean. The available literature pertaining to genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense), genetic advance (GA), Genetic advance over per cent mean (GAM), inter relationship between vegetable pod yield and its component traits, direct and indirect effects of various traits towards vegetable pod yield and diversity in cluster bean other leguminaceous vegetables are outlined under the following headings.

### **2.1 Variability, heritability and genetic advance**

Two basic requirements for any trait improvement are variation and selection. For effective selection, information on the nature and the magnitude of variation is available in the material with regard to component characters contributing to yield and the part played by the environment in the expression of these characters is essential. The magnitude of variability is measured in terms of genotypic coefficient of variation, phenotypic coefficient of variation and environmental coefficient of variation. In any selection programme emphasis on yield and its component characters lies solely on their heritability and genetic advance. The degree to which variability of a character is transmitted to progeny is of utmost importance in vegetable breeding which is called heritability. Genetic advance under selection is the improvement in the mean genotypic value of the selected families over base population, which depends upon the genetic variability existing in the population, the heritability of the character under selection and the intensity of selection. Therefore, for rational improvement of crop, understanding of the magnitude of genetic variability and the extent to which the desirable characters are heritable becomes essential.

### **2.1.1 Variability**

The determination of genetic variability and its partitioning into various components is necessary to have an insight into the genetic nature of yield and its components. Study of partitioning the total variability into heritable and environmental components had its beginning work of Johanson (1909), Nilson-Ehle (1909) and East (1916). Based on the study on non-segregating populations, Charles and Smith (1939), Powers (1942) separated genetic variance from total variance using estimate of environmental variance. Sivasubramanian and Menon (1973) classified the review of literature on genotypic coefficient of variation and phenotypic coefficient of variation as low, medium and high values for getting uniformity in comparing different values.

### **2.1.2 Heritability**

Heritability measures the relative amount of the heritable portion of variability. Sometimes heritable variation is masked by non-heritable components. Hence it is necessary to classify the total heritability using genetic parameters into broad sense heritability and narrow sense heritability. Broad sense heritability is the ratio of genotypic variance to the total variance in non-segregating population (Hanson *et al.*, 1956).

### **2.1.3 Genetic Advance**

Genetic advance is the measure of improvement that can be achieved by practicing selection in a population. It is the ultimate goal of the plant breeder of have higher genetic advance in the material selected. In cluster bean, there are several reports available indicating high genetic advance for yield and yield contributing characters. However, some of the reports were contradicting the above findings, where genetic advance was low for most of the characters.

The review of literature on different traits in cluster bean indicated existence of wide range of variability, heritability and genetic advance for the characters studied is furnished in the Table 1.

**Table 1. Review of literature on mean, variability, heritability and genetic advance in cluster bean and other related vegetable crops**

| Sl. No. | Character         | Crop         | Range         | PCV (%) | GCV (%) | $h^2$ | GA    | GAM (%)      | Reference                         |
|---------|-------------------|--------------|---------------|---------|---------|-------|-------|--------------|-----------------------------------|
| 1.      | Plant height (cm) | Cluster bean | 73.27-114.40  | -       | -       | -     | -     | -            | Sanghi <i>et al.</i> (1964)       |
|         |                   |              | 72.7 - 201.8  | -       | 24.04   | 46.04 | 30.56 | -            | Mital <i>et al.</i> (1968)        |
|         |                   |              | 73.72 -103.31 | 9.05    | 7.39    | 67.00 |       | 12.43        | Saindass <i>et al.</i> (1978)     |
|         |                   |              | -             | -       | -       | 89.10 | 41.5  | -            | Dabas <i>et al.</i> (1982)        |
|         |                   |              | 42.50 -121.50 | 22.00   | 21.50   | -     | -     | 43.29        | Hanchinamani (2003)               |
|         |                   |              | 78.07 -161.53 | 20.73   | 20.02   | 93.56 | 39.95 | -            | Anandhi and Oommen (2007)         |
|         |                   |              | 43.10-93.77   | 17.91   | 14.97   | 69.90 | 14.67 | 25.78        | Girish (2011)                     |
|         |                   |              | 32.10-100.85  | 35.60   | 35.40   | 98.90 | -     | 31.08        | Rai <i>et al.</i> (2012)          |
|         |                   |              | 51.33- 167.83 | 19.37   | 17.87   | 85.00 | 43.53 | -            | Jitender <i>et al.</i> (2014)     |
|         |                   | -            | 20.09         | 19.76   | 96.77   |       | 40.05 | Patil (2014) |                                   |
|         |                   | French bean  | 65.40 -80.40  | -       | 30.20   | 74.17 | -     | 46.75        | Sharma <i>et al.</i> (1977)       |
|         |                   |              | 33.00 -161.00 | 59.13   | 52.16   | 96.14 | -     | -            | Joshi and Mehra (1983)            |
|         |                   |              | 33.50 -52.10  | 13.58   | 10.60   | 60.90 | -     | 17.06        | Govanakoppa (2001)                |
|         |                   |              | 14.60 -69.00  | -       | 83.10   | 84.21 | -     | 63.06        | Shah <i>et al.</i> (1999)         |
|         |                   |              | 24.43- 42.44  | 17.99   | 16.02   | 79.40 | -     | 29.45        | Nimbalkar <i>et al.</i> (2002)    |
|         |                   | Cowpea       | 28. 95 -59.71 | -       | 51. 20  | 97.20 | -     | -            | Lakshmi and Goud (1977)           |
|         |                   |              | 41.80 -89.20  | -       | -       | 91.72 | 18.65 | 27.73        | Backiyarani and Nandarajan (1996) |
|         |                   |              | 47.40-137.60  | 34.72   | 34.71   | 99.95 | -     | 91.62        | Archana and Rajesh (2013)         |

| Sl. No.   | Character | Crop         | Range          | PCV (%) | GCV (%) | h <sup>2</sup> | GA                            | GAM (%) | Reference                      |
|-----------|-----------|--------------|----------------|---------|---------|----------------|-------------------------------|---------|--------------------------------|
|           |           |              | -              | 21.26   | 14.02   | 43.44          | -                             | 18.83   | Tharware <i>et al.</i> (1991)  |
|           |           |              | 44.30 - 263.86 | 35.71   | 35.28   | 97.60          | -                             | 71.81   | Kumar <i>et al.</i> (2009)     |
| 2.        | Branches  | Cluster bean | 7.05 - 12.25   | -       | 21.35   | 46.99          | -                             | 21.27   | Sanghi <i>et al.</i> (1964)    |
|           |           |              | -              | -       | 50.78   | 69.48          |                               | 32.59   | Mital <i>et al.</i> (1968)     |
|           |           |              | 0.00 to 9.45   | -       | -       | 79.00          | 15.13                         | 72.00   | Saindass <i>et al.</i> (1978)  |
|           |           |              | -              | -       | -       | 94.20          | -                             | 82.70   | Dabas <i>et al.</i> (1982)     |
|           |           |              | 0.00 - 22.10   | 59.21   | 56.08   | 89.70          | -                             | -       | Hanchinamani (2003)            |
|           |           |              | 5.60 - 12.53   | 20.29   | 19.43   | 91.65          | -                             | 38.32   | Anandhi and Oommen (2007)      |
|           |           |              | 0.00 - 15.60   | 21.26   | 18.72   | 77.60          | 4.27                          | 33.99   | Girish (2011)                  |
|           |           |              | 0.00 - 9.09    | 44.48   | 43.36   | 95.00          | -                             | 49.10   | Rai <i>et al.</i> (2012)       |
|           |           |              | 6.83 to 14.00  | 22.22   | 18.80   | 72.00          | 3.41                          | -       | Jitender <i>et al.</i> (2014)  |
|           |           |              | -              | 43.33   | 42.51   | 96.24          |                               | 85.92   | Patil (2014)                   |
|           |           | French bean  | 3.13 - 4.66    | -       | 98.67   | 39.35          | -                             | 12.89   | Shah <i>et al.</i> (1999)      |
|           |           |              | 3.04 - 4.00    | 11.15   | 5.01    | 20.20          | -                             | 4.65    | Nimbalkar <i>et al.</i> (2002) |
|           |           |              | 2.53 - 6.86    | 24.91   | 20.83   | 69.94          | 35.89                         | -       | Kumar <i>et al.</i> (2009)     |
|           |           | Cowpea       | -              | 22.03   | 10.85   | 24.25          | 11.01                         | -       | Tharware <i>et al.</i> (1991)  |
|           |           |              | 10.66 - 22.53  | 28.16   | 27.99   | 98.78          | -                             | 73.45   | Archana and Rajesh (2013)      |
| Moth bean | -         | 29.51        | 14.07          | 47.60   | 32.60   |                | Muhammad <i>et al.</i> (2007) |         |                                |
| 3.        | Leaves    | Cowpea       | -              | 23.40   | 21.2    | 82.07          | 6.55                          | 39.57   | Mary and Gopalan (2006)        |
|           |           | French bean  | -              | 19.17   | 18.19   | 90.10          | 19.22                         | 35.57   | Prakash and Ram (2014)         |
|           |           | Cowpea       | -              | 25.94   | 24.22   | 87.16          | 46.57                         | -       | Nwofia <i>et al.</i> (2012)    |

| Sl. No. | Character                    | Crop         | Range          | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                           |
|---------|------------------------------|--------------|----------------|---------|---------|----------------|-------|---------|-------------------------------------|
|         |                              | Snap bean    | -              | 23.69   | 14.56   | 85.70          | 17.42 | -       | Alem <i>et al.</i> (2013)           |
| 4.      | Plant spread (E-W) (cm)      | Cluster bean | 18.50 - 31.10  |         |         | 79.50          | 5.47  | 21.60   | Girish (2011)                       |
|         |                              |              | 27.50 - 54.00  |         |         | 93.60          | 10.5  | 33.60   | Mohamadali (2001)                   |
|         |                              |              | 6.38 - 41.00   | 127.04  | 33.65   | 26.50          | 6.15  | 27.27   | Hanchinamani (2003)                 |
|         | (N-S) (cm)                   | Cluster bean | 13.5 - 30.60   | 16.10   | 15.64   | 94.30          | 6.79  | 31.29   | Girish (2011)                       |
| 5.      | Leaf Area (cm <sup>2</sup> ) | Pea          | 60.00 - 122.00 | -       | 149.00  | -              | -     | -       | Asif <i>et al.</i> (2002)           |
|         |                              |              | -              | 13.30   | 12.84   | 93.20          | 3.30  | 25.52   | Girish <i>et al.</i> (2013)         |
|         |                              |              | 0.7 - 6.9      | 32.73   | 31.49   | 93.00          | -     | 2.98    | Jitender <i>et al.</i> (2014)       |
|         |                              |              | -              | 32.45   | 19.25   | 85.20          | 23.52 | -       | Alem <i>et al.</i> (2013)           |
| 6.      | Leaf area index              | Cluster bean | -              | 37.43   | 36.40   | 94.55          |       | 72.92   | Patil (2014)                        |
|         |                              | Cowpea       | 0.57 - 3.66    | 47.80   | 45.17   | 89.29          | -     | -       | Archana and Rajesh (2013)           |
| 7.      | Days to first flowering      | Cluster bean | 54.00 - 87.00  | -       | 6.34    | 67.41          | -     | -       | Mital <i>et al.</i> (1968)          |
|         |                              |              | -              | -       | -       | 86.80          | 13.60 | -       | Dabas <i>et al.</i> (1982)          |
|         |                              |              | 30.50 - 59.00  | 21.21   | 4.45    | 4.40           | -     | 1.91    | Hanchinamani (2003)                 |
|         |                              |              | -              | 7.72    | 6.91    | 80.13          | -     | 12.74   | Patil (2014)                        |
|         |                              |              | 30.50 - 40.00  | 8.08    | 7.47    | 85.40          | 4.98  | 14.22   | Girish (2011)                       |
|         |                              | Cowpea       | 25.0 - 66.0    | 34.50   | 32.10   | 93.02          | 26.41 | -       | Sakrajitjana and Das (1983)         |
|         |                              |              | 32.50 - 93.50  | -       | -       | 95.70          | -     | 16.28   | Sreekumar and Manikantan (1996)     |
|         |                              |              | -              | -       | -       | 84.00          | -     | 12.65   | Narayanankutty <i>et al.</i> (2003) |
|         |                              |              | 35.33 - 57.00  | 10.26   | 9.59    | 87.33          | 18.46 | -       | Kumar <i>et al.</i> (2009)          |
|         |                              | French bean  | 33.83 - 48.16  | -       | 17.42   | 95.24          | -     | 35.90   | Shah <i>et al.</i> (1986)           |

| Sl. No. | Character                      | Crop          | Range          | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                         |
|---------|--------------------------------|---------------|----------------|---------|---------|----------------|-------|---------|-----------------------------------|
|         |                                |               | 31.00 - 47.00  | -       | -       | 89.63          | -     | 14.97   | Shah <i>et al.</i> (1999)         |
|         |                                |               | 26.00 - 35.50  | 7.48    | 6.52    | 76.00          | -     | 11.71   | Govanakoppa (2001)                |
| 8.      | Fifty per cent flowering       | Cluster bean  | 29.33 - 33.00  | 4.44    | 4.13    | 86.22          | 7.88  | -       | Anandhi and Oommen (2007)         |
|         |                                |               | 29.50 - 42.50  | 8.87    | 8.67    | 95.60          | -     | 61.70   | Rai <i>et al.</i> (2012)          |
|         |                                |               | -              | 18.96   | 18.09   | 91.07          | -     | 35.57   | Patil (2014)                      |
|         |                                | French bean   | 47.00 - 83.33  | 4.36    | 4.06    | 86.44          | -     | 7.79    | Singh <i>et al.</i> (2000)        |
|         |                                |               | 28.11 - 35.00  | 6.10    | 5.92    | 94.40          | -     | 11.87   | Nimbalkar <i>et al.</i> (2002)    |
|         |                                | Moth bean     | -              | 8.53    | 6.16    | 72.2           | -     | 11.24   | Muhammad <i>et al.</i> (2007)     |
|         |                                |               | 33.33 - 100.33 | 40.09   | 40.40   | 99.73          | -     | -       | Archana and Rajesh (2013)         |
|         |                                | Dolichos bean | 68.00 - 121.67 | 16.55   | 15.29   | 85.43          | 29.18 | -       | Pan <i>et al.</i> (2001)          |
| 9.      | Number of clusters per plant   | Cluster bean  | 17.30 - 27.95  | -       | 5.03    | 4.16           | -     | 2.12    | Sanghi <i>et al.</i> (1964)       |
|         |                                |               | 5.34 - 19.04   | -       | 24.90   | 31.42          | -     | 28.78   | Saindass <i>et al.</i> (1973)     |
|         |                                |               | -              | -       | -       | 83.20          | 70.50 | -       | Dabas <i>et al.</i> (1982)        |
|         |                                |               | 9.90 - 67.25   | 51.02   | 49.89   | 95.60          | -     | 46.00   | Hanchinamani (2003)               |
|         |                                |               | 9.40 - 71.53   | 47.60   | 46.29   | 94.58          | 92.72 | -       | Anandhi and Oommen (2007)         |
|         |                                |               | 6.80 - 12.50   | 16.12   | 10.22   | 40.20          | 1.33  | 13.35   | Girish (2011)                     |
|         |                                |               | 12.80 - 49.67  | 34.85   | 32.22   | 85.50          | -     | 17.30   | Rai <i>et al.</i> (2012)          |
|         |                                |               | -              | 36.69   | 36.45   | 98.69          | -     | 74.60   | Patil (2014)                      |
| 10.     | Days to vegetable pod maturity | Cowpea        | 5.00 - 14.00   | -       | -       | 72.88          | -     | 47.38   | Backiyarani and Nandarajan (1996) |
|         |                                |               | 3.26 - 7.20    | 25.15   | 24.73   | 96.69          | -     | 64.20   | Archana and Rajesh (2013)         |
|         |                                |               | 12.80 - 49.67  | 34.85   | 32.22   | 85.50          | -     | 17.30   | Rai <i>et al.</i> (2012)          |

| Sl. No. | Character                          | Crop          | Range          | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                           |
|---------|------------------------------------|---------------|----------------|---------|---------|----------------|-------|---------|-------------------------------------|
|         |                                    | Cluster bean  | 89.00 - 117.00 | -       | 7.23    | 77.38          | -     | -       | Mital <i>et al.</i> (1968)          |
|         |                                    |               | -              | -       | -       | 81.40          | 11.80 | -       | Dabas <i>et al.</i> (1982)          |
|         |                                    |               | 21.22 - 77.50  | 22.88   | 17.47   | 58.30          | -     | 27.48   | Hanchinamani (2003)                 |
|         |                                    |               | 43.50 - 59.00  | 7.02    | 6.29    | 80.40          | 5.56  | 11.62   | Girish (2011)                       |
|         |                                    | Cowpea        | 64.00 -121.00  | -       | -       | 99.70          | -     | 44.44   | Tyagi <i>et al.</i> (2000)          |
|         |                                    |               | 60.80 - 77.33  | -       | -       | 87.50          | 12.74 | -       | Narayanankutty <i>et al.</i> (2003) |
| 11.     | Number of vegetable pods per plant | Cluster bean  | 75.50 -185.00  | 23.41   | 22.18   | 94.50          | -     | 50.86   | Rai <i>et al.</i> (2012)            |
|         |                                    |               | 36.88- 85.33   | 23.40   | 22.65   | 98.00          | -     | 27.38   | Jitender <i>et al.</i> (2014)       |
|         |                                    | Dolichos bean | 96.99 - 933.19 | 79.19   | 75.08   | 89.90          | -     | -       | Pan <i>et al.</i> (2001)            |
|         |                                    | Cowpea        | 6.60 - 14.40   | 25.13   | 24.84   | 97.70          | -     | 64.82   | Archana and Rajesh (2013)           |
| 12.     | Vegetable pod yield (g/plant)      | Cluster bean  | 2.30 - 35.20   | -       | 59.39   | 65.59          | -     | 85.37   | Mital <i>et al.</i> (1968)          |
|         |                                    |               | 21.50 - 168.50 | 57.64   | 57.42   | 99.20          | -     | -       | Hanchinamani (2003)                 |
|         |                                    |               | 117.33 -383.33 | 30.06   | 28.29   | 88.53          | -     | 54.83   | Anandhi and Oommen (2007)           |
|         |                                    |               | 34.60 - 103.20 | 27.77   | 16.92   | 37.1           | 13.53 | 21.24   | Girish (2011)                       |
|         |                                    |               | 57.74 - 222.97 | 21.12   | 29.55   | 93.90          | -     | 5.68    | Rai <i>et al.</i> (2012)            |
|         |                                    |               | 2.41 - 22.77   | 34.24   | 33.01   | 98.00          | 10.36 | -       | Jitender <i>et al.</i> (2014)       |
|         |                                    | Cowpea        | 1.00 - 18.00   | 59.80   | 56.50   | 94.53          | 8.80  | -       | Sakrajitjana and Das (1983)         |
|         |                                    |               | 87.13 - 789.75 | 58.55   | 58.34   | 99.30          | -     | -       | Narayanankutty <i>et al.</i> (2003) |
|         |                                    | Pea           | 54.33 - 91.52  | -       | -       | 76.80          | -     | 31.49   | Sharma <i>et al.</i> (1997)         |
|         |                                    | Winged bean   | 10.38 - 15.28  | -       | -       | -              | -     | -       | Philip and Ramachandran (1986)      |
|         |                                    | Dolichos bean | 880 - 395      | 44.38   | 34.05   | 58.86          | 56.11 | -       | Pan <i>et al.</i> (2001)            |

| Sl. No. | Character                    | Crop         | Range          | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                         |
|---------|------------------------------|--------------|----------------|---------|---------|----------------|-------|---------|-----------------------------------|
| 13.     | Number of dry pods per plant | Cowpea       | 12.80 - 44.33  | 27.98   | 23.88   | 72.83          | -     | 41.98   | Kumar <i>et al.</i> (2009)        |
|         |                              | Winged bean  | 5.00 - 51.75   | 44.79   | 44.28   | 97.70          | -     | 90.17   | Mohamadali and Madalageri (2007)  |
| 14.     | Dry pod yield (g/plant)      | Winged bean  | 33.75 - 265.83 | 45.99   | 41.57   | 81.70          | -     | 77.42   | Mohamadali and Madalageri (2007)  |
|         |                              | Cluster bean | 11.12 - 61.50  | 35.24   | 30.23   | 73.60          | -     | 53.44   | Hanchinamani (2003)               |
|         |                              |              | 8.65 - 23.62   | 29.04   | 16.2    | 31.1           | 2.90  | 18.08   | Girish (2011)                     |
|         |                              |              | -              | 21.55   | 21.07   | 95.59          | -     | 42.44   | Patil (2014)                      |
| 15.     | Cluster length (cm)          | Cluster bean | 2.62 - 16.40   | 43.32   | 38.49   | 79.00          | 5.77  | -       | Hanchinamani (2003)               |
| 16.     | Pod length (cm)              | Cluster bean | 4.07 - 5.15    | -       | 7.90    | 67.23          | 13.32 | -       | Sanghi <i>et al.</i> (1964)       |
|         |                              |              | 4.07 - 9.78    | -       | 23.09   | 75.14          | -     | 37.35   | Mital <i>et al.</i> (1968)        |
|         |                              |              | -              | -       | -       | 60.70          | -     | 32.90   | Dabas <i>et al.</i> (1982)        |
|         |                              |              | 4.28 - 12.50   | 33.25   | 30.39   | 83.50          | -     | 57.16   | Hanchinamani (2003)               |
|         |                              |              | 4.94 - 14.39   | 24.35   | 22.63   | 86.37          | 43.30 | -       | Anandhi and Oommen (2007)         |
|         |                              |              | 5.09 - 9.87    | 18.87   | 18.09   | 91.90          | 1.94  | 35.78   | Girish (2011)                     |
|         |                              |              | 4.44 - 10.30   | 28.04   | 27.83   | 98.50          | -     | 3.19    | Rai <i>et al.</i> (2012)          |
|         |                              |              |                | 10.29   | 7.27    | 49.99          | 10.60 | -       | Patil (2014)                      |
|         |                              | Cowpea       | 11.91 - 21.95  | -       | 16.27   | 95.40          | -     | 32.86   | Lakshmi and Goud (1977)           |
|         |                              |              | 13.50 - 27.00  | -       | -       | 85.46          | 4.99  | -       | Sakarjitjana and Das (1983)       |
|         |                              |              | 10.3 - 18.10   | 17.82   | 16.02   | 87.45          | -     | 30.12   | Backiyarani and Nandarajan (1996) |
|         |                              |              | 9.40-28.00     | 22.95   | 22.46   | 95.76          | 45.29 |         | Kumar <i>et al.</i> (2009)        |
|         |                              |              | 12.10 - 17.73  | 13.67   | 12.94   | 89.60          | -     | 25.25   | Tyagi <i>et al.</i> (2000)        |

| Sl. No. | Character               | Crop          | Range         | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                           |
|---------|-------------------------|---------------|---------------|---------|---------|----------------|-------|---------|-------------------------------------|
|         |                         |               | 13.18 - 47.48 | 30.17   | 29.74   | 97.20          | -     | 60.38   | Narayanankutty <i>et al.</i> (2003) |
|         |                         |               | 10.26 - 15.46 | 10.76   | 10.17   | 89.38          | -     | 25.39   | Archana and Rajesh (2013)           |
|         |                         | Winged bean   | 16.73 - 21.31 | -       | -       | -              | -     | -       | Philip and Ramachandran (1986)      |
|         |                         | Dolichos bean | 4.74 - 16.69  | 19.81   | 19.27   | 94.62          |       | 38.61   | Pan <i>et al.</i> (2001)            |
| 17.     | Number of seeds per pod | Cluster bean  | 4.10 - 7.70   | -       | -       | 43.06          | -     | 21.45   | Sanghi <i>et al.</i> (1964)         |
|         |                         |               | 5.88 - 10.04  | -       | 5.42    | 21.63          | -     | 2.52    | Mital <i>et al.</i> (1968)          |
|         |                         |               | 6.99 - 8.27   | -       | -       | 61.90          | -     | 1.21    | Saindass <i>et al.</i> (1973)       |
|         |                         |               | -             | -       | -       | 72.30          | 9.40  | -       | Dabas <i>et al.</i> (1982)          |
|         |                         |               | 4.00 - 9.50   | 16.41   | 9.42    | 32.90          | -     | 11.10   | Hanchinamani (2003)                 |
|         |                         |               | 7.10 - 9.97   | 7.86    | 7.48    | 90.36          | 14.63 | -       | Anandhi and Oommen (2007)           |
|         |                         |               | 4.95 - 7.95   | 12.22   | 5.01    | 16.80          | 0.26  | 4.22    | Girish (2011)                       |
|         |                         |               | 5.30 - 8.10   | 11.98   | 11.33   | 78.00          | -     | 1.58    | Rai <i>et al.</i> (2012)            |
|         |                         |               | 6.5 - 9.78    | 9.08    | 6.65    | 54.00          | -     | 85.0    | Jitender <i>et al.</i> (2014)       |
|         |                         |               | -             | 9.18    | 8.35    | 82.79          | -     | 15.66   | Patil (2014)                        |
|         |                         | Cowpea        | 7.00 - 18.00  | -       | -       | 89.32          | -     | -       | Backiyarani and Nandarajan (1996)   |
|         |                         |               | 9.00 - 15.00  | -       | -       | 54.00          | -     | 14.95   | Tyagi <i>et al.</i> (2000).         |
|         |                         |               | 11.65 - 18.90 | -       | -       | 77.50          | -     | 17.83   | Narayanankutty <i>et al.</i> (2003) |
|         |                         |               | 9.30 - 17.76  | 13.14   | 12.03   | 83.79          | 22.69 | -       | Kumar <i>et al.</i> (2009)          |
|         |                         |               | 8.80 - 13.80  | 11.28   | 10.86   | 92.63          | -     | 27.60   | Archana and Rajesh (2013)           |
|         |                         | Dolichos bean | 2.93 - 5.87   | 10.82   | 10.38   | 91.98          | 20.47 | -       | Pan <i>et al.</i> (2001)            |
|         |                         | Winged bean   | 6.59 - 15.00  | 20.56   | 18.30   | 79.30          | -     | 33.53   | Mohamadali and Madalageri (2007)    |

| Sl. No.     | Character               | Crop         | Range         | PCV (%) | GCV (%) | h <sup>2</sup> | GA                               | GAM (%) | Reference                        |                            |
|-------------|-------------------------|--------------|---------------|---------|---------|----------------|----------------------------------|---------|----------------------------------|----------------------------|
|             |                         | Mothbean     | -             | 11.18   | 5.86    | 53.60          | 13.36                            | -       | Muhammad <i>et al.</i> (2007)    |                            |
| 18.         | Seed yield (g/plant)    | Cluster bean | 7.95 - 19.92  | -       | 7.45    | 4.20           | -                                | 3.15    | Sanghi <i>et al.</i> (1964)      |                            |
|             |                         |              | 3.92 - 13.96  | 39.90   | 19.20   | 23.88          | -                                | 19.56   | Saindass <i>et al.</i> (1973)    |                            |
|             |                         |              | -             | -       | -       | 84.40          | 76.5                             | -       | -                                | Dabas <i>et al.</i> (1982) |
|             |                         |              | -             | 45.11   | 42.37   | 88.20          | -                                | 81.97   | Hanchinamani (2003)              |                            |
|             |                         |              | 5.95 - 18.10  | 32.94   | 26.31   | 63.8           | 4.57                             | 43.30   | Girish (2011)                    |                            |
|             |                         |              | -             | 27.30   | 26.96   | 97.56          | 54.86                            | -       | Patil (2014)                     |                            |
|             |                         | Cowpea       | -             | -       | -       | 99.80          | -                                | 52.88   | Tyagi <i>et al.</i> (2000)       |                            |
|             |                         |              | -             | 51.32   | 34.01   | 43.40          | 46.36                            | -       | Selvam <i>et al.</i> (2000)      |                            |
|             |                         |              | 1.98 - 8.18   | 41.48   | 39.55   | 90.9           | 77.69                            | -       | Nehru <i>et al.</i> (2009)       |                            |
|             |                         |              | 12.97 - 56.07 | 34.86   | 30.23   | 75.22          | 54.03                            | -       | Kumar <i>et al.</i> (2009)       |                            |
|             |                         |              | 9.46 - 14.66  | 11.25   | 10.08   | 80.44          | -                                | 23.88   | Archana and Rajesh (2013)        |                            |
| Winged bean | 10.80 - 147.57          | 55.72        | 54.65         | 96.20   | -       | -              | Mohamadali and Madalageri (2007) |         |                                  |                            |
| 19.         | Hundred seed weight (g) | Cluster bean | 2.37 - 3.45   | -       | 14.84   | 75.47          | -                                | 28.62   | Sanghi <i>et al.</i> (1964)      |                            |
|             |                         |              | 2.60 - 4.24   | -       | 11.28   | 51.29          | -                                | 13.11   | Mital <i>et al.</i> (1968)       |                            |
|             |                         |              | -             | -       | -       | 95.90          | -                                | 25.90   | Dabas <i>et al.</i> (1982)       |                            |
|             |                         |              | 2.47 - 4.67   | 18.83   | 4.54    | 5.80           | -                                | 11.10   | Hanchinamani (2003)              |                            |
|             |                         |              | 3.11 - 3.96   | 7.65    | 5.57    | 53.00          | 0.29                             | 8.38    | Girish (2011)                    |                            |
|             |                         |              | 0.99 - 3.35   | 20.81   | 20.68   | 98.00          | -                                | 1.25    | Jitender <i>et al.</i> (2014)    |                            |
|             |                         |              | -             | 7.31    | 6.56    | 80.64          | -                                | 12.15   | Patil (2014)                     |                            |
|             |                         | Cowpea       | 4.6 -12.6     | 24.97   | 23.48   | 93.38          | -                                | 57.29   | Backiyarani and Nadarajan (1996) |                            |

| Sl. No. | Character                  | Crop         | Range        | PCV (%) | GCV (%) | h <sup>2</sup> | GA    | GAM (%) | Reference                           |
|---------|----------------------------|--------------|--------------|---------|---------|----------------|-------|---------|-------------------------------------|
|         |                            |              | -            | -       | -       | 97.90          | -     | 32.41   | Tyagi <i>et al.</i> (2000)          |
|         |                            |              | 6.70 -14.96  | 18.83   | 18.21   | 93.50          | -     | 36.29   | Narayanankutty <i>et al.</i> (2003) |
|         |                            |              | 6.23 - 28.60 | 35.58   | 35.01   | 96.78          | -     | 70.95   | Kumar <i>et al.</i> (2009)          |
|         |                            |              | 8.33 - 15.16 | 17.34   | 17.05   | 96.71          | -     | 44.27   | Archana and Rajesh (2013)           |
|         |                            | Winged bean  | 20.75 34.50  | 13.26   | 9.97    | 56.50          | -     | 15.44   | Mohamadali and Madalageri (2007)    |
| 20.     | Chlorophyll Content (mg/g) | Cluster bean | 0.71-0.84    | 4.75    | 4.58    | 93.00          | 0.07  | -       | Jitender <i>et al.</i> (2014)       |
|         |                            | Cowpea       | 24.62 -39.93 | 12.12   | 10.12   | 69.74          | -     | 22.31   | Archana and Rajesh (2013)           |
| 21.     | Number of pods per cluster | Cluster bean | 3.88 - 6.99  | -       | -       | 25.00          | -     | 9.66    | Saindass <i>et al.</i> (1978)       |
|         |                            |              | 3.33 - 11.67 | 20.17   | 11.98   | 35.29          | -     | 14.56   | Vijay (1988)                        |
|         |                            |              | 1.82 - 10.71 | 4.97    | 4.95    | -              | -     | -       | Anila and Balakrishnan (1990)       |
|         |                            |              | 2.20 - 19.50 | 44.55   | 40.87   | 84.20          | -     | 77.22   | Hanchinamani (2003)                 |
|         |                            |              | 2.03 - 4.93  | 26.21   | 22.14   | -              | -     | -       | Dwivedi (2009)                      |
|         |                            |              | 3.13 - 5.87  | 12.97   | 11.03   | 71.90          | -     | -       | Saini <i>et al.</i> (2010)          |
|         |                            |              | 2.72 - 4.67  | 13.08   | 12.30   | 88.41          | 23.83 | -       | Singh <i>et al.</i> (2010)          |

## 2.2 Correlation and Path Analysis

Sanghi and Sharma (1964) studied sixty four indigenous varieties of cluster bean for different plant characters to find out their association with yield. There was significant positive correlation with number of pods per plant, clusters per plant, branches per plant and pod length to yield. Partial correlation of yield was significant with number of clusters per plant, pods per plant, branches per plant and 100 seed weight. Mital and Thomas (1969) reported high positive correlation between yield, branches and pod number at both genotypic as well as at phenotypic levels. Seed weight exhibited negative correlation with yield at all the levels. Amongst the yield components, plant height was positively correlated in both the seasons with all the characters except seed weight. A significant positive association was observed between height and number of branches in both the seasons at genotypic level. Correlation of pod length was negative with seed weight.

Choudhary and Lodhi (1980) reported that the characters like branches per plant, leaves per plant, leaf weight and stem weight had positive and significant correlation with green fodder and dry matter yield per plant. Path analysis revealed that, number of leaves, leaf weight and stem weight were the major component characters for both green fodder yield and dry matter yield in cluster bean. Number of clusters per plant and number of pods per plant were positively correlated with themselves and also with seed yield per plant. Path coefficient analysis revealed that number of pods per plant was the most important component character of the seed yield. However, number of branches per plant and number of clusters per plant affected seed yield indirectly *via* pods per plant (Ramnath and Saini, 1980).

Brindha *et al.* (1996) reported that the green pod yield per plant had positive and strong correlation with plant height at final harvest, braches per plant, days to flowering, days to maturity, pod length, pod breadth, pod weight, seeds per pod and pods per plant at phenotypic and genotypic levels.

Genotypic and phenotypic correlation and path coefficient were worked out in 28 diverse genotypes of cluster bean (Arumugarangarajan *et al.*, 2000). The trait clusters per

plant, branches per plant, pods per cluster, plant height and pod yield per plant were positively associated with seed yield at phenotypic levels. These traits were also found to exhibit positive and significant inter-relationship among themselves. The path analysis indicated a high magnitude of positive and direct effects of clusters per plant on seed yield. Except plant height other yield attributing traits like pod length and seeds per pod showed positive direct effect on seed yield. Patel and Choudhari (2001) reported that the genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients. Grain yield per plant was found to be positively and significantly associated with all characters except gum content and pod length. Number of seeds per pod, number of pods per plant and pod length were the most important component characters which directly contributed to seed yield.

Singh *et al.* (2002) conducted a study to determine the direct and indirect effects of various grain yield components on 43 genotypes of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.). Positive and significant correlations of grain yield were observed with the number of branches per plant, number of clusters per plant and number of pods per plant. Pods per plant had a significant and positive association with days to 50 per cent flowering, plant height, number of branches per plant and number of clusters per plant. The number of clusters per plant was positively and significantly correlated with plant height and number of branches per plant. Days to 50 per cent flowering had a positive significant association with plant height and a negative significant association with 100 seed weight. Days to 50 per cent flowering, followed by the number of clusters per plant, 100 seed weight (g) and number of pods per plant exhibited the maximum positive direct effect to seed yield but plant height had a negative direct effect on yield. The maximum indirect effects were observed in plant height through days to 50 per cent flowering. Pods per plant through days to 50 per cent flowering and the number of clusters per plant exerted good indirect effects on grain yield. The indirect effects of the number of branches per plant through the number of clusters per plant and the number of clusters per plant through the number of pods per plant were moderate, whereas 100 seed weight had negative indirect effects on grain yield *via* days to 50 per cent flowering.

Hanchinamani (2003) carried out correlation and path coefficient analysis in 80 genotypes which revealed significant and positive association of vegetable pod yield per plant and seed yield per plant with number of branches per plant, number of leaves per plant, plant spread E-W direction, number of clusters per plant, cluster length, number of seeds per pod, dry pod yield per plant and seed endosperm gum content. Path analysis studies revealed high direct effects of plant height, number of leaves per plant, number of clusters per plant and dry pod yield per plant.

Singh *et al.* (2004) conducted an experiment to study the relationship between seed yield and its components in 176 cluster bean lines. Seed yield per plant was positively and significantly correlated with plant height, branches per plant, clusters per plant and pods per plant. Plant height exhibited significant correlation with branches per plant, clusters per plant and pods per plant. Branches per plant exhibited positive correlation with clusters per plant and pods per plant. The number of clusters per plant was significantly correlated with pods per plant. Seeds per pod had negative direct effect on seed yield. Clusters per plant had appreciable positive direct effects and highly significant positive correlation with seed yield.

Singh *et al.* (2005) carried out correlation studies in twenty-four advanced cluster bean genotypes. High estimates of the phenotypic and genotypic coefficients of variation were obtained for pod yield per plant, seed yield per plant, pods per plant, clusters per plant, days to flowering and branches per plant. High heritability (broad sense) accompanied by high genetic advance was observed for seed yield, pod yield, pods per plant, clusters per plant, days to flowering, branches per plant, plant height and days to maturity. The path analysis revealed that pod yield per plant had direct positive effect on seed yield per plant followed by days to maturity, pod length, pods per plant, 100 seed weight and plant height.

One hundred genotypes of cluster bean were evaluated by Saini *et al.* (2010) and reported that the seed yield per plant was positively associated with pods per plant, clusters per plant, biological yield per plant, primary branches per plant and pods per cluster. Non significant positive association of seed yield per plant with days to

flowering, maturity and plant height were also shown desirable association in cluster bean and indicated that early and dwarf genotypes were more desirable for cluster bean. It was observed on the basis of desirable direct effects of each character on seed yield per plot obtained through path analysis that pods per plant followed by clusters per plant, test weight, biological yield per plant, seeds per pod, harvest index and branches per plant had positive direct effects and low or negative direct effects of days to maturity, days to 50 per cent flowering, reproductive period, pod length and plant height on seed yield.

Singh *et al.* (2010) evaluated 44 genotypes of cluster bean and reported that days to flowering appeared to have high correlation with days to maturity, primary branches per plant, plant height, pods per clusters, pods per plant, biological yield per plot and seeds per pod. Seed yield per plot was significantly and positively correlated with biological yield per plot, pods per plant, seeds per pod, primary branches per plant, clusters per plant, days to maturity, harvesting index and days to 50 per cent flowering. The path analysis revealed that biological yield per plot had direct positive effect on seeds per pod followed by harvesting index, pods per plant, days to 50 per cent flowering and test weight.

Correlation and path analysis were studied during 2005, 2006 and 2007 among 40 genotypes of cluster bean (Rakesh *et al.*, 2011b) found highest correlation was found with seed yield and pods per plant , seeds per pod , secondary branches per plant , plant height and primary branches per plant . Path analysis indicated the highest direct and positive effect of pods per plant , seeds per pod and 100 seed weight on seed yield. So number of pods and number of branches are important characters for improvement of seed yield in cluster bean.

Cluster bean green pod yield per plant showed positive and significant correlation with dry pod yield per plant, green pod yield per plot, number of clusters per plant, plant height both at 45 and 90 DAS, plant spread (North-South )direction at 45 DAS, stem girth, number of pods per cluster, cluster length and pod length. Dry pod yield per plant showed positive and highly significant association with green pod yield per plant (1.002 and 0.987), green pod yield per plot (0.966 and 0.847), number of clusters per plant

(0.997 and 0.800), plant spread (East-West) direction at 45 DAS (0.416 and 0.403), number of pods per cluster (0.663 and 0.800) and plant height at 45 and 90 DAS (0.843, 0.828 and 0.699, 0.546) at both genotypic and phenotypic levels, respectively. The path analysis revealed that dry pod yield per plant, green pod yield per plot and dry pod yield per plot had high direct effect on green pod yield per plant at both genotypic and phenotypic levels, respectively (Girish, 2011).

Magalingam *et al.* (2013) reported from his studies on correlation and path analysis of clusterbean, that the individual green pod weight, percentage of pod set, number of flowers per cluster and number of pods per plant exhibited significant positive correlation and direct positive effect on yield. Hence, these traits may be used as selection indices for yield improvement of dolichos bean.

Thirty genotypes of cluster bean were evaluated during rainy season and studied for correlation and that indicated positive association of vegetable pod yield with plant height, pods per cluster, pods per plant and pod yield per plant at genotypic and phenotypic levels. Genotypic path analysis shows that yield per plant exhibited positive direct effect and had strong positive association with yield per hectare. The positive indirect effects were through days to 50 per cent flowering, pods per cluster and pod breadth. Phenotypic path effects shows that yield per plant had high positive direct effect and strong degree of association for pod yield per hectare. Hence looking into the direct effect of traits plant height, pods per plant, pod length and pod breadth which can be used for improvement of cluster bean (Rai *et al.*, 2012).

Mehra and Kumar (2012) in their experiment on path analysis in French bean reported the positive direct effect of pod yield per plant and pod yield per hectare were enhanced by its positive indirect effect *via* number of pods per cluster, seed yield per plant, number of pods per plant, 100-seed weight and days to 50 per cent flowering. Hence from path coefficient analysis it revealed that pod yield per plant and numbers of pods per cluster were the most important traits affecting pod yield per hectare.

Ahmed and Kamaluddin (2013) reported that seed yield was found to be positively correlated with days to 50 per cent flowering, plant height, pod length, number of pods per plant and number of seeds per pod. Path coefficient analysis revealed that 50 per cent flowering, number of pods per plant, pod length and 100 seed weight showed positive direct effects on seed yield.

Kiran *et al.* (2014) reported that number of pods plant per plant, pod width, pod weight and pod length had positive correlation with pod yield per plant. The traits like number of branches and leaf length showed positive relation with yield at the same time, days to 50 per cent flowering and days to first picking showed negative effect on yield in dolichos bean. Path analysis revealed that selection based on number of pods plant per plant, pod weight could be effective in developing high yielding genotypes of dolichos bean.

In cowpea, seed yield was significantly correlated with number of branches, number of pods per plant, pod weight and number of seeds per pod (Mallikarjun *et al.*, 1993)

Tyagi *et al.* (2000) reported that seed yield per plant had high significant and positive correlation with days to 50 per cent flowering, plant height, pod length, number of pods per plant, seed weight per pod and hundred seed weight at both phenotypic and genotypic levels. The path coefficient analysis indicated that, higher seed weight per pod, number of pods per plant and hundred seed weight are important for selection.

Nehru *et al.* (2009) carried out correlation studies in cowpea during early and late kharif seasons, using 14 genotypes and they revealed that seed yield was correlated positively with plant height, branches per plant, clusters per plant and pods per plant during early *kharif* but during late *kharif* seed yield was correlated with only plant height at both the genotypic and phenotypic levels.

Kumari *et al.* (2010) carried out the correlation studies in cowpea and the results of genotypic correlation revealed that days to fifty per cent flowering had highly positive significant correlation with days to maturity. Plant height was highly positively

significant with branches per plant and pods per plant. The seed yield was positively and significantly correlated with days to maturity, branches per plant and pods per plant.

Vijay *et al.* (1980) studied correlation and path coefficient analysis for seed yield and its components in 17 cultivars of winged bean. Their study revealed that, seed yield per plant showed positive and significant correlation with number of dry pods per plant, hundred seed weight and days to flowering. Path analysis revealed that, the number of dry pods per plant, weight of dry pods per plant and hundred seed weight exhibited positive and direct effect on seed yield, while the pod length showed negative direct effect. Days to flowering had negative direct effect on seed yield.

Motior *et al.* (1997) reported significant and positive correlation of seed yield with pods per plant and hundred seed weight in winged bean.

Singh *et al.* (2011) reported maximum positive significant association with number of pods per plant (0.708) at both genotypic and phenotypic levels for pod yield per plant. Path analysis revealed positive association with number of pods per plant, pod length, pod width and seed length, while days to first flowering had negative direct effect on pod yield per plant.

Kousar *et al.* (2007) worked on path coefficient analysis in mung bean. Pods per plant depicted maximum direct effect on seed yield followed by test weight and protein content. Days of 50 per cent flowering, days to maturity, plant height, number of pods per cluster, number of pods plant and number of seeds per pod showed moderate to low positive effect on seed yield, except days to maturity, which showed negative direct effect on seed yield. The genotypic and phenotypic correlation among yield and yield contributing traits revealed that seed yield was positively correlated with number of pods per plant and plant height at both genotypic and phenotypic levels. Seed protein content was observed to be negatively correlated with seed yield at genotypic level.

### 2.3 Genetic Divergence

Genetic divergence arises due to geographical separation or due to genetic barriers to crossability. One of the potent techniques measuring genetic divergence is  $D^2$  statistics proposed by Mahalanobis (1928), which measures the degree of diversification and determines the relative contribution of each component character to the total divergence. Genetic diversity plays an important role in plant breeding because a greater heterosis can be expected between the divergent strains than those between closely related strains.

Mahalanobis (1928) developed  $D^2$  statistics which provides a measure of magnitude of divergence between any two individuals under study. This technique is in the form of a generalized distance, which considers the variation produced by any character and its conjoint effect that it bears on other characters. Mahalanobis also pointed out that  $D^2$  would remain constant when samples were drawn from two different populations irrespective of the size of representative sample. This indicates that  $D^2$  provided a measure of actual magnitude of divergence between two individuals under comparison.

In cluster bean, Shanmugam (1983) reported that, forty-three types selected for the investigation formed as many as fifteen clusters. Among the fifteen clusters, the cluster VII and XV showed high genetic divergence; hence the crossing between the genotypes of these two clusters may result in the development of useful progenies. Among the different characters, dry matter yield and the green fodder yield contributed maximum to the genetic divergence. Gipson and Balakrishnan (1992) assessed the genetic divergence among 56 genotypes of cluster bean using Mahalanobis  $D^2$  statistics. These genotypes were grouped in to eight clusters including two single variety clusters. Genotypes of different eco-geographical regions were found to cluster together. The characters namely number of pods per plant and number of pods per cluster contributed maximum towards genetic divergence. Among the eight clusters, the clusters III and VII showed high genetic distance.

According to Henry *et al.* (1984) genetic divergence in cluster bean for 11 characters could be grouped in to five and eight clusters in environments E<sub>1</sub> and E<sub>2</sub> respectively. Seed yield, pods per plant, clusters per plant, branches per plant, plant height, days to maturity and hundred seed weight in environment E<sub>1</sub>, while seed yield, days to maturity and hundred seed weight in environment E<sub>2</sub> were mainly responsible for contributing towards genetic divergence. Cluster I from clusters IV and V in E<sub>1</sub> and cluster II from cluster I and V in E<sub>2</sub> had high statistical distance. Hanchinamani (2003) reported genetic divergence in cluster bean for 17 characters. There were eighty genotypes which were divided into 12 clusters. The cluster IX showed maximum intra-cluster distance. The maximum inter cluster distance was observed between cluster III and I. Among the 17 characters included in D<sup>2</sup> analysis, number of leaves per plant contributed maximum to genetic diversity followed by vegetable pod yield per plant and plant height. Singh *et al.* (2003) carried out an investigation to measure the extent of genetic diversity in 60 genotypes. All the genotypes were fell in 3 clusters only. Primary branches per plant seemed to contribute maximum to the diversity both at genotypic and inter cluster levels. Rakesh *et al.* (2011a) during 2006-07 studied diversity in several genotypes and grouped them into 7 different clusters. Cluster analysis revealed that genotypes HGS 884, HGS 26–01 and HGS 02–20 will be useful for genetic resources.

Forty five genotypes of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) were assessed for genetic diversity using Mahalanobis D<sup>2</sup> technique and genotypes were grouped into eight clusters. The cluster VII with genotypes showed maximum intra cluster diversity and inter cluster distance revealed the maximum divergence between cluster VII and VIII (Girish *et al.*, 2013).

Manivannan and Anandakumar (2013) assessed forty two cluster bean genotypes for genetic divergence using Mahalanobis D<sup>2</sup> technique and all characters investigated and grouped into 15 different clusters. The maximum intra cluster distance was observed in cluster XIV. The maximum inter-cluster distance was recorded between cluster VI and cluster XV. The per cent contribution towards genetic diversity was highest from 100 seed weight and seed yield per plant

Thirty one genotypes of cluster bean were investigated for genetic divergence using Mahalanobis  $D^2$  technique by Shabarish Rai and Dharmatti (2013). The maximum intra cluster distance was observed in cluster I and intercluster distance was high between cluster II and cluster III. The per cent contribution towards genetic diversity was high for pod yield per hectare followed by pod length and plant height.

In cowpea, Thaware *et al.* (1997) assessed genetic divergence in 30 genotypes of forage cowpea using  $D^2$  statistics for seven developmental characters. Genotypes were grouped in to seven clusters. Two characters, viz., branches per plant and leaf number per plant were the highest contributors to  $D^2$  values. Thirty-seven genotypes were grouped into 11 clusters using Mahalanobis  $D^2$  statistics. In general, the inter-cluster distance was higher than intra cluster distances. The maximum inter-cluster distance was observed between clusters VIII and X followed by clusters VI and X and clusters VIII and IX, respectively. The intra-cluster distance was maximum in cluster VII in cowpea (Narayanankutty *et al.*, 2003).

Natarajan *et al.* (1988) evaluated 45 diverse genotypes for eight characters. On the basis of  $D^2$  analysis, the 45 genotypes were grouped into five clusters with seed weight and days to flowering contributing maximum to divergence in mung bean. Thirty mung bean genotypes were evaluated by Manivannan *et al.* (1998) for eight yield components. Genotypes were grouped into eight clusters based on their genetic diversity. Plant height contributed the most towards divergence followed by pod length, number of pods, seeds per pod and clusters per plant.

Forty genotypes of mung grown in four environments (2 season  $\times$  2 spacing's) were analysed for standardized distances for mean grain yield per plot so as to make selection for heterosis for yield (Singh, 1988). All genotypes were included in nine clusters. Genotypes included in a cluster were similar in response to environmental changes. In mung bean, 34 genotypes were grouped into five clusters. Cluster I and II had eight genotypes each, while cluster III had six genotypes. Similarly, clusters IV and V had five and seven genotypes, respectively. Variability observed in the parents was related to the genetic diversity of the parents selected under the study. Intra-cluster

distance varied from 9.32 to 46.93. The highest inter-cluster distance was observed between III and IV followed by I and V and IV and V (Tawar *et al.*, 1988).

Nandi *et al.* (2000) studied twenty eight hyacinth bean genotypes from different states which fell into five clusters based on  $D^2$  values and concluded that differences in cluster means existed for almost all eight characters studied. Cluster I had low mean values for days to first flowering (63.91), Cluster-II had both highest pods per plant as well as high 100 seed weight. Higher mean pod girth was associated with cluster IV. Cluster V had maximum mean pod length, pod weight, seeds per pod and total green pod yield per plant.

Basavarajappa and Gowda (2000) assessed the 144 field bean germplasm lines collected from Southern Karnataka. The phenotypic characters *viz.*, seed yield, pods per plant, inflorescence per plant, branches per plant and days to 50 per cent flowering contributed substantially to the genetic divergence.

# **MATERIAL AND METHODS**

### **III. MATERIAL AND METHODS**

The present investigation on “Genetic variability studies in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub)” was undertaken under the Hill Zone of Karnataka during 2014-2015 at Department of Vegetable Science, College of Horticulture, Mudigere, Chikmagalur District, Karnataka. The details of the experiment with respect to material used and techniques adopted during the investigation are presented in this chapter.

#### **3.1 Geographical location of the experimental site**

Mudigere is situated in Hill Zone of Karnataka state at 13° 25' Northern latitude, 75° 45' East longitude with an altitude of 976 meter above mean sea level.

#### **3.2 Climatic conditions**

Mudigere comes under Zone-9 region of agro-climatic zones of Karnataka, is benefited by both South-West and North-East monsoons. The mean rainfall of this area is about 2500 mm, which is distributed over a period of six to seven months (June to December) with a peak during June and July.

The meteorological data during the experimental period was recorded at the meteorological observatory of the Zonal Agricultural and Horticulture Research Station, Mudigere and same is presented in Appendix I.

#### **3.3 Soil characteristics**

The experiment was conducted in sandy loam soil. Soil samples were collected from each replication and the composite samples were analysed for physical and chemical composition of the soil. The soil composition is presented in Appendix II.

### **3.4 Experimental details**

#### **3.4.1 Design and layout of the experiment:**

The experiment was conducted by adopting Randomized Complete Block Design (RCBD) with two replications. The plan and layout of the experiment is depicted in Figure 1.

#### **The details of the experiment are as follows:**

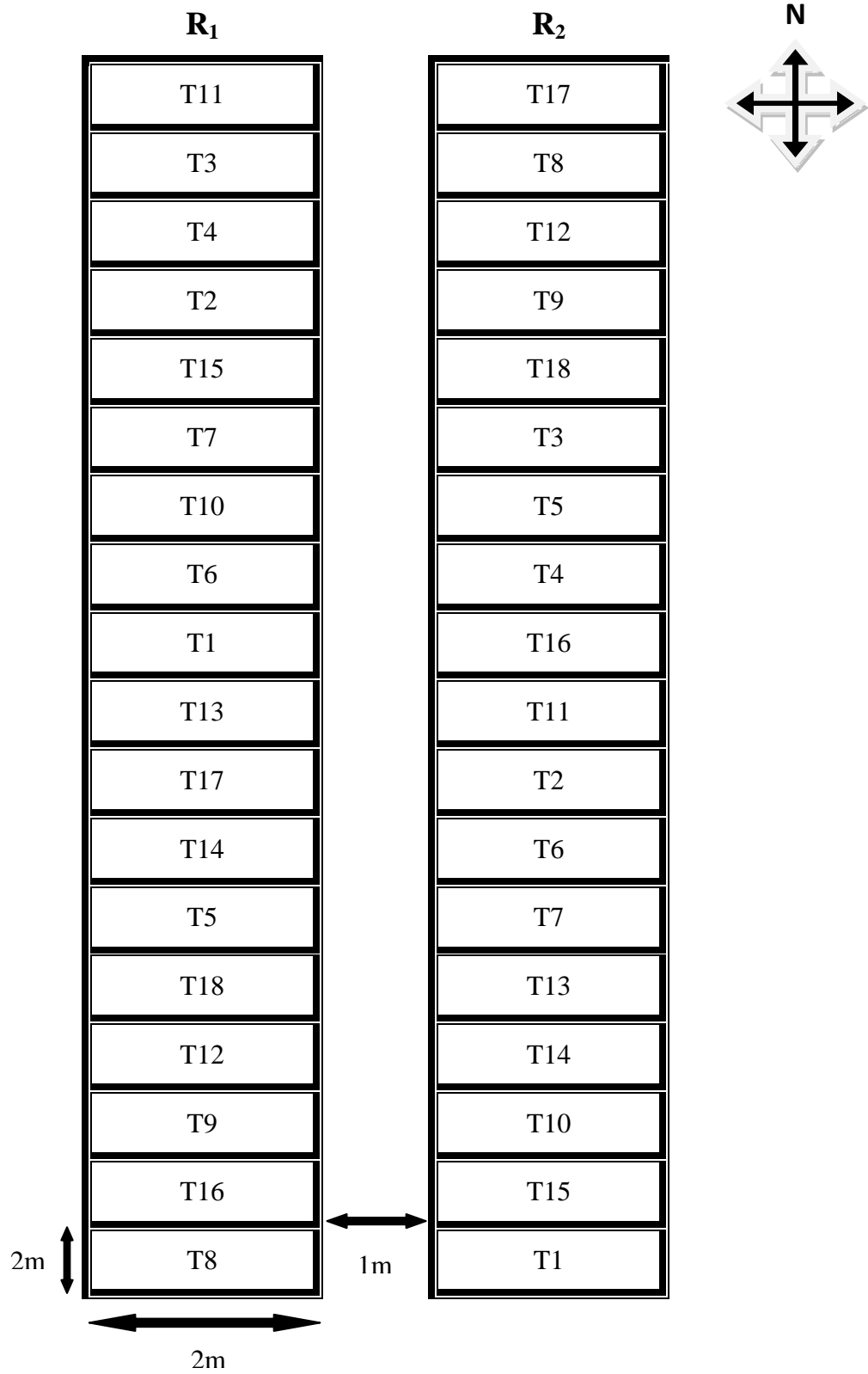
|                           |   |                |
|---------------------------|---|----------------|
| Number of treatments      | : | 18 (genotypes) |
| Experimental design       | : | RCBD           |
| Replications              | : | 2              |
| Spacing                   | : | 45 cm × 20 cm  |
| Size of plot              | : | 2 m × 2 m      |
| Number of plants per plot | : | 20             |

#### **3.4.2 Experimental material**

The experimental material comprising eighteen genotypes which were collected from different regions of Karnataka. The list of genotypes with their sources of collection is furnished in Table 2.

#### **3.4.3 Preparation of experimental plot and sowing**

The experimental area was ploughed repeatedly and brought to a fine tilth. The Farm yard manure was incorporated in to the soil before final harrowing and recommended basal dose of fertilizers (25: 75: 60 kg NPK /ha) were applied before sowing. The plots of requisite dimension were prepared as per the plan. A gap of 1m between two replications was provided for laying out the irrigation channels and working space. Seeds collected from various sources were used for sowing. The ridges and furrows were opened at 45 cm and seeds were sown by dibbling two to three seeds per hill on the side of ridge at 20 cm distance. The sowing was done on February 21, 2014 during summer season and the plots were irrigated immediately after sowing. Thinning of excess seedlings and gap filling was done one week after sowing and remaining top dressing with 50 per cent nitrogen fertilizer was applied at 35 days after sowing.



**Fig. 1. Plan and layout of the experimental plot**

**Table 2. List of cluster bean genotypes used in the experiment with their source of collection**

| <b>Sl. No.</b> | <b>Genotypes</b> | <b>Source of Collection</b> |
|----------------|------------------|-----------------------------|
| 1              | AVT-II GR-3      | K.R.C.C.H, Arabhavi         |
| 2              | HG-3-100         | K.R.C.C.H, Arabhavi         |
| 3              | AVT-II GR-I      | K.R.C.C.H, Arabhavi         |
| 4              | CAZ-G-06         | K.R.C.C.H, Arabhavi         |
| 5              | HG-04-875        | K.R.C.C.H, Arabhavi         |
| 6              | AVT-II GR-2      | K.R.C.C.H, Arabhavi         |
| 7              | RGC -986         | K.R.C.C.H, Arabhavi         |
| 8              | Gokak Local      | K.R.C.C.H, Arabhavi         |
| 9              | AVT-I GR-9       | K.R.C.C.H, Arabhavi         |
| 10             | AVT-II GR-6      | K.R.C.C.H, Arabhavi         |
| 11             | AVT-I GR-14      | COH, Bagalkot               |
| 12             | AVT- I GR-24     | COH, Bagalkot               |
| 13             | IVT-I GR-23      | COH, Bagalkot               |
| 14             | IVT-I GR-21      | COH, Bagalkot               |
| 15             | AVT-I GR-13      | COH, Bagalkot               |
| 16             | IVT-I GR-20      | COH, Bagalkot               |
| 17             | AVT-I GR-15      | COH, Bagalkot               |
| 18             | Pusa Navbahar    | K.R.C.C.H, Arabhavi         |

K.R.C.C.H – Kittur Rani Chennama College of Horticulture.

COH – College of Horticulture.

### **3.5 After care**

#### **3.5.1 Weeding and irrigation**

The plots were kept weed-free by hand weeding at 30 and 60 DAS. Irrigation was given at an interval of five to seven days during the experimental period.

#### **3.5.2 Plant protection**

Bacterial blight disease was noticed during growth stage and it was controlled by spraying carbendazium @ 0.5 per cent.

#### **3.5.3 Harvesting**

The crop harvested at its right stage of maturity, *i.e.*, when pods turn to dark green colour, development maximum size and before they attain fiber content for vegetable purpose and for seed purpose, it should be harvested when the pods turn to brown colour, these harvested pods are dried, threshed and seeds are extracted.

### **3.6 Observations recorded**

Ten plants in each experimental plot was randomly selected avoiding border plants, of which, five plants were considered for vegetable purpose and remaining five plants for seed purpose. The selected five plants were tagged for taking observations on various growth and yield parameters by picking tender green pods at weekly intervals for vegetable purpose. Another five plants were left for recording seed yield parameters. The seed weight, number and other parameters were recorded after harvesting the fully matured pods.

#### **3.6.1 Growth parameters**

The observations for all growth characters were recorded by using five randomly selected tagged plants in each plot and the average of the five plants were computed. Growth parameters *viz.*, plant height, number of branches, number of leaves per plant and plant spread were recorded at 30 and 60 days interval and final observation on these parameters were recorded at harvest.

### **3.6.1.1 Plant height**

The height of the plant was measured from ground level to the tip of the plant and expressed in centimeters.

### **3.6.1.2 Number of branches**

Number of branches arising from the main stem was counted and the mean values were expressed in numbers.

### **3.6.1.3 Number of leaves per plant**

Number of leaves arising from plant was counted and expressed in numbers.

### **3.6.1.4 Plant spread**

It was measured by recording the plant spread from North-South and East - West direction in tagged plants. Average was worked out and expressed in centimeters.

### **3.6.1.5 Leaf area**

Healthy and matured leaves were selected and leaf area was measured by using leaf area meter and expressed in square centimeter.

### **3.6.1.6 Leaf area index**

Leaf area index was recorded at 60 (maturity stage) days. It was calculated as suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area covered per plant (cm}^2\text{)}}$$

## **3.6.2 Yield parameters**

### **3.6.2.1 Days taken for first flowering**

The days were counted from the date of sowing to appearance of the first flower in each experimental plot and recorded as number of days taken for first flowering.

### **3.6.2.2 Days taken for fifty per cent flowering**

The days were counted from the date of sowing to fifty per cent of plant flowering in each experimental plot and recorded as number of days for fifty per cent flowering.

### **3.6.2.3 Number of clusters per plant**

The number of the clusters produced by the tagged plants in each experimental plot was counted and recorded and average was computed.

### **3.6.2.4 Number of pods per cluster**

The number of the pods per cluster produced by the tagged plants in each experimental plot was counted and recorded and average was computed.

### **3.6.2.5 Days taken for first vegetable pod harvest**

The days were counted from the date of sowing to date of first vegetable pod picking.

### **3.6.2.6 Number of pods per plant**

Number of pods produced on each tagged plants were counted and the mean values were expressed in number.

### **3.6.2.7 Pod yield per plant**

The weight of green vegetable pods harvested from the tagged plants was recorded separately. The sum of all harvests was considered as pod yield and expressed in grams.

### **3.6.2.8 Number of dry pods per plant**

The dry pod numbers per plant was computed by counting the number of the pods harvested from the tagged plants in each experimental plot after maturity and the average number of dry pods per plant was worked out and recorded.

### **3.6.2.9 Dry pod yield per plant**

The dry pod yield was computed by adding the weight of dry pods per plant from the tagged plants in each experimental plot after maturity and average weight of dry pods per plant was worked out and recorded. It was expressed in grams.

### **3.6.2.10 Pod length**

The length of each selected pod was measured from the base to tip and average of 10 pods was computed and expressed in centimeters.

### **3.6.2.11 Number of seeds per pod**

Ten dry pods from each experimental plot were randomly picked and seeds were counted and average number of seeds per pod was worked out.

### **3.6.2.12 Seed yield per plant**

The seeds from all the dry pods harvested from five plants tagged for seed purpose were extracted and weighed. The average value of five plants was worked out and it was expressed in grams.

### **3.6.2.13 Pod yield per plot**

The vegetable pod yield per plot was computed by summing up all the harvested pods of each treatment and expressed in kilograms.

### **3.6.2.14 Pod yield per hectare :**

Total vegetable pod yield was expressed in per hectare basis from the harvestable pod yield using the following formula and expressed in quintals.

$$\text{Yield per hectare (q)} = \frac{\text{Yield per plot (kg)} \times 10,000 \text{ (m}^2\text{)}}{\text{Net area of the plot (m}^2\text{)}} \times 100$$

### 3.6.2.15 Hundred seed weight

One hundred seeds from each experimental plot were counted and their weight was recorded. It was expressed in grams.

### 3.6.3 Biochemical parameter

#### 3.6.3.1 Chlorophyll content

Chlorophyll content of leaf was analyzed by collecting the healthy fully matured second leaf from the center of the plant at peak vegetative stage. Total chlorophyll content of leaf tissue was determined by using Dimethyl sulfoxide (DMSO) as suggested by Sadasivam and Manickam (2005).

#### Chlorophyll estimation procedure

Fresh and fully matured leaves from the plant were brought to laboratory in polyethylene bag from the research field and were cut into pieces. Known weight of sample (100 mg) was incubated in 7.0 ml of Dimethyl sulfoxide at 65<sup>0</sup> C for 120 minutes. After the incubation, supernatant was collected by decanting and leaf tissue was discarded. Then the volume of the supernatant was made up to 10 ml using DMSO.

The absorbance of the extract was measured at 645 nm and 663 nm by using Dimethyl sulfoxide as blank in spectrophotometer.

The total chlorophyll content was calculated by using formulae given below

$$\text{Total chlorophyll} = \{20.2 (A_{663}) + 8.02(A_{645})\} \frac{V}{1000 \times W \times a}$$

Where,

A = Absorbance at specific wave length (645 nm and 663 nm)

V = Volume of the extract (10 ml)

W = Fresh weight of the sample (100 mg)

a = Path length of light in cuvette (1 cm)

### 3.7 Biometrical parameters

The data collected on the quantitative characters were subjected for statistical analysis and following different statistical parameters were worked out.

#### 3.7.1 Analysis of variance (ANOVA)

Analysis of variance was done separately for each character for all treatments.

The model of analysis of variance was given below.

| Source      | D.F        | SS  | MSS            | Cal. F    |
|-------------|------------|-----|----------------|-----------|
| Replication | r-1        | RSS | RSS/(r-1)      | TMSS/EMSS |
| Treatments  | t-1        | TSS | TSS/(t-1)      |           |
| Error       | (r-1)(t-1) | ESS | ESS/(r-1)(t-1) |           |
| Total       | (rt-1)     | TSS |                |           |

Where,

t = Number of treatments (genotypes)

r = Number of replications

SS= Sums of square, MSS = Mean Sum of Squares , DF = Degrees of Freedom

The standard error was calculated as,  $SEm = \sqrt{EMSS/r}$

The significance of treatments mean squares and replication mean squares were tested by comparing with error mean squares referring to 'F' table values at 5 and 1 per cent level of probabilities.

#### 3.7.2 Estimation of genetic variability parameters

##### 3.7.2.1 Genotypic, phenotypic and environmental variance

The variance due to genotype, phenotype and environment were computed as follows.

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MS due to genotypes (adj)} - \text{MS due to error (intra block)}}{r \text{ (replication)}}$$

Environmental variance ( $\sigma_e^2$ ) = Error mean sum of squares

Phenotypic variance ( $\sigma_p^2$ ) =  $\sigma_g^2 + \sigma_e^2$  (MS due to error)

Where, 'r' is number of replications.

### 3.7.2.2 Genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficients of variation were estimated according to Burton and Devane (1953) based on estimate of genotypic and phenotypic variance.

#### Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sigma_g}{\bar{X}} \times 100$$

#### Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sigma_p}{\bar{X}} \times 100$$

Where,

$\bar{X}$  = General mean

r = Number of replications

$\sigma_g$  = Genotypic standard deviation

$\sigma_p$  = Phenotypic standard deviation

GCV and PCV were classified as suggested by Burton and Devane (1953)

0-10% : Low

10-20% : Moderate

20% and above : High

### 3.7.2.3 Heritability ( $h^2$ )

The broad sense heritability ( $h^2$ ) was estimated by following the procedure suggested by Weber and Moorthy (1952) as indicated here below.

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,  $h^2$  (%) = Heritability (Broad sense)

$\sigma^2_g$  = Genotypic variance

$\sigma^2_p$  = Phenotypic variance

Heritability was categorised (Robinson *et al.*, 1949) as mentioned below

0 - 30% = Low

30 - 60% = Moderate

60% and above = High

#### **3.7.2.4 Expected genetic advance**

Genetic advance for each character was predicted by the formula given by Johnson *et al.* (1955).

$$GA = h^2 \times \sigma_p \times k$$

Where  $k$  = Selection differential (2.06) at 5 per cent selection intensity

$h^2$  = Heritability in broad sense

$\sigma_p$  = Phenotypic standard deviation.

#### **3.7.2.5 Genetic advance as per cent of mean (GAM)**

Genetic advance as percentage over mean was worked out as suggested by Johnson *et al.* (1955).

$$\text{Genetic advance over mean (GAM)} = \frac{GA}{\bar{X}} \times 100$$

Where,  $GA$  = Genetic advance

$\bar{X}$  = General mean

The genetic advance as per cent of mean was categorized as suggested by Johnson *et al.* (1955) and the same is given below.

0-10% : Low

11-20% : Moderate

21% and above : High

### 3.7.2.6 Correlation analysis

The correlation co-efficient among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated by employing formula (Al-Jibouri *et al.*, 1958).

$$\text{Phenotypic correlation} = r_{xy} (p) = \frac{\text{Cov}_{xy} (p)}{\sqrt{V_x (p) \times V_y (p)}}$$

$$\text{Genotypic correlation} = r_{xy} (g) = \frac{\text{Cov}_{xy} (g)}{\sqrt{V_x (g) \times V_y (g)}}$$

Where,

- $\text{Cov}_{xy} (G)$  = Genotypic covariance between x and y
- $\text{Cov}_{xy} (P)$  = Phenotypic covariance between x and y
- $V_x (G)$  = Genotypic variance of character 'x'
- $V_x (P)$  = Phenotypic variance of character 'x'
- $V_y (G)$  = Genotypic variance of character 'y'
- $V_y (P)$  = Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table 'r' values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

### 3.7.2.7 Path co-efficient analysis

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$$\begin{aligned} r_{1y} &= a + r_{12}b + r_{13}c + \dots + r_{1i}i \\ r_{2y} &= a + r_{21}a + b + r_{23}c + \dots + r_{2i}i \\ r_{3y} &= r_{31}a + r_{32}b + c + \dots + r_{3i}i \\ r_{1y} &= r_{11}a + r_{12}b + r_{13}c + \dots + I \end{aligned}$$

Where,

$r_{1y}$  to  $r_{Iy}$  = Co-efficient of correlation between causal factors 1 to I with dependent characters y.

$r_{12}$  to  $r_{II}$  = Co-efficient of correlation among causal factors

a, b, c,.....i = Direct effects of characters 'a' to 'I' on the dependent character 'y'

Residual effect (R) was computed as follows.

$$\text{Residual effect (R)} = 1 - \sqrt{a^2 + b^2 + c^2 + \dots + i^2 + 2abr_{12} + 2acr_{13} + \dots}$$

### 3.7.2.8 Genetic divergence

Mahalanobis (1928)  $D^2$  statistic was used for assessing the genetic divergence between different populations. The  $D^2$  analysis was carried out using the data recorded on germplasms. Mahalanobis generalized distance ( $D^2$ ) between any two populations is given by the formula

$$D^2 = \sum \lambda^{ij} \sigma^i \sigma^j$$

Where,  $D^2$  = Square of generalized distance

$\lambda^{ij}$  = Reciprocal of the common dispersal index

$\sigma^i = \mu_{i1} - \mu_{i2}$

$\sigma^j = \mu_{j1} - \mu_{j2}$

$\mu$  = General mean

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

### Clustering $D^2$ values

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

### **Intra and inter-cluster distance**

The intra and inter-cluster distances were calculated by following the formula described by Singh and Chaudhary (1977).

$$\text{Genetic advance over mean (GAM)} = \frac{\sum D_i^2}{N}$$

Where,

$\sum D_i^2$  = Sum of distances between all possible combinations of the entries included in the cluster

N = Number of all possible combinations

$$\text{Square of inter-cluster distance} = \frac{\sum D_{ij}^2}{n_i n_j}$$

Where,

$\sum D_{ij}^2$  = Sum of distances between all possible combinations ( $n_i n_j$ ) of the entries included in the cluster

$n_i$  = Number of entries in the cluster i

$n_j$  = Number of entries in the cluster j.

# **EXPERIMENTAL RESULTS**

## **IV. EXPERIMENTAL RESULTS**

The present investigation was conducted to assess the nature and extent of “Genetic variability in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub)” at College of Horticulture, Mudigere. The results of the experiment are presented in this chapter.

### **4.1 Analysis of Variance**

Analysis of variance showed significant differences among the genotypes for all the characters studied both at five and one per cent level of significance. The mean sums of squares of genotypes for all different characters are presented in Table 3, 4 and 5.

### **4.2 Genetic Component of Variation:**

#### **4.2.1 Variability, Heritability and Genetic Advance of cluster bean genotypes**

With a view to understand the extent to which the observed variations are due to genetic factors, the range, mean, phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability ( $h^2$ ), genetic advance (GA) and genetic advance as per cent of mean (GAM) were worked out. The data revealed that wide range of variability, heritability and genetic advance for characters studied is furnished here under.

##### **4.2.1.1 Variability of growth parameters of cluster bean genotypes**

Data on variability, heritability, genetic advance of genotypes for growth parameters of cluster bean are presented in Table 6. The *per se* performance of genotypes for all these parameters are presented in Appendices III, IV and V.

###### **4.2.1.1.1 Plant height**

At 30 DAS, plant height ranged between 4.39 cm (IVT- I GR-21) to 15.35 cm (RGC-986) with a grand mean of 10.24 cm. The GV and PV were 9.24 and 9.50, respectively. The estimates of GCV, PCV and heritability were high (29.68%, 33.15%, and 80.20%, respectively) along with high genetic advance as per cent of mean (54.75%), whereas at 60 DAS, the plant height ranged between 30.00 cm (AVT-II GR-I) to 45.30

**Table 3. Analysis of variance (mean sum of squares) for growth parameters in cluster bean**

| Sl. No. | Source of variation /characters | Replication | Treatments (Genotypes) | Error     | S. Em ± | C.D (5%) |
|---------|---------------------------------|-------------|------------------------|-----------|---------|----------|
|         | <b>Degree of freedom</b>        | <b>1</b>    | <b>17</b>              | <b>17</b> |         |          |
| 1       | Plant height (cm) at 30 DAS     | 5.085       | 20.785**               | 2.289     | 1.06    | 3.19     |
| 2       | Plant height (cm) 60 DAS        | 0.809       | 54.191**               | 16.846    | 2.90    | 8.65     |
| 3       | Plant height (cm) at 90 DAS     | 220.671     | 339.637**              | 30.421    | 3.90    | 11.63    |
| 4       | Number of branches at 60 DAS    | 0.0277      | 4.789**                | 0.7166    | 0.59    | 1.78     |
| 5       | Number of branches at 90 DAS    | 0.302       | 26.911**               | 2.450     | 1.10    | 3.30     |
| 6       | Plant spread N-S (cm) at 30 DAS | 18.806      | 7.152*                 | 2.328     | 1.07    | 3.21     |
| 7       | Plant spread N-S (cm) at 60 DAS | 24.944      | 105.582**              | 25.415    | 3.56    | 10.63    |
| 8       | Plant spread N-S (cm) at 90 DAS | 136.305     | 662.913**              | 150.953   | 8.68    | 25.92    |
| 9       | Plant spread E-W (cm) at 30 DAS | 2.200       | 8.856**                | 1.371     | 0.82    | 2.47     |
| 10      | Plant spread E-W (cm) at 60 DAS | 47.840      | 47.608**               | 9.392     | 2.16    | 6.46     |
| 11      | Plant spread E-W (cm) at 90 DAS | 99.666      | 514.055**              | 89.882    | 6.70    | 20.00    |
| 12      | Number of leaves at 30 DAS      | 11.787      | 23.688*                | 3.976     | 1.41    | 4.20     |
| 13      | Number of leaves at 60 DAS      | 298.425     | 309.62**               | 94.18     | 6.86    | 20.47    |
| 14      | Number of leaves at 90 DAS      | 550.68      | 337.54*                | 111.91    | 7.48    | 22.31    |
| 15      | Leaf area (cm <sup>2</sup> )    | 1.130       | 16.570*                | 6.318     | 1.77    | 5.30     |
| 16      | Leaf area index                 | 0.0266      | 0.605**                | 0.093     | 0.21    | 0.64     |
| 17      | Chlorophyll content (mg/g)      | 0.804       | 2.319**                | 0.267     | 0.36    | 1.09     |

\* & \*\* indicates significant at 5% and 1% level, respectively; DAS- Days After Sowing

**Table 4. Analysis of variance (mean sum of squares) for vegetable pod yield parameters in cluster bean**

| Sl. No. | Source of variation/characters             | Replication | Treatments (Genotypes) | Error     | S.Em ± | C.D (5%) |
|---------|--------------------------------------------|-------------|------------------------|-----------|--------|----------|
|         | <b>Degree of freedom</b>                   | <b>1</b>    | <b>17</b>              | <b>17</b> |        |          |
| 1       | Days to first flowering                    | 1.934       | 3.393**                | 0.353     | 0.42   | 1.25     |
| 2       | Days to 50 per cent flowering              | 0.187       | 3.254**                | 0.8594    | 0.54   | 1.62     |
| 3       | Days taken for first vegetable pod harvest | 10.454      | 4.064*                 | 1.510     | 0.86   | 2.59     |
| 4       | Number of clusters per plant               | 6.760       | 27.902**               | 2.077     | 1.01   | 3.04     |
| 5       | Number of pods per cluster                 | 0.013       | 5.772**                | 0.903     | 0.67   | 2.00     |
| 6       | Number of vegetable pods per plant         | 50.955      | 2025.605**             | 71.560    | 5.98   | 17.84    |
| 7       | Cluster length (cm)                        | 0.160       | 1.334*                 | 0.487     | 0.49   | 1.47     |
| 8       | Pod length (cm)                            | 0.656       | 0.803*                 | 0.280     | 0.37   | 1.11     |
| 9       | Pod yield per plant (g)                    | 294.69      | 1306.36**              | 88.51     | 6.65   | 19.85    |
| 10      | Pod yield per plot (kg)                    | 0.11        | 0.52**                 | 0.03      | 0.12   | 0.39     |
| 11      | Pod yield per ha (q)                       | 73.67       | 326.59**               | 22.12     | 3.22   | 9.92     |

\* & \*\* indicates significant at 5% and 1% level, respectively

**Table 5. Analysis of variance (mean sum of squares) for seed parameters in cluster bean**

| Sl. No. | Source of variation/characters   | Replication | Treatments (Genotypes) | Error     | S.Em $\pm$ | C.D (5%) |
|---------|----------------------------------|-------------|------------------------|-----------|------------|----------|
|         | <b>Degree of freedom</b>         | <b>1</b>    | <b>17</b>              | <b>17</b> |            |          |
| 1       | Number of dry pods per plant (g) | 275.33      | 2382.756**             | 150.511   | 8.67       | 25.88    |
| 2       | Dry pod yield per plant (g)      | 137.866     | 802.393**              | 201.325   | 10.03      | 29.93    |
| 3       | Number of seeds per pod.         | 0.180       | 0.835**                | 0.228     | 0.33       | 1.00     |
| 4       | Seed yield per plant (g)         | 12.017      | 123.807**              | 36.590    | 4.27       | 12.76    |
| 5       | 100 seed weight (g)              | 0.069       | 0.066**                | 0.016     | 0.09       | 0.27     |

\* & \*\* indicates significant at 5% and 1% level, respectively.

**Table 6. Estimates of mean, range, components of variance, heritability and genetic advance for different growth parameters in cluster bean**

| Sl. No. | Characters                             | Mean±S.Em   | Range        | GV     | PV     | GCV (%) | PCV (%) | h <sup>2</sup> (%) | GA    | GAM (%) |
|---------|----------------------------------------|-------------|--------------|--------|--------|---------|---------|--------------------|-------|---------|
| 1       | Plant height (cm)at 30 DAS             | 10.24± 1.07 | 4.39-15.35   | 9.24   | 9.50   | 29.68   | 33.15   | 80.20              | 5.60  | 54.75   |
| 2       | Plant height (cm) 60 DAS               | 36.31±2.90  | 30.0-45.3    | 19.02  | 35.86  | 12.01   | 16.49   | 53.00              | 65.40 | 18.01   |
| 3       | Plant height (cm) at 90 DAS            | 67.30±3.9   | 47.50-90.00  | 155.26 | 185.02 | 18.47   | 20.20   | 83.60              | 23.40 | 34.78   |
| 4       | Number of branches per plant at 60 DAS | 4.25±0.50   | 0.00-7.50    | 2.03   | 2.75   | 33.53   | 38.90   | 74.00              | 2.50  | 76.13   |
| 5       | Number of branches per plant at 90 DAS | 7.70±1.0    | 0.00-15.00   | 12.23  | 14.68  | 45.36   | 49.70   | 83.33              | 23.40 | 34.78   |
| 6       | Plant spread N-S (cm) at 30 DAS        | 7.77±1.07   | 4.89-10.97   | 19.96  | 27.99  | 2.41    | 4.74    | 50.90              | 2.28  | 29.34   |
| 7       | Plant spread N-S (cm) at 60 DAS        | 27.27±3.5   | 15.85-43.8   | 40.08  | 65.49  | 23.21   | 29.67   | 61.20              | 10.20 | 37.40   |
| 8       | Plant spread N-S (cm) at 90 DAS        | 60.96±8.6   | 28.65-94.70  | 255.98 | 406.93 | 26.24   | 33.09   | 62.9               | 26.14 | 42.87   |
| 9       | Plant spread E-W (cm) at 30 DAS        | 7.46±0.8    | 4.90- 12.20  | 3.74   | 5.11   | 25.91   | 30.29   | 73.20              | 3.40  | 45.66   |
| 10      | Plant spread E-W (cm) at 60 DAS        | 25.56±2.17  | 14.75-35.37  | 19.10  | 28.50  | 17.10   | 20.88   | 67.00              | 7.37  | 28.84   |
| 11      | Plant spread E-W (cm) at 90 DAS        | 58.83±6.7   | 32.60-100.70 | 212.08 | 301.96 | 24.75   | 29.53   | 70.20              | 25.14 | 42.73   |
| 12      | Number of leaves at 30 DAS             | 9.77±1.4    | 5.10-18.20   | 9.85   | 13.83  | 32.12   | 38.05   | 71.30              | 5.45  | 55.86   |
| 13      | Number of leaves at 60 DAS             | 57.10±6.8   | 31.12-69.50  | 107.71 | 201.90 | 18.17   | 24.88   | 53.40              | 15.61 | 27.34   |
| 14      | Number of leaves at 90 DAS             | 68.02±7.4   | 41.00-84.50  | 112.82 | 224.73 | 15.61   | 22.03   | 50.20              | 15.50 | 22.79   |
| 15      | Leaf area (cm <sup>2</sup> )           | 36.97±1.7   | 33.48-43.37  | 5.12   | 11.44  | 6.12    | 9.15    | 44.80              | 3.12  | 8.44    |
| 16      | Leaf area index                        | 1.79±0.22   | 0.82-2.77    | 0.25   | 0.34   | 28.22   | 32.96   | 73.30              | 0.89  | 49.79   |
| 17      | Chlorophyll content(mg/g)              | 3.12±0.37   | 1.24-4.44    | 1.02   | 1.29   | 32.41   | 36.39   | 79.30              | 1.86  | 59.47   |

GV – Genotypic Variance    GCV – Genotypic Coefficient of Variation  
 PV- Phenotypic Variance    PCV - Phenotypic Coefficient of Variation

h<sup>2</sup>- Heritability in broad sense  
 GA – Genetic Advance

GAM- Genetic Advance as per cent Mean  
 Days After Sowing

cm (IVT-I GR-21) with grand mean of 36.31 cm. The GV and PV were 19.02 and 35.86, respectively. The moderate estimates of GCV and PCV (12.01% and 16.49%, respectively), moderate heritability (53%) coupled with moderate genetic advance as per cent of mean (18.01%) was observed for this trait.

The plant height ranged between 47.50 cm (AVT-I GR-13) to 90.0 cm (Pusa Navbahar) with mean values of 67.30 cm. The genotypic and phenotypic variances were 155.26 and 185.02, respectively. Moderate estimates of GCV (18.47%) and PCV (20.20%) and high heritability (83.60%) coupled with high genetic advance as per cent of mean (34.78%) was observed at 90 DAS.

#### **4.2.1.1.2 Number of branches per plant**

The number of branches per plant ranged from 0.00 (Pusa Navbahar) to 7.5 (Gokak Local) with a mean of 4.25. The GV and PV were (2.03 and 2.75, respectively). The estimates of GCV (33.53%) and PCV (38.90%) were high. High heritability (74.00%) together with high GAM (76.13%) was observed at 60 DAS. While in 90 DAS, the number of branches per plant ranged from 0.00 (Pusa Navbahar) to 15.00 (Gokak Local) with a mean of 7.70. The GV and PV were (12.23% and 14.68%, respectively). The estimates of GCV, PCV, heritability and GAM were high *i.e.* 45.36%, 49.70%, 83.33% and 34.78%, respectively (Plate 1).

#### **4.2.1.1.3 Plant spread**

Plant spread (North - South) which ranged from 4.89 cm (IVT- I GR-20) to 10.97 cm (RGC-986) at 30 DAS, 15.85 cm (IVT-I GR-23) to 43.8 cm (AVT-II GR-2) at 60 DAS and 28.65 cm (AVT-II GR-3) to 94.70 cm (HG-04-875) at 90 DAS. The mean values at 30, 60 and 90 DAS were 7.77 cm, 27.27 cm and 60.96 cm, respectively. Phenotypic coefficient of variation (4.74%) and genotypic coefficient of variation (2.41%) were low at 30 DAS. Whereas, at 60 and 90 DAS recorded high PCV (29.67% and 33.09%, respectively), GCV (23.21% and 26.24%, respectively) and heritability (61.20% and 62.90%, respectively) coupled with high GAM (37.40% and 42.87%,



**Plate 1. Variability in plant spread and branching in cluster bean genotypes**

respectively). However, it showed moderate heritability (50.90%) with high GAM (29.34%) at 30 DAS (Plate 1).

Plant spread ( East - West ) ranged from 4.90 cm (AVT-I GR-15) to 12.20 cm (AVT-II GR-2) at 30 DAS, 14.75 cm in genotype IVT-I GR-23 and 35.37 cm in genotype AVT-I GR-14 at 60 DAS and it ranged from 32.60 cm (AVT-II GR-3) to 100.70 cm (HG-04-875) at 90 DAS. The estimates of PV (5.11, 28.50 and 301.96, respectively) were higher than GV (3.74, 19.10 and 212.08, respectively) at all three intervals. PCV and GCV were high (30.29 % and 25.91% at 30 DAS), (29.53% and 24.75% at 90 DAS) and high to moderate GCV and PCV at 60 DAS (20.88% and 17.10%, respectively). Higher heritability (73.20%, 67.00% and 70.20%, respectively) coupled with high genetic advance over mean (45.66%, 28.84% and 42.73%, respectively) were found at 30, 60 and 90 DAS.

#### **4.2.1.1.4 Number of leaves per plant**

The number of leaves per plant were ranged from 5.10 (IVT-I GR-21) to 18.20 (AVT-II GR-I) with average leaves of 9.77. The PV and GV were moderate (13.83 and 9.85, respectively). The GCV (32.12%), PCV (38.05%), heritability (71.30%) and genetic advance as per cent of mean (55.86%) were high at 30 DAS.

The number of leaves at 60 DAS ranged between 31.12 (IVT- I GR-21) to 69.50 (AVT-II GR-2) with average mean of 57.10. The PV and GV were (201.90 and 107.71, respectively). The GCV and heritability were moderate (18.17 and 53.40%, respectively), PCV (24.88%) and GAM (27.34%) showed high values for this trait.

At 90 DAS, the number of leaves per plant ranged from 41.00 in the genotype AVT – I GR-15 to 84.50 in the genotype IVT-I GR-23 with an average mean of 68.02. Moderate GCV (15.61%), high PCV (22.03%), moderate heritability (50.20%) and high genetic advance as per cent of mean (22.79%) was noticed for this trait. The PV and GV were 224.73 and 112.82, respectively.

#### **4.2.1.1.5 Leaf area**

Leaf area was estimated which ranged between 33.48 cm<sup>2</sup> (AVT-II GR-01) to 43.37 cm<sup>2</sup> (AVT-I GR-15) with average mean of 36.97 cm<sup>2</sup>. The GCV (6.12%) and PCV (9.15%) were low. Moderate heritability (44.80%) with low genetic advance as per cent of mean (8.44%) was observed for this trait. The phenotypic variance and genotypic variance were 11.44 and 5.12, respectively.

#### **4.2.1.1.6 Leaf area index**

Leaf area index was calculated which ranged between 0.82 (IVT-I GR-21) to 2.77 (IVT-I GR-23) with average mean of 1.79. The PV and GV were (0.34 and 0.25, respectively). Wide variation with GCV (28.22%), PCV (32.96%) coupled with high heritability (73.30%) and high genetic advance as per cent of mean (49.79%) was observed for this trait.

#### **4.2.1.1.7 Chlorophyll content**

Total chlorophyll content was calculated which ranged from 1.24 mg/g (IVT-I GR-20) to 4.44 mg/g (AVT-II GR-2) with average mean of 3.12 mg/g. The PV (1.29) was higher than GV (1.02). The GCV (32.41%) and PCV (36.39%) were high along with high heritability (79.30%) and genetic advance as per cent of mean (59.47%).

#### **4.2.1.2 Variability in vegetable pod yield and yield parameters**

Data on variability, heritability, genetic advance of genotypes for vegetable pod yield and yield parameters are presented in Table 7.

The genotypes *viz.*, AVT-II GR-3, AVT-II GR-2 and Pusa Navbahar took least number of days (31.40) to first flowering while IVT-I GR-21 and AVT-I GR-13 took maximum number of days (35.20) with an average of 33.16 days for appearance of first flower. The PV and GV were (1.87 and 1.52, respectively). The estimate of PCV (4.12%) was higher than GCV (3.71%). High heritability (81.10%) coupled with low genetic advance as per cent of mean (6.89 %) was observed for the trait (Plate 2).

**Table 7. Estimates of mean, range, components of variance, heritability and genetic advance for vegetable pod yield parameters in cluster bean**

| Sl. No. | Characters                                 | Mean $\pm$ S.Em  | Range       | GV     | PV      | GCV (%) | PCV (%) | h <sup>2</sup> (%) | GA    | GAM (%) |
|---------|--------------------------------------------|------------------|-------------|--------|---------|---------|---------|--------------------|-------|---------|
| 1       | Days to first flowering                    | 33.16 $\pm$ 0.4  | 31.4-35.2   | 1.52   | 1.87    | 3.71    | 4.12    | 81.10              | 2.28  | 6.89    |
| 2       | Days to fifty per cent flowering           | 33.95 $\pm$ 0.5  | 31.9-35.8   | 1.33   | 1.92    | 3.39    | 4.08    | 69.10              | 1.97  | 5.81    |
| 3       | Days taken for first vegetable pod harvest | 43.60 $\pm$ 0.86 | 40.70-46.50 | 1.27   | 2.78    | 2.59    | 3.82    | 45.80              | 1.57  | 3.61    |
| 4       | Number of clusters per plant               | 10.07 $\pm$ 1.01 | 3.70-17.0   | 12.91  | 14.99   | 35.65   | 38.41   | 86.10              | 6.87  | 68.17   |
| 5       | Number of pods per cluster                 | 5.96 $\pm$ 0.6   | 3.30-8.50   | 2.43   | 3.33    | 26.16   | 30.63   | 72.90              | 2.74  | 46.03   |
| 6       | Number of vegetable pods per plant         | 71.51 $\pm$ 5.9  | 17.80-112.7 | 977.02 | 1048.58 | 43.70   | 45.27   | 93.20              | 62.15 | 86.90   |
| 7       | Cluster length (cm)                        | 6.95 $\pm$ 0.4   | 6.10-8.95   | 0.42   | 0.91    | 9.36    | 13.73   | 46.50              | 0.91  | 13.16   |
| 8       | Pod length (cm)                            | 5.15 $\pm$ 0.3   | 3.75-6.50   | 0.26   | 0.54    | 9.96    | 14.27   | 48.20              | 0.73  | 14.16   |
| 9       | Pod yield per plant (g)                    | 73.03 $\pm$ 6.65 | 26.00-110.5 | 608.92 | 697.44  | 33.66   | 36.03   | 87.30              | 47.49 | 64.79   |
| 10      | Pod yield per plot (kg)                    | 1.41 $\pm$ 6.65  | 0.47-2.19   | 0.23   | 0.27    | 34.55   | 36.88   | 87.80              | 0.94  | 66.67   |
| 11      | Pod yield per ha (q)                       | 36.34 $\pm$ 3.33 | 11.87-54.75 | 149.09 | 169.90  | 34.55   | 36.88   | 87.80              | 23.56 | 66.67   |

GV – Genotypic Variance  
PV- Phenotypic Variance

GCV – Genotypic Coefficient of Variation  
PCV - Phenotypic Coefficient of Variation

h<sup>2</sup>- Heritability in broad sense  
GA – Genetic Advance

GAM- Genetic Advance as per cent Mean



**Plate 2. Promising genotypes for earliness**

The genotype Pusa Navbahar showed early flowering and took 31.90 days for fifty per cent flowering while IVT-I GR-21 took maximum number of days (35.80) with an average of 33.95 days for appearance of fifty per cent flowering. The estimates of PCV (4.08%) were higher than GCV (3.39%). Higher heritability (69.10%) with low genetic advance as per cent of mean (5.81%) was noticed in this trait. The PV and GV were 1.92 and 1.33, respectively.

The genotype AVT-II GR-9 took least number of days taken for first harvest (40.70) while AVT-I GR-13 took maximum number of days (46.50) for attaining vegetable pod maturity. On an average, genotypes took 43.60 days for first harvest. The PV and GV were (2.78 and 1.27, respectively). The estimates of PCV and GCV were low (3.82% and 2.59%, respectively). Moderate heritability (45.80%) in broader sense with low genetic advance as per cent of mean (3.61%) was observed for this trait.

Wide range of variability was observed for number of clusters per plant which ranged between 3.70 (IVT-I GR-20) to 17.00 (HG-04-872) with average value of 10.07. Moderate PV and GV (14.99 and 12.91, respectively), high GCV (35.65 %) and PCV (38.41%) with high heritability (86.10%) and high genetic advance as per cent of mean (68.17%) was observed for this trait.

Maximum number of pods per cluster was recorded in IVT-I GR-20 (3.30) and minimum in AVT-II GR-2 and Gokak Local (8.50) with an average number of pods (5.96) per cluster. The estimates of GCV (26.16%), PCV (30.63%), heritability (72.90%) and genetic advance as per cent of mean (46.03%) were observed high for this trait. The PV and GV were 3.33 and 2.43, respectively.

Number of vegetable pods per plant ranged from 17.80 (IVT-I GR-20) to 112.70 (HG-04-875) with a mean value of 71.51. The PV and GV were (1048.58 and 977.02, respectively). The high GCV (43.70%), PCV (45.27%) and heritability (93.20%) coupled with high genetic advance as per cent of mean (86.90%) was noticed for this trait.

The cluster length ranged from 6.10 cm (AVT-I GR-13 and HG-04-875) to 8.95 cm (IVT-I GR-23) with a grand mean of 6.95 cm. The PV (0.91) was greater than GV

(0.42). The estimate of PCV (13.73%) was also higher than GCV (9.36%). However, moderate heritability (46.50%) and moderate genetic advance as per cent of mean (13.16%) was observed in this trait.

Length of pod varied from 3.75 cm (IVT-I GR-21) to 6.50 cm (Pusa Navbahar) with an average length of 5.15 cm. The GCV (9.96%) was low and PCV (14.27%) was moderate. Moderate heritability (48.20%) with moderate genetic advance as per cent of mean (14.16%) was observed for this trait. The PV and GV were 0.54 and 0.26, respectively (Plate 3).

Pod yield per plant ranged between 26.00 g (IVT-I GR-20) to 110.5 g (Gokak Local) with average mean of 73.03 g. The estimates PCV (36.03%) and GCV (33.66%) were high along with high genetic advance as per cent of mean (64.79%) and high heritability (87.30%) was observed in this character. The PV and GV were 697.44 and 608.92, respectively

Pod yield per plot which ranged from lesser in IVT GR-20 (0.47 kg) to higher in Gokak Local (2.19 kg). The average weight of pods per plot was 1.41 kg. High values of GCV (33.55%) and PCV (36.88%) coupled with high heritability (87.80%) and high genetic advance as per cent of mean (66.67%) was observed for this character. The PV and GV were 0.27 and 0.23, respectively (Plate 4).

Pod yield per hectare ranged from 11.87 q to 54.75q ((IVT GR-20 and Gokak Local, respectively) with an average yield of 36.34 q. The GCV (34.55%), PCV (36.88%) and heritability (87.80%) were high coupled with GAM (66.67). The PV and GV were 169.90 and 149.09, respectively.

#### **4.2.1.3 Variability in seed yield and yield parameters**

Data on variability, heritability, genetic advance of genotypes for seed yield and yield parameters are presented in Table 8.

Number of dry pods per plant with range between 19.50 (AVT-I GR-13) to 148.90 (Gokak Local) with a mean value of 64.88. The PV and GV were (1266.62 and

**Table 8. Estimates of mean, range, components of variance, heritability and genetic advance for seed yield parameters in cluster bean**

| Sl. No. | Characters                       | Mean $\pm$ S.Em  | Range        | GV      | PV      | GCV (%) | PCV (%) | $h^2$ (%) | GA    | GAM (%) |
|---------|----------------------------------|------------------|--------------|---------|---------|---------|---------|-----------|-------|---------|
| 1       | Number of dry pods per plant (g) | 64.88 $\pm$ 8.6  | 19.50-148.90 | 1116.12 | 1266.62 | 51.49   | 54.85   | 88.10     | 64.6  | 99.57   |
| 2       | Dry pod yield per plant (g)      | 59.64 $\pm$ 10.0 | 23.00-101.15 | 300.53  | 501.85  | 29.06   | 37.55   | 59.90     | 27.63 | 46.3    |
| 3       | Number of seeds per pod.         | 7.67 $\pm$ 0.3   | 6.65-9.00    | 0.30    | 0.53    | 7.177   | 9.50    | 57.0      | 0.85  | 11.16   |
| 4       | Seed yield per plant (g)         | 33.46 $\pm$ 4.2  | 17.00-45.00  | 43.6    | 80.19   | 19.73   | 26.75   | 54.40     | 10.03 | 29.97   |
| 5       | 100 seed weight (g)              | 3.46 $\pm$ 0.09  | 3.17-3.87    | 0.02    | 0.04    | 4.54    | 5.89    | 59.50     | 0.25  | 7.22    |

GV – Genotypic Variance  
PV- Phenotypic Variance

GCV – Genotypic Coefficient of Variation  
PCV - Phenotypic Coefficient of Variation

$h^2$ - Heritability in broad sense  
GA – Genetic Advance

GAM- Genetic Advance as per cent Mean



**Plate 3. Variability for pod character's in cluster bean genotypes**



**Plate 4. Promising genotypes for vegetable pod yield**

1116.12, respectively). Higher variability *i.e.* GCV (51.49%) and PCV (54.85%) was coupled with high heritability (88.10%) and GAM (99.57%) was recorded for this trait.

The mean value of dry pod yield per plant was 59.64 g and which ranged low in AVT-I GR-13 (23.00g) and high in Gokak Local (101.15g). The GCV (29.06 %), PCV (37.55%) and heritability (59.90%) were high coupled with high genetic advance as per cent of mean (46.30%). PV and GV were 501.85 and 300.53, respectively.

Number of seeds per pod ranged between 6.65 g (AVT-I GR-15) (g) to 9.00 g (Pusa Navbahar and AVT-II GR-I) with an average of 7.67 g. The phenotypic variance and genotypic variance were (0.53% and 0.30%, respectively). The GCV (7.17%) and PCV (9.50%) were low, moderate heritability (57.00%) with low genetic advance as per cent of mean (11.16%) was noticed in this trait.

Seed yield per plant ranged between 17.00 g (AVT-I GR-13) to 45.00 g (Gokak Local) with mean value of 33.46 g. The GCV (19.73%) was moderate and PCV (26.75%) was high with moderate heritability (54.40%) and high genetic advance as per cent of mean (29.97%). The PV and GV were 80.19 and 43.60, respectively.

Hundred seed weight which ranged between 3.17g (Pusa Navbahar) to 3.87g (AVT-I GR-24) with grand mean of 3.46. The PV and GV were (0.04 and 0.02, respectively). The GCV and PCV (4.54% & 5.89%, respectively) were low with moderate heritability (59.50%) and low genetic advance as per cent of mean (7.22%) was observed for this trait.

### **4.3 Correlation Studies**

The genotypic and phenotypic correlation studies were carried out to know the nature of relationship existing between vegetable pod yield, seed yield and their component characters and are presented in Table 9 and 10.

Among 22 characters studied, number of pods per plant (0.558), pod yield per plant (0.612), pod yield per plot (0.614), number of dry pods per plant (0.583), dry pod

**Table 9. Genotypic correlation coefficient for growth, vegetable pod yield and seed yield 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           | 22           |
|----|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1  | <b>1.000</b> | 0.288        | 0.275        | 0.239        | -0.309       | 0.097        | -0.320       | 0.800*       | 0.624**      | 0.664**      | 0.348*       | -0.767**     | 0.074        | 0.093        | 0.178        | -0.049       | -0.053       | 0.079        | 0.164        | -0.101       | -0.012       | 0.084        |
| 2  |              | <b>1.000</b> | 0.039        | 0.286        | 0.445**      | 0.202        | 0.192        | 0.536**      | -0.237       | -0.367*      | 0.075        | 0.400*       | 0.624**      | 0.479**      | 0.485*       | 0.716**      | 0.724**      | 0.464**      | 0.547**      | 0.159        | -0.711**     | 0.287        |
| 3  |              |              | <b>1.000</b> | 0.946*       | 0.464**      | 0.601**      | 0.354*       | 0.304        | 0.229        | 0.208        | -0.222       | -0.683**     | 0.409*       | 0.666**      | 0.370*       | 0.389*       | 0.384*       | 0.369*       | 0.207        | -0.361*      | 0.044        | 0.333*       |
| 4  |              |              |              | <b>1.000</b> | 0.676**      | 0.784**      | 0.548**      | 0.518**      | -0.042       | -0.091       | -0.188       | -0.372*      | 0.611**      | 0.831**      | 0.600**      | 0.636**      | 0.633**      | 0.473**      | 0.183        | -0.185       | -0.294       | 0.263        |
| 5  |              |              |              |              | <b>1.000</b> | 0.481**      | 0.793**      | 0.233        | -0.514**     | -0.714**     | -0.185       | -0.208       | 0.868**      | 0.944**      | 0.751**      | 0.795**      | 0.799**      | 0.432**      | 0.196        | 0.056        | -0.614**     | 0.295        |
| 6  |              |              |              |              |              | <b>1.000</b> | 0.395*       | 0.600**      | -0.049       | -0.105       | 0.276        | -0.368*      | 0.469**      | 0.880**      | 0.642**      | 0.449**      | 0.438**      | 0.177        | 0.408**      | -0.533**     | -0.271       | -0.394*      |
| 7  |              |              |              |              |              |              | <b>1.000</b> | 0.239        | -0.359*      | -0.498**     | -0.314       | -0.172       | 0.548**      | 0.665**      | 0.344*       | 0.418*       | 0.425**      | 0.424*       | 0.232        | -0.230       | -0.577**     | 0.401*       |
| 8  |              |              |              |              |              |              |              | <b>1.000</b> | 0.146        | 0.063        | -0.194       | -0.193       | 0.540**      | 0.699**      | 0.623**      | 0.442**      | 0.439**      | 0.382*       | 0.096        | -0.293       | -0.408*      | 0.140        |
| 9  |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.999**      | 0.244        | -0.275       | -0.486**     | -0.177       | -0.481**     | -0.482**     | -0.490**     | -0.265       | 0.236        | -0.606**     | 0.635**      | -0.432**     |
| 10 |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.279        | -0.514       | -0.636**     | -0.351*      | -0.531**     | -0.617**     | -0.626**     | -0.440**     | 0.430**      | -0.597**     | 0.866**      | -0.521**     |
| 11 |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.088       | -0.392*      | -0.525**     | -0.298       | -0.341*      | -0.339*      | -0.481**     | 0.538**      | 0.120        | 0.642**      | -0.694**     |
| 12 |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.154        | 0.175        | -0.054       | 0.326        | 0.344*       | 0.367*       | 0.297        | 0.336*       | -0.383*      | -0.155       |
| 13 |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.814**      | 0.881**      | 0.952**      | 0.951**      | 0.769**      | 0.549**      | 0.218        | -0.850**     | 0.558**      |
| 14 |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.756**      | 0.807**      | 0.808**      | 0.672**      | 0.251        | -0.269       | -0.550**     | 0.186        |
| 15 |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.825**      | 0.821**      | 0.551**      | 0.299        | 0.008        | -0.660**     | 0.388*       |
| 16 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.999**      | 0.770**      | 0.659**      | 0.255        | -0.856**     | 0.612**      |
| 17 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.773**      | 0.675**      | 0.271        | -0.860**     | 0.614**      |
| 18 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.745**      | 0.129        | -0.680**     | 0.583**      |
| 19 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.335*       | -0.468**     | 0.988**      |
| 20 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.185       | 0.577**      |
| 21 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.483**      |
| 22 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> |

Critical r- 1% =0.423 5% = 0.329

\*Significant at 5%

\*\* Significant at 1%

@ character

- 1.Plant height (cm) at 60 DAS
- 2.Plant height (cm) at 90 DAS
- 3.Number of Branches at 60 DAS
- 4.Number of Branches at 90 DAS
- 5.Plant Spread N-S (cm) at 60 DAS

- 6.Plant Spread N-S (cm) at 90 DAS
- 7.Plant Spread E-W (cm) at 60 DAS
- 8.Plant Spread E-W (cm) at 90 DAS
- 9.Days taken for first flowering
- 10.Days taken for fifty per cent flowering

- 11.Days taken for first vegetable pod harvest
- 12.Pod length (cm)
- 13.Number of pods per plant
- 14.Number of pods per cluster
- 15.Number of clusters per plant

- 16.Pod yield per plant (g)
- 17.Pod yield per plot (kg)
- 18.Number of dry pods per plant
- 19.Dry pod yield per plant (g)
- 20.Number of seeds per pod

- 21.Hundred seed weight (g)
- 22.Seed yield per plant (g)

**Table 10. Phenotypic correlation coefficient for growth, vegetable pod yield and seed yield 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           | 22           |
|----|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1  | <b>1.000</b> | 0.301        | 0.368 *      | 0.240        | -0.120       | 0.174        | -0.108       | 0.540 **     | 0.429**      | 0.426**      | 0.110        | -0.250       | 0.088        | 0.037        | 0.222        | 0.065        | 0.065        | 0.005        | 0.008        | -0.218       | 0.171        | 0.074        |
| 2  |              | <b>1.000</b> | 0.120        | 0.283        | 0.325        | 0.264        | 0.197        | 0.470* *     | -0.130       | -0.212       | -0.036       | 0.318        | 0.598**      | 0.411 *      | 0.470 **     | 0.667*       | 0.669 * *    | 0.391 *      | 0.346 *      | 0.079        | -0.471**     | 0.149        |
| 3  |              |              | <b>1.000</b> | 0.871 **     | 0.263        | 0.462**      | 0.307        | 0.222        | 0.159        | 0.153        | -0.087       | -0.318       | 0.402*       | 0.589 **     | 0.428 **     | 0.434 *      | 0.420 *      | 0.244        | 0.037        | -0.180       | 0.058        | 0.070        |
| 4  |              |              |              | <b>1.000</b> | 0.427 *      | 0.584**      | 0.430**      | 0.286        | -0.042       | -0.053       | -0.104       | -0.185       | 0.620 **     | 0.805 **     | 0.586 **     | 0.654*       | 0.641**      | 0.419 *      | 0.156        | -0.147       | -0.217       | 0.157        |
| 5  |              |              |              |              | <b>1.000</b> | 0.532 * *    | 0.702* *     | 0.294        | -0.353*      | -0.367*      | -0.275       | -0.010       | 0.588 **     | 0.461 * *    | 0.431 **     | 0.492 *      | 0.495* *     | 0.276        | 0.216        | -0.058       | -0.413*      | 0.191        |
| 6  |              |              |              |              |              | <b>1.000</b> | 0.452 * *    | 0.597* *     | 0.062        | 0.119        | 0.007        | -0.088       | 0.355*       | 0.544 * *    | 0.459 **     | 0.361*       | 0.344 *      | 0.135        | -0.132       | -0.328       | -0.095       | -0.223       |
| 7  |              |              |              |              |              |              | <b>1.000</b> | 0.320        | -0.227       | -0.249       | -0.251       | -0.011       | 0.403 *      | 0.409 *      | 0.226        | 0.324        | 0.328        | 0.341 *      | 0.231        | -0.144       | -0.250       | 0.211        |
| 8  |              |              |              |              |              |              |              | <b>1.000</b> | 0.137        | 0.133        | -0.093       | -0.013       | 0.383 *      | 0.364 *      | 0.460**      | 0.320        | 0.323        | 0.301        | 0.112        | -0.141       | -0.197       | 0.035        |
| 9  |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.935**      | 0.071        | -0.184       | -0.413*      | -0.145       | -0.416 *     | -0.408 *     | -0.414 *     | -0.185       | -0.096       | -0.428* *    | 0.480 **     | -0.147       |
| 10 |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.179        | -0.194       | -0.494 **    | 0.220        | -0.424 **    | -0.468*      | -0.477 * *   | -0.256       | -0.092       | -0.453 * *   | 0.493**      | -0.132       |
| 11 |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.032       | -0.231       | -0.177       | -0.110       | -0.164       | -0.162       | -0.233       | -0.149       | 0.038        | 0.203        | -0.367*      |
| 12 |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.127       | 0.141        | 0.011        | 0.233        | 0.242        | 0.291        | 0.216        | 0.135        | -0.176       | -0.009       |
| 13 |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.780* *     | 0.849**      | 0.937*       | 0.935 * *    | 0.719* *     | 0.439* *     | 0.163        | -0.647 **    | 0.396*       |
| 14 |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.730 **     | 0.781 *      | 0.773* *     | 0.591* *     | 0.214        | -0.163       | -0.438 **    | 0.098        |
| 15 |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.815 *      | 0.805 * *    | 0.456 * *    | 0.168        | 0.037        | -0.489 **    | 0.186        |
| 16 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.998 * *    | 0.683* *     | 0.491 * *    | 0.19         | -0.580 **    | 0.364*       |
| 17 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.696 * *    | 0.511 * *    | 0.205        | -0.566 **    | 0.384*       |
| 18 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.692 * *    | 0.092        | -0.488 **    | 0.571**      |
| 19 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | 0.219        | -0.356 *     | 0.802**      |
| 20 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.069       | 0.255        |
| 21 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> | -0.277       |
| 22 |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              | <b>1.000</b> |

Critical r- 1% =0.423 5%= 0.329

\*Significant at 5%

\*\* Significant at 1%

@ character

- 1.Plant height (cm) at 60 DAS
- 2.Plant height (cm) at 90 DAS
- 3.Number of Branches at 60 DAS
- 4.Number of Branches at 90 DAS
- 5.Plant Spread N-S (cm) at 60 DAS

- 6.Plant Spread N-S (cm) at 90 DAS
- 7.Plant Spread E-W (cm) at 60 DAS
- 8.Plant Spread E-W (cm) at 90 DAS
- 9.Days taken for first flowering
- 10.Days taken for fifty per cent flowering

- 11.Days taken for first vegetable pod harvest
- 12.Pod length (cm)
- 13.Number of pods per plant
- 14.Number of pods per cluster
- 15.Number of clusters per plant

- 16.Pod yield per plant (g)
- 17.Pod yield per plot (kg)
- 18.Number of dry pods per plant
- 19.Dry pod yield per plant (g)
- 20.Number of seeds per pod

- 21.Hundred seed weight (g)
- 22.Seed yield per plant (g)

yield per plant (0.988), number of seeds per pod (0.577) and hundred seed weight (0.483) showed highly significant correlation with seed yield per plant.

#### **4.3.1 Genotypic correlation**

Plant height at 60 DAS was highly significantly correlated with first flowering (0.624), fifty per cent flowering (0.664) and significant correlation with plant spread (East-West) at 90 DAS (0.800) and showed highly significant negative correlation with pod length (-0.767).

Plant height at 90 DAS exhibited highly significant and positive correlation with plant spread (North – South) at 60 DAS (0.455), plant spread (East-West) at 90 DAS (0.536), number of pods per plant (0.624), number of pods per cluster (0.479), pod yield per plant (0.716), pod yield per plot (0.724), number of dry pods per plant (0.464), dry pod yield per plant (0.547) and significant correlation with pod length (0.400) and number of clusters per plant (0.485). It also had highly significant and negative correlation with hundred seed weight (-0.711) and significant with fifty per cent flowering (-0.367).

High degree of association was found for number of branches per plant at 60 DAS with plant spread (North –South) at 60 DAS (0.464), plant spread (North-South) at 90 DAS (0.601), number of pods per cluster (0.666) and significant correlation with number of branches per plant at 90 DAS (0.946), plant spread (East –West) at 60 DAS (0.354), number of pods per plant (0.409), number of clusters per plant (0.370), pod yield per plant (0.389), pod yield per plot (0.384), number of dry pods per plant (0.369) and seed yield per plant (0.333). Whereas, it showed highly significant negative correlation with pod length (-0.683) and significant with number of seeds per pod (-0.361).

Number of branches per plant at 90 DAS exhibited highly significant and positive correlation with plant spread (North –South) at 60 DAS (0.676), plant spread (North-South) at 90 DAS (0.784), plant spread (East-West) at 60 DAS (0.548), plant spread (East-West) at 90 DAS (0.518), number of pods per plant (0.611), number of pods per cluster (0.831), number of clusters per plant (0.600), pod yield per plant (0.636), pod

yield per plot (0.633) and number of dry pods per plant (0.473). It also had significant negative correlation with pod length (-0.372).

Plant spread (North-South) at 60 DAS exhibited highly significant and positive correlation with plant spread (North-South) at 90 DAS (0.481), plant spread (East-West) at 60 DAS (0.793), number of pods per plant (0.868), number of pods per cluster (0.944), number of clusters per plant (0.751), pod yield per plant (0.795), pod yield per plot (0.799) and number of dry pods per plant (0.432). It also showed highly significant negative correlation with first flowering (-0.514), fifty per cent flowering (-0.714) and hundred seed weight (-0.614).

Plant spread (North –South) at 90 DAS showed highly significant and positive correlation with plant spread (East –West) at 90 DAS (0.600), number of pods per plant (0.469), number of pods per cluster (0.880), number of clusters per plant (0.642), pod yield per plant (0.449), pod yield per plot (0.438), dry pod yield per plant (0.408) and significant correlation with plant spread (East-West) at 60 DAS (0.395). It also exhibited highly significant negative correlation with number of seeds per pod (-0.533) and significant with pod length (-0.368) and seed yield per plant (-0.394).

Plant spread (East-West) at 60 DAS exhibited highly significant and positive correlation with number of pods per plant (0.548), number of pods per cluster (0.665), pod yield per plot (0.425) and significant with number of dry pods per plant (0.424), number of clusters per plant (0.344), pod yield per plant (0.418) and seed yield per plant (0.401). It had highly significant negative correlation with fifty per cent flowering (-0.498) and hundred seed weight (-0.577) and significant correlation with first flowering (-0.359).

Plant spread (East-West) at 90 DAS exhibited highly significant and positive correlation with number of pods per plant (0.540), number of pods per cluster (0.699), number of clusters per plant (0.623), pod yield per plant (0.422), pod yield per plot (0.439) and significant correlation with number of dry pods per plant (0.382). Negative correlation was observed with hundred seed weight (-0.408).

Days to first flowering exhibited highly significant and positive correlation with fifty per cent flowering (1.003) and hundred seed weight (0.635). It also exhibited highly significant negative correlation with number of pods per plant (-0.486), number of clusters per plant (-0.481), pod yield per plant (-0.482), pod yield per plot (-0.490), number of seeds per pod (-0.606) and seed yield per plant (-0.432).

Fifty per cent flowering exhibited highly significant and positive correlation with dry pod yield per plant (0.430) and hundred seed weight (0.866). It also shown highly significant negative correlation with number of pods per plant (-0.636), number of clusters per plant (-0.531), pod yield per plant (-0.617), pod yield per plot (-0.626), number of dry pods per plant (-0.440), number of seeds per pod (-0.597) and seed yield per plant (-0.521) and significant with number of pods per cluster (-0.351).

Days taken for first vegetable pod harvest shown highly significant and positive correlation with dry pod yield per plant (0.538) and hundred seed weight (0.642). Highly negative correlation was found with characters like number of pods per cluster (-0.525), number of dry pods per plant (-0.481) and seed yield per plant (-0.694) and significant correlation through number of pods per plant (-0.392), pod yield per plant (-0.341) and pod yield per plot (-0.339).

Pod length showed significant correlation with pod yield per plot (0.344), number of dry pods per plant (0.367) and number of seeds per pod (0.336). It showed negatively significant correlation with hundred seed weight (-0.383).

Number of pods per plant had highly significant correlation with number of pods per cluster (0.814) and number of clusters per plant (0.881), pod yield per plant (0.952), pod yield per plot (0.951), number of dry pods per plant (0.769), dry pod yield per plant (0.549) and seed yield per plant (0.558). It showed negative significant correlation with hundred seed weight (-0.850).

Number of pods per cluster showed highly significant correlation with number of cluster per plant (0.756), pod yield per plant (0.807), pod yield per plot (0.808) and

number of dry pods per plant (0.672). It had highly negative significant correlation with hundred seed weight (-0.550).

Number of clusters per plant exhibited highly significant correlation with pod yield per plant (0.825), pod yield per plot (0.821), number of dry pods per plant (0.551) and significant correlation with seed yield per plant (0.388). The negative significant correlation was noticed with hundred seed weight (-0.660).

Pod yield per plant had highly significant correlation with pod yield per plot (0.999), number of dry pods per plant (0.770), dry pod yield per plant (0.659) and seed yield per plant (0.612). It also revealed highly negative significant correlation with hundred seed weight (-0.856).

Pod yield per plot indicated highly significant correlation with number of dry pods per plant (0.773), dry pod yield per plant (0.675) and seed yield per plant (0.614). It also had highly negative significant correlation with hundred seed weight (-0.860).

Number of dry pods per plant exhibited highly significant correlation with dry pod yield per plant (0.745) and seed yield per plant (0.583). It also showed highly negative significant correlation with hundred seed weight (-0.680).

Dry pod yield per plant had highly significant correlation with seed yield per plant (0.988) and significantly correlated with number of seeds per pod (0.335). Highly negative significant correlation was found with hundred seed weight (-0.468).

Number of seeds per pod exhibited highly significant positive correlation with seed yield per plant (0.577).

Hundred seed weight exhibited highly significant correlation with seed yield per plant (0.483).

### 4.3.2 Phenotypic correlation

The high association of plant height at 60 DAS was positive with plant spread (East-West) at 90 DAS (0.540), days taken for first flowering (0.429), first fifty per cent flowering (0.426) and showed significant correlation with number of branches at 60 DAS (0.368).

Number of branches per plant at 90 DAS indicated highly significant and positive correlation with plant spread (East-West) at 90 DAS (0.470), number of pods per plant (0.598), number of clusters per plant (0.470), pod yield per plot (0.669) and it had significant and positive correlation with pod yield per plant (0.667), number of pods per cluster (0.411) number of dry pods per plant (0.391) and dry pod yield per plant (0.346). It also exhibited highly significant and negative correlation with hundred seed weight (-0.471).

Number of branches at 60 DAS had highly significant and positive correlation with number of branches at 90 DAS (0.871), plant spread (North-South) at 90 DAS (0.462), number of pods per cluster (0.589) and number of clusters per plant (0.428), while it showed significant correlation with plant spread (East-West) at 60 DAS (0.307), number of pods per plant (0.402), pod yield per plant (0.434) and pod yield per plot (0.420).

Number of branches at 90 DAS recorded highly significant and positive association with plant spread (North-South) at 90 DAS (0.584), plant spread (East-West) at 60 DAS (0.430), number of pods per plant (0.620), number of pods per cluster (0.805), number of clusters per plant (0.586) and pod yield per plot (0.641), while it had significant correlation with plant spread (North-South) at 60 DAS (0.427), number of dry pods per plant (0.419) and pod yield per plant (0.654).

At phenotypic level, plant spread (North-South) at 60 DAS had highly significant and positive correlation with plant spread (North-South) at 90 DAS (0.532), plant spread (East-West) at 60 DAS (0.702), number of pods per plant (0.588), number of pods per cluster (0.461), number of clusters per plant (0.431) and pod yield per plot (0.495).

However, significant correlation with pod yield per plant (0.492) and negative significant correlation with first flowering (-0.353), fifty per cent flowering (-0.367) and hundred seed weight (-0.413).

Plant spread (North-South) at 90 DAS had highly significant and positive correlation with plant spread (East-West) at 60 DAS (0.452), plant spread (East-West) at 90 DAS (0.597), number of pods per cluster (0.544) and number of clusters per plant (0.459). It also showed significant correlation with pod yield per plant (0.361), number of pods per plant (0.355) and pod yield per plot (0.344).

Plant spread (East-West) at 60 DAS indicated significant positive association with number of pods per plant (0.403), number of pods per cluster (0.409) and number of dry pods per plant (0.341).

At 90 DAS, plant spread (East-West) had highly significant and positive correlation with number of cluster per plant (0.460) and significant positive correlation with number of pods per plant (0.383) and number of pods per cluster (0.364).

First flowering exhibited highly significant and positive correlation with fifty per cent flowering (0.935) and hundred seed weight (0.480). It also revealed highly significant and negative correlation with number of seeds per pod (-0.428), significant and negative correlation with number of pods per plant (-0.413), number of clusters per plant (-0.416), pod yield per plant (-0.408) and pod yield per plot (-0.414).

Days to fifty per cent flowering had highly significant positive correlation with hundred seed weight (0.493). However, it showed highly negative and significant correlation with number of pods per plant (-0.494), number of clusters per plant (-0.424), pod yield per plot (-0.477), number of seeds per pod (-0.453) and significant negative correlation with pod yield per plant (-0.468).

Days taken for first vegetable pod harvest showed negative and significant correlation with seed yield per plant (-0.367).

Number of pods per plant shown highly significant positive correlation with number of pods per cluster (0.780), number of clusters per plant (0.849), pod yield per plot (0.935), number of dry pods per plant (0.719) and dry pod yield per plant (0.439), while, it showed significant correlation with pod yield per plant (0.937) and seed yield per plant (0.396). However, it showed highly significant negative correlation with hundred seed weight (-0.647).

Number of pods per cluster was highly significant and positively correlated with number of clusters per plant (0.730), pod yield per plot (0.773) and number of dry pods per plant (0.591), while, it had significant correlation with pod yield per plant (0.781). It also showed highly negative correlation with hundred seed weight (-0.438).

Number of clusters per plant shown highly significant positive correlation with pod yield per plot (0.805), number of dry pods per plant (0.456) and significant correlation with pod yield per plant (0.815). However, it gave highly negative significant correlation with hundred seed weight (-0.489).

Pod yield per plant shown highly significant positive correlation with pod yield per plot (0.998), number of dry pods per plant (0.683), dry pod yield per plant (0.491) and significant correlation with seed yield per plant (0.364). However, it had highly significant negative correlation with hundred seed weight (-0.580).

Pod yield per plot showed highly significant positive correlation with number of dry pods per plant (0.696) and dry pod yield per plant (0.511). It exhibited significant correlation for seed yield per plant (0.384). However, it showed highly significant negative correlation with hundred seed weight (-0.566).

Number of dry pods per plant exhibited highly significant correlation with dry pod yield per plant (0.692) and seed yield per plant (0.571). However, it showed significant negative correlation with hundred seed weight (-0.488).

Dry pod yield per plant showed highly significant correlation with seed yield per plant (0.802) and negative significant correlation was observed with hundred seed weight (-0.356).

#### **4.4 Path Coefficient Analysis**

The correlation coefficient would only indicate the relationship of independent variable with the dependent variable without specifying cause and effect relationship. Using path coefficient analysis, it is possible to resolve the correlations, which will provide direct and indirect contribution of different quantitative traits. The genotypic and phenotypic path coefficient analysis was done for vegetable pod yield per plant and seed yield per plant. Results for these parameters are presented in Table 11 and 12.

The path coefficient analysis for vegetable pod was performed with a set of 16 independent characters, *viz.*, plant height at 90 DAS (0.7162), number of branches at 90 DAS (0.6360), plant spread (North-South) at 60 and 90 DAS (0.7952 & 0.4499, respectively), plant spread (East-West) at 90 DAS (0.4420), pod yield per plot (1.000), dry pod yield per plant (0.6590) and seed yield per plant (0.6123).

##### **4.4.1 Genotypic path coefficient analysis**

Plant height at 60 DAS exhibited positive direct effect (0.0108) and negative association with vegetable yield per plant ( $r_G = -0.0499$ ). It showed positive indirect effect through plant spread (East-West) at 90 DAS (0.0086) and fifty per cent flowering (0.0071). It also showed negative indirect effect through plant spread (East-West) at 60 DAS (-0.0035) and plant spread (North-South) at 90 DAS (-0.0033).

Plant height at 90 DAS had negative direct effect (-0.0584) and significant positive association with vegetable pod yield per plant ( $r_G = 0.7162$ ). Positive indirect effects were through hundred seed weight (0.0415) followed by fifty per cent flowering (0.0215). It also showed negative indirect effect through days taken for first vegetable pod harvest (-0.0044) followed by yield per plot (-0.0423).

**Table 11. Genotypic path coefficient analysis for vegetable pod yield, seed yield and its component characters in cluster bean**

| @  | 1             | 2              | 3              | 4             | 5             | 6             | 7              | 8             | 9             | 10             | 11             | 12            | 13            | 14             | 15            | 16             | rG        |
|----|---------------|----------------|----------------|---------------|---------------|---------------|----------------|---------------|---------------|----------------|----------------|---------------|---------------|----------------|---------------|----------------|-----------|
| 1  | <b>0.0108</b> | 0.0031         | 0.0030         | 0.0026        | -0.0033       | 0.0010        | -0.0035        | 0.0086        | 0.0067        | 0.0071         | 0.0038         | -0.0006       | 0.0018        | -0.0011        | -0.0001       | 0.0009         | -0.0499   |
| 2  | -0.0169       | <b>-0.0584</b> | -0.0023        | -0.0167       | -0.0260       | -0.0118       | -0.0112        | -0.0313       | 0.0139        | 0.0215         | -0.0044        | -0.0423       | -0.0320       | -0.0093        | 0.0415        | -0.0168        | 0.7162**  |
| 3  | -0.0059       | -0.0009        | <b>-0.0215</b> | -0.0203       | -0.0100       | -0.0129       | -0.0076        | -0.0065       | -0.0049       | -0.0045        | 0.0048         | -0.0083       | -0.0045       | 0.0078         | -0.0010       | -0.0072        | 0.3897*   |
| 4  | 0.0138        | 0.0165         | 0.0546         | <b>0.0577</b> | 0.0390        | 0.0453        | 0.0317         | 0.0300        | -0.0025       | -0.0053        | -0.0109        | 0.0366        | 0.0106        | -0.0107        | -0.0170       | 0.0152         | 0.6360**  |
| 5  | -0.0112       | 0.0162         | 0.0169         | 0.0245        | <b>0.0363</b> | 0.0175        | 0.0288         | 0.0085        | -0.0187       | -0.0259        | -0.0067        | 0.0290        | 0.0071        | 0.0020         | -0.0223       | 0.0107         | 0.7952**  |
| 6  | 0.0004        | 0.0009         | 0.0026         | 0.0034        | 0.0021        | <b>0.0043</b> | 0.0017         | 0.0026        | -0.0002       | -0.0005        | 0.0012         | 0.0019        | -0.0018       | -0.0023        | -0.0012       | -0.0017        | 0.4499**  |
| 7  | 0.0177        | -0.0106        | -0.0196        | -0.0303       | -0.0439       | -0.0219       | <b>-0.0553</b> | -0.0133       | 0.0199        | 0.0275         | 0.0174         | -0.0235       | -0.0129       | 0.0127         | 0.0319        | -0.0222        | 0.4184*   |
| 8  | 0.0261        | 0.0175         | 0.0099         | 0.0169        | 0.0076        | 0.0196        | 0.0078         | <b>0.0326</b> | 0.0048        | 0.0021         | -0.0063        | 0.0143        | 0.0031        | -0.0096        | -0.0133       | 0.0046         | 0.4420**  |
| 9  | 0.0324        | -0.0123        | 0.0119         | -0.0022       | -0.0267       | -0.0025       | -0.0187        | 0.0076        | <b>0.0519</b> | 0.0520         | 0.0127         | -0.0254       | -0.0122       | -0.0315        | 0.0330        | -0.0224        | -0.4824** |
| 10 | -0.0739       | 0.0409         | -0.0233        | 0.0102        | 0.0795        | 0.0118        | 0.0554         | -0.0071       | -0.1117       | <b>-0.1113</b> | -0.0311        | 0.0697        | 0.0479        | 0.0666         | -0.0964       | 0.0581         | -0.6170** |
| 11 | -0.0037       | -0.0008        | 0.0023         | 0.0020        | 0.0019        | -0.0029       | 0.0033         | 0.0020        | -0.0026       | -0.0029        | <b>-0.0105</b> | 0.0036        | 0.0057        | -0.0013        | -0.0068       | 0.0073         | -0.3417*  |
| 12 | -0.0500       | 0.6770         | 0.3590         | 0.5918        | 0.7469        | 0.4094        | 0.3972         | 0.4105        | -0.4583       | -0.5850        | -0.3170        | <b>0.9342</b> | 0.6310        | 0.2534         | -0.8035       | 0.5745         | 0.9998**  |
| 13 | 0.0168        | 0.0558         | 0.0211         | 0.0187        | 0.0201        | -0.0416       | 0.0237         | 0.0098        | -0.0241       | -0.0439        | -0.0549        | 0.0689        | <b>0.1019</b> | 0.0342         | -0.0477       | 0.1008         | 0.6590**  |
| 14 | 0.0007        | -0.0011        | 0.0024         | 0.0012        | -0.0004       | 0.0035        | 0.0015         | 0.0019        | 0.0040        | 0.0039         | -0.0008        | -0.0018       | -0.0022       | <b>-0.0066</b> | 0.0012        | -0.0038        | 0.2553    |
| 15 | -0.0001       | -0.0039        | 0.0002         | -0.0016       | -0.0034       | -0.0015       | -0.0032        | -0.0023       | 0.0035        | 0.0048         | 0.0036         | -0.0048       | -0.0026       | -0.0010        | <b>0.0056</b> | -0.0027        | -0.8560** |
| 16 | -0.0739       | 0.0409         | -0.0233        | 0.0102        | 0.0795        | 0.0118        | 0.0554         | -0.0071       | -0.1117       | 0.0433         | 0.0576         | -0.0510       | -0.0820       | -0.0479        | 0.0401        | <b>-0.0830</b> | 0.6123**  |

Diagonal values indicates direct effect

Residual = 0.0095

\* Significant at 5%

\*\* Significant at 1%

rG- Genotypic correlation with vegetable pod yield per plant

@ Characters

1.Plant height (cm)at 60 DAS

2.Plant height (cm) at 90 DAS

3.Number of branches at 60 DAS

4.Number of branches at 90 DAS

5.Plant spread N-S (cm) at 60 DAS

6.Plant spread N-S (cm) at 90 DAS

7.Plant spread E-W (cm) at 60 DAS

8.Plant spread E-W (cm) at 90 DAS

9.Days taken for first flowering

10. Days taken for fifty per cent flowering

11. Days taken for first vegetable pod harvest

12. Pod yield per plot (kg)

13.Dry pod yield per plant (g)

14.Number of seeds per pod

15.Hundred seed weight (g)

16.Seed yield per plant (g)

**Table 12. Phenotypic path coefficient analysis for vegetable pod yield, seed yield and its component characters in cluster bean**

| @  | 1             | 2              | 3             | 4              | 5              | 6             | 7             | 8              | 9              | 10            | 11             | 12            | 13             | 14            | 15             | 16             | rP        |
|----|---------------|----------------|---------------|----------------|----------------|---------------|---------------|----------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|----------------|-----------|
| 1  | <b>0.0162</b> | 0.0049         | 0.0060        | 0.0039         | -0.0020        | 0.0028        | -0.0018       | 0.0088         | 0.0070         | 0.0069        | 0.0018         | 0.0011        | 0.0001         | -0.0036       | 0.0028         | 0.0012         | 0.0654    |
| 2  | -0.0010       | <b>-0.0032</b> | -0.0004       | -0.0009        | -0.0010        | -0.0008       | -0.0006       | -0.0015        | 0.0004         | 0.0007        | 0.0001         | -0.0021       | -0.0011        | -0.0003       | 0.0015         | -0.0005        | 0.6671**  |
| 3  | 0.0078        | 0.0026         | <b>0.0213</b> | 0.0185         | 0.0056         | 0.0098        | 0.0065        | 0.0047         | 0.0034         | 0.0033        | -0.0019        | 0.0090        | 0.0008         | -0.0038       | 0.0012         | 0.0015         | 0.4340**  |
| 4  | -0.0040       | -0.0048        | -0.0146       | <b>-0.0167</b> | -0.0072        | -0.0098       | -0.0072       | -0.0048        | 0.0007         | 0.0009        | 0.0018         | -0.0108       | -0.0026        | 0.0025        | 0.0036         | -0.0026        | 0.6545**  |
| 5  | 0.0030        | -0.0082        | -0.0066       | -0.0107        | <b>-0.0251</b> | -0.0134       | -0.0176       | -0.0074        | 0.0089         | 0.0092        | 0.0069         | -0.0124       | -0.0054        | 0.0015        | 0.0104         | -0.0048        | 0.4924**  |
| 6  | 0.0075        | 0.0114         | 0.0200        | 0.0252         | 0.0230         | <b>0.0432</b> | 0.0195        | 0.0258         | 0.0027         | 0.0051        | 0.0003         | 0.0149        | -0.0057        | -0.0142       | -0.0041        | -0.0097        | 0.3613*   |
| 7  | -0.0005       | 0.0008         | 0.0013        | 0.0018         | 0.0030         | 0.0019        | <b>0.0042</b> | 0.0013         | -0.0010        | -0.0010       | -0.0011        | 0.0014        | 0.0010         | -0.0006       | -0.0011        | 0.0009         | 0.3244    |
| 8  | -0.0209       | -0.0182        | -0.0086       | -0.0111        | -0.0114        | -0.0231       | -0.0124       | <b>-0.0386</b> | -0.0053        | -0.0051       | 0.0036         | -0.0125       | -0.0043        | 0.0055        | 0.0076         | -0.0013        | 0.3202    |
| 9  | -0.0031       | 0.0009         | -0.0012       | 0.0003         | 0.0026         | -0.0005       | 0.0016        | -0.0010        | <b>-0.0073</b> | -0.0068       | -0.0005        | 0.0030        | 0.0007         | 0.0031        | -0.0035        | 0.0011         | -0.4083*  |
| 10 | 0.0082        | -0.0041        | 0.0029        | -0.0010        | -0.0070        | 0.0023        | -0.0048       | 0.0025         | 0.0179         | <b>0.0191</b> | 0.0034         | -0.0091       | -0.0018        | -0.0087       | 0.0095         | -0.0025        | -0.4687** |
| 11 | -0.0017       | 0.0006         | 0.0014        | 0.0016         | 0.0043         | -0.0001       | 0.0040        | 0.0015         | -0.0011        | -0.0028       | <b>-0.0157</b> | 0.0025        | 0.0023         | -0.0006       | -0.0032        | 0.0058         | -0.1645   |
| 12 | 0.0650        | 0.6650         | 0.4180        | 0.6377         | 0.4925         | 0.3419        | 0.3266        | 0.3215         | -0.4114        | -0.4739       | -0.1611        | <b>0.9935</b> | 0.5082         | 0.2045        | -0.5632        | 0.3818         | 0.9980**  |
| 13 | 0.0000        | -0.0015        | -0.0002       | -0.0007        | -0.0009        | 0.0006        | -0.0010       | -0.0005        | 0.0004         | 0.0004        | 0.0006         | -0.0022       | <b>-0.0042</b> | -0.0009       | 0.0015         | -0.0034        | 0.4919**  |
| 14 | -0.0016       | 0.0006         | -0.0013       | -0.0010        | -0.0004        | -0.0023       | -0.0010       | -0.0010        | -0.0030        | -0.0032       | 0.0003         | 0.0015        | 0.0016         | <b>0.0071</b> | -0.0005        | 0.0018         | 0.1901    |
| 15 | -0.0083       | 0.0228         | -0.0028       | 0.0105         | 0.0200         | 0.0046        | 0.0121        | 0.0095         | -0.0233        | -0.0239       | -0.0098        | 0.0274        | 0.0172         | 0.0033        | <b>-0.0484</b> | 0.0134         | -0.5807** |
| 16 | -0.0014       | -0.0027        | -0.0013       | -0.0029        | -0.0035        | 0.0041        | -0.0039       | -0.0006        | 0.0027         | 0.0024        | 0.0067         | -0.0071       | -0.0147        | -0.0047       | 0.0051         | <b>-0.0184</b> | 0.3642*   |

Diagonal values indicates direct effect

Residual = 0.0043

\* Significant at 5%

\*\* Significant at 1%

rP- Phenotypic correlation with vegetable pod yield per plant

@ Characters

1.Plant height (cm) at 60 DAS

2.Plant height (cm) at 90 DAS

3.Number of branches at 60 DAS

4.Number of branches at 90 DAS

5.Plant spread N-S (cm) at 60 DAS

6.Plant spread N-S (cm) at 90 DAS

7.Plant spread E-W (cm) at 60 DAS

8.Plant spread E-W (cm) at 90 DAS

9.Days taken for first flowering

10. Days taken for fifty per cent flowering

11. Days taken for first vegetable pod harvest

12. Pod yield per plot (kg)

13.Dry pod yield per plant (g)

14.Number of seeds per pod

15.Hundred seed weight (g)

16.Seed yield per plant (g)

Number of branches at 60 DAS exhibited negative direct effect (-0.0215) and significant correlation with vegetable pod yield per plant ( $r_G = 0.3897$ ). It had positive indirect effect *via*. number of seeds per pod (0.0078) and days taken for first vegetable pod harvest (0.0048). However, it showed negative indirect effect through number of branches at 90 DAS (-0.0203) and plant spread (North-South) at 90 DAS (-0.0129).

Number of branches at 90 DAS showed positive direct effect (0.0577) and significant association with vegetable pod yield per plant ( $r_G = 0.6360$ ). It had positive indirect effect through number of branches at 60 DAS (0.0546), plant spread (North-South) at 90 DAS (0.0453) and negative indirect effect through hundred seed weight (-0.0170) and days taken for first vegetable pod harvest (-0.0109).

Plant spread (North-South) at 60 DAS showed positive direct effect (0.0363) and significant association with vegetable pod yield per plant ( $r_G = 0.7952$ ). The positive indirect effect through pod yield per plot (0.0290) followed by plant spread (East-West) at 60 DAS (0.0288). However, it showed negative indirect effect through fifty per cent flowering (-0.0259) and hundred seed weight (-0.0233).

Plant spread (North-South) at 90 DAS had positive direct effect (0.0043) and highly significant association with vegetable pod yield per plant ( $r_G = 0.4499$ ). It had positive indirect effect through number of branches at 90 DAS (0.0034), plant spread (East-West) at 90 DAS (0.0026) and number of branches at 60 DAS (0.0026). However, it showed negative indirect effect through number of seeds per pod (-0.0023) and dry pod yield (-0.0018).

Plant spread (East-West) at 60 DAS exhibited negative direct effect (-0.0553) and highly significant association with vegetable pod yield per plant ( $r_G = 0.4184$ ). It had positive indirect effect through hundred seed weight (0.0319) and fifty per cent flowering (0.0275). However, it showed negative indirect effect through plant spread (North-South) at 60 DAS (-0.0439) and number of branches at 90 DAS (-0.0303).

Plant spread (East-West) at 90 DAS showed positive direct effect (0.0326) and highly significant association with vegetable pod yield per plant ( $r_G = 0.4420$ ) and

positive indirect effect *via* plant height at 60 DAS (0.0261) and plant spread (North-South) at 90 DAS (0.0196). However, it showed negative indirect effect through hundred seed weight (-0.0133) and number of seeds per pod (-0.0096).

Days to first flowering exhibited positive direct effect (0.0519) and highly significant negative association with vegetable pod yield per plant ( $r_G = -0.4824$ ). It also showed positive indirect effect through fifty per cent flowering (0.0520), hundred seed weight (0.0330) and negative indirect effects through number of seeds per pod (-0.0315) and plant spread (North-South) at 60 DAS (-0.0267).

Fifty per cent flowering showed negative direct effect (-0.1113) and highly significant negative association with vegetable pod yield per plant ( $r_G = -0.6170$ ). It also exhibited positive indirect effect through plant spread (North-South) at 60 DAS (0.0795), yield per plot (0.0697) and negative indirect effects through first flowering (-0.1117) and plant height at 60 DAS (-0.0739).

Days taken for first vegetable pod harvest exhibited negative direct effect (-0.0105) and highly significant negative association with vegetable pod yield per plant ( $r_G = -0.3417$ ). It also showed positive indirect effect through seed yield per plant (0.0073), dry pod yield per plant (0.0057) and negative indirect effects were through hundred seed weight (-0.0068) and plant height at 60 DAS (-0.0037).

Pod yield per plot had positive direct effect (0.9342) and highly significant association with vegetable pod yield per plant ( $r_G = 0.9998$ ). It had positive indirect effect through plant spread (North-South) at 60 DAS (0.7469), plant height at 90 DAS (0.6770) and negative indirect effects *via* hundred seed weight (-0.8035) and fifty per cent flowering (-0.5850).

Dry pod yield per plot showed positive direct effect (0.0109) and highly significant positive association with vegetable pod yield per plant ( $r_G = 0.6590$ ). Positive indirect effects were observed through pod yield per plot (0.0689), plant height at 90 DAS (0.0588) and negative indirect effects were through hundred seed weight (-0.0477) and fifty per cent flowering (-0.0439).

Number of seeds per pod exhibited negative direct effect (-0.0066) and associated with vegetable pod yield per plant ( $r_G=0.2553$ ). Positive indirect effects were observed through first flowering (0.0040) and fifty per cent flowering (0.0039). It was also showed negative indirect effects through seed yield per plant (-0.0038).

Hundred seed weight showed positive direct effect (0.0056) and highly significant negative association with vegetable pod yield per plant ( $r_G= -0.8560$ ). Positive indirect effects were observed through fifty per cent flowering (0.0048), first flowering (0.0035) and negative effects through pod yield per plot (-0.0048) and plant height at 90 DAS (-0.0039).

Seed yield per plant exhibited negative direct effect (-0.0830) and highly significant positive association with vegetable pod yield per plant ( $r_G= 0.6123$ ). Positive indirect effects were observed through plant spread (North-South) at 60 DAS (0.0795), days taken for first vegetable pod harvest (0.0576) and negative effects through first flowering (-0.1117) and dry pod yield per plant (-0.0820).

#### **4.4.2 Phenotypic path coefficient analysis**

Plant height at 60 DAS had positive direct effect (0.0612) and positive association with vegetable yield per plant ( $r_P= 0.0654$ ). Positive indirect effects were observed through plant spread (East-West) at 90 DAS (0.0088) followed by first flowering (0.0070) and negative effects through number of seeds per pod (-0.0036) and plant spread (North-South) at 60 DAS (-0.0020).

Plant height at 90 DAS exhibited negative direct effect (-0.0032) and positive highly significant association with vegetable yield per plant ( $r_P= 0.6671$ ). It was also showed positive indirect effects through hundred seed weight (0.0015), fifty per cent flowering (0.0007) and negative indirect effects were through pod yield per plot (-0.0021).

Path analysis revealed that number of branches at 60 DAS exhibited positive direct effect (0.0213) and positive highly significant association with vegetable yield per

plant ( $rP=0.4340$ ). Positive indirect effects were observed *via* number of branches at 90 DAS (0.0185) and plant spread (North-South) at 90 DAS (0.0098). Negative indirect effects were through number of seeds per pod (-0.0038) and days taken for first vegetable pod harvest (-0.0019).

Number of branches at 90 DAS exhibited negative direct effect (-0.0167) and positive highly significant association with vegetable yield per plant ( $rP=0.6545$ ). Positive indirect effects were observed *via* hundred seed weight (0.0036), number of seeds per pod (0.0025) and negative indirect effects were through pod yield per plot (-0.0108) and number of branches at 60 DAS (-0.0146).

Plant spread (North-South) at 60 DAS showed negative direct effect (-0.0251) and positive highly significant association with vegetable yield per plant ( $rP=0.4924$ ). It showed positive indirect effects *via* hundred seed weight (0.0104), fifty per cent flowering (0.0092) and negative indirect effects were through plant spread (East-West) at 60 DAS (-0.0176) and plant spread (North-South) at 90 DAS (-0.0134).

Plant spread (North-South) at 90 DAS showed positive direct effect (0.0432) and positive highly significant association with vegetable yield per plant ( $rP=3613$ ). While it, showed positive indirect effects through plant spread (East-West) at 90 DAS (0.0258), number of branches at 90 DAS (0.0252) and negative indirect effects were through number of seeds per pod (-0.0142) and seed yield per plant (-0.0097).

Plant spread (East-West) at 60 DAS exhibited positive direct effect (0.0042) and had positive association with vegetable yield per plant ( $rP= 0.3244$ ). It had positive indirect effects through plant spread (North-South) at 60 DAS (0.0030), plant spread (North-South) at 90 DAS (0.0019) and negative effects through hundred seed weight (-0.0011).

Plant spread (East-West) at 90 DAS exhibited negative direct effect (-0.0386) and had positive association with vegetable yield per plant ( $rP= 0.3202$ ). It showed positive indirect effects through hundred seed weight (0.0076), number of seeds per pod (0.0055) and negative effects through plant spread (North-South) at 90 DAS (-0.0231).

First flowering had negative direct effect (-0.0073) and highly negative association with vegetable yield per plant ( $rP = -0.4083$ ). However, it showed positive indirect effects through number of seeds per pod (0.0031), plant spread (North-South) at 60 DAS (0.0026) and negative effects through fifty per cent flowering (-0.0068) and hundred seed weight (-0.0035).

Fifty per cent flowering showed positive direct effect (0.0191) and had highly negative association with vegetable yield per plant ( $rP = -0.4687$ ). It also showed positive indirect effects *via* first flowering (0.0179), hundred seed weight (0.0095) and negative effects through number of seeds per pod (-0.0087) and plant spread (North-South) at 60 DAS (-0.0070).

Days taken for first vegetable pod harvest showed negative direct effect (-0.0157) and had negative association with vegetable yield per plant ( $rP = -0.1645$ ). It also showed positive indirect effects *via* seed yield per plant (0.0058) and plant spread (North-South) at 60 DAS (0.0043). However, it showed negative effects through hundred seed weight (-0.0032).

Results revealed that pod yield per plot exhibited positive direct effect (0.9935) and had highly significant positive association with vegetable yield per plant ( $rP = 0.9980$ ). It showed positive indirect effects *via* plant height at 90 DAS (0.6650), plant height at 60 DAS (0.0650) and negative indirect effects through hundred seed weight (-0.5632) and fifty per cent flowering (-0.4739).

Dry pod yield per plot exhibited negative direct effect (-0.0042) and had highly significant positive association with vegetable yield per plant ( $rP = 0.4919$ ). It also showed positive indirect effects through hundred seed weight (0.0015), days taken for first vegetable pod harvest (0.0006) and negative indirect effects through seed yield per plant (-0.0034) and pod yield per plot (-0.0022).

Number of seeds per pod showed positive direct effect (0.0071) and had positive association through vegetable pod yield plant (0.1901). It exhibited positive indirect effects through seed yield per plant (0.0018), dry pod yield per plant (0.0016) and

negative indirect effects through fifty per cent flowering (-0.0032) and first flowering (-0.0030).

Hundred seed weight exhibited negative direct effect (-0.0484) and had highly significant negative association with vegetable yield per plant ( $rP = -0.5807$ ). However, it showed positive indirect effects through plant height at 90 DAS (0.0228), plant spread (North-South) at 60 DAS (0.0200). It also showed negative indirect effects through fifty per cent flowering (-0.0239) and first flowering (-0.0233).

Seed yield per plant exhibited negative direct effect (-0.0184) and had highly significant positive association with vegetable yield per plant ( $rP = 0.3642$ ). It showed indirect positive effects through days taken for first vegetable pod harvest (0.0067) and hundred seed weight (0.0051). It also showed negative indirect effects through pod yield per plot (-0.0071) and number of seeds per pod (-0.0047).

#### **4.5 Genetic Divergence**

Eighteen cluster bean genotypes were evaluated for 17 characters and the data obtained was subjected to  $D^2$  statistics to assess the genetic divergence. As many as three divergent clusters were grouped by using Tocher's method.

##### **4.5.1 Relative contribution of different characters towards total divergence**

The relative contribution of different characters towards total for genetic divergence ( $D^2$ ) is given in Table 13. Dry pod yield per plant contributed maximum (29.41%) towards genetic diversity followed by number of dry pods per plant (24.18%), seed yield per plant (16.99%), pod yield per plant (16.34%), number of clusters per plant (6.54%), number of pods per plant (3.92%), pod yield per plot (1.96%). Whereas, days taken for first vegetable pod harvest (0.65%) shown least contribution. The characters like plant height, number of branches, plant spread (North-South), plant spread (East-West), pod length, chlorophyll content, days to first per cent flowering, days taken for fifty per cent flowering and number of pods per cluster showed no contribution towards divergence.

**Table 13. Per cent contribution of various characters towards diversity in cluster bean genotypes**

| Source                                     | Number of times ranked | Contribution (%) |
|--------------------------------------------|------------------------|------------------|
| Plant height (cm) at 90 DAS                | 0                      | 0.00             |
| Number of branches at 90 DAS               | 0                      | 0.00             |
| Plant spread (cm) North-South at 90 DAS    | 0                      | 0.00             |
| Plant spread (cm) East-West at 90 DAS      | 0                      | 0.00             |
| Chlorophyll content (mg/g)                 | 0                      | 0.00             |
| Days taken for first flowering             | 0                      | 0.00             |
| Days taken for fifty per cent flowering    | 0                      | 0.00             |
| Days taken for first vegetable pod harvest | 1                      | 0.65             |
| Pod length (cm) at 90 DAS                  | 0                      | 0.00             |
| Number of pods per plant                   | 6                      | 3.92             |
| Number of pod per cluster                  | 0                      | 0.00             |
| Number of clusters per plant               | 10                     | 6.54             |
| Pod yield per plant (g)                    | 25                     | 16.34            |
| Pod yield per plot (kg)                    | 3                      | 1.96             |
| Number of dry pods per plant               | 37                     | 24.18            |
| Dry pod yield per plant (g)                | 45                     | 29.41            |
| Seed yield per plant (g)                   | 26                     | 16.99            |

**DAS – Days After Sowing**

#### **4.5.2 Grouping of cluster bean genotypes**

Eighteen genotypes were grouped into three clusters by treating estimated  $D^2$  values as the squares of generalized distances. The distribution pattern of entries in various clusters is given in Table 14.

Cluster I was found largest having 16 genotypes followed by cluster II and III had one genotype each.

Intra and inter cluster average  $D^2$  values are presented in Table 15. Among the three clusters, cluster I with 16 number of genotypes showed maximum intra cluster diversity ( $D^2 = 385.39$ ). The clusters II and III had no intra-cluster distance ( $D^2 = 0.000$ ) as they possessed single genotype each.

Based on distance between clusters (inter-cluster distance), the maximum divergence was observed between cluster I and III ( $D^2=1479.25$ ) closely followed by cluster I and II ( $D^2= 766.71$ ) and cluster II and III ( $D^2=674.61$ ), respectively.

#### **4.5.2 Mean performance of characters in clusters**

Cluster mean for 17 characters are summarized in Table 16. The lowest cluster mean for plant height was observed in cluster I (65.8 cm) followed by cluster II (67.4 cm) and highest cluster mean was observed in cluster III (90.0 cm). The lowest cluster mean for number of branches was observed in cluster III (0.0) followed by cluster II (4.6) and highest cluster mean was observed in cluster I (8.3). The lowest cluster mean for plant spread (North-South) at 90 DAS was observed in cluster III (33.8 cm) and the highest cluster mean was observed in cluster II and cluster I (62.5 cm each). The lowest cluster mean for plant spread (East-West) at 90 DAS was observed in cluster II (43.8 cm) followed by cluster III (51.2 cm) and highest cluster mean was observed in cluster I (60.2 cm). The lowest cluster mean for chlorophyll content was observed in cluster II (1.4 mg/g) followed by cluster I (3.2 mg/g) and highest cluster mean was observed in cluster III (3.3 mg/g).

**Table 14. Grouping of 18 cluster bean genotypes in to different clusters based on D<sup>2</sup> statistics values**

| <b>Clusters</b> | <b>Number of genotypes</b> | <b>Genotypes included in the cluster</b>                                                                                                                                                            |
|-----------------|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I               | 16                         | AVT-II GR-3, HG-3-100, AVT-II GR-1, CAZ-G-06, HG-04-875, AVT-II GR-2, RGC -986, GOKAK LOCAL, AVT-I GR-9, AVT-II GR-6, AVT-I GR-14, AVT- I GR-24, IVT-I GR-23, IVT-I GR-21, AVT-I GR-13, IVT-I GR-20 |
| II              | 1                          | AVT-I GR-15                                                                                                                                                                                         |
| III             | 1                          | Pusa Navbahar                                                                                                                                                                                       |

**Table 15. Average intra and inter cluster  $D^2$  values and D values in cluster bean genotypes**

|                    | <b>Cluster I</b>         | <b>Cluster II</b>     | <b>Cluster III</b>    |
|--------------------|--------------------------|-----------------------|-----------------------|
| <b>Cluster I</b>   | <b>385.39</b><br>(19.63) | 766.17<br>(27.67)     | 1479.25<br>(38.46)    |
| <b>Cluster II</b>  |                          | <b>0.00</b><br>(0.00) | 674.61<br>(25.97)     |
| <b>Cluster III</b> |                          |                       | <b>0.00</b><br>(0.00) |

**Diagonal values indicates intra cluster distance**

**Table 16. Mean value of 17 characters for three clusters in cluster bean genotypes**

| @ \ *              | 1    | 2   | 3    | 4    | 5   | 6    | 7    | 8    | 9   | 10   | 11  | 12   | 13   | 14  | 15   | 16   | 17   |
|--------------------|------|-----|------|------|-----|------|------|------|-----|------|-----|------|------|-----|------|------|------|
| <b>Cluster I</b>   | 65.8 | 8.3 | 62.5 | 60.2 | 3.2 | 33.2 | 34.0 | 43.5 | 5.0 | 73.3 | 6.1 | 10.3 | 73.2 | 1.4 | 65.8 | 57.9 | 33.5 |
| <b>Cluster II</b>  | 67.4 | 4.6 | 62.5 | 43.8 | 1.4 | 34.1 | 35.0 | 43.0 | 5.7 | 29.9 | 5.5 | 7.3  | 58.5 | 1.1 | 31.0 | 57.0 | 27.0 |
| <b>Cluster III</b> | 90.0 | 0.0 | 33.8 | 51.2 | 3.3 | 31.4 | 31.9 | 44.7 | 6.5 | 84.0 | 4.0 | 8.0  | 89.0 | 1.7 | 83.9 | 89.5 | 38.0 |

@ = Characters      \*= Cluster

1. Plant height (cm) at 90 DAS
2. Number of branches per plant at 90 DAS
3. Plant spread (cm) N-S at 90 DAS
4. Plant spread (cm) E-W at 90 DAS
5. Chlorophyll content (mg/g)
6. Days taken for first flowering

7. Days taken for fifty per cent flowering
8. Days taken for first vegetable pod harvest
9. Pod length (cm) at 90 days
10. Number of pods per plant
11. Number of pods cluster
12. Number of clusters per plant

13. Pod yield (g) per plant
14. Pod yield (kg) per plot
15. Number of dry pods per plant
16. Dry pod yield (g) per plant
17. Seed yield per plant (g)

The lowest cluster mean for days taken to first flowering was observed in cluster III (31.4) followed by cluster I (33.2) and the highest cluster mean was observed in cluster II (34.1). The lowest cluster mean for days taken to fifty per cent flowering was observed in cluster III (31.9) followed by cluster I (34.0) whereas highest cluster mean was observed in cluster II (35.0). The lowest cluster mean for days taken for first vegetable pod harvest was observed in cluster II (43.0) followed by cluster I (43.5) and the highest cluster mean was observed in cluster III (44.7). The lowest cluster mean for pod length was observed in cluster I (5.0 cm) followed by cluster II (5.7 cm) and the highest cluster mean was observed in cluster III (6.5cm). The lowest cluster mean for number of pods per plant was observed in cluster II (29.9) followed by cluster I (73.3) and the highest cluster mean was observed in cluster III (84.0). The lowest cluster mean for number of pods per cluster was observed in cluster III (4.0) followed by cluster I (5.5). Highest cluster mean was observed in cluster III (6.1).

The lowest cluster mean for number of clusters per plant was observed in cluster II (7.3) followed by cluster III (8.0) and the highest cluster mean was observed in cluster I (10.30). The lowest cluster mean for pod yield per plant was observed in cluster II (58.5 g) followed by cluster I (73.2 g) and the highest cluster mean was observed in cluster III (89.0g).

The lowest cluster mean for pod yield per plot was observed in cluster II (1.10 kg) followed by cluster I (1.4 kg) and the highest cluster mean was observed in cluster III (1.7 kg). The lowest cluster mean for number of dry pods per plant was observed in cluster II (31.00) followed by cluster I (65.80) and the highest cluster mean was observed in cluster III (83.90). The lowest cluster mean for dry pod yield per plant was observed in cluster II (57.00 g) followed by cluster I (57.90 g) and the highest cluster mean was observed in cluster III (89.50 g). The lowest cluster mean for seed yield per plant was observed in cluster II (27.00 g) followed by cluster I (33.50 g) and the highest cluster mean was observed in cluster III (38.00 g).

# **DISCUSSION**

## V. DISCUSSION

Success of any crop improvement programme depends largely on the extent of variability present in the germplasm for the traits for which the improvement is aimed at. The knowledge of genetic variability and association of various characters are essential in proper planning of the breeding programmes. With this regard, in the present study, 18 genotypes of cluster bean were evaluated for green vegetable pod yield and seed yield along with their contributing characters. The magnitude of variability, broad sense heritability and genetic advance as per cent of mean was estimated. The association among the characters and their direct and indirect effects on vegetable pod and seed yield and the extent of genetic divergence in the genotypes was studied. The results obtained are discussed in this chapter.

### **5.1 Variability, heritability, genetic advance and genetic advance as per cent of mean**

Eighteen genotypes were evaluated to know the amount of variability for yield and yield attributing characters. The analysis of variance indicated highly significant differences among genotypes for all the characters studied *viz.*, plant height, number of branches, first flowering, fifty per cent flowering, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, pod yield per plant, pod yield per hectare, number of dry pods per plant, dry pod yield per plant, number of seeds per pod, hundred seed weight, seed yield per plant etc. Results clearly indicates that wide range of variability exists for yield and yield components among the genotypes studied. This variability may be due to the presence of variation in number of dry pods per plant, dry pod yield per plant, number of vegetable pods per plant, vegetable pod yield per plant, plant height and number of leaves. Therefore, there is a scope for selection for majority of traits in the genotypes. This was in accordance with results of Rai *et al.* 2012 and Girish (2011) in cluster bean.

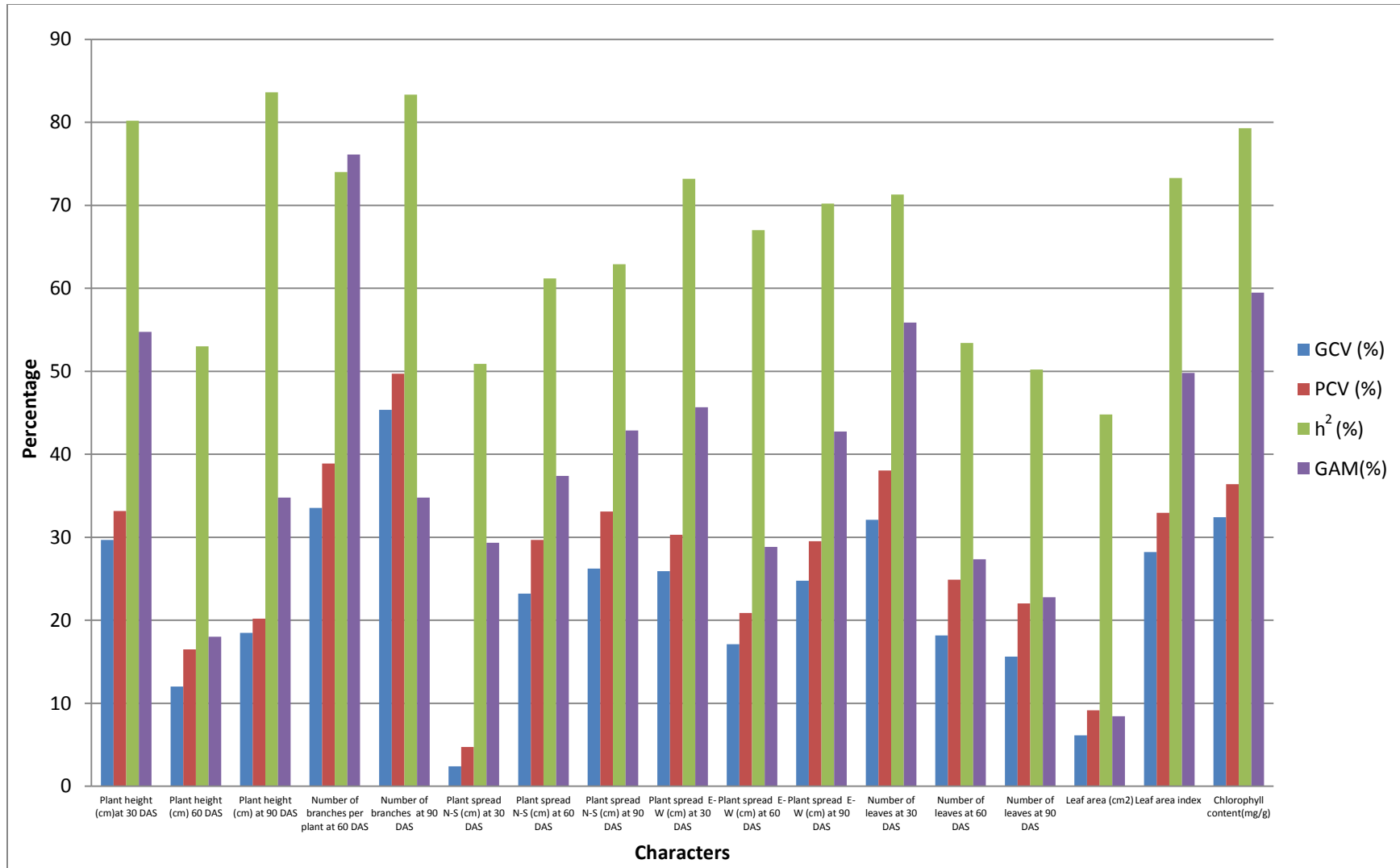
Wide range of variation was observed for all the traits indicated the presence of sufficient amount of variation among the genotypes under studied. These results were in accordance with the findings of Girish (2011).

The range in the values reflects the amount of phenotypic variability which is not reliable, since it includes genotypic, environmental, both genotype and environmental interaction components and does not reveal as to which character is showing higher degree of variability. Further, the phenotype of crop is influenced by additive gene effect (heritable), dominance (non-heritable) and epistasis (non-allelic interaction). Hence, it becomes necessary to split the observed variability into phenotypic coefficient of variation and genotypic coefficient of variation, which ultimately indicate the extent of variability existing for various traits. However, even this does not give a correct picture about the extent of inheritance of the character. Therefore, the heritability of a character can be relied upon, as it enables the plant breeder to decide an extent of selection pressure to be applied under particular environment, which separates out the environmental influence from the total variability. Never-the-less, its use would be limited as this is prone to change with the environment, material, *etc.* The estimation of heritability has a greater role to play in determining the effectiveness of selection of a character provided if it is considered in conjunction with the predicted genetic advance as suggested by Johnson *et al.* (1955). Heritability is influenced by biometrical method, generation of hybrid, sample size of experimental material and environment.

### **5.1.1 Growth parameters**

The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters under study indicating that the apparent is not due to genotypes but also due to environment and selection for such traits is sometimes ineffective. Higher values of phenotypic and genotypic coefficient of variations were observed for several characters (Fig. 2).

High phenotypic and genotypic coefficient variations at 30 DAS and moderate phenotypic coefficient of variation at 90 DAS was recorded for plant height indicated limited variability offering scope for improvement of the character. Anandhi and Oommen (2007) also reported moderate GCV and PCV for plant height at 60 and 90 DAS in cluster bean.



**Fig. 2. PCV, GCV, h<sup>2</sup> and genetic advance as per cent of mean for growth parameters in cluster bean**

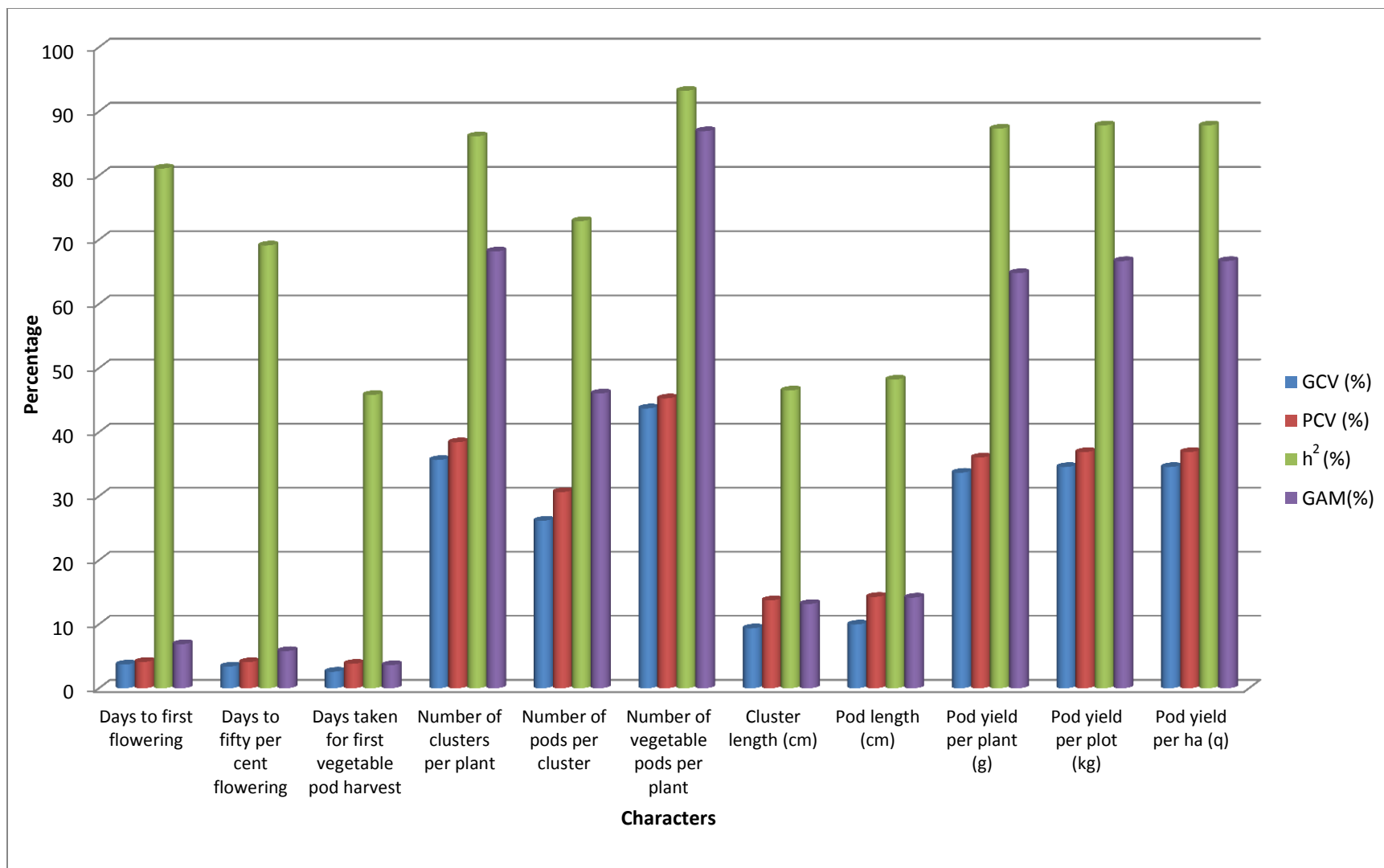
It appears that phenotypic variability may be a good measure of genotypic variability for characters such as plant height and number of branches per plant and plant spread (North-South and East-West) as the estimates of GCV and PCV were closer and parallel indicating that they are comparatively least affected by environment and hence could be relied upon in the improvement of these parameters.

Moderate heritability and low genetic advance as per cent of mean was reported for characters like leaf area. These results are similar to the results obtained by Girish (2011). High heritability and high genetic advance as per cent of mean was recorded for all the growth characters except plant height at 60 DAS, number leaves at 60 and 90 DAS and leaf area indicated that heritability could be mainly due to additive gene effect and selection may be more effective. These results are in accordance with results of Dabas *et al.* (1982) and Hanchinamani (2003) in cluster bean. Moderate heritability and genetic advance over mean was observed for plant height at 60 DAS.

### **5.1.2 Vegetable pod and yield parameters**

High PCV and GCV values were observed for number of vegetable pods per plant, number of clusters per plant, pod yield per plant, pod yield per plot, pod yield per hectare and number of pods per cluster. These results are similar with the findings of Rai *et al.* (2012) and Hanchinamani (2003). Moderate to low PCV and GCV was found in pod length and cluster length. These results are in accordance with the results of Patil (2014). Low PCV and GCV was found in days to first flowering, days to fifty per cent flowering and days taken to first vegetable pod harvest indicates environment is playing a significant role in expression of these characters and selection will be ineffective in these characters. These results are in accordance with the results of Girish (2011) and Hanchinamani (2003) (Fig. 3).

The attributes like number of pods per cluster, cluster length and pod length showed wide difference between phenotypic and genotypic coefficient of variance thereby implying greater environmental effect in the manifestation of these characters. These results are in conformity with the of results obtained by Girish (2011) and Mital *et al.* (1968) in cluster bean.



**Fig. 3. PCV, GCV,  $h^2$  and genetic advance as per cent of mean for vegetable pod parameters in cluster bean**

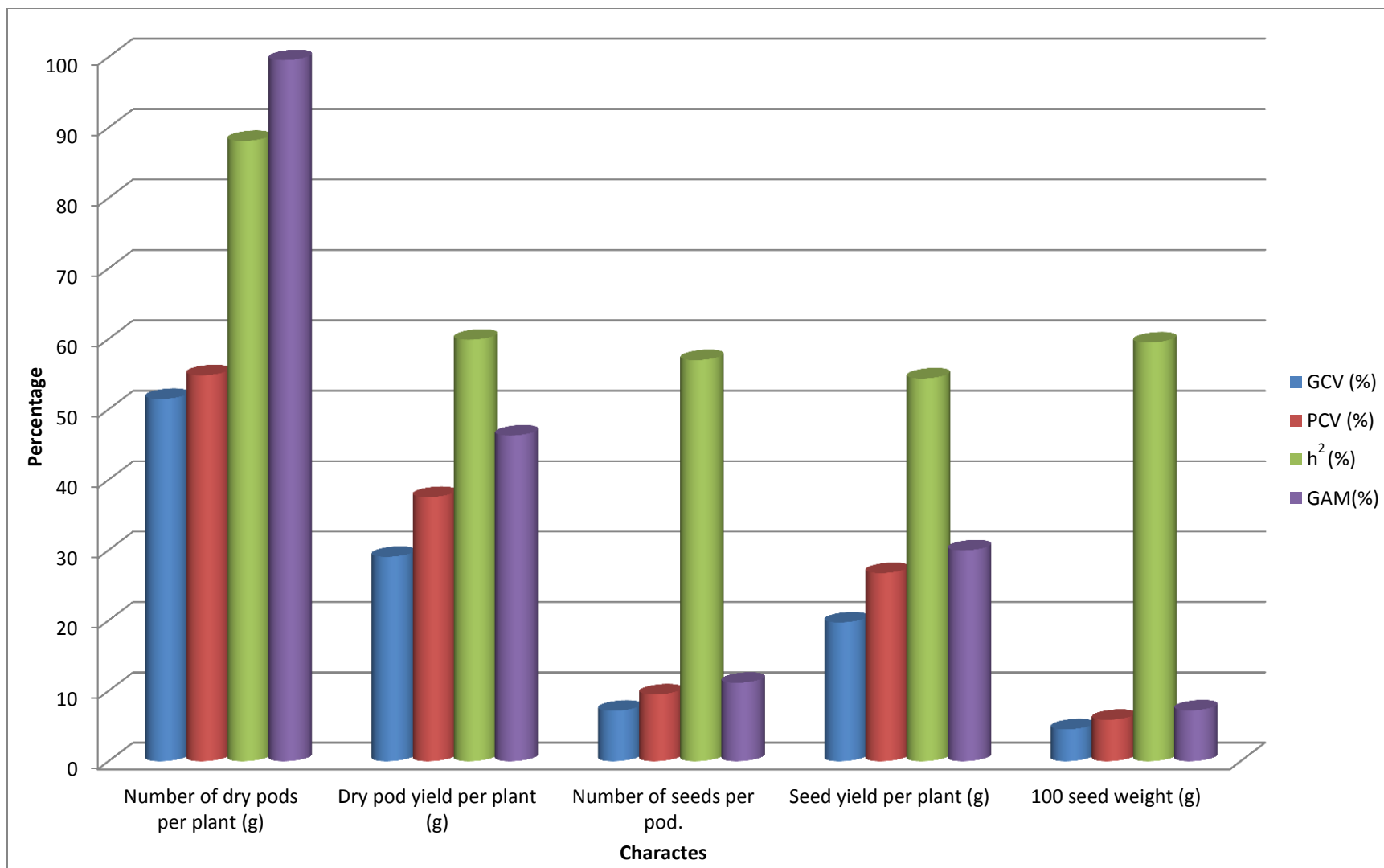
High heritability coupled with low genetic advance over mean was recorded for days to first flowering and days to fifty per cent flowering. It is an indicative of non-additive gene action and high heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be effective. These results are similar with findings of Anandhi and Oommen (2007) in cluster bean. Singh *et al.* (2000) and Nimbalkar *et al.* (2002) in French bean. Moderate heritability with moderate genetic advance as per cent of mean was recorded for pod length and cluster length. These results are similar with the findings of Patil (2014).

### **5.1.3 Seed yield and yield parameters**

High to high PCV and GCV were observed for number of dry pods per plant and dry pod yield per plant. These results are similar with the findings of Ramesh Kumar *et al.* (2009) in cowpea. High to moderate PCV and GCV were observed for seed yield per plant. These results are in agreement with the findings of Saindass *et al.* (1973). Low to low PCV and GCV were observed for number of seeds per pod and hundred seed weight indicates that the environment is playing a significant role in expression of such characters and selection will be ineffective in these characters. These results are in parallel with the findings of Hanchinamani (2003), Anandhi and Oommen (2007), Girish (2011) and Jitender *et al.* (2014).

High heritability coupled with high genetic advance over mean was recorded for number of dry pods per plant. It indicates that this is mainly due to additive gene effects and selection is rewarding in this character. These results are in conformity with the results of Kumar *et al.* (2009) in cowpea (Fig. 4).

Moderate to high genetic advance over mean was observed in dry pod yield per plant and seed yield per plant. These findings are in agreement with the findings of Selvam *et al.* (2000) in cowpea. Moderate to low genetic advance over mean was observed for hundred seed weight. These results are parallel with the findings of Girish *et al.* (2011) and Mital *et al.* (1968).



**Fig. 4. PCV, GCV,  $h^2$  and genetic advance as per cent of mean for seed parameters in cluster bean**

## **5.2 Correlation studies**

### **5.2.1 Correlation studies for vegetable pod, seed yield and its component characters**

Variability studies provide information on the extent of improvement possible in different characters, but they do not throw light on the extent and nature of relationship existing between yield and various contributory characters. As a rational approach for the improvement of yield, selection has to be made for components of yield, since there may not be gene for yield per se but for various yield components. Further, many of these yield contributing characters are interacted in desirable and undesirable direction. Hence, a knowledge regarding the association of various characters among themselves and with economic characters is necessary for making indirect selection for improvement of economic characters. Character association or correlation is a measure of the degree of association between two characters.

The phenotypic correlations indicate the extent of the observed relationship between two characters. This does not give true genetic picture of the relationship because it includes hereditary as well as environmental influences. Genotypic correlation provides an estimate of inherent association between genes controlling any two characters. Hence, it is of greater significance and could be effectively utilized in formulating an effective selection scheme. Therefore, in the present study, the genotypic and phenotypic correlation coefficients were worked out in cluster bean for vegetable pod yield and its components, seed yield and its component characters. A narrow difference between genotypic correlation and phenotypic correlation was observed for most of the characters, indicating that inherent association between these two characters genetically, but the phenotypic value is lessened by the significant interaction of environment. These results are similar with the results of Hanchinamani (2003) and Girish *et al.* (2012).

Plant height at 90 DAS exhibited significant and positive correlation with plant spread (East-West) at 90 DAS, number of pods per plant, number of pods per cluster and pod yield per plot at both the levels. These findings are in agreement with Singh *et al.* (2002), Hanchinamani (2003) and Girish *et al.* (2012). It also had highly significant and

negative correlation with hundred seed weight and significant with fifty per cent flowering.

Number of branches per plant at 90 DAS had highly significant and positive correlation with plant spread (North-South) at 90 DAS, plant spread (East-West) at 60 DAS, number of pods per plant , number of pods per cluster , number of clusters per plant and pod yield per plot at both genotypic and phenotypic levels. Whereas, it exhibited significant negative correlation with pod length. These results are confirmed with results of Hanchinamani (2003) and Singh *et al.* (2004).

Pod length showed significant correlation with plant height at 90 DAS, pod yield per plot, number of dry pods per plant and number of seeds per pod. It showed negative significant correlation with plant height at 60 DAS, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North-South) at 90 DAS and hundred seed weight. Similar results were observed by Singh *et al.* (2002), Hanchinamani (2003) and Saini *et al.* (2010).

Pod yield per plant exhibited significant correlation with plant height at 90 DAS, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North-South) at 60 DAS, plant spread (North- South) at 90 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, number of pods per plant, number of pods per cluster and number of clusters per plant, pod yield per plot, number of dry pods per plant, dry pod yield per plant and seed yield per plant. However, it showed negative significant correlation with first flowering, fifty per cent flowering, days taken for first vegetable pod harvest and hundred seed weight. These results are in conformity with findings of Girish *et al.* (2012).

Correlation coefficient analysis revealed that seed yield per plant had significant correlation number of branches at 60 DAS, plant spread (East-West) at 60 DAS, number of pods per plant, number of clusters per plant, pod yield per plant, pod yield per plot, number of dry pods per plant, dry pod yield per plant, number of seeds per pod, hundred seed weight and negatively correlated with first flowering, fifty per cent flowering and

days taken for first vegetable pod harvest. These results are in accordance with the results of Ahmed and Kamaluddin (2013), Girish *et al.* (2012) in cluster bean and Kumari *et al.* (2010) in cowpea.

Positive and significant association was found between the important characters. Number of pods per plant with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (North- South) at 90 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, number of pods per cluster, number of clusters per plant, pod yield per plot, number of dry pods per plant and dry pod yield per plant and seed yield per plant. Number of pods per cluster with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (North- South) at 90 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, number of pods per plant, number of clusters per plant, pod yield per plot and number of dry pods per plant. Number of clusters per plant with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (North- South) at 90 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, number of pods per plant, number of clusters per plant, pod yield per plot and number of dry pods per plant. Number of dry pods per plant with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, pod length, number of pods per plant, number of pods per cluster, number of clusters per plant, pod yield per plant, pod yield per plot, dry pod yield per plant and seed yield per plant. Dry pod yield per plant with plant height at 90 DAS, plant spread (North- South) at 90 DAS, fifty per cent flowering, days taken for first vegetable pod harvest, number of pods per plant, pod yield per plant, pod yield per plot, number of dry pods per plant, seed yield per plant and number of seeds per pod. The significant  $r$  values indicating that the association between two characters is high. Increase in one variable will also increase other variables and vice versa. These results were similar with the results of Kousar *et al.* (2007) in mung

bean, Saini *et al.* (2010), Hanchinamani (2003), Girish *et al.* (2012) in cluster bean and Vijay *et al.* (1980) in cowpea.

Whereas, these traits had negative association like number of pods per plant with first flowering, fifty per cent flowering, days taken for first vegetable pod harvest and hundred seed weight. Number of pods per cluster with fifty per cent flowering, days taken for first vegetable pod harvest and hundred seed weight. Number of clusters per plant with first flowering, fifty per cent flowering and hundred seed weight. Number of dry pods per plant with days taken for first vegetable pod harvest, fifty per cent flowering and hundred seed weight. Dry pod yield per plant with hundred seed weight. It indicates that as the early flowering and maturity occurs, there will be decrease in other component characters. These results are similar with the findings of Singh *et al.* (2005) and Hanchinamani (2003).

### **5.2.2 Path analysis**

Path analysis by Dewey and Lu (1959) gives cause and effect relationship critically breaking up different direct and indirect effects which finally make up correlation coefficient.

Though correlation analysis indicates the association pattern of the component traits with yield, they simply represent the overall influence of a particular trait on yield rather than providing cause and effect relationship. The path analysis as suggested by Dewey and Lu (1959) helps to resolve these correlations further and throw more light on the way in which the component traits interact to influence yield. This enables the breeders to specifically identify important component traits of yield and utilize the genetic stock for improvement in planned way. In the present study, path coefficient analysis between the components of vegetable pod yield in cluster bean was worked out.

Path analysis at genotypic level revealed that vegetable pod yield per plant was directly influenced by pod yield per plot, dry pod yield per plant and number of branches at 90 DAS. Hence, selection for any of these independent traits leads to improving the genotypes for vegetable pod yield per plant.

The importance of vegetable pod yield per plant has been highlighted by Girish (2011), Ramnath and Saini (1980) and Patel and Choudari (2001). The path analysis confirms the earlier studies that pod yield per plot, dry pod yield per plant and numbers of branches at 90 DAS are important traits that contribute to the vegetable pod yield per plant.

At genotypic level, days taken for fifty per cent flowering had negative direct effect on vegetable yield per plant and it showed positive indirect contribution towards yield through plant spread (North-South) at 60 DAS and yield per plot. Similarly, seed yield per plant and plant height at 90 DAS had negative direct effect with pod yield per plant. It showed positive indirect contribution towards yield through plant spread (North-South) at 60 DAS and days taken for first vegetable pod harvest. Hundred seed weight and fifty per cent flowering also contributed indirectly through plant height at 90 DAS. This is mainly due to indirect effect of flowering traits with their component traits.

Vegetable pod yield per plant at genotypic level had significant association with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (North- South) at 90 DAS, plant spread (East- West) at 60 DAS, plant spread (East- West) at 90 DAS, pod yield per plot, dry pod yield per plant and seed yield per plant. Negative correlation was also observed with first flowering, fifty per cent flowering, days taken for first vegetable pod harvest and hundred seed weight. It indicates that the correlation is mainly due to both direct and indirect effects. Hence, direct and indirect selection for these traits would reward for improvement of yield.

In phenotypic level, vegetable pod yield per plant had positive direct effect with pod yield per plot, plant spread (North – South) at 90 DAS and number of branches at 90 DAS. Therefore, selection of these independent traits can improve the vegetable pod yield per plant. These results are in conformity with the findings of Girish (2011) and Ramnath and Saini (1980).

The negative direct effects were through hundred seed weight, plant spread (East-West) at 90 DAS followed by plant spread (North –South) at 60 DAS. Hundred seed weight had positive indirect effect *via* plant height at 90 DAS, plant spread (North-South) at 60 DAS. Plant spread (East – West) at 90 DAS *via* hundred seed weight and number of seeds per pod. Hundred seed weight and fifty per cent flowering also contributed indirectly through plant spread (North –South) at 60 DAS.

Vegetable pod yield per plant at phenotypic level had significant association with plant height at 90 days, number of branches at 60 DAS, number of branches at 90 DAS, plant spread (North- South) at 60 DAS, plant spread (North- South) at 90 DAS, pod yield per plot, dry pod yield per plant and seed yield per plant. While, negative correlation was observed with first flowering, fifty per cent flowering and hundred seed weight. It indicates that correlation is mainly due to direct effect of the traits and it reveals the true relationship between them and direct selection for such traits will be effective for further improvement.

From the present path analysis study in cluster bean, may be concluded that improvement in vegetable pod yield per plant could be brought by selection for component characters like pod yield per plot, dry pod yield per plant and number of branches at 90 DAS.

The very low residual effect obtained in the present study indicating that much of the variation in yield has been accounted and that the choice of the characters was correct and needs further consideration. From the above, it could be summarized that both vegetative and yield attributing character were not much contributing to the yield and therefore may be considered carefully to construct indices for selection of the superior genotypes.

### **5.3 Genetic Divergence**

The Success of a breeding programme depends upon the selection of parents. It has been found that the progenies derived from crossing divergent parents give divergent and useful progenies. The  $D^2$  analysis proposed by Mahalanobis (1928) has been reported

to be an effective tool to assess the genetic divergence. Such an analysis eventually helps to choose desirable parents for recombination breeding and thus results in the development of superior varieties.

Quantification of genetic diversity existing within and between groups of germplasm is important and particularly useful in proper choice of parents for realising higher heterosis and obtaining useful recombinants.  $D^2$  Statistics is a unique method for disseminating populations considering a set of parameters together rather than inferring from indices based upon morphological similarities: eco-geographical diversity and phylogenetic relationships.

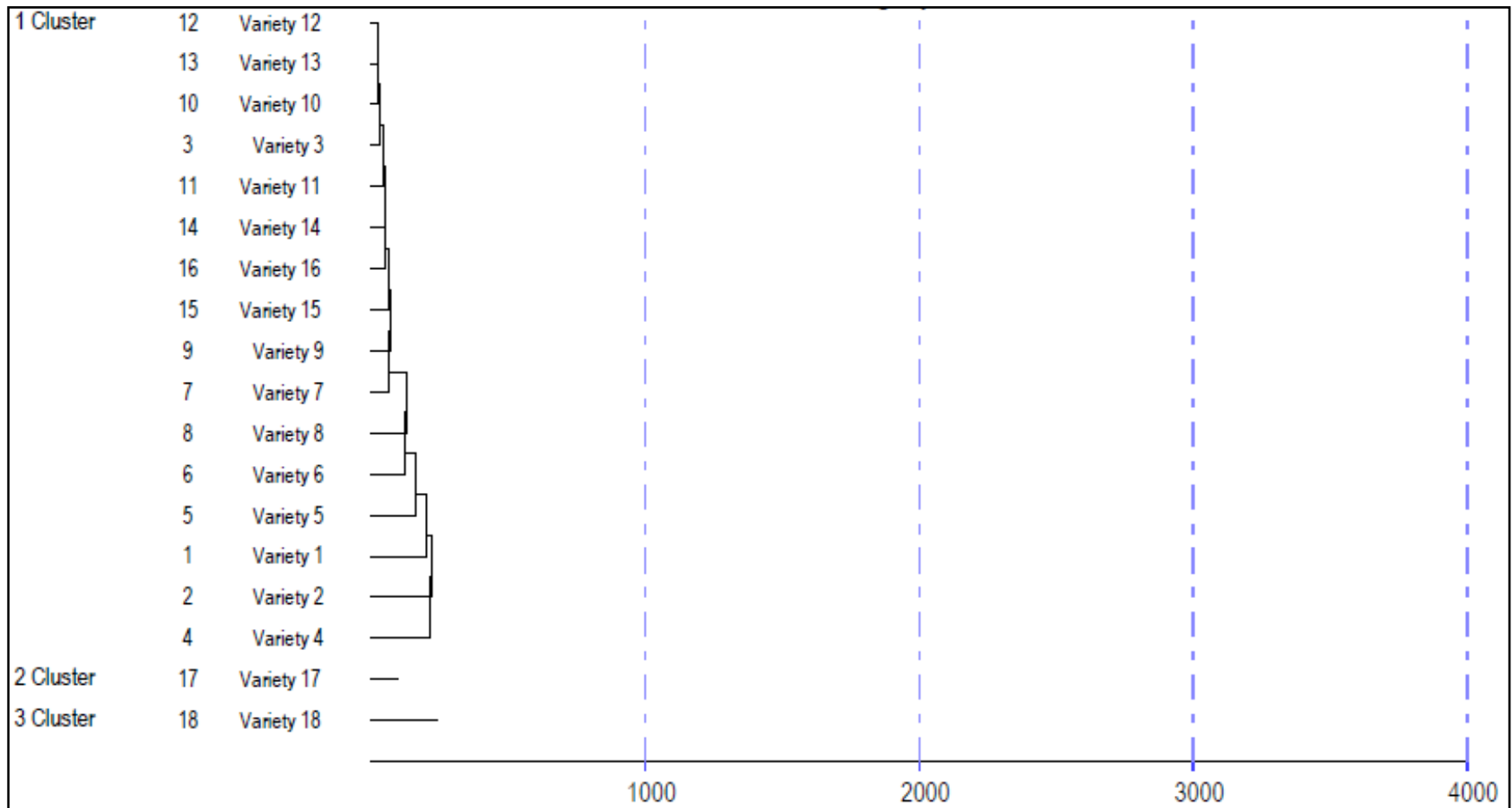
### **5.3.1 Generalized distance**

Based on  $D^2$  values eighteen cluster bean genotypes were grouped into 3 clusters, 16 genotypes in cluster I and one genotype each in clusters II and III. The formation of solitary clusters may be due to total isolation preventing the gene flow or intensive human selection for diverse adaptive complexes (Fig. 5).

The eighteen genotypes were grouped into three clusters and had high range of  $D^2$  values ranging between 0.00 to 1479.25. For genetic diversity geographical diversity is not an index, which is observed by clustering pattern. This concludes that clustering pattern is because of the maximum differences in characters contributing towards diversity. This is confirmed by observing the present eighteen genotypes which are collected from different sources are grouped under different clusters.

Maximum contribution of characters towards total diversity was by dry pod yield per plant followed by number of dry pods per plant and seed yield per plant. This indicates that these are the important characters contributing to diversity. These results are in accordance with findings of Basavarajappa and Gowda (2000) in mung bean, Henry *et al.* (1984) and Shanmugam (1983).

Among the three clusters, cluster I with 16 number of genotypes showed maximum intra cluster distance ( $D^2=385.39$ ) revealed that the presence of divergence in



**Fig. 5. Tocher's method of clustering pattern in cluster bean genotypes**

cluster I. Based on distance between clusters (inter-cluster distance), the maximum divergence was observed between cluster I and III ( $D^2=1479.25$ ) indicated that the cluster I comprised of 16 genotypes which are highly divergent from cluster III, which includes one genotype. Selection of genotypes is recommended from the clusters which shows higher inter cluster distance with higher yielding genotypes as parents in recombination breeding programmes for obtaining desirable segregants. These results are similar with the findings of Rai *et al.* (2013).

The characters like plant height at 90 DAS, chlorophyll content, days taken for first vegetable pod harvest, pod length, number of pods per plant, pod yield per plant, pod yield per plot, number of dry pods per plant, dry pod yield per plant and seed yield per plant had higher cluster mean values in cluster III followed cluster I which includes the characters such as number of branches per plant at 90 DAS, plant spread (North –South) at 90 DAS, plant spread (East –West) at 90 DAS, number of pods per cluster and number of clusters per plant. However, in cluster II had lower mean values for plant spread (North-South) at 90 DAS, days taken for first flowering and days taken for first vegetable pod harvest.

From the results it suggest that parameters like number of branches per plant at 90 DAS, plant spread (North –South) at 90 DAS, plant spread (East –West) at 90 DAS, number of pods per cluster and number of clusters per plant are most reliable for selection of genotypes for further improvement. Similar, results were obtained by Rai *et al.* (2013).

### **Salient features of investigation**

1. There was wide range of variability for growth characters like number of branches at 60 and 90 DAS. Whereas, in yield characters like number of pods per plant, number of clusters per plant, pod yield, number of dry pods per plant and dry pod yield per plant. Therefore, such genotypes having high variability for these traits can be used for future crop improvement programme.
2. Path analysis revealed that pod yield per plot and plant spread North-South at 90 DAS had highest positive effect and also had significant association with vegetable yield at both genotypic and phenotypic levels.
3. Dry pod yield per plant and number of dry pods per plant, seed yield per plant and pod yield per plant contributed highest for genetic diversity. Highest inter cluster mean was found in cluster I and III. So genotypes present in these cluster will provide chances of selecting highly divergent parents.

### **Future line of work**

1. Highly divergent genotypes can be utilized for heterosis breeding programme.
2. Identified high yielding genotypes could be tested over different locations and seasons for their yield and stability.
3. Mutation and hybridization breeding programme can be taken up to create desirable variability in cluster bean.
4. Screening of genotypes for incidence of pest and disease has to be taken up.

# **SUMMARY**

## VI. SUMMARY

The principle objective of the present investigation was to study and highlight genetic variability and diversity present among different cluster bean genotypes collection and to know the association between different quantitative characters. The study was undertaken during summer 2014 at College of Horticulture, Mudigere by following Randomised Complete Block Design (RCBD). The data obtained on 33 various characters were subjected to statistical analysis for elucidating the information on genetic variation existing for different component characters of vegetable pod yield and seed yield. The genetic variation was assessed by using parameters like genotypic and phenotypic coefficient of variation, heritability and genetic advance over mean (GAM). The inter character correlation and path analysis were also worked out to know the relationship of different characters with vegetable pod and seed yield. The 18 cluster bean genotypes were subjected to  $D^2$  Statistics to assess the genetic divergence. The salient findings of the investigation are summarized here under.

Analysis of variance revealed highly significant difference among the accessions for all the quantitative characters studied. Among growth parameters, high estimates of GCV and PCV were found for number of branches at 90 and 60 DAS and chlorophyll content. Narrow difference between GCV and PCV were observed indicating that these are least affected by the environment.

High GCV and PCV values were observed for number of vegetable pods per plant, number of clusters per plant, pod yield, number of dry pods per plant and dry pod yield per plant were high and indicating the presence of wide variability in the genotype.

GCV and PCV estimates were moderate for plant height both at 60 DAS, whereas, leaf area and plant spread North-South at 30 DAS showed very low estimates of PCV and GCV. This indicated low variability in the genotype stock which necessitating generation of new variability for these characters. Days to first flowering, days to fifty per cent flowering, days taken to first vegetable pod harvest, number of seeds per pod

and hundred seed weight showed very narrow difference between GCV and PCV indicates that these are least affected by the environment and are stable.

High heritability and high genetic advance as per cent of mean was recorded for all the growth characters except plant height at 60 DAS, plant spread (North –South) at 30 DAS, number of leaves at 60 DAS, 90 DAS and leaf area indicating the predominance of additive gene action for the expression of these characters.

Among the vegetable and seed parameters, high heritability and high genetic advance as per cent of mean were recorded for number of vegetable pods per plant, number of clusters per plant, number of pods per cluster, number of dry pods per plant, vegetable pod yield, dry pod yield and seed yield per plant which indicated the predominance of additive genes in expression of these traits.

Moderate heritability and low genetic advance over per cent mean were recorded for leaf area, days taken for first vegetable maturity and hundred seed weight which indicated the predominance of additive gene action in expression of these traits.

Correlation studies revealed that highly significant and positive association of vegetable pod yield per plant with plant height at 90 DAS, number of branches at 90 DAS, plant spread (North-South) at 60 and 90 DAS, plant spread (East-West) at 90 DAS, number of pods per plant, number of pods per cluster, number of cluster per plant, number of dry pods per plant, dry pod yield per plant and seed yield per plant. Whereas, vegetable pod yield per plant had negative and highly significant correlation with first flowering, fifty per cent flowering and hundred seed weight.

Path analysis for vegetable pod yield per plant revealed that plant height at 90 DAS, number of branches at 90 DAS, plant spread (North-South) at 60 and 90 DAS, plant spread (East-West) at 90 DAS, pod yield per plot, dry pod yield per plant and seed yield per plant are being chief contributing characters for yield at both genotypic and phenotypic levels. Thus, these characters deserve weightage during selection.

$D^2$  statistics helped in grouping of eighteen cluster bean genotypes into 3 distinct clusters. The cluster I consisted of 16 genotypes followed by Cluster II and cluster III with one genotype each. Cluster I showed maximum intra cluster distance ( $D^2 = 385.39$ ).

Inter cluster distance revealed the maximum divergence between clusters I and III ( $D^2= 1479.25$ ) followed by clusters I and II ( $D^2= 766.71$ ) and was least between clusters II and III (674.61). Select genotypes from the clusters showed higher inter cluster distance with higher pod yield as parents in recombination breeding programmes for obtaining desirable segregants. Among the characters studied, dry pod yield per plant contributed maximum to the genetic diversity followed by number of dry pods per plant, seed yield per plant and number of pods per plant.

It was evident from the study that considerable degree of variability exists among the genotypes for vegetable pod yield and its component characters. The most promising genotypes for vegetable pod yield were Gokak local, HG-04-875, AVT-II GR-2, CAZ-G-06, RGC -986 and Pusa Navbahar. Genotypes like Pusa Navbahar, AVT-II GR-3 and AVT-II GR-2 were found early in flowering.

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## VII. REFERENCES

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\*Originals not seen.

# **APPENDICES**

## APPENDIX- I

Monthly mean meteorological data recorded during the experimental period at ZAHRS, Mudigere during summer season

| Month        | Rainfall (mm) | Temperature ( <sup>0</sup> C) |         | Relative humidity (%) |
|--------------|---------------|-------------------------------|---------|-----------------------|
|              |               | Maximum                       | Minimum |                       |
| January 2014 | Nil           | 26.90                         | 14.62   | 63.25                 |
| February     | Nil           | 27.12                         | 15.16   | 60.53                 |
| March        | Nil           | 32.0                          | 18.5    | 68                    |
| April        | 188.7         | 31.41                         | 18.78   | 78.9                  |
| May          | 265.6         | 31.53                         | 18.53   | 74.54                 |
| June         | 306.4         | 28.25                         | 17.8    | 73.6                  |
| July         | 1185.4        | 26.40                         | 17.19   | 72.38                 |
| August       | 542.6         | 26.29                         | 17.35   | 88.22                 |
| September    | 365.4         | 27.41                         | 18.75   | 90.63                 |
| October      | 88            | 26.46                         | 18.01   | 81.70                 |
| November     | 12            | 26.96                         | 17.41   | 73.46                 |
| December     | 19            | 26.80                         | 14.91   | 74.29                 |

## APPENDIX-II

**Soil physical and chemical properties at experimental site, College of Horticulture,  
Mudigere during 2014-15**

| Particulars                   | Values | Method adopted                                             |
|-------------------------------|--------|------------------------------------------------------------|
| <b>Physical properties</b>    |        |                                                            |
| Coarse sand (%)               | 44.3   | International pipette method (Piper, 1966)                 |
| Fine sand (%)                 | 23.4   |                                                            |
| Silt (%)                      | 18.6   |                                                            |
| Clay (%)                      | 20.1   |                                                            |
| <b>Chemical properties</b>    |        |                                                            |
| Available nitrogen (kg/ha)    | 150.3  | Alkaline permanganate method<br>(Subbaiah and Asija, 1956) |
| Available phosphorus (kg/ ha) | 23.7   | Bray's Extractant No-1 method<br>(Jackson,1967)            |
| Available potassium (kg /ha)  | 126.1  | Neutral Normal Ammonium Acetate<br>method (Jackson, 1967)  |
| Organic carbon (%)            | 0.89   | (Black 1965)                                               |
| Soil pH                       | 5.30   | PH meter (Jackson, 1967)                                   |
| EC ds/m at 250 C              | 0.17   | Conductivity bridge (Jackson, 1967)                        |
| Exchangeable Calcium          | 14.00  | EDTA Versenate Titration method<br>(Black, 1965)           |
| Exchangeable Magnesium        | 8.03   | EDTA Versenate Titration method<br>(Black, 1965)           |
| Available Sulphur             | 7.50   | Turbidometric method (Bardsley and<br>Lancaster, 1960)     |

**Appendix III. *Per se* performance of cluster bean genotypes for growth characters**

| Genotypes     | Plant height (cm) |        |        | Number of branches per plant |        | Number of leaves per plant |        |        | Plant spread North-South (cm) |        |        | Plant spread East – West (cm) |        |         | Leaf Area (cm <sup>2</sup> ) | Leaf Area Index | Chlorophyll content (mg/g) |
|---------------|-------------------|--------|--------|------------------------------|--------|----------------------------|--------|--------|-------------------------------|--------|--------|-------------------------------|--------|---------|------------------------------|-----------------|----------------------------|
|               | 30 DAS            | 60 DAS | 90 DAS | 60 DAS                       | 90 DAS | 30 DAS                     | 60 DAS | 90 DAS | 30 DAS                        | 60 DAS | 90 DAS | 30 DAS                        | 60 DAS | 90 DAS  |                              |                 |                            |
| AVT-II GR-3   | 14.170            | 31.850 | 48.500 | 3.500                        | 4.900  | 13.300                     | 64.600 | 73.900 | 9.200                         | 20.700 | 28.650 | 10.950                        | 21.200 | 32.600  | 34.120                       | 1.325           | 3.585                      |
| HG-3-100      | 11.500            | 30.800 | 56.100 | 3.350                        | 5.375  | 12.000                     | 58.400 | 78.400 | 9.950                         | 31.600 | 67.800 | 7.300                         | 28.200 | 67.900  | 39.820                       | 2.400           | 1.855                      |
| AVT-II GR-I   | 10.390            | 30.000 | 59.600 | 3.500                        | 7.000  | 18.200                     | 68.300 | 79.000 | 7.320                         | 22.400 | 41.000 | 7.450                         | 25.500 | 45.600  | 33.480                       | 2.110           | 3.800                      |
| CAZ-G-06      | 12.250            | 42.200 | 76.500 | 4.500                        | 9.500  | 13.800                     | 64.400 | 74.000 | 10.000                        | 26.200 | 75.500 | 8.750                         | 25.550 | 74.000  | 34.470                       | 1.845           | 4.265                      |
| HG-04-875     | 12.200            | 44.000 | 84.000 | 6.000                        | 13.000 | 6.800                      | 66.500 | 81.600 | 8.950                         | 29.700 | 94.700 | 7.840                         | 26.400 | 100.700 | 34.460                       | 2.340           | 3.860                      |
| AVT-II GR-2   | 14.850            | 36.350 | 76.000 | 5.200                        | 12.000 | 7.700                      | 69.500 | 81.000 | 10.200                        | 43.800 | 71.800 | 12.200                        | 31.500 | 61.100  | 34.800                       | 2.015           | 4.440                      |
| RGC -986      | 15.350            | 32.400 | 79.100 | 6.000                        | 11.500 | 9.700                      | 65.900 | 74.500 | 10.970                        | 40.100 | 81.300 | 11.100                        | 31.700 | 50.500  | 34.530                       | 1.805           | 2.125                      |
| Gokak Local   | 11.260            | 32.350 | 67.500 | 7.500                        | 15.000 | 9.100                      | 64.400 | 71.500 | 8.900                         | 31.000 | 64.300 | 8.100                         | 30.300 | 45.000  | 37.940                       | 2.030           | 4.050                      |
| AVT-I GR-9    | 13.500            | 39.000 | 72.200 | 5.000                        | 10.000 | 5.800                      | 54.200 | 61.500 | 8.220                         | 36.200 | 67.700 | 6.530                         | 25.900 | 73.700  | 42.530                       | 1.920           | 3.530                      |
| AVT-II GR-6   | 11.450            | 41.750 | 88.500 | 4.500                        | 9.500  | 12.000                     | 62.100 | 62.500 | 7.600                         | 23.100 | 65.900 | 5.810                         | 27.500 | 78.600  | 35.320                       | 1.825           | 4.225                      |
| AVT-I GR-14   | 8.810             | 34.000 | 58.200 | 3.300                        | 6.325  | 9.500                      | 65.125 | 75.500 | 6.850                         | 29.550 | 62.600 | 4.960                         | 35.375 | 62.300  | 36.050                       | 2.100           | 3.050                      |
| AVT- I GR-24  | 8.340             | 40.700 | 61.000 | 4.700                        | 5.600  | 13.000                     | 60.375 | 66.500 | 7.290                         | 23.800 | 47.100 | 6.860                         | 22.600 | 57.400  | 37.780                       | 2.345           | 4.050                      |
| IVT-I GR-23   | 7.660             | 42.500 | 66.500 | 4.050                        | 6.500  | 9.900                      | 61.000 | 84.500 | 5.963                         | 15.850 | 43.500 | 6.255                         | 14.750 | 48.150  | 39.605                       | 2.775           | 2.420                      |
| IVT-I GR-21   | 4.395             | 45.300 | 60.500 | 4.600                        | 5.250  | 5.100                      | 31.125 | 49.500 | 5.025                         | 20.750 | 41.875 | 5.625                         | 23.625 | 64.000  | 37.450                       | 0.820           | 3.540                      |
| AVT-I GR-13   | 6.930             | 32.800 | 47.500 | 3.700                        | 7.500  | 8.700                      | 58.550 | 69.000 | 6.900                         | 23.800 | 85.000 | 7.470                         | 21.400 | 53.400  | 36.780                       | 1.275           | 1.480                      |
| IVT-I GR-20   | 6.390             | 35.800 | 52.465 | 3.500                        | 5.200  | 9.200                      | 46.000 | 55.500 | 4.890                         | 22.833 | 62.300 | 5.960                         | 25.467 | 49.100  | 37.980                       | 1.295           | 1.245                      |
| AVT-I GR-15   | 6.110             | 30.800 | 67.400 | 3.700                        | 4.600  | 6.700                      | 32.400 | 41.000 | 5.050                         | 21.500 | 62.500 | 4.900                         | 20.167 | 43.800  | 43.370                       | 1.165           | 1.440                      |
| Pusa Navbahar | 8.850             | 31.000 | 90.000 | 0.000                        | 0.000  | 5.400                      | 35.000 | 45.000 | 7.230                         | 28.100 | 33.800 | 6.310                         | 23.000 | 51.200  | 34.985                       | 0.890           | 3.300                      |
| S.Em ±        | 1.06              | 2.90   | 3.90   | 0.59                         | 1.10   | 1.41                       | 6.86   | 7.48   | 1.07                          | 3.56   | 8.68   | 0.82                          | 2.16   | 6.70    | 1.77                         | 0.21            | 0.36                       |
| C.D (5%)      | 3.19              | 8.65   | 11.63  | 1.78                         | 3.30   | 4.20                       | 20.47  | 22.31  | 3.21                          | 10.63  | 25.92  | 2.47                          | 6.46   | 20.00   | 5.30                         | 0.64            | 1.09                       |
| C.D (1%)      | 4.38              | 11.89  | 15.98  | 2.45                         | 4.53   | 5.77                       | 28.12  | 30.66  | 4.42                          | 14.61  | 35.60  | 3.39                          | 8.88   | 27.47   | 7.28                         | 0.88            | 1.49                       |

**DAS : Days After Sowing**

**Appendix IV. *Per se* performance of cluster bean genotypes for vegetable pod yield characters**

| <b>Genotypes</b> | <b>Days to 1<sup>st</sup> flowering</b> | <b>Days to 50% flowering</b> | <b>Days taken for first vegetable pod harvest</b> | <b>Cluster length (cm)</b> | <b>Pod Length (cm)</b> | <b>Number of pods / plant</b> | <b>Number of Pods /cluster</b> | <b>Number of Cluster / plant</b> | <b>Pod yield (g) / plant</b> | <b>Pod yield (kg) / plot</b> | <b>Pod yield (q) / ha</b> |
|------------------|-----------------------------------------|------------------------------|---------------------------------------------------|----------------------------|------------------------|-------------------------------|--------------------------------|----------------------------------|------------------------------|------------------------------|---------------------------|
| AVT-II GR-3      | 31.400                                  | 32.800                       | 43.200                                            | 7.450                      | 5.200                  | 56.500                        | 4.100                          | 10.900                           | 63.500                       | 1.225                        | 30.625                    |
| HG-3-100         | 32.500                                  | 32.800                       | 41.400                                            | 6.650                      | 5.610                  | 96.000                        | 7.500                          | 12.500                           | 72.000                       | 1.385                        | 34.625                    |
| AVT-II GR-I      | 31.600                                  | 32.500                       | 41.400                                            | 7.500                      | 5.350                  | 54.000                        | 5.000                          | 7.500                            | 65.000                       | 1.260                        | 31.500                    |
| CAZ-G-06         | 33.000                                  | 34.100                       | 43.800                                            | 6.500                      | 4.560                  | 109.000                       | 6.500                          | 16.500                           | 101.000                      | 1.925                        | 48.125                    |
| HG-04-875        | 32.000                                  | 33.100                       | 43.500                                            | 6.100                      | 5.050                  | 112.700                       | 8.300                          | 17.000                           | 110.500                      | 2.150                        | 53.750                    |
| AVT-II GR-2      | 31.400                                  | 32.100                       | 44.100                                            | 6.350                      | 5.000                  | 112.500                       | 8.500                          | 15.500                           | 103.000                      | 2.040                        | 51.000                    |
| RGC -986         | 31.800                                  | 32.500                       | 44.100                                            | 6.750                      | 4.470                  | 100.000                       | 6.800                          | 13.000                           | 92.000                       | 1.750                        | 43.750                    |
| Gokak Local      | 33.500                                  | 33.900                       | 43.000                                            | 8.500                      | 5.410                  | 109.000                       | 8.500                          | 9.700                            | 112.500                      | 2.190                        | 54.750                    |
| AVT-I GR-9       | 34.500                                  | 35.100                       | 40.700                                            | 6.250                      | 4.900                  | 93.100                        | 7.200                          | 11.500                           | 88.500                       | 1.700                        | 42.500                    |
| AVT-II GR-6      | 34.600                                  | 35.100                       | 44.300                                            | 7.100                      | 6.250                  | 71.500                        | 7.250                          | 10.000                           | 79.500                       | 1.555                        | 38.875                    |
| AVT-I GR-14      | 33.500                                  | 34.100                       | 43.100                                            | 6.550                      | 5.200                  | 57.500                        | 5.900                          | 7.500                            | 55.000                       | 1.045                        | 26.125                    |
| AVT- I GR-24     | 34.600                                  | 35.400                       | 44.700                                            | 7.050                      | 5.000                  | 64.550                        | 4.500                          | 9.000                            | 63.000                       | 1.225                        | 30.625                    |
| IVT-I GR-23      | 34.300                                  | 34.800                       | 44.700                                            | 8.950                      | 5.200                  | 59.100                        | 5.500                          | 9.100                            | 61.500                       | 1.150                        | 28.750                    |
| IVT-I GR-21      | 35.200                                  | 35.800                       | 43.600                                            | 6.300                      | 3.750                  | 27.165                        | 3.500                          | 4.700                            | 30.000                       | 0.580                        | 14.500                    |
| AVT-I GR-13      | 34.100                                  | 35.100                       | 46.500                                            | 6.100                      | 5.020                  | 33.000                        | 5.500                          | 8.000                            | 49.000                       | 0.925                        | 23.125                    |
| IVT-I GR-20      | 33.400                                  | 35.000                       | 45.100                                            | 6.200                      | 4.650                  | 17.800                        | 3.300                          | 3.700                            | 26.000                       | 0.475                        | 11.875                    |
| AVT-I GR-15      | 34.100                                  | 35.000                       | 43.000                                            | 7.700                      | 5.710                  | 29.900                        | 5.500                          | 7.300                            | 58.500                       | 1.110                        | 27.750                    |
| Pusa Navbahar    | 31.400                                  | 31.900                       | 44.700                                            | 7.100                      | 6.500                  | 84.000                        | 4.000                          | 8.000                            | 89.000                       | 1.755                        | 43.875                    |
| S.Em±            | 0.42                                    | 0.54                         | 0.86                                              | 0.49                       | 0.37                   | 5.98                          | 0.67                           | 1.01                             | 6.65                         | 0.12                         | 3.22                      |
| C.D (5%)         | 1.25                                    | 1.62                         | 2.59                                              | 1.47                       | 1.11                   | 17.84                         | 2.00                           | 3.04                             | 19.85                        | 0.38                         | 9.62                      |
| C.D (1%)         | 1.72                                    | 2.23                         | 3.56                                              | 2.02                       | 1.53                   | 24.51                         | 2.75                           | 4.17                             | 27.26                        | 0.52                         | 13.22                     |

**Appendix V. *Per se* performance of cluster bean genotypes for seed yield characters**

| <b>Genotypes</b> | <b>Number of dry pod / plant</b> | <b>Dry yield (g) / plant</b> | <b>Number of seeds / pod</b> | <b>100 seed weight (g)</b> | <b>Seed yield (g) / plant</b> |
|------------------|----------------------------------|------------------------------|------------------------------|----------------------------|-------------------------------|
| AVT-II GR-3      | 50.100                           | 64.300                       | 7.835                        | 3.495                      | 38.700                        |
| HG-3-100         | 109.700                          | 44.500                       | 7.300                        | 3.350                      | 28.000                        |
| AVT-II GR-I      | 55.000                           | 56.250                       | 9.000                        | 3.480                      | 40.750                        |
| CAZ-G-06         | 105.400                          | 77.500                       | 7.320                        | 3.225                      | 43.500                        |
| HG-04-875        | 86.900                           | 64.650                       | 8.000                        | 3.330                      | 35.000                        |
| AVT-II GR-2      | 85.700                           | 74.150                       | 7.800                        | 3.385                      | 38.750                        |
| RGC -986         | 33.900                           | 32.500                       | 7.600                        | 3.350                      | 25.500                        |
| Gokak Local      | 148.900                          | 101.150                      | 7.800                        | 3.355                      | 45.000                        |
| AVT-I GR-9       | 62.200                           | 67.050                       | 7.300                        | 3.325                      | 39.450                        |
| AVT-II GR-6      | 90.700                           | 59.500                       | 6.950                        | 3.500                      | 27.000                        |
| AVT-I GR-14      | 42.500                           | 59.750                       | 7.000                        | 3.380                      | 34.500                        |
| AVT- I GR-24     | 51.000                           | 67.125                       | 8.500                        | 3.875                      | 38.750                        |
| IVT-I GR-23      | 36.250                           | 35.500                       | 7.800                        | 3.445                      | 23.000                        |
| IVT-I GR-21      | 44.835                           | 64.750                       | 7.300                        | 3.645                      | 36.500                        |
| AVT-I GR-13      | 19.500                           | 23.000                       | 7.630                        | 3.700                      | 17.000                        |
| IVT-I GR-20      | 30.300                           | 35.500                       | 7.300                        | 3.650                      | 26.000                        |
| AVT-I GR-15      | 31.065                           | 57.000                       | 6.650                        | 3.660                      | 27.000                        |
| Pusa Navbahar    | 83.900                           | 89.500                       | 9.000                        | 3.170                      | 38.000                        |
| S.Em ±           | 8.67                             | 10.03                        | 0.33                         | 0.09                       | 4.27                          |
| C.D (5%)         | 25.88                            | 29.93                        | 1.00                         | 0.27                       | 12.76                         |
| C.D (1%)         | 35.55                            | 41.12                        | 1.38                         | 0.37                       | 17.53                         |