Studies on genetic diversity for yield, quality and yield attributing traits in cluster bean [Cyamopsis tetragonoloba (L.) Taub.] genotypes

Bakang K. Kgasudi¹, G. Kranthi Rekha², K. Uma Jyothi³ and K. Sasikala⁴

¹,²,³ Department of Vegetable Science
⁴Department of Agronomy
College of Horticulture, Dr YSR Horticultural University, Venkataramannagudem, West Godavari District- 534101, Andhra Pradesh, India
E-Mail: bkgasudi@gmail.com

Abstract
The study was carried out to assess the genetic divergence among 56 cluster bean genotypes using Mahalanobis $D^2$. Fifty-six genotypes were grouped into 8 clusters based on 11 characters. The intra-cluster distances were seen to be lower than the inter-cluster distances. The maximum inter-cluster distance was noticed between cluster VI and VII whereas, inter-cluster $D^2$ value was least between cluster I and V. The maximum intra-cluster distance was observed in cluster IV. Clusters V, VII and VIII had only one genotype each and hence intra-cluster distance was 0.00. The per cent contribution towards genetic diversity was maximum in 100 seed weight (52.08%) followed by the protein content of pods (45.19%). On the basis of inter-cluster distances observed, the genotypes with specific characters can be utilized for the hybridization programme.

Keywords
Genetic divergence, cluster bean, Mahalanobis $D^2$, cluster distance

Cluster bean [Cyamopsis tetragonoloba (L.) Taub] is a versatile, multipurpose and underexploited leguminous vegetable crop of the arid and semi-arid region belonging to the family Leguminosae. It is a drought-tolerant, hardy and deep-rooted summer annual legume cultivated for its green pods, fodder and manure. Although cluster bean is a minor crop due to its better and finer guar gum qualities, it is considered as an important cash crop for industrial gum production and for several pharmaceutical and nutraceutical products. It has been reported that the cultivated species C. tetragonoloba was developed from a drought-tolerant wild African species C. senegalensis (Mudgil et al., 2014), while Vavilov (1951) suggested India be the centre of variability for cluster bean. The crop is widely grown in countries like India, Pakistan, Indonesia and other parts of Southern and Southeastern Asia as a vegetable and fodder crop for a long time

Despite the importance of this crop, only limited breeding work has been done and very little attention has been given for its genetic improvement in the past, to enhance the productivity levels of Kharif cluster bean. Information on the nature and magnitude of genetic diversity present in the genotypes is a prerequisite. The availability of genetic diversity is essential for any crop improvement programme. The inclusion of diverse parents in hybridization programme serves the purpose of producing desirable recombinants. Multivariate analysis of Mahalanobis $D^2$ statistic is a powerful tool in quantifying the degree of divergence at the genotypic level. The grouping of the genotypes based on $D^2$ analysis will be useful in choosing suitable parental lines for heterosis breeding. (Rao, 1952). Therefore, an attempt in the present investigation was made to study the degree of genetic diversity in cluster bean genotypes.

An investigation was carried out at the College of Horticulture, Dr Y. S. R. Horticultural University, Venkataramannagudem, West Godavari district during the Kharif season of 2018 using 56 cluster bean genotypes (table 1). Genotypes were evaluated with two replications with the spacing of 45 cm x 15 cm. Optimum management
The analysis of variance showed significant differences among the genotypes for all 11 characters studied in 56 cluster bean genotypes. This suggested the presence of an appreciable amount of diversity among the genotypes under study. Fifty-six genotypes were grouped into eight clusters presented in Table 2. Cluster I was the largest with 33 genotypes followed by cluster III with eight genotypes, cluster IV with six genotypes, cluster II with four genotypes and cluster VI with 2 genotypes. Cluster V, cluster VII and cluster VIII were monogenotypic. Clustering between genetic diversity was in agreement with Singh et al. (2003), Pathak et al. (2009) and Girish et al. (2012). Cluster mean values of eleven characters are presented in Table 3. The highest mean for plant height (110.73 cm) was shown by cluster V, while the lowest was seen in cluster VII (75.81 cm). Cluster VII had the maximum cluster mean for the number of branches per plant (11.70) and cluster V and VI (0.00) had the minimum value. Cluster II exhibited the maximum mean value (6.04 cm) for internodal length and minimum value in VIII (4.50 cm). The minimum mean value for days to 50% flowering was seen in cluster IV (25.92) and maximum value in cluster V (29.00). Cluster V showed a maximum mean value for the number of branches per pod (0.00) and a minimum value in cluster II (7.53). The maximum mean value for an average weight of 50 pods was observed in cluster VI (173.50 g) and minimum mean value in cluster VIII (51.00 g). Maximum mean values for pod length was exhibited in cluster VI (10.35 cm). The minimum mean value was in cluster III and VII (6.25 cm).

Table 1. List of cluster bean genotypes used in the present study

| Treatment | Genotypes       | Source                  | Treatment | Genotypes       | Source                  |
|-----------|-----------------|-------------------------|-----------|-----------------|-------------------------|
| T1        | IC-113272       | NBPG, Jodhpur           | T24       | IC-116626       | NBPG, Jodhpur           |
| T2        | IC-113277       | NBPG, Jodhpur           | T25       | IC-113376       | NBPG, Jodhpur           |
| T3        | IC-113278       | NBPG, Jodhpur           | T26       | IC-113377       | NBPG, Jodhpur           |
| T4        | IC-113281       | NBPG, Jodhpur           | T27       | IC-113378       | NBPG, Jodhpur           |
| T5        | IC-113308       | NBPG, Jodhpur           | T28       | IC-116619       | NBPG, Jodhpur           |
| T6        | IC-113374       | NBPG, Jodhpur           | T29       | IC-116626       | NBPG, Jodhpur           |
| T7        | IC-113376       | NBPG, Jodhpur           | T30       | IC-116652       | NBPG, Jodhpur           |
| T8        | IC-113377       | NBPG, Jodhpur           | T31       | IC-116660       | NBPG, Jodhpur           |
| T9        | IC-113378       | NBPG, Jodhpur           | T32       | IC-116779       | NBPG, Jodhpur           |
| T10       | IC-113379       | NBPG, Jodhpur           | T33       | IC-116705       | NBPG, Jodhpur           |
| T11       | IC-113380       | NBPG, Jodhpur           | T34       | IC-116825       | NBPG, Jodhpur           |
| T12       | IC-113382       | NBPG, Jodhpur           | T35       | IC-116925       | NBPG, Jodhpur           |
| T13       | IC-113383       | NBPG, Jodhpur           | T36       | IC-116930       | NBPG, Jodhpur           |
| T14       | IC-113390       | NBPG, Jodhpur           | T37       | IC-116932       | NBPG, Jodhpur           |
| T15       | IC-113393       | NBPG, Jodhpur           | T38       | IC-384974       | NBPG, Jodhpur           |
| T16       | IC-113394       | NBPG, Jodhpur           | T39       | IC-384986       | NBPG, Jodhpur           |
| T17       | IC-113395       | NBPG, Jodhpur           | T40       | IC-522399       | NBPG, Jodhpur           |
| T18       | IC-113396       | NBPG, Jodhpur           | T41       | IC-522399       | NBPG, Jodhpur           |
| T19       | IC-113399       | NBPG, Jodhpur           | T42       | IC-522511       | NBPG, Jodhpur           |
| T20       | IC-113503       | NBPG, Jodhpur           | T43       | IC-522421       | NBPG, Jodhpur           |
| T21       | IC-113506       | NBPG, Jodhpur           | T44       | IC-522487       | NBPG, Jodhpur           |
| T22       | IC-113523       | NBPG, Jodhpur           | T45       | IC-522506       | NBPG, Jodhpur           |
| T23       | IC-113568       | NBPG, Jodhpur           | T46       | IC-52249        | NBPG, Jodhpur           |
| T24       | IC-113513       | NBPG, Jodhpur           | T47       | RGC-986         | NBPG, Jodhpur           |
| T25       | IC-116569       | NBPG, Jodhpur           | T48       | PLG-85          | NBPG, Jodhpur           |
| T26       | IC-116607       | NBPG, Jodhpur           | T49       | RGC-1038        | NBPG, Jodhpur           |
| T27       | IC-116608       | NBPG, Jodhpur           | T50       | IC-421850       | NBPG, Jodhpur           |
| T28       | IC-116619       | NBPG, Jodhpur           | T51       | IC-421855       | NBPG, Jodhpur           |
| T29       | IC-113376       | NBPG, Jodhpur           | T52       | IC-51063        | NBPG, Jodhpur           |
| T30       | IC-113377       | NBPG, Jodhpur           | T53       | Thar Bhadavi    | CIAH, Bikaner, Rajasthan|
| T31       | IC-113378       | NBPG, Jodhpur           | T54       | MDU-1           | TNAU, Coimbatore         |
| T32       | IC-113379       | NBPG, Jodhpur           | T55       | Chitra Gold     | Vagro seeds Pvt. Ltd, Hyderabad |
| T33       | IC-113380       | NBPG, Jodhpur           | T56       | Navbahar (Check)| IARI, New Delhi         |

The analysis of variance showed significant differences among the genotypes for all 11 characters studied in 56 cluster bean genotypes. This suggested the presence of an appreciable amount of diversity among the genotypes under study. Fifty-six genotypes were grouped into eight clusters presented in Table 2. Cluster I was the largest with 33 genotypes followed by cluster III with eight genotypes, cluster IV with six genotypes, cluster II with four genotypes and cluster VI with 2 genotypes. Cluster V, cluster VII and cluster VIII were monogenotypic. Clustering between genetic diversity was in agreement with Singh et al. (2003), Pathak et al. (2009) and Girish et al. (2012). Cluster mean values of eleven characters are presented in Table 3. The highest mean for plant height (105.73 cm) was shown by cluster V, while the lowest was seen in cluster VII (75.81 cm). Cluster VII had the maximum cluster mean for the number of branches per plant (11.70) and cluster V and VI (0.00) had the minimum value. Cluster II exhibited the maximum mean value (6.06 cm) for internodal length and minimum value in VIII (4.50 cm). The minimum mean value for days to 50% flowering was seen in cluster IV (25.92) and maximum value in cluster V (29.00). Cluster V showed a maximum mean value for the number of pods per cluster (10.90) and a minimum value in cluster II (7.53). The maximum mean value for an average weight of 50 pods was observed in cluster VI (173.50 g) and minimum mean value in cluster VIII (51.00 g). Maximum mean values for pod length was exhibited in cluster VI (10.35 cm). The minimum mean value was in cluster III and VII (6.25 cm).
Table 2. Distribution of cluster bean genotypes into clusters, as per Mahalanobis $D^2$ values

| Cluster | Count | Genotype | Source |
|---------|-------|----------|--------|
| I       | 33    | IC-113568 |        |
|         |       | RGC-986   |        |
|         |       | IC-113374 |        |
|         |       | IC-116607 |        |
|         |       | IC-113394 |        |
|         |       | PLG-85    |        |
|         |       | IC-116705 |        |
|         |       | IC-116825 |        |
|         |       | IC-522511 |        |
|         |       | IC-113378 |        |
|         |       | IC-113379 |        |
| I       | 4     | IC-116619 |        |
|         |       | IC-113399 |        |
|         |       | IC-113390 |        |
|         |       | IC-113513 |        |
|         |       | RGC-1038  |        |
| III     | 8     | IC-113376 |        |
|         |       | IC-116930 |        |
|         |       | IC-113278 |        |
|         |       | IC-113380 |        |
|         |       | IC-113393 |        |
|         |       | IC-384986 |        |
|         |       | IC-522421 |        |
| IV      | 6     | IC-113503 |        |
|         |       | Chitra Gold |    |
|         |       | Pusa Navbahar |   |
| V       | 1     | IC-116932 |        |
| VI      | 2     | Thar Bhadavi |      |
|         |       | MDU-1     |        |
| VII     | 1     | IC-116925 |        |
| VIII    | 1     | IC-113281 |        |
Table 3. Cluster mean values for different characters of cluster bean genotypes

| Characters                | Clusters I | Clusters II | Clusters III | Clusters IV | Clusters V | Clusters VI | Clusters VII | Clusters VIII |
|---------------------------|------------|-------------|--------------|-------------|------------|-------------|--------------|--------------|
| Plant height (cm)         | 91.87      | 96.87       | 88.68        | 102.83      | 105.73     | 98.50       | 75.81        | 77.31        |
| Number of branches per plant | 7.62      | 5.85        | 6.21         | 5.45        | 0.00       | 0.00        | 11.70        | 9.60         |
| Internodal length (cm)    | 5.09       | 6.04        | 5.38         | 5.66        | 4.70       | 5.58        | 5.25         | 4.50         |
| Days to 50% flowering     | 27.03      | 27.50       | 27.31        | 25.92       | 29.00      | 26.75       | 26.50        | 26.00        |
| Number of pods per cluster| 8.82       | 7.53        | 8.37         | 7.98        | 10.90      | 8.90        | 7.56         | 7.56         |
| Average weight of 50 pods (g) | 78.89     | 80.63       | 70.94        | 126.83      | 111.00     | 173.50      | 76.00        | 51.00        |
| Pod length (cm)           | 5.09       | 6.04        | 5.38         | 5.66        | 4.70       | 5.58        | 5.25         | 4.50         |
| Number of seeds per pod   | 7.84       | 8.13        | 7.55         | 8.07        | 6.20       | 8.80        | 9.40         | 7.80         |
| 100 seed weight (g)       | 3.32       | 3.98        | 3.17         | 4.25        | 2.78       | 4.72        | 2.45         | 3.69         |
| Pod yield per plant (g)   | 202.30     | 208.15      | 199.15       | 262.28      | 224.60     | 152.10      | 191.10       |              |
| Protein content of pods (%) | 14.95     | 14.93       | 23.45        | 21.40       | 15.49      | 14.56       | 20.53        | 29.15        |

Cluster VII had the maximum mean value for the number of seeds per pod (9.40), the minimum value was in cluster V (6.20). The highest mean value for 100 seed weight was in cluster VI (4.72 g) and the minimum value was in cluster VII (2.45 g). The highest mean value for pod yield per plant was in the cluster IV (262.28 g) and the minimum was in cluster VII (152.10 g). The highest mean value for pod yield per plant was in the cluster IV (262.28 g) and the minimum was in cluster VII (152.10 g). The maximum mean value of protein content of the pods was in cluster VIII (29.15%) and the minimum was in cluster VI (14.56%). Mean values of clusters could be utilized based on the objective of the breeding program. That is, if the breeder’s aim is to improve the earliness of the crop one must choose the genotypes from characters which have a minimum cluster to mean values such as days to flower initiation, days to 50% flowering and days to first harvest. For other parameter selection might be considered from the clusters having maximum cluster mean value. Similar results were obtained by Singh et al. (2003), Pathak et al. (2009) and Girish et al. (2012).

Cluster distances presented in table 4, showed maximum intracluster distance in cluster IV (2063.90). Clusters V, VII and VIII had only one genotype each and hence intra cluster distance was 0.00. The maximum inter-cluster distance was noticed between cluster VI and VII (39402.44) indicating that these two clusters show the maximum genetic divergence which can be utilized in hybridization programs to get the heterotic advantage as reported by Singh et al. (2003) and Rai and Dharmatti (2014). However, inter-cluster D² value was least between cluster I and V (2793.31) clearly indicating that they are genetically similar.

Table 4. Cluster distances of cluster bean genotypes

| Cluster | I    | II   | III  | IV   | V    | VI   | VII  | VIII  |
|---------|------|------|------|------|------|------|------|-------|
| I       | 1450.32 | 4098.81 | 7394.82 | 8261.03 | 2793.31 | 13525.31 | 9232.92 | 15132.91 |
| II      | 1663.19 | 12966.99 | 4499.08 | 10119.42 | 4421.65 | 20215.20 | 17492.31 | |
| III     | 1752.70 | 9834.25 | 5726.05 | 26252.39 | 4177.35 | 4040.50 | | |
| IV      | 2063.90 | 14556.70 | 7043.25 | 20704.45 | 8631.06 | | | |
| V       | 0.00   | 24742.77 | 3473.37 | 15826.42 | | | | |
| VI      | 708.70 | 39402.44 | 27572.32 | | | | | |
| VII     | 0.00   | 12194.60 | | | | | | |
| VIII    | 0.00   | | | | | | | |

Apart from genetic divergence, due importance should be given to the performance of character with a maximum contribution towards divergence. The number of times each of the 11 characters appeared in the first rank and its respective per cent contribution towards diversity was worked out and presented in figure 1. Hundred seed weight contributed the maximum (52.08%) towards genetic divergence followed by the protein content of pods (14.93%) and pod length (0.06%). In the same manner, these characters ranked 802, 696, 26, 13, 2 and 1 a number of times, respectively. On contrary plant height, internodal length, days to 50% flowering, the average weight of 50 pods and pod yield per plant did not contribute towards genetic divergence. These results were in accordance with the findings of Choyal et al. (2017), Wankhade et al. (2017) and Rishita (2018) in cluster bean genotypes.
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Based on the results of the present investigation, an extensive range of genetic diversity has been explored in cluster bean genotypes. It is suggested that hybridization programme between the genotypes of the distinct group to obtain superior genotypes from the segregating generation to overcome the yield constraints in the Kharif cluster bean can be performed. Cataloguing and documenting the diversity of genotypes is essential for future cluster bean breeding programme.

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