Character association and discriminant function method of selection in cluster bean [Cyamopsis tetragonoloba (L.) Taub.] Genotypes

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Abstract
The study was conducted on 56 cluster bean genotypes to study the linear combination of characters associated with pod yield. Correlation, path analysis and selection index were studied for pod yield using the characters viz., plant height at final harvest (cm), days to 50% flowering, average weight of 50 pods (g), pod length (cm) and protein content of pods. The genotypic correlation coefficients were higher than phenotypic correlation coefficients for all the characters studied. Plant height displayed high positive direct effect on pod yield per plant. Average weight of 50 pods, pod length and protein content of pods exhibited low positive direct effects on pod yield per plant. The index value for each genotype was determined and the genotypes were ranked accordingly. The highest value was recorded in check Pusa Navbahar followed by MDU-1, Chitra Gold, IC-51063 and IC-522421. These genotypes were identified to be genetically superior.

Keywords: Correlation, path analysis, selection index, cluster bean, pod yield

Introduction
Cluster bean [Cyamopsis tetragonoloba (L.) Taub] is also known as guar bean, has a chromosome number of 2n = 2x=14. It is an arid legume crop, mostly cultivated in the arid and semi-arid areas as it is drought tolerant. The long deep taproot system enables the plant to grasp maximum water from the soil making it an ultimate drought resistant crop. It has the freedom from serious pests and diseases and long storage life of the harvested pods. It is a self-pollinated crop belonging to family leguminosae. Guar is characterized as a short day erect or bushy annual plant. Cluster bean is rich in dietary fibre, potassium and folate which protect the heart from various cardiovascular complications. It is a reservoir of different amino acids including glutamine, arginine, aspartic acid and leucine. Iron and calcium present in cluster bean helps in strengthening the bones. It also works as a good laxative, stimulating bowel movement, improving digestive system and help in flushing out unwanted chemicals.

Yield is a complex character and is known to be associated with a number of component characters and is highly affected by environmental variations. These characters are themselves interrelated. An understanding of correlation between yield and its attributing characters is essential to formulate guide lines for crop selection. Partitioning of total correlation into direct and indirect effect by path coefficient analysis helps in making the selection more effective. The path coefficient analysis reveals that, whether the association of the component characters with pod yield per plant is due to their direct effect on pod yield per plant, or is a consequence of their indirect effect via some other trait(s).

Breeding and selection programmes often encompass several characters simultaneously (Hill et al., 1998) [6]. When considering several traits, it is desirable to choose individuals with the best combination of characters. The basis for such a selection is selection index, which takes into account a combination of characters according to their relative weight. Thus each individual character has an index value and selection is based on the sum of the scores (values) of the different characters. Gain from selection for any given character is expected to decrease as additional characters are included in the index, so the choice for characters to be include must be done objectively. In cluster bean, selection indices have been effectively used in
identifying some traits as selection criteria to improve seed yield. Elsyed (1999) [14] concluded that maximum efficiency of selection was obtained when all the important yield components were included in the index. Keeping the above context in view, the present study was carried out to formulate character association and selection strategies for improvement of cluster bean pod yield.

**Material and Methods**

An investigation comprised of 56 genotypes of cluster bean (Table 1) and it was carried out at College of Horticulture, Dr. Y. S. R. Horticultural University, Venkataramannagudem, West Godavari district during kharif season of 2018. Genotypes were evaluated with two replications with spacing of 45 cm x 15 cm. Optimum management practices were followed uniformly for raising the crop. Observations were recorded on five competitive and randomly selected plants from each plot in each replication for all the genotypes. There were 6 characters studied viz., plant height at final harvest (cm), days to 50% flowering, average weight of 50 pods (g), pod length (cm), protein content of pods (%) and pod yield per plant (g). The expected genetic advance of these indices was determined according to the formula suggested by Robinson et al. (1951) [10], in which a set of simultaneous equations, constructed from the genotypic and phenotypic variances and covariance’s of the characters involved, was solved, as follows.

\[
\begin{align*}
&b_1p_1 + b_2p_2 + \ldots + b_np_n = g_{ly}\ \\
&b_1p_12 + b_2p_22 + \ldots + b_np_n2 = g_{2y}\ \\
&b_1p_1n + b_2p_2n + \ldots + b_np_nn = g_{n}\ \\
\end{align*}
\]

Where: P: is the phenotypic variance or covariance.

g: is the genotypic variance or covariance.

\[
\begin{align*}
b_1p_11 + b_2p_21 + \ldots + b_np_n1 = g_{1y}\ \\
b_1p_12 + b_2p_22 + \ldots + b_np_n2 = g_{2y}\ \\
\vdots\ \\
b_1p_1n + b_2p_2n + \ldots + b_np_nn = g_{n}\ \\
\end{align*}
\]

\[
\begin{align*}
&b_1p_112 + b_2p_212 + \ldots + b_np_n12 = g_{12y}\ \\
&b_1p_122 + b_2p_222 + \ldots + b_np_n22 = g_{22y}\ \\
&\vdots\ \\
&b_1p_1n2 + b_2p_2n2 + \ldots + b_np_nn2 = g_{n2y}\ \\
&b_1p_11n + b_2p_21n + \ldots + b_np_n1n = g_{1n}\ \\
&b_1p_12n + b_2p_22n + \ldots + b_np_n2n = g_{2n}\ \\
&\vdots\ \\
&b_1p_1nn + b_2p_2nn + \ldots + b_np_nnn = g_{nn}\ \\
\end{align*}
\]

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

| Treatment | Genotypes | Source          | Treatment | Genotypes | Source          |
|-----------|-----------|----------------|-----------|------------|----------------|
| T1        | IC-113272 | NBPG, Jodhpur  | T9        | IC-116626  | NBPG, Jodhpur  |
| T2        | IC-113277 | NBPG, Jodhpur  | T10       | IC-116652  | NBPG, Jodhpur  |
| T3        | IC-113278 | NBPG, Jodhpur  | T11       | IC-116660  | NBPG, Jodhpur  |
| T4        | IC-113281 | NBPG, Jodhpur  | T12       | IC-116779  | NBPG, Jodhpur  |
| T5        | IC-113308 | NBPG, Jodhpur  | T13       | IC-116705  | NBPG, Jodhpur  |
| T6        | IC-113374 | NBPG, Jodhpur  | T14       | IC-116825  | NBPG, Jodhpur  |
| T7        | IC-113376 | NBPG, Jodhpur  | T15       | IC-116925  | NBPG, Jodhpur  |
| T8        | IC-113377 | NBPG, Jodhpur  | T16       | IC-116930  | NBPG, Jodhpur  |
| T9        | IC-113378 | NBPG, Jodhpur  | T17       | IC-116932  | NBPG, Jodhpur  |
| T10       | IC-113379 | NBPG, Jodhpur  | T18       | IC-384974  | NBPG, Jodhpur  |
| T11       | IC-113380 | NBPG, Jodhpur  | T19       | IC-384986  | NBPG, Jodhpur  |
| T12       | IC-113382 | NBPG, Jodhpur  | T20       | IC-522399  | NBPG, Jodhpur  |
| T13       | IC-113383 | NBPG, Jodhpur  | T21       | IC-522389  | NBPG, Jodhpur  |
| T14       | IC-113390 | NBPG, Jodhpur  | T22       | IC-522511  | NBPG, Jodhpur  |
| T15       | IC-113393 | NBPG, Jodhpur  | T23       | IC-523421  | NBPG, Jodhpur  |
| T16       | IC-113394 | NBPG, Jodhpur  | T24       | IC-522487  | NBPG, Jodhpur  |
| T17       | IC-113395 | NBPG, Jodhpur  | T25       | IC-522506  | NBPG, Jodhpur  |
| T18       | IC-113396 | NBPG, Jodhpur  | T26       | IC-52249   | NBPG, Jodhpur  |
| T19       | IC-113399 | NBPG, Jodhpur  | T27       | RGC-986    | NBPG, Jodhpur  |
| T20       | IC-113503 | NBPG, Jodhpur  | T28       | PLG-85     | NBPG, Jodhpur  |
| T21       | IC-113506 | NBPG, Jodhpur  | T29       | RGC-1038   | NBPG, Jodhpur  |
| T22       | IC-113523 | NBPG, Jodhpur  | T30       | IC-421850  | NBPG, Jodhpur  |
| T23       | IC-113568 | NBPG, Jodhpur  | T31       | IC-421855  | NBPG, Jodhpur  |
| T24       | IC-113513 | NBPG, Jodhpur  | T32       | IC-51063   | NBPG, Jodhpur  |
| T25       | IC-116569 | NBPG, Jodhpur  | T33       | CIAH, Bikaner, Rajasthan |
| T26       | IC-116607 | NBPG, Jodhpur  | T34       | MDU-1      | NDAU, Coimbatore |
| T27       | IC-116608 | NBPG, Jodhpur  | T35       | Chitra Gold | Vagro seeds Pvt. Ltd, Hyderabad |
| T28       | IC-116619 | NBPG, Jodhpur  | T36       | Pusa Navbahar (Check) | IARI, New Delhi |

The genotypic and phenotypic correlation coefficients were determined for all possible pairwise combinations between the characters. Path coefficient analysis was calculated, following the procedure suggested by Dewey and Lu (1959) [1]. It was used for partitioning the genotypic correlation between pod yield per plant and five of its components into direct and indirect effects. Different selection indices were formed using the six characters and pod yield per plant was used as the ultimately desired product. Different phenotypic weights (b’s) were assigned to the six characters. These weights were computed according to the method suggested by Robinson et al. (1951) [10], in which a set of simultaneous equations, constructed from the genotypic and phenotypic variances and covariance’s of the characters involved, was solved, as follows.

P11: is an estimate of the phenotypic variance of character x1.
P12: is an estimate of phenotypic covariance between characters x1 and x2.
g1y: is an estimate of the genotypic covariance between characters x1 and xy.
(Yield = dependent character).
b: is the selection weight.
b1: is the selection weight for the character x1.
b2: is the selection weight for the character x2.
The standard formula for selection index is: \( I = b_1X_1 + b_2X_2 + \ldots + b_nX_n \).
A number of selection indices were constructed. They were composed of indices that are based on single character and those based on the possible combinations of the characters. The expected genetic advance of these indices was determined according to the formula suggested by Robinson et al. (1951) [10].

\[ GA = k \sqrt{b_1g_{ly} + b_2g_{2y} + \ldots + b_ng_{ny}} \]

Where: k: is the selection differential in standard units, its value is 2.06 when selection intensity is 5%.
b: is the selection weight.
g: is the genotypic variance or covariance.

The estimates of genetic advance from selection were in grams of pod yield per plant. Then they were expressed as percentage of the genetic progress obtained from pod yield per plant alone, which was assumed to be 100%, and it was used to compare the relative efficiencies of the different selection indices.

Results and Discussion

The genotypic (g) and phenotypic (p) correlation coefficients were worked out for 6 characters in fifty six genotypes of cluster bean and presented in table 2. In general genotypic correlation coefficients were higher than phenotypic correlation coefficients for all the characters studied.

Table 2: Genotypic and phenotypic correlation coefficient for different characters of cluster bean genotypes

| Characters                  | Plant height (cm) | Days to 50% flowering | Average weight of 50 pods (g) | Pod length (cm) | Protein content of pods (%) | Pod yield per plant (g) |
|-----------------------------|-------------------|------------------------|--------------------------------|----------------|----------------------------|------------------------|
| Plant height (cm)           | R<sub>g</sub> 1.000 | -0.194*                | 0.448 **                       | 0.309 **        | -0.103                     | 0.477**                |
| Days to 50% flowering       | R<sub>p</sub> -0.099 | -0.105                | -0.052                         | -0.173          | -0.384**                   | -0.434**               |
| Average weight of 50 pods (g)| R<sub>g</sub> 1.000 | 0.101                 | 0.803 **                       | -0.086          | 0.479**                    | -0.230**               |
| Pod length (cm)             | R<sub>p</sub> -0.101 | -0.090                | -0.067                         | 0.347**         | 0.425**                    | 0.357**                |
| Protein content of pods (%) | R<sub>p</sub> -0.063 | 1.000                 | 0.169                          | 0.139           |                            |                        |

Plant height recorded significant positive association with average weight of 50 pods (rg= 0.448, rp= 0.382), pod length (rg= 0.309, rp= 0.233) and pod yield per plant (rg= 0.477, rp= 0.434) at both genotypic and phenotypic levels. Average weight of 50 pods showed positive significant association with pod length (rg= 0.803, rp= 0.750) and pod yield per plant (rg= 0.479, rp= 0.347) at both genotypic and phenotypic levels. Pod length displayed positive significant correlation with pod yield per plant (rg= 0.425, rp= 0.357) at genotypic and phenotypic level. Protein content of pods did not show significant correlation with pod yield per plant. Similar result was found by Singh et al. (2005) [11], Mahla and Kumar (2006) [8] and Divya and Abdul (2016) [3].

Days to 50% flowering exhibited significant negative association with pod yield per plant (rg= -0.384, rp= -0.230) at both genotypic and phenotypic levels. These were in agreement with the results reported by Girish et al. (2012) [5] and Patil et al. (2016) [9].

Path analysis was carried out at genotypic level considering pod yield per plant as dependent character. Results were presented in table 3 and Fig.1 below.

Table 3: Path analysis for different characters of cluster bean genotypes at genotypic level

| Characters | PH | DFF | AWF | PL | PC | PYP |
|------------|----|-----|-----|----|----|-----|
| PH         | 0.305 | -0.059 | 0.137 | 0.094 | -0.031 | 0.477** |
| DFF        | 0.051 | -0.264 | 0.028 | 0.014 | 0.046 | -0.384** |
| AWF        | 0.084 | -0.020 | 0.187 | 0.150 | -0.016 | 0.479** |
| PL         | 0.055 | -0.009 | 0.143 | 0.178 | -0.012 | 0.425** |
| PC         | -0.019 | -0.032 | -0.016 | -0.012 | 0.183 | 0.169 |

Fig 1: Diagram of the direct and indirect relationships of pod yield per plant with its components at genotypic level
Plant height displayed high positive direct effect (0.305) and high positive correlation coefficient (rg= 0.477) with pod yield per plant. It exhibited low positive indirect effects via average weight of 50 pods (0.137) while other characters were negligible. Average weight of 50 pods had low positive direct effect (0.187) and high positive correlation coefficient (0.479) with pod yield per plant. Its indirect effect was low via pod length (0.150) whereas other characters were negligible. Pod length displayed low positive direct effect (0.178) and high positive correlation coefficient (0.425) with pod yield per plant. Its indirect effect was low via average weight of 50 pods (0.143) while other characters were negligible. Protein content of pods exhibited low positive direct effect (0.183) and low positive correlation coefficient (0.169) with pod yield per plant. Its indirect effects were negligible. These results were in accordance with the findings of Ibrahim et al. (2005) and Ibrahim et al. (2012).

Days to 50% flowering showed moderate negative direct effect (-0.264) and high negative correlation coefficient (rg= -0.384) with pod yield per plant. Its indirect effects were negligible. The expected genetic advances in pod yield per plant and the relative efficiencies of different selection indices, involving the pod yield per plant as an independent variable and five yield components, singly and in different combinations are shown in table 4. The individual trait indices, viz., average weight of 50 pods and plant height had the highest relative efficiencies (126.06% and 23.76%). This means that these characters were more efficient in determining the genotypic value of a genotype than selection based on pod yield per plant alone. Also it indicates their importance as yield attributing characters. These results are in line with the findings of Ibrahim et al. (2012).

These findings were further confirmed by the fact that whenever average weight of 50 pods and plant height were added to or replaced with other characters in a selection index, the efficiency of such index was tremendously improved. The minimum genetic advances -0.17% and 0.36% and the minimum relative efficiencies -0.67% and 1.39% were obtained by the indices having single traits, viz., days to 50% flowering and protein content of pods, respectively. This is in accordance with Elsyed (1999) and Ibrahim et al. (2012).

Furthermore, when days to 50% flowering and protein content of pods were added to or replaced another character in a selection index, the relative efficiency of such an index was drastically reduced. Therefore, it could be concluded that days to 50% flowering and protein content of pods are an inefficient selection criterion for the improvement of pod yield in cluster bean. Similar findings were reported by Ibrahim et al. (2012).

In this study, the expected genetic advance and the relative efficiency of the index was increased with the increase in the number of characters involved. The selection index involving all the six characters exhibited the highest expected genetic

### Table 4: Expected genetic advance and relative efficiency in cluster bean genotypes

| Character | Genetic advance (%) | Relative efficiency (%) | Character | Genetic advance (%) | Relative efficiency (%) |
|-----------|---------------------|------------------------|-----------|---------------------|------------------------|
| X6        | 25.81               | 100.00                 | X2, X3, X5| 22.68               | 87.87                  |
| X1        | 6.13                | 23.76                  | X2, X3, X6| 7.76                | 30.05                  |
| X2        | -0.17               | -0.67                  | X2, X4, X5| 36.33               | 140.75                 |
| X3        | 32.54               | 126.06                 | X2, X4, X6| 20.84               | 80.76                  |
| X4        | 1.06                | 4.11                   | X2, X5, X6| 31.23               | 120.99                 |
| X5        | 0.36                | 1.39                   | X3, X4, X5| 26.49               | 102.65                 |
| X1, X2    | 48.00               | 185.98                 | X3, X4, X6| 7.79                | 30.20                  |
| X1, X3    | 24.30               | 94.16                  | X3, X5, X6| 7.41                | 28.70                  |
| X1, X4    | 33.93               | 131.45                 | X4, X5, X6| 20.82               | 80.66                  |
| X1, X5    | 48.49               | 187.87                 | X1, X2, X3, X4| 20.39              | 78.99                  |
| X1, X6    | 28.47               | 110.30                 | X1, X2, X3, X5| 18.78              | 72.74                  |
| X2, X3    | 23.60               | 91.44                  | X1, X2, X3, X6| 3.93               | 15.24                  |
| X2, X4    | 36.45               | 141.22                 | X1, X2, X4, X5| 29.41              | 113.97                 |
| X2, X5    | 61.01               | 236.39                 | X1, X2, X4, X6| 17.33              | 67.15                  |
| X2, X6    | 31.36               | 122.27                 | X1, X2, X5, X6| 27.44              | 106.31                 |
| X3, X4    | 28.69               | 111.17                 | X1, X3, X4, X5| 20.96              | 81.19                  |
| X3, X5    | 26.30               | 102.65                 | X1, X3, X4, X6| 3.86               | 14.95                  |
| X3, X6    | 7.79                | 30.20                  | X1, X3, X5, X6| 0.88               | 3.43                   |
| X4, X5    | 41.79               | 161.92                 | X1, X4, X5, X6| 17.26              | 66.86                  |
| X4, X6    | 20.84               | 80.76                  | X2, X3, X4, X5| 22.60              | 87.56                  |
| X5, X6    | 31.86               | 123.45                 | X2, X3, X4, X6| 7.75               | 30.04                  |
| X1, X2, X3| 20.62               | 79.88                  | X2, X3, X5, X6| 7.40               | 28.66                  |
| X1, X2, X4| 30.23               | 117.14                 | X2, X4, X5, X6| 20.81              | 80.64                  |
| X1, X2, X5| 47.52               | 184.10                 | X3, X4, X5, X6| 7.41               | 28.70                  |
| X1, X2, X6| 27.44               | 106.33                 | X1, X2, X3, X4, X5| 18.58              | 72.00                  |
| X1, X3, X4| 24.26               | 93.99                  | X1, X2, X3, X4, X6| 3.85              | 14.91                  |
| X1, X3, X5| 21.00               | 81.37                  | X1, X2, X3, X5, X6| 0.73               | 2.84                   |
| X1, X3, X6| 3.94                | 15.25                  | X1, X2, X4, X5, X6| 17.24              | 66.78                  |
| X1, X4, X5| 31.89               | 123.55                 | X1, X3, X4, X5, X6| 0.37               | 1.42                   |
| X1, X4, X6| 17.34               | 67.18                  | X2, X3, X4, X5, X6| 7.40               | 28.65                  |
| X1, X5, X6| 28.40               | 110.03                 | X1, X2, X3, X4, X5, 6| 65.73              | 254.66                 |
| X2, X3, X4| 23.49               | 91.00                  | X2, X3, X4, X5, X6| 20.81              | 80.64                  |

**Character Definitions:**
- **X1:** Plant height at final harvest (cm)
- **X2:** Days to 50% flowering
- **X3:** Average weight of 50 pods (g)
- **X4:** Pod length (cm)
- **X5:** Protein content of pods (%)
- **X6:** Pod yield per plant (g)
advance (65.73%) and the maximum relative efficiency (254.66%). Similar conclusions were obtained by Elsyed (1999) [4] and Ibrahim et al. (2012) [7] in cluster bean. Although this index exceeded the straight selection based on pod yield per plant per se by 154.66% the genetic advance was relatively low. The selection indices of 56 cluster bean genotypes are presented in Table 5. The index value for each genotype was determined and the genotypes were ranked accordingly. In the present study, the highest value was recorded in check Pusa Navbahar (688.57) followed by MDU-1 (598.556). Chitra Gold (587.482), IC-51063 (470.535) and IC-522421 (448.285). These genotypes were identified to be genetically superior. Similar findings were recorded by Divya (2011) [3].

### Table 5: Selection indices arranged in descending order

| Rank | Accession no.      | Selection index | Rank | Accession no.      | Selection index |
|------|--------------------|-----------------|------|--------------------|-----------------|
| 1    | Pusa Navbahar (Check) | 688.570         | 29   | IC-113503          | 386.236         |
| 2    | MDU-1              | 598.556         | 30   | IC-113513          | 386.13          |
| 3    | Chitra Gold        | 587.482         | 31   | IC-384974          | 383.217         |
| 4    | IC-51063           | 470.535         | 32   | IC-113272          | 375.67          |
| 5    | IC-522421          | 448.285         | 33   | IC-116569          | 374.926         |
| 6    | IC-113399          | 438.279         | 34   | IC-113379          | 374.815         |
| 7    | IC-384986          | 433.791         | 35   | IC-113523          | 372.408         |
| 8    | IC-421855          | 429.987         | 36   | IC-113576          | 371.419         |
| 9    | IC-113506          | 427.108         | 37   | IC-116607          | 370.752         |
| 10   | IC-116932          | 423.554         | 38   | IC-113374          | 369.115         |
| 11   | Thar Bhadavi       | 422.089         | 39   | IC-113390          | 367.563         |
| 12   | IC-116930          | 421.32          | 40   | IC-116608          | 363.739         |
| 13   | IC-116705          | 417.902         | 41   | IC-522511          | 361.255         |
| 14   | IC-113396          | 417.102         | 42   | IC-421850          | 360.455         |
| 15   | IC-113393          | 417.037         | 43   | IC-113382          | 360.238         |
| 16   | IC-522506          | 414.028         | 44   | IC-116660          | 359.855         |
| 17   | IC-113378          | 412.052         | 45   | IC-116652          | 358.195         |
| 18   | IC-522487          | 411.47          | 46   | IC-522399          | 357.556         |
| 19   | PLG-85             | 408.751         | 47   | IC-113281          | 352.338         |
| 20   | IC-113395          | 403.433         | 48   | RGC-1038           | 350.696         |
| 21   | IC-52249           | 402.073         | 49   | IC-113277          | 344.76          |
| 22   | IC-113377          | 398.972         | 50   | IC-116825          | 344.014         |
| 23   | IC-113383          | 396.962         | 51   | IC-113278          | 339.23          |
| 24   | IC-113380          | 395.097         | 52   | IC-116619          | 338.39          |
| 25   | IC-522389          | 394.321         | 53   | IC-116925          | 337.034         |
| 26   | IC-113308          | 393.507         | 54   | IC-116779          | 336.979         |
| 27   | IC-113394          | 388.685         | 55   | RGC-986            | 332.018         |
| 28   | IC-113568          | 388.656         | 56   | IC-116626          | 331.214         |

### Conclusion
It could be concluded that, average weight of 50 pods and plant height were the most important yield contributing characters, as pointed out by correlation, path analysis and selection index. These characters were positively associated with each other and with pod yield per plant, suggesting that simultaneous improvement in these characters will be rewarding. Selection index worked out considering several yield related characters would be more efficient in identifying a superior genotype. Use of selection index enables more efficient selection for yield improvement than strait selection for yield alone.

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