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ELUCIDATING GENETIC VARIABILITY AND YIELD COMPONENTS IN CLUSTER BEAN GERMPLASM THROUGH VARIABILITY AND ASSOCIATION STUDIES

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SUMMARY

The present investigation was conducted at Dry Land Research Area, CCS Haryana Agricultural University, Hisar during *kharif*, 2022. Data were recorded on 17 quantitative traits for genetic variability and association studies among morpho-biochemical traits using 50 cluster bean genotypes. High PCV, GCV, heritability along with high genetic advance as percent of mean were observed in no. of pods per plant, no. of clusters on main stem, no. of clusters on side branches, no. of clusters per plant and no. of branches per plant. Seed yield per plant was positively and significantly associated with no. of pods per plant, no. of clusters on side branches, no. of clusters per plant, no. of pods per cluster on main stem, no. of pods per cluster on side branches, 100 seed weight and gum content. Path analysis revealed that the no. of pods per plant, 100-seed weight, no. of branches per plant, no. of pods per cluster on main stem, days to maturity, days to 50% flowering and gum content would be selected as important ones towards seed yield as they showed high positive direct effect on seed yield.

Key words: Cluster bean, variability, correlation and path coefficient

Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub] is a drought hardy leguminous crop which gives good returns to the farmers of arid and semi-arid areas. The areas with light to medium textured soil, temperature 25-40°C, rainfall 250-400 mm and relative humidity 50-65% are most suitable for its cultivation (Satpal *et al.,* 2020). Cluster bean has been cultivated in Indian subcontinent since ancient times and used as fodder, vegetable (green pods) and sometimes for green manuring (Zubair *et al.* 2017; Panchta *et. al.*, 2016). Now, this crop is regarded as an industrial crop due to versatile use of its galactomannan gum (Guar gum) which is found in the endosperm of its seed. Guar gum is an important export commodity for India as during the year 2023-24, country has exported 417,674.38 MT of guar gum to 111 countries for the worth of Rs. 4,489.40 Crores. The major export destinations for guar gum are U.S.A, Germany, Russia, Norway and Netherland (APEDA, 2023).

The variability present in germplasm is estimated with genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). Heritability coupled with genetic advance as per cent of mean are helpful in predicting whether selection would be rewarding or not. Yield is a complex character to which various independent characters contributes. Therefore, before starting a breeding programme, prior knowledge of yield contributing characters in essential. The correlation and path analysis can assist to know the yield attributing characters (Nguyen *et al.* 2019). Considering the above facts, the present study was conducted to assess the nature and magnitude of genetic variability and association of seed yield with attributing characters in cluster bean.

MATERIALS AND METHODS

The present study was conducted in randomized block design at the Dryland Research Farm, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar during *Kharif* 2022 containing of fifty cluster bean genotypes including checks, HG 2-20, HG 563 and RGC 1033. Three rows of 1.5 m length of each genotype were sown keeping row-to-row spacing of 45 cm and plant to plant distance of 15 cm. The crop was raised with recommended agronomic practices. Data were recorded on 17 quantitative traits namely, Plant height (cm), days to 50% flowering, days to maturity, no. of pods per plant, no. of clusters on main stem, no. of clusters on side branches, no. of clusters per plant, no. of pods per cluster on main stem, no. of pods per cluster on side branches, no. of seeds per pod, pod length (cm), no. of branches per plant, 100-seed weight (g), gum content (%), crude protein (%), bacterial leaf blight severity (%) and seed yield per plant (g). The observation for most of the characters except days to 50% flowering and BLB intensity was taken on maturity.

The nitrogen content obtained by micro-Kjeldhal method (Stuart, 1936) was multiplied by with a factor 6.25 in order to determine the protein content (Dubetz and Welis, 1968). The galactomannan was extracted, purified, precipitated and finally dissolved for the estimation of gum content (%) using method given by Das *et al.* (1977) and further improved by Joshi (2004).

Observations for bacterial leaf blight disease intensity were recorded in natural conditions using 0-9 disease scale followed by AINP on Arid legumes (2020-21), ICAR-IIPR, Kanpur, India. The percent disease index was calculated as:

$$\text{Percent Disease Severity} = \frac{\text{Sum of all Individual rating} \times 100}{\text{Total no. of leaves assessed} \times \text{Maximum rating}}$$

Five plants from each replication selected randomly, were tagged and 6-8 leaves from each plant were selected at random for assessing the infected leaf area, according to standard method using 0-9 scale (Table 1).

TABLE 1

Disease rating scale used for recording percent disease intensity of Bacterial leaf blight in cluster bean genotypes

Grade	Percent Disease Intensity	Disease Reaction
0	0	Disease Free
1	0.1-5	Highly Resistant
2-3	5.1-10	Resistant
4-5	10.1-20	Moderately Resistant
6-7	20.1-50	Susceptible
8-9	>50	Highly Susceptible

Statistical analysis was carried out according to Fisher (1918) for analysis of variance; Burton and De Vane (1953) for estimation of phenotypic and genotypic coefficients of variation, heritability and genetic advance; Al-Jibouri *et al.*(1958) for correlation coefficient, Dewey and Lu (1959) for path analysis. The data were analyzed using the OPSTAT programme.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) of all the 17 quantitative characters in the 50 genotypes of cluster bean was done. The ANOVA revealed significant differences for most of the traits studied at 5% level of significance indicating presence of diversity among different genotypes. These results of ANOVA justified the further analysis of data. The mean sum of squares of all the traits is presented in Table 2. Previous researches *viz.*, Khalid *et al.*, (2017), Reddy *et al.*, (2018), Deepashree *et al.*, (2021) have reported a wide variability for cluster bean on many morphological, biological and productive traits. Similar findings were also reported by Panchta *et al.* (2020), Thangam *et al.* (2020), Ugale *et al.* (2020) and Tambitkar *et al.* (2021) and Gaikwad (2021) for yield and attributing traits in cowpea.

The results of variability parameters *viz.,* general mean, range of mean, phenotypic and genotypic coefficient of variation, heritability and genetic advance as per cent of mean have been presented in Table 3. The characters exhibited higher values of PCV than the corresponding GCV values, which indicated the environmental influence on these characters. The characters *viz.*, no. of clusters on side branches, no. of clusters on main stem, no. of pods per plant, no. of clusters per plant and no. of branches per plant exhibited high values of GCV and PCV; no. of pods per cluster on side branches, seed yield per plant (g) and no. of pods per cluster on main stem showed moderate values of GCV and PCV, whereas bacterial leaf blight severity (%), 100-seed weight (g), no. of seeds per pod, gum content (%), crude protein (%), pod length (cm), plant height (cm), days to maturity and days to 50% flowering showed low estimates of GCV and PCV. These findings were in corroboration with the reports of Santhosha *et al.* (2017) who also reported similar results for no. of pods in a cluster and Reddy *et al.* (2018) for no. of branches per plant and no. of clusters in a plant in cluster bean. Deepashree *et al.*, (2021) also reported high PCV and GCV for no. of branches per plant, no. of clusters per plant and no. of pods in a cluster on main stem and side branches in cluster bean.

TABLE 2
Analysis of variance for different traits in 50 genotypes of Cluster bean

S. No.	Characters	Mean sum of squares			CV (%)
		Replication 2	Genotypes 49	Error 98	
1.	Plant height (cm)	44.24	68.13**	26.99	2.03
2.	Days to 50% flowering	0.04	3.96	0.43	1.14
3.	Days to maturity	1.60	41.49**	1.19	5.87
4.	No. of pods per plant	82.22	1816.8*	48.75	10.01
5.	No. of clusters on main stem	0.14	12.38**	0.65	16.06
6.	No. of clusters on side branches	3.86	116.20**	3.64	13.65
7.	No. of clusters per plant	2.54	110.85**	3.49	9.85
8.	No. of pods per cluster on main stem	0.78	1.88	0.39	13.33
9.	No. of pods per cluster on side branches	0.32	0.96	0.46	16.46
10.	No. of seeds per pod	0.32	0.47**	0.44	7.62
11.	Pod length (cm)	0.03	0.06	0.05	4.19
12.	No. of branches per plant	0.04	8.45**	0.76	14.77
13.	100-seed weight (g)	0.01	0.09*	0.02	5.59
14.	Gum content (%)	0.52	6.90**	1.21	3.97
15.	Crude protein (%)	1.00	3.92	1.37	4.92
16.	Bacterial leaf blight severity (%)	10.21	29.70**	2.59	4.82
17.	Seed yield per plant (g)	4.10	30.53**	4.40	11.89

** Significant at 1% level, * Significant at 5% level.

TABLE 3
Mean, range, phenotypic and genotypic coefficient of variation, heritability, and genetic advance as % of mean for various traits in cluster bean

Characters	Mean ±SE(m)	Range	Coefficient of variation		Heritability (%)	Genetic advance as % of mean
			GCV	PCV		
Plant height (cm)	88.54 ± 3.00	64.00- 99.69	4.18	7.20	33.69	5.00
Days to 50% flowering	32.48 ± 0.38	27.66- 34.33	3.35	3.91	73.05	5.89
Days to maturity	95.70 ± 0.63	74.66- 101.66	3.83	4.00	91.81	7.56
No. of pods per plant	69.72± 4.03	21.33- 109.66	34.81	36.22	92.36	68.92
No. of clusters on main stem	5.02 ± 0.47	3.00- 14.00	39.40	42.55	85.75	75.16
No. of clusters on side branches	13.88 ± 1.10	3.00- 22.66	43.83	45.90	91.16	86.19
No. of clusters per plant	19.04 ± 1.08	3.036- 28.66	31.49	32.99	91.09	61.90
No. of pods per cluster on main stem	4.74 ± 0.36	4.00- 8.33	14.83	19.94	55.32	22.72
No. of pods per cluster on side branches	4.13 ± 0.39	3.33- 6.00	18.91	19.21	26.61	10.53
No. of seeds per pod	8.73 ± 0.38	8.00- 10.00	7.22	7.71	2.49	0.40
Pod length (cm)	5.64 ± 0.13	5.36- 6.03	4.19	4.36	7.47	0.67
No. of branches per plant	5.84±0.50	0.66- 8.33	27.10	30.87	77.11	49.09
100-seed weight (g)	2.62±0.08	2.25- 3.01	7.97	8.18	53.25	8.97
Gum content (%)	27.74±0.63	24.9- 30.60	5.97	6.36	60.97	7.99
Crude protein (%)	23.80±0.67	21.32- 26.11	5.87	6.26	38.21	4.93
Bacterial leaf blight severity (%)	33.46±0.93	27.40- 39.05	9.98	10.19	77.67	16.31
Seed yield per plant (g)	17.65±1.21	3.40- 23.79	16.72	20.52	66.43	28.08

** Significant at 1% level, * Significant at 5% level.

Moderate GCV and PCV were observed for no. of pods per plant on main stem and side branches and seed yield per plant. Moderate GCV and PCV for days to flowering, no. of pods per cluster, no. of pods per plant and seed yield per plant were also reported by Singh *et al*. (2016), Goudar *et al*. (2017), Kumar *et al*. (2017) in cluster bean. Moderate GCV and PCV values for plant height, stem girth, pod length, 100

TABLE 4
Phenotypic correlation coefficient for different characters in cluster bean

Characters	PH (cm)	DFF	DM	PPP	CMS	CSB	TC	PPCMS	PPCSB	SPP	PL (cm)	BPP	100 SW (g)	GC (%)	PC (%)	BLBI (%)
PH (cm)																
DFF	0.286**															
DM	0.374**	0.606**														
PPP	-0.091	-0.200*	-0.107													
CMS	0.059	-0.077	-0.072	0.133												
CSB	-0.103	-0.214**	-0.106	0.826**	-0.235**											
TC	-0.085	-0.245**	-0.133	0.891**	0.100	0.944**										
PPCMS	-0.142	-0.339**	-0.434**	0.190*	0.366**	0.015	0.140									
PPCSB	-0.052	-0.357**	-0.427**	0.214**	0.222**	0.090	0.168*	0.616**								
SPP	0.187*	0.000	0.058	-0.019	0.119	-0.043	-0.004	0.141	0.139							
PL (cm)	0.205*	-0.105	0.022	0.073	0.238**	-0.039	0.041	0.108	0.015	0.080						
BPP	0.013	-0.008	0.139	0.164*	-0.380**	0.451**	0.332**	-0.244**	-0.197*	-0.066	-0.064					
100 SW (g)	-0.001	-0.177*	-0.191*	0.575**	0.161*	0.537**	0.604**	0.336**	0.248**	0.061	-0.036	-0.019				
GC (%)	0.121	-0.130	-0.126	0.624**	0.138	0.553**	0.613**	0.318**	0.233**	0.015	0.069	0.078	0.553**			
CP (%)	0.039	0.120	0.059	0.123	-0.081	0.122	0.098	0.091	0.027	0.023	-0.156	0.055	0.055	0.077		
BLBI (%)	0.071	0.264**	0.169*	-0.665**	-0.199*	-0.566**	-0.647**	-0.363**	-0.300**	0.079	-0.128	-0.052	-0.583**	-0.534**	0.007	
SYP (g)	0.070	-0.248**	-0.148	0.740**	0.152	0.679**	0.747**	0.334**	0.285**	-0.024	0.099	0.118	0.630**	0.672**	0.128	-0.650**

PH-Plant Height (cm), DFF-Days to 50% Flowering, DM-Days to maturity, PPP-Pods per plant, CMS-Clusters on main Stem, CSB-Clusters on side branches, TC- No. of clusters per plant, PPCMS-Pods per cluster on main stem, PPCSB-Pods per cluster on side branch, SPP-Seeds per pod, PL-Pod length (cm), BPP-Branches per plant, 100 SW-100 seed weight (g), GC-Gum content (%), PC-Protein content (%), BLBI-Bacterial leaf blight severity (%), SYPP-Seed yield per plant (g).

TABLE 5

Direct (diagonal) and Indirect (off diagonal) Path coefficients based on phenotypic correlation on seed yield per plant in cluster bean

	PH	DFF	DM	PPP	CMS	CSB	TC	PPCMS	PPCSB	SPP	PL	BPP	100SW	GC	PC	BLBI	Gen. corr. with main
PH	0.300	0.195	0.282	-0.263	-0.013	0.317	0.009	-0.106	-0.071	-0.026	-0.237	0.113	-0.002	0.094	-0.025	0.052	0.018
DFF	0.193	0.304	0.307	-0.485	0.021	0.470	0.019	-0.397	-0.120	0.008	0.054	-0.009	-0.315	-0.118	-0.108	0.236	-0.326
DM	-0.206	0.227	0.410	-0.200	0.014	0.189	0.008	-0.365	-0.109	-0.009	-0.040	0.180	-0.322	-0.062	-0.033	0.154	-0.164
PPP	0.044	-0.083	-0.046	1.777	-0.022	-1.642	-0.060	0.146	0.054	0.009	-0.033	0.176	0.957	0.340	-0.088	-0.560	0.969
CMS	-0.023	-0.037	-0.032	0.230	-0.173	0.437	-0.006	0.297	0.063	-0.013	-0.194	-0.596	0.253	0.103	0.081	-0.160	0.231
CSB	0.051	-0.076	-0.041	1.559	0.041	-1.871	-0.061	0.027	0.022	0.015	0.034	0.583	0.828	0.298	-0.070	-0.470	0.868
TC	0.045	-0.090	-0.053	1.673	-0.016	-1.772	-0.064	0.126	0.043	0.011	-0.030	0.400	0.931	0.340	-0.045	-0.534	0.965
PPCMS	0.054	-0.203	-0.253	0.437	-0.087	-0.085	-0.014	0.593	0.176	-0.032	-0.031	-0.428	0.620	0.203	-0.068	-0.389	0.495
PPCSB	0.161	-0.274	-0.335	0.726	-0.083	-0.304	-0.021	0.783	0.133	-0.023	-0.016	-0.383	0.771	0.267	-0.218	-0.496	0.69
SPP	-0.406	-0.129	0.187	-0.821	-0.116	1.436	0.036	0.988	0.157	-0.019	-0.402	-0.933	0.142	0.185	-0.057	-0.093	0.156
PL	-0.315	-0.073	0.073	0.260	-0.149	0.280	-0.008	0.081	0.009	-0.034	-0.226	-0.159	0.355	0.162	0.347	-0.354	0.249
BPP	-0.033	-0.003	0.072	0.304	0.100	-1.057	-0.025	-0.246	-0.049	0.017	0.035	1.032	0.049	0.077	-0.003	-0.043	0.227
100SW	0.001	-0.087	-0.120	1.549	-0.040	-1.411	-0.054	0.335	0.094	-0.003	-0.073	0.046	1.098	0.365	0.006	-0.692	1.013
GC	-0.072	-0.091	-0.064	1.536	-0.045	-1.420	-0.055	0.306	0.090	-0.009	-0.093	0.203	1.019	0.393	-0.094	-0.544	1.059
PC	-0.017	0.075	0.032	0.358	0.032	-0.300	-0.007	0.093	0.067	-0.003	0.181	0.008	-0.015	0.085	-0.435	-0.036	0.117
BLBI	-0.022	0.101	0.089	-1.405	0.039	1.242	0.048	-0.326	-0.093	0.003	0.113	-0.063	-1.072	-0.302	0.022	-0.708	-0.918

Residual effect - 0.211

PH-Plant height (cm), DFF-Days to 50% flowering, DM-Days to maturity, PPP-Pods per plant, CMS-Clusters on main stem, CSB-Clusters on side branches, TC- No. of clusters per plant, PPCMS-Pods per cluster on main stem, PPCSB-Pods per cluster on side branch, SPP-Seeds per pod, PL-Pod length (cm), BPP-Branches per plant, 100 SW-100 seed weight (g), GC-Gum content (%), PC-Protein content (%), BLBI- Bacterial leaf blight severity (%), SYPP-Seed yield per plant (g).

seed weight and protein content were also reported by Santhosha *et al*. (2017) in cluster bean.

Low PCV and GCV were observed for plant height, days to 50% flowering, days to maturity, no. of seeds per pod, pod length, 100 seed weight, gum content and protein content. Similarly, Choyal *et al*. (2018), Reddy *et al*. (2018) and Rishitha *et al*. (2019) also reported low estimated of GCV and PCV for days to 50 per cent flowering in cluster bean. Low estimates of GCV and PCV indicates the presence of narrow genetic base in the traits. Hence, in order to create variations in these traits either mutation breeding or hybridization with divergent parents for recovering transgressive segregants can be done.

High heritability along with high genetic advance were observed in no. of clusters on side branches, no. of clusters on main stem, no. of pods per plant, no. of clusters per plant, no. of branches per plant and seed yield per plant (g). Hence, simple selection could be rewarding for the improvement of the traits showing high estimates of heritability coupled with high genetic advance. The results of present study are in agreement with the findings of Kumar *et al.* (2017) and Choyal *et al*. (2018) for seed yield per plant; Santhosha *et al.* (2017) and Reddy *et al.* (2018) for gum content of seed endosperm, Gowd *et al*. (2019) for no. of branches and no. of clusters per plant, Santhosha *et al*. (2017), Reddy *et al*. (2018) and Gowd *et al*. (2019) for pod length in cluster bean.

In the present study phenotypic correlation coefficients were estimated for 17 quantitative characters to find out the association of seed yield per plant with other yield contributing characters (Table 4). The seed yield per plant was found significantly and positively correlated with no. of pods per plant, no. of clusters on side branches, no. of clusters per plant, no. of pods per cluster on main stem, no. of pods per cluster on side branches, 100 seed weight and gum content. Negative and significant correlation of seed yield per plant was observed with days to 50% flowering and bacterial leaf blight severity. The results obtained are in corroboration with the previous results reported by Vir *et al*., (2015) for no. of pods per plant, no. of pods per cluster and no. of clusters per plant which showed positive and significant correlations with seed yield per plant in cluster bean.

To correlation studies alone is not sufficient to estimate the real contribution of an individual character towards seed yield per plant. Path coefficient splits the correlation into direct as well as indirect effect of one variable on the dependent variable through the other traits and hence provides a clear and more realistic picture about the correlation. The path coefficient analysis was done on genotypic correlations and results have been presented in Table 4.The no. of pods per plant had highest direct and positive effect on seed yield per plant followed by 100-seed weight, no. of branches per plant, no. of pods per cluster on main stem, days to maturity, days to 50% flowering and gum content. However, the characters *viz*., no. of clusters on side branches and bacterial leaf blight severity showed direct and negative effect on seed yield per plant. High positive indirect effect on seed yield per plant was exerted by no. of clusters on side branches, no. of clusters per plant, 100 seed weight, no. of seeds per pod, no. of pods per plant and gum content. Similar findings were also reported by Boghara *et al*. (2016), Lekshmanan and Vahab *et al*. (2018), who observed that the characters *viz*., no. of clusters per plant and no. of pods per plant, exerted significantly positive direct effect on seed yield per plant in cluster bean. Brar *et al*. (2017) and Choyal *et al.* (2018) also reported the same results for cluster bean. The negative indirect effect was exerted on seed yield per plant by bacterial leaf blight severity. Therefore, indirect selection based on no. of pods per plant, 100 seed weight, no. of branches per plant, no. of pods per cluster on main stem, days to maturity, days to 50% flowering and gum content would be effective in order to achieve high seed yield per plant.

CONCLUSION

The present study indicated wide variation and high heritability coupled with high genetic advance as per cent of mean for various characters. This offers potential to evolve new cluster bean varieties through simple breeding methods. Further, to develop high yielding cluster bean varieties indirect selection can be done based on the characters like no. of pods per plant, 100 seed weight, no. of branches per plant, no. of pods per cluster on main stem, days to maturity, days to 50% flowering and gum content.

REFERENCES

Al-Jibouri, H. Miller, P. A. and H. F. Robinson, 1958: Genotypic and environmental variances and covariances in an upland Cotton cross of interspecific origin 1. *Agronomy journal*, **50**(10): 633-636.

Annual Report, All India Network Project on Arid Legumes (2020-21). ICAR- Indian Institute of Pulses Research, Kanpur, U.P., India.

APEDA 2023: *https://www.apeda.gov.in/apedawebsite/SubHead_Products/Guargum.htm.*

Boghara, M. C., H. L. Dhaduk, S. Kumar, M. J. Parekh, N. J. Patel and R. Sharma, 2016: Genetic divergence, path analysis and molecular diversity analysis in cluster bean (*Cyamopsis tetragonoloba* L. Taub.). *Industrial crops and products*, **89**: 468-477.

Brar, S. K., and P. Singh, 2017: Response of cluster bean (*Cyamopsis tetragonoloba* L. Taub.) cultivars to dual inoculation with fixing and phosphorous solubizing bacteria. *Legume Research - An International Journal*, **40**(1): 100-104.

Burton, G. W., and D. E., Devane, 1953: Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material 1. *Agronomy journal*, **45**(10): 478-481.

Choyal P, R. Dewangan, N.D., Ramesh, K.S. Seervi and D. Seervi, 2018: Genetic variability studies in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub]. *International Journal of Chemical Studies*, **6**(4): 967-970.

Das, B., S. K. Arora and Y. P. Luthra, 1977: A rapid method for determination of gum in guar (*Cyamopsis tetragonoloba* (L.) Taub.). In Proceedings of 1st ICAR Guar Research Workshop, Jodhpur. 117-123.

Deepashree, G., V. D. Gasti, N. Raut, R. Chittapur, S. G. Reddi and G. Kustagi, 2021: Genetic variability studies in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] for growth, yield and quality parameters. *The Pharma Innovation Journal*, **10**(4): 666-670.

Dewey, D.R. and K. Lu, 1959: A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy journal*. **51**(9): 515-518.

Dubetz, S. and S. A. Wells, 1968: Reaction of barley varieties to nitrogen fertilizer. *The Journal of Agricultural Science,* **70**(3): 253-256.

Fisher, R. A., 1925: Theory of statistical estimation. In Mathematical proceedings of the Cambridge philosophical society, Cambridge University Press. **22**(5): 700-725.

Gaikwad, B.S. 2021: Analysis of genetic variability in m^2 generation of cowpea [*Vigna unguiculata* (L.) WALP]. *International Journal of Researches in Biosciences, Agriculture and Technology*. **9**(2): 211-215.

Goudar, R., V. Srinivasa and D. Lakshmana, 2017: Genetic variability and divergence studies in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub] under hill zone of Karnataka, India. *Legume Research-An International Journal*, **40**(2): 237-240.

Gowd, Y.M.T, S.S.P. Reddy, T.B. Priya, D.Y., Kiran, R.A. Reddy, 2019: Genetic variability studies in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub]. *Plant Archives*; **19**(2):3341-3344.

Joshi, U. N., 2004: Advances in chemistry, biochemistry and industrial utilization of guar seed. Guar, Indian Society of Forage Research, Hisar and Agricultural and Processed Food Products Export Development (APEDA), New Delhi. 197-229.

Khalid, M. A. U. R., L. H. Akhtar, R. Minhas, S. J. Bukhari, M. Zubair, and M. A. Iqbal, 2017:. Screening of guar accessions [*Cyamopsis tetragonoloba* (L.) Taub.] for higher yield potential under irrigated conditions. *African Journal of Agricultural Research*, **12**(37): 2788-2794.

Kumar, P., D.K. Garg, M. Kumar, G. Vishnoi and H.L. Barupal, 2017: Variability, heritability and genetic advance analysis for yield and its contributing traits in cluster bean. *Journal of Pharmacognosy and Phytochemistry*, **6**(4): 1010-1012.

Lekshmanan, D. K., and M. A. Vahab, 2018: Correlation and path coefficient analysis of yield and its component characters among different accessions of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Legume Research-An International Journal*, **41**(1): 53-56.

Nguyen, N.V., R. K. Arya and R. Panchta, 2019: Studies on genetic parameters, correlation and path coefficient analysis in cowpea. *Range Management & Agroforestry*, **40** (1): 49-58.

Panchta, R., S. Arya, D.P. Singh, Satpal and R. Kumar, 2020: Genetic variability and association studies in cowpea [*Vigna unguiculata* (L.) Walp] for seed yield and related traits. *Forage Research*, **46**(3): 232-235.

Panchta, R., Satpal and S.K. Pahuja, 2016: Evaluation of Cluster bean genotypes in summer for yield and its contributing traits under Haryana conditions. *Forage Research,* **42**(1): 62-64.

Panchta, R., Satpal and. R.S. Khatri, 2017: Variability, Correlation and Path Analysis studies in Clusterbean Genotypes during summer season under Haryana conditions. *International Journal of Pure and Applied Biosciences*, **5**(3): 485-489.

Reddy, D.R., P. Saidaiah, K.R. Reddy, S.R. Pandravada, and A. Geetha, 2018: Genetic variability for growth, pod and quality attributes in germplasm of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Legume Research* ISSN*:* 0250-5371.

Rishitha, G., R.R. Lakshmi, K.U. Jyothi, and K.U. Krishna, 2019: Studies on genetic variability, heritability and genetic advance for yield and yield attributing characters in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *International Journal of Current Microbiology and Applied Science*, **8**(8): 1307-1312.

Santhosha, G. R., E. Shashikanth, V. D. Gasti, G. Prabhuling, V. D. Rathod and R. Mulge, 2017: Genetic variability studies in cluster bean [*Cyamopsis tetragonaloba* (L.) Taub.] for growth, yield and quality parameters. *Legume Research*, **1**(40): 232-236.

Satpal, R. Panchta, S. Arya, D. P. Singh, S. Kumar and Neelam, 2020: Performance of cluster bean genotypes as influenced by crop geometry and fertilizer levels. *Forage Research*, **45** (4): 314-317.

Stuart, N. W. 1936: Adaptation of the micro-Kjeldahl method for the determination of nitrogen in plant tissues. *Plant Physiology* **11**(1): 173.

Tambitkar, N.B., U.B. Pethe, S.S. Desai, J.J. Kadam, and R.V. Dhopavkar, 2021: Genetic variability studies in cowpea genotypes. *Journal of Pharmacognosy and Phytochemistry*. **10**(1): 239-242.

Thangam, M., K. Ramachandrudu, K.J. Ashok, S.A. Safeena, and D.S. Priya, 2020: Variability and genetic divergence in vegetable cowpea germplasm of Goa. *Journal of Horticultural Sciences*. **15**(1): 45-51.

Ugale, P.N., M.P. Wankhade, and A.B. Bagade, 2020a: Genetic variability studies in cowpea (*Vigna unguiculata* (L.) Walp.). *Journal of Pharmacognosy and Phytochemistry*. **9**(6): 476-479.

Vir, O., and A. K. Singh, 2015: Variability and correlation analysis in the germplasm of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] in hyper hot arid climate of Western India. *Legume Research*, **38**(1): 37-42.

Zubair, M., L.H. Akhtar, R. Minhas, M.S. Bukhari, I. Ali, A. Sadiq and S. Hussain, 2017: Performance of guar genotypes under irrigated and drought stress conditions as evaluated through PCA and cluster analysis. *International Journal of Biology and Biotechnology*, **14**(4): 623-628.