

Multivariate Analysis of Genetic Diversity In Mung bean [*Vigna radiata* (L.) Wilczek] Using Mahalanobis Statistic

Abstract-

Mung bean is a significant pulse crop in India, known for its high protein content, ranging from 25-28%. Understanding the genetic diversity within mung bean populations is essential for identifying genotypes that can enhance crop improvement and for the effective utilization of available genetic resources. This study aimed to evaluate the extent and patterns of morphological diversity among various mung bean genotypes and to determine the key traits contributing to genetic diversity using multivariate analysis. The present study was conducted at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, during the *kharif* season of 2023. Using Mahalanobis D² statistics, 40 mung bean genotypes were grouped into 9 distinct clusters. Cluster I was the largest, comprising 15 genotypes, followed by Cluster II with 11 genotypes. Clusters IV with 4 genotypes. Cluster V and Cluster VII each had 3 genotypes; and Clusters III, VI, VIII and IX each contained a single genotype. The greatest inter-cluster distance was observed between Cluster VII and Cluster VIII (17.12), indicating that genotypes (PM 15-12, PM 5, IPM 2-14) and (Vamban 2) can be hybridized together to produce significant genetic diversity in segregating generation among the genotypes included in these clusters. Therefore, the substantial genetic distance observed within and among the clusters should be leveraged by selecting and crossing the most genetically divergent parents in future mung bean breeding programmes.

Keywords: Cluster, genetic diversity, mahalanobis D² statistics, multivariate

INTRODUCTION

“Mung bean [*Vigna radiata* (L.) Wilczek], a self-pollinated legume, belongs to the family Leguminosae and sub-family Papilionaceae, with a chromosome number $2n = 2x = 22$. Mung bean is a *kharif* season crop and is the third most important pulse crop of India. The grains are consumed whole or in split form as dal. It is mainly grown in South Asia countries including India, Pakistan, Bangladesh, Sri Lanka, Cambodia, Vietnam, Indonesia and Malaysia. Notably, Asia contributes to 90% of the global mung bean production. In India, mung bean represents 10% of the total pulse production; covering an area of approximately 5.54 million hectares with an annual production of 3.67 million metric tonnes and an average yield of around 663 kg/ha” (Economic and Statistics Directorate, 2022). Genetic diversity plays a pivotal role in the collection, documentation and utilisation of germplasm for crop improvement programs. The importance of genetic diversity in different crop improvement programmes is well emphasized by De Pace *et al.* (2011), Verma *et al.* (2018), Bohra *et al.* (2015), Chandra *et al.* (2017) and Meena *et al.* (2017). Utilizing genetic diversity effectively in crops aid in selecting appropriate parents for hybridization and achieving breeding goals (Chaudhary, *et al.* 2017). The objectives of this study were to evaluate the genetic diversity among 40 mung bean genotypes based on phenotypic traits, to classify the genotypes into homogenous groups, to estimate the genetic distances and relationships among the genotypes, and to identify the key traits contributing to this diversity using multivariate techniques.

MATERIALS AND METHOD

Forty mung bean genotypes were evaluated during the *kharif* season of 2023 using a randomised block design (RBD) with three replications at the N.E.B. Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar. The research centre is located in the Tarai belt, positioned 30 km south of the foothills of the Shivalik range of the Himalayas, with coordinates at 29°N latitude and 79.29°E longitude and at an altitude of 243.83m above mean sea level. Each test genotype was grown in a two row plot of 4 meters length. A row to row spacing of 30 cm and plant to plant spacing of 10 cm was maintained. All the recommended agronomic practices were carefully followed to ensure optimal crop growth. In the present study, the D^2 statistic, a robust method was used to access the genetic divergence among 40 elite mung bean genotypes.

Data were collected on ten morphological traits namely: days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of pods per cluster, pod length (cm), number of pods per plant, number of seeds per pod, one hundred seed weight (g), and seed yield per plant (g). Observations for all the characters were recorded on five randomly selected competitive plants from each genotype in each replication except for days to 50% flowering and days to maturity for which the data was recorded on whole plot basis. The mean value for the each replication was used for statistical analysis using the INDOSTAT statistical package.

RESULTS AND DISCUSSION

Table 1 presents the analysis of variance for yield and its related components using a randomized block design. The analysis demonstrated that significant genetic variation exists among the experimental mung bean genotypes for all studied traits. Initially, significant differences among genotypes were identified for each individual character. The highly significant V statistic value of 1795.15, which exceeded the tabulated χ^2 value, indicated significant differences among the genotypes when all traits were considered simultaneously (Table 2). D^2 values were computed for all possible pairs of genotypes. Using Tocher's method (Rao, 1952), the 40 mung bean genotypes were grouped into 9 distinct clusters. The distribution of genotypes into each of these 9 clusters is presented in Table 3 and illustrated in Fig. 1.

Table 1: Analysis of variance for ten different characters among 40 mung bean genotypes

S.no.	Characters	Mean sum of squares		
		Replication	Treatment	Error
		2	39	78
1.	Days to 50% flowering	5.00	36.44**	2.31
2.	Days to maturity	21.78	120.63**	11.25
3.	Plant height (cm)	23.23	416.37**	29.38
4.	No. of primary branches	0.60	0.77**	0.40
5.	No. of pods/ cluster	1.04	1.18**	1.03

6.	Pod length	0.24	1.32**	0.15
7.	No. of pods/plant	18.96	589.19**	18.19
8.	No. of seeds/pod	0.32	2.68**	0.76
9.	100 seed weight	0.11	0.92**	0.05
10.	Seed yield/plant	1.28	22.09**	3.40

*Significance at 5% and **Significance at 1%

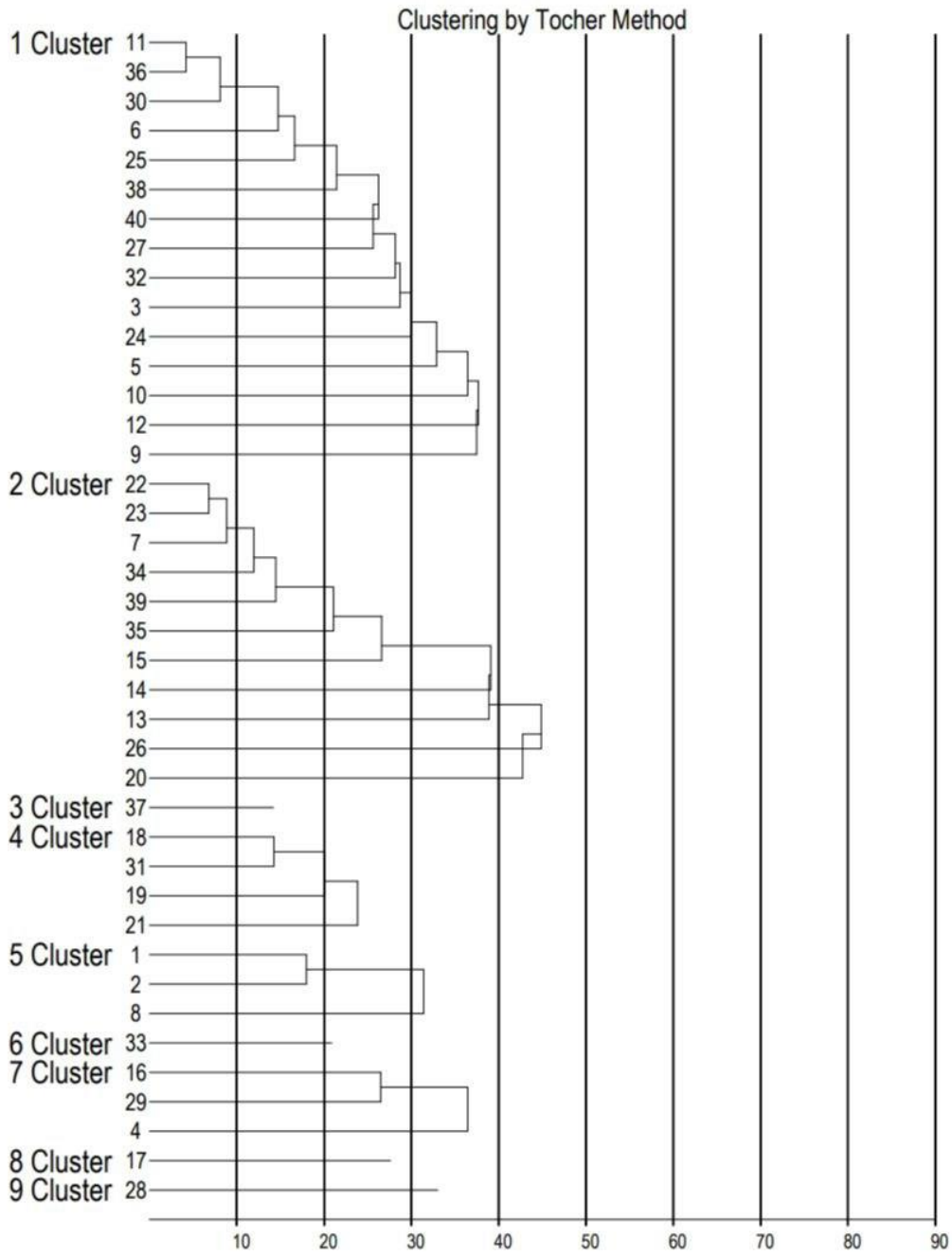


Fig. 1: Dendrogram showing the clustering pattern of 40 mung bean genotypes

Table 2: Wilks Test for 40 mung bean genotypes for yield and its attributes

S.No.	Content	Value
1.	Determinate of error matrix	23556.30868E-3
2.	Determinate of error + variety matrix	86983.081E+5
3.	Wilks criterion	27081.48344E-13
4.	M	91
5.	Degree of freedom	390
6.	V statistic	1795.15

Table 3: Clustering of 40 mung bean genotypes (Tocher's method) for yield and related attributes

Cluster	Number of genotypes		Genotypes included	Place of Origin
I	15	13	PM 3, PM 15-19, PM 15-13, PM 4, PM 15-7, PM 15-8, PM 7, PM 8, PM 15-15, PM 15-10, PM 9, PM 2, PM 15-21	GBPUA&T
		1	IPM 02-3	IIPR, KANPUR
		1	LGG 460	RARS, LAM
II	11	6	PM 15-5, PM 15-6, PM 15-17, PM 15-3, PM 15-18, PM 15-9	GBPUA&T
		3	SML 1082, SML 1808, ML 818	PAU, LUDHIANA
		1	HUM 12	VARANASI
		1	Pusa Vishal	IARI, NEW DELHI
III	1	1	PM 15-20	GBPUA&T
IV	4	3	PM 15-14, PM 15-2, PM 15-4	GBPUA&T
		1	SML 1815	PAU, LUDHIANA
V	3	2	IPM 02-19, IPM 02-13	IIPR, KANPUR
		1	Sona Mung 1	IIPR, KANPUR
VI	1	1	PM 15-16	GBPUA&T
VII	3	2	PM 15-12, PM 5	GBPUA&T
		1	IPM 2-14	IIPR, KANPUR
VIII	1	1	Vamban 2	NPRC, VAMBAN
IX	1	1	PM 15-11	GBPUA&T

It is evident from Table 3 that Cluster I was the largest, containing 15 genotypes, followed by Cluster II (11 genotypes), Clusters IV (4 genotypes), Cluster V and Cluster VII each had 3 genotypes. Clusters III, VI, VIII and IX each contained a single genotype. The maximum intra-cluster distance was recorded for Cluster VII (6.73) followed by Cluster V (6.12), Cluster II (6.1), Cluster I (5.79) and Cluster IV (5.32) while rest of the Clusters *viz.* III, VI, VIII and IX had zero intra-cluster distances as they were solitary clusters. The highest inter-cluster distance was observed between Cluster VII and Cluster VIII (17.12) which was

followed by Cluster IV and Cluster VII (14.87) and Cluster II and Cluster VIII (14.16), indicating that genotypes included in these clusters if hybridized together, they will produce wide spectrum of genetic variability in segregating generations from which desirable plants can be selected. This genetic diversity in the present investigation provides an excellent opportunity to select appropriate donors from divergent clusters that are likely to exhibit maximum heterosis and offer extensive genetic variability for yield and yield-contributing factors. Kumar *et al.* (2019), Priya *et al.* (2020), Chandra *et al.* (2021), Joshi *et al.* (2022) and Rahangdale *et al.* (2023) also obtained grouping of genotypes in to different clusters in different crops while working with different experimental material. It is also evident from the Table 4 that inter cluster distances are of high magnitude than the intra cluster distance indicating that the genotypes included in different clusters may have been adapted to different environments resulting in greater genetic divergence. The present study evaluated mung bean genotypes across several clusters to identify potential donor parents based on the cluster means for various agronomic traits (Table 5). The genotypes included in Cluster II were earliest maturing with the 50% flowering in 39.79 days and maturity in 89.16 days, are ideal for breeding early maturing varieties. Cluster VIII exhibited the highest plant height (98.92 cm), while Cluster IV had the most primary branches (4.42) and the highest seed yield per plant (15.61 g). It indicated that if the genotypes from cluster II are hybridized with the genotypes included in cluster IV, the recombinant genotypes with high yield and early maturity can be obtained. Cluster V had the most pods per cluster (6.36). Cluster VI showed the longest pod length (9.42 cm), and Cluster IV had the most pods per plant (74.00). Clusters III and IX had the highest seeds per pod (12.65), and Cluster VII had the highest 100-seed weight (4.88 g). These findings highlighted specific clusters for targeted breeding programmes to improve mung bean traits. The selection and choice of parents mainly depend on the contribution of traits to total divergence (Verma *et al.* 2018, Yadav *et al.* 2024 and Bhatt *et al.* 2024). The number of times each of the 10 traits appeared in the first rank and its respective percent contribution to diversity is presented in Table 6. Among all traits, the number of pods per plant contributed the most (40.26%) to diversity, ranking first in 314 out of 780 combinations, followed by 100-seed weight (20.77% with 162 times ranked first), days to 50% flowering (15.64% with 122 times ranked first), and plant height (12.18% with 95 times ranked first). The traits like pods per plant, 100 seed weight and pod length are important yield parameters in any pulse crop (Verma *et al.* 2018 and Naing *et al.* 2021) and in the present study these traits are contributing to the total divergence. The high contribution of pods per plant, days to 50% flowering and 100 seed weight towards total genetic diversity was also reported earlier by Priya *et al.* (2020), Joshi *et al.* (2022) and Rahangdale *et al.* (2023). It is also evident from the results that in present investigation the trait number of pods per cluster had zero percent contribution towards the total diversity. This indicating that trait may have been fixed in the experimental population. All genotypes are having non-significant differences for pods per cluster resulting in no genetic variation for this trait or the trait pods per cluster may be highly correlated with other traits. The variation for pods per cluster is already captured by some other traits or the gene controlling pods per cluster has multiple effects and the variation for this trait is not contributing to the overall diversity. Similar results were previously reported by Chandra *et al.* (2017), Markam *et al.* (2018) and Sneha *et al.* (2020). In the present study it was observed that the genotypes originated in different eco-geographical regions grouped together into different and in the same clusters. The grouping of genotypes originated in different geographical regions including it to same cluster may be due to their common ancestry which results in similar genetic makeup despite developed in different regions or due to the convergent evolution. It may be due to which genotypes have evolved similar traits independently in response to similar environmental pressure. It may also be due to breeding programs may have used similar parental material and breeding strategies

resulting in similar kind of genotypes. (Chandra *et al.* 2021) also reported inclusion of genotypes originated in different regions in to similar cluster. Present result indicated that geographical diversity does not necessarily correlate with genetic diversity.

Table 4: Average intra and inter-cluster distances (D^2 values) for 9 clusters of mung bean genotypes

Cluster	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Cluster I	5.79	8.12	7.44	8.05	9.6	7.1	11.51	9.19	8.08
Cluster II		6.1	7.85	11.08	10.06	9.01	8.43	14.16	10.12
Cluster III			0	7.89	12.24	6.4	11.28	12.4	8.19
Cluster IV				5.32	12.84	8.55	14.87	10.49	9.08
Cluster V					6.12	10.86	12.03	12.98	9.42
Cluster VI						0	11.44	11.43	6.68
Cluster VII							6.73	17.12	11.11
Cluster VIII								0	11.05
Cluster IX									0

* Bold values (diagonal) indicated intra cluster distances

Table 5: Cluster means for different character of mung bean genotypes

Cluster	DFE	DM	PH	NPB	PPC	PL	NPP	NSP	HSW	SYP
Cluster I	43.71	94.78	80.56	3.91	5.92	7.7	53.62	11.76	3.49	13.35
Cluster II	39.79	89.16	71.06	4	5.55	8.08	42.61	11.61	3.95	11.45
Cluster III	42.32	101.63	68.98	4.33	5.67	8.31	61	12.65	4.06	13.76
Cluster IV	42.74	92.32	67.44	4.42	5.98	7.68	74	11.91	3.67	15.61
Cluster V	44.89	95.36	57.19	3.56	6.36	7.45	30.11	11.24	2.81	7.36
Cluster VI	46.65	104.32	69.11	4	5.66	9.42	61.33	9.65	3.72	12.09
Cluster VII	45.12	96.22	67.5	3.56	6.25	8.25	30.78	11.66	4.88	10.62
Cluster VIII	49.67	104.34	98.92	4	4.66	6	58.67	12.34	3.08	12.74
Cluster IX	51.32	109.97	55.03	4.33	5.4	8.33	51	12.65	3.95	14.25

DFE- Days to 50% flowering, **DM**- Days to maturity, **PH**- Plant height (cm), **NPB**- Number of primary branches per plant, **PPC**- Number of pods per cluster, **PL**- Pod length, **NPP**- Number of pods per plant, **NSP**-Number of seeds per pod, **HSW**- One hundred seed weight (g) and **SYP**- Seed yield per plant (g).

Table 6: Contribution of different characters towards total divergence

S. No.	Characters	Times ranked 1st	Contribution (%)
1	Days to 50% flowering	122	15.64
2	Days to maturity	28	3.59
3	Plant height (cm)	95	12.18
4	No. of primary branches	3	0.38
5	No. of pods/ cluster	0	0
6	Pod Length (cm)	33	4.23
7	No. of pods/plant	314	40.26
8	No. of seeds/pod	11	1.41
9	100 seed weight	162	20.77
10	Seed yield/plant	12	1.54

CONCLUSION

In the present study 40 mung bean genotypes were grouped into 9 different clusters using Tocher's method. Cluster I was the largest, comprising 15 genotypes, followed by Cluster II with 11 genotypes. Clusters IV with 4 genotypes. Cluster V and Cluster VII each had 3 genotypes; and Clusters III, VI, VIII and IX each contained a single genotype. It was observed that the genotypes originated in different eco-geographical regions grouped together in the same clusters indicating that there is no relationship between geographical and genetic diversity. Maximum inter-cluster D^2 value (17.12) was recorded between Cluster VII and Cluster VIII, indicating that crosses between these clusters would likely be most productive. The number of pods per plant contributed to genetic diversity was (40.26%).

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

References

1. Bhatt, A. Verma, S. K., Panwar, R. K., Yadav, H., Pragati, K., Kumawat, S. and Naresh, T. 2024. Assessment of genetic variability, correlation, and path coefficient for yield and its contributing traits in Pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Journal of Experimental Agriculture International*, 46(8): 125-134.
2. Bohra, A., Bajpai, G. C. and Verma, S. K. 2015. Yield factor analysis in F₄ and F₅ progenies derived from interspecific hybridization between cultivated and wild pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Legume Research*, 38(3): 303-307.
3. Chandra, D., Verma, S. K., Gaur, A. K., Bisht, C., Gautam, A., Chauhan, C. and Yadav, H. 2021. Heterosis, Combining Ability, Genetic Diversity and their Interrelationship in Pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Legume Research*, DOI: 10.18805/LR-4628
4. Chandra, G. S., Lavanya, G. R. and Kulkarni, S. D. 2017. Studies on Genetic diversity in Greengram [*Vigna radiata* (L.) Wilczek] for seed yield characters. *J. Pharmacogn. Phytochem.*, 6(6): 1765-1767.
5. Chaudhary, R., Verma, S. K., Panwar, R. K., Chourasiya, V. K. and Pandey, D. 2017. Morphological characterization of lentil [*Lens culinaris* (L.) Medikus] varieties based on six qualitative traits. *Journal of Pharmacognosy and phytochemistry*, 6(5): 1611-1615.
6. De Pace, C., Pasquini, M., Vaccino, P., Bizzarri, M., Nocente, F., Corbellini, M., Caceres, M. E., Cionini, P. G., Vittori, D. and Vida, G. 2011. Deployment of either a whole or dissected wild nuclear genome into the wheat gene pool meets the breeding challenges posed by the sustainable farming systems. *Plant Gene. Res.*, 9(2): 352-356.
7. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, India. 2022. First Advance Estimates of Production of Food grains for 2022-23, published by Directorate of Economics and Statistics, New Delhi, pp 1-4.
8. Joshi, D. P., Parmar, L. D., Meena, R. K. and Chaudhary, G. K. 2022. Estimation of genetic diversity in mung bean [*Vigna radiata* (L.) Wilczek] genotypes grown in Gujarat. *Int. J. Legume Res.*, 45(7): 828-833.
9. Kumar, A., Sharma, N. K., Kumar, R., Chandel, D. and Yadav, M. K. 2019. Genetic divergence studies in mung bean germplasm under arid environment. *Int. J. Chem. Stud.*, 7(2): 1617-1619.
10. Markam, N. K., Nair, S. K., Khute, I. K. and Preeti, P. 2018. Genetic divergence studies in mung bean [*Vigna radiata* (L.) Wilczek] genotypes. *Green Farming Int. J.*, 9(2): 231-234.
11. Meena, S. S., Verma, S. K., Chaudhary, R., Panwar, R. K. and Singh, J. P. 2017. Genetic variability and inter-relationship among yield contributing characters in advance lines of pigeonpea [*Cajanus cajan* (L.) Millspaugh] grown at different altitudes. *Chemical Science Review and Letters*, 6 (22): 1120–1128.
12. Naing, T., Verma, S. K., Yadav, H., Chauhan, C., Gautam, A., Karn, A. and Gaur, A. K. 2021. Assessment of Morphological and Molecular Genetic Diversity in Pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *Legume Research*. 45(9): 1088-1093.
13. Priya, C. S., Babu, D. R., Rajesh, A. P. and Hari, N. 2020. Genetic divergence among mung bean germplasm pertaining to grain yield and yield components. *Int. J. Chem. Stud.*, 8(4): 2045-2050.
14. Rahangdale, S., Lakhani, J. P., Singh, S. K., Barela, A., Kumar, P. and Prajapati, S. S. 2023. Multivariate analysis for study of genetic divergence in mung bean [*Vigna radiata* (L.) Wilczek] genotypes. *Environ. Conserv. J.*, 24(3): 40-46.

15. Rao, C. R. 1952. Advanced statistical methods in biometrical research. John Wiley and Sons, Inc. New York. 357-363.
16. Sneha, M., Saravanan, S., Premkumari, S. and Pillai, M. A. 2020. An appraisal of genetic divergence in some indigenous collections of mung bean [*Vigna radiata* (L.) Wilczek]. *Electron. J. Plant Breed.*, 11(2): 620-625.
17. Verma, S. K., Bisht, C., Gaur, A. K. and Chandra, D. 2018. Study on some genetic parameters for yield and related traits in pigeonpea [*Cajanus cajan* (L.) Millspaugh] genotypes. *Chemical Science Review and Letters*, 7(25): 70-76.
18. Verma, S. K., Gaur, A. K., Bisht, C. and Chandra, D. 2018. Estimation of genetic diversity for yield and its component traits in pigeonpea using D^2 statistics. *Journal of Hill Agriculture*, (9)4: 383-386.
19. Yadav, H., Panwar, R. K., Verma, S. K., Arora, A., Rana, A. and Pragati, K. 2024. Elucidation of genetic variability for seed yield and its component traits, along with association studies in pigeonpea [*Cajanus cajan* (L.) Millspaugh]. *International Journal of Plant & Soil Science*, 36(1): 207-216.

UNDER PEER REVIEW

UNDER PEER REVIEW

UNDER PEER REVIEW