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Morphological variation among Brahmi (*Bacopa monnieri*) germplasm accessions in Andhra Pradesh

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Abstract
The current research on" Morphological variations among Brahmi (*Bacopa monnieri*) germplasm accessions in A.P." was conducted at Dr. Y.S.R. Horticultural University, Horticultural Research Station, Venkataramannagudem, Andhra Pradesh. For 17 characteristics, genetic divergence was examined using Mahalanobis D^2 analysis on 22 Brahmi accessions. The accessions were classified into five clusters based on morphological characteristics. The greatest inter-cluster distance was found between clusters III and IV, indicating that there was a lot of diversity, and the greatest intra-cluster distance was found in cluster II, indicating that it has the greatest number of distinct accessions within the cluster. Cluster III has high mean values for plant height (54.42 cm), number of leaves (83.50), number of nodes per 15 cm stolon length (7.25), length of the stem (53.63 cm), number of branches (15.0), fresh weight of the leaves (375.00 gm^{-2}), dry weight of the leaves (93.50 gm^{-2}), dry weight of stolon+branches (153.75 gm^{-2}), dry weight of total biomass (247.25 gm^{-2}) but low mean values for leaf area (3.23 cm^2), basal leaf area (411.79 mm^2) As a result, these divergent and attractive genotypes may be exploited in future crop enhancement programmes of Brahmi.

Keywords: Mahalanobis D^2 analysis, genetic divergence, cluster analysis

Introduction
Bacopa monnieri, a Scrophulariaceae family member, is a tiny prostrate plant found in the tropics of Asia, America, and Australia. In India, it is known as "Brahmi" or "Herb of the Thinker." It is distinguished by thick leaves and delicate purple blooms. *B. monnieri* was placed second among important Indian medicinal plants in a study by (Rajani *et al*., 2004) [4] who considered medicinal value, economic relevance, and the potential for future research and development. *Bacopa monnieri* grows in Nepal, Sri Lanka, China, Taiwan, Vietnam, Florida, and other southern states of the United States. The yearly demand or trade in this crop has increased due to its potential use in the pharmaceutical industry and the ayurvedic medical system to cure a number of ailments. To record variety it is required to select elite accessions according to active principle content, molecularly classify wild populations, and improve *in vitro* propagation procedures (appropriate for a variety of populations) for conservation. Roshini *et al*. (2008) [5] studied 11 Brahmi accessions gathered from diverse locations of Kerala, India, and found diversity in 30 characteristics, including 12 qualitative and 18 quantitative attributes. Reddy *et al*. (2010) [2] studied the heterogeneity exhibited in 29 *Bacopa monnieri* accessions obtained from various eco-geographic sites in Kerala. The observed diversity in shoot length, leaf length, leaf breadth, leaf area, number of flowers, internodal length, number of leaves, and biomass has been quantified.
Genetic diversity is essential for a species' survival because it provides for required adaptation to present biotic and abiotic environmental circumstances, as well as the potential to modify the genetic composition to cope with environmental changes. Apart from making it easier to produce new lines, the present study's findings will assist breeders in developing varieties with specific characteristics such as quality improvement and tolerance to biotic and abiotic challenges.

Materials and Methods
The experiment was carried out at the Horticultural Research Station in Venkataramannagudem during 2022 to 2023. The trial was done in randomised block design with two replications. From the current germplasm, 22 Brahmi accessions were chosen for genetic divergence research.

The terminal cuttings with 10 cm length were planted in a randomised block configuration with two replications. Observations were made on five randomly selected plants from each replication for 17 different characteristics, including plant height (cm), number of leaves, leaf area (cm^2), number of nodes per 15 cm stolon length, pedicel length (cm), number of stolons in m^2 area, basal leaf area (mm^2), stolon length (cm), leaf size (cm^2), length of the stem (cm), number of branches, fresh weight of the leaves (gm^{-2}), dry weight of the leaves (gm^{-2}), dry weight of stolon+branches (gm^{-2}), dry weight of total biomass (gm^{-2}), fresh herbage yield (gm^{-2}) and total dry herbage yield (q ha^{-1}).The accessions were divided into five groups based on the relative magnitude of their D^2 levels.

Statistical analysis

Mahalanobis D^2 statistics were used to analyse genetic divergence. The brahmi accessions were classified into several clusters using Tocher's approach (Rao, 1952) [1].

Results and Discussion

Cluster I has eleven accessions, Cluster II has seven accessions, Cluster III has two accessions, and Cluster IV and V each have one accession, as shown in Table-1. Table 2 displays the cluster mean values of 17 characters. Five groups were formed after genotypes were clustered and genetic diversity was measured using Mahalanobis D2 statistics for characteristics. Cluster II had the greatest intra-cluster distance. Clusters III and V had the highest inter-cluster distance, indicating the most genetic divergence that could potentially be used in crop enhancement efforts. Because the inter-cluster distance was larger than the intra-cluster distance, the present study indicated heterogeneity between clusters and homogeneity across genotypes inside a cluster. Genotypes with genetic divergence might therefore function as parents in a hybridization attempt.

Table 1: Distribution of genotypes into different clusters

S. No.	Clusters	No. of genotypes	Genotypes of cluster
1	Cluster I	11	APBm-7, APBm-18, APBm-4, APBm-19, APBm-14, APBm-8, APBm-22, APBm-15, APBm-5, APBm-20, APBm-12
2	Cluster II	7	APBm-1, APBm-11, APBm-2, APBm-17, APBm-10, APBm-9, APBm-13
3	Cluster III	2	APBm-6, APBm-21
4	Cluster IV	1	APBm-3
5	Cluster V	1	APBm-16

Cluster means are as follows

Cluster III had the highest cluster mean for plant height (54.42 cm), number of leaves (83.50), number of nodes per 15 cm stolon length (7.25), length of the stem (53.63 cm), number of branches (15.0), fresh weight of the leaves (375.00 gm^{-2}), dry weight of the leaves (93.50 gm^{-2}), dry weight of stolon+branches (153.75 gm^{-2}), and dry weight of total biomass (247.25 gm^{-2}), while it had the lowest cluster mean for leaf area (3.23 cm^2), basal leaf area (411.79 mm^2) and leaf size (0.44 cm^2). Cluster IV exhibited the smallest cluster mean in terms of pedicel length (1.51 cm), stolon length (1.49 cm), fresh weight of leaves (117.50 gm^{-2}), dry weight of leaves (27.50 gm^{-2}), dry weight of stolon +branches (46.00 gm^{-2}), dry weight of total biomass (86.00 gm^{-2}), fresh herbage yield (1.99 q ha^{-1}) and dry herbage yield (0.84 q ha^{-1}). Cluster V had the greatest cluster mean values for pedicel length (1.61 cm), basal leaf area (975.84 mm^2), stolon length (3.09 cm), leaf size (1.77 cm^2), fresh herbage yield (550.45 q ha^{-1}) and dry herbage yield (259.55 q ha^{-1}), while it had the lowest mean for number of stolons in m^2 area (550.0). Cluster II had the largest number of stolons per m^2 area (716.71) and the lowest total dry herbage yield (108.83 q ha^{-1}). Plant height (43.30 cm) and stem length (42.51 cm) had the lowest cluster mean values in Cluster I.

Table 2: Mean values of clusters

S. No	Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
1.	Plant height (cm)	43.30	48.54	54.42	47.88	45.38
2	Number of leaves at 10 cm stolon	47.11	43.67	83.50	29.50	26.84
3	Leaf area (cm^2)	3.64	3.58	3.23	4.01	3.82
4	Number of nodes at 15 cm stolon	6.42	7.00	7.25	6.50	5.34
5	Pedicel length(cm)	1.59	1.58	1.52	1.51	1.61
6	Number of stolons in m^2 area	633.64	716.71	700.00	633.50	550.00
7	Basal leaf area(mm^2)	644.66	826.23	411.79	487.82	975.84
8	Stolon length (cm)	2.30	2.09	2.52	1.49	3.09
9	Leaf size (cm^2)	0.72	1.07	0.44	0.65	1.77
10	Length of the stem (cm)	42.51	47.43	53.63	46.92	44.59
11	Number of branches	12.02	12.79	15.00	7.17	6.84
12	Fresh weight of the leaves (gm^{-2})	221.77	195.33	375.00	117.50	188.00
13	Dry weight of the leaves (gm^{-2})	56.77	51.07	93.50	27.50	37.00
14	Dry weight of the stolon+branches (gm^{-2})	106.64	70.29	153.75	46.00	79.50
15	Dry weight of total biomass (gm^{-2})	163.41	121.36	247.25	86.00	116.50
16	Fresh herbage yield (q ha^{-1})	404.66	285.81	304.10	198.60	550.45
17	Total dry herbage yield (q ha^{-1})	166.58	108.83	128.20	83.25	259.55

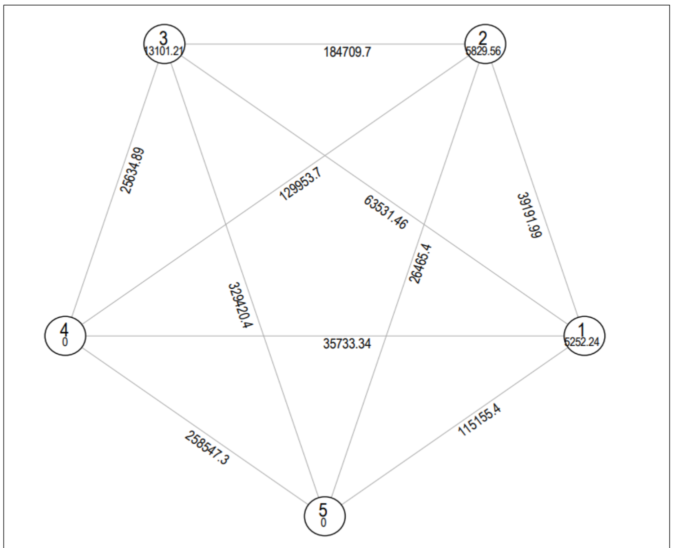
Intra and inter cluster distances

Table-3 displays the inter and intra cluster distances. The D^2 values were used to calculate the inter and intra cluster distances. The greatest inter-cluster distance was seen between clusters V and IV (258547.30), indicating that these two clusters are the most divergent with the greatest genetic distance, which may be used in hybridization initiatives to gain heterotic advantage. Cluster IV and III had the shortest inter-cluster distance, indicating that these two clusters had less genetic diversity. Cluster III had the greatest intra-cluster distance, whereas Cluster I had the smallest.

In the present study, the inter cluster distance was greater compared to the intra cluster distance, indicating that there is homogeneity inside a cluster and heterogeneity across clusters. As a result, we may employ the accessions from various clusters for a future crop enhancement plan. Similar results in brahmi were found by Mathur *et al*. (2003) [3], Roshini *et al*. (2008) [5] and Reddy *et al*. (2010) [2].

Table 3: Inter and intra cluster distances of Brahmi accessions.

Cluster	I	II	III	IV	V
I	5252.24	39191.99	63531.46	35733.34	115155.40
II		5829.56	184709.70	129953.70	26465.40
III			13101.21	25634.89	329420.40
IV				0.00	258547.30
V					0.00



Mahalnobis Euclidean Disatnce (Not to the Scale)

Conclusion

The distance that exists from and among the accessions is shown by the cluster analysis. 17 accessions were classified into 5 clusters. The research clusters (APBm-6 and APBm-21) had the most variety in terms of morphological characteristics. These accessions may be employed in the hybridization programme for high yielding characteristics.

Future scope

Divergent accessions can be utilised to enhance Brahmi crop, particularly in hybridization programmes. The genotypes of Cluster III and Cluster V showed maximum genetic diversity. Hence, these genotypes can be used for crop improvement.

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