Received: 21 Feb 2022 | Accepted: 18 Jul 2022 | Online: 05 Aug 2022

Electronic Journal of Plant Breeding

Research Note

Genetic divergence, trait association and path analysis studies in browntop millet germplasm

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Abstract
Twenty five genotypes of brown top millet were considered for genetic divergence, association and path analysis during *Kharif*, 2019. Among the eight yield components studied panicle length (23.67 %) contributed the maximum for divergence followed by fodder yield (14.33 %) and harvest index (13.67%). Divergence studies grouped twenty five genotypes into seven clusters. Among seven clusters, cluster I was the largest having 11 genotypes after which came cluster II with 5 genotypes, cluster III with 3 genotypes, clusters IV and V with 2 genotypes and clusters VI and VII with one genotype each. The maximum intra cluster distance was noticed in cluster IV (8.0788) indicating the highest variability. The maximum inter cluster distance was observed between cluster VI and cluster VII (54.086). Understanding the results obtained from trait association and path analysis revealed positive association and high positive direct effects by fodder yield and harvest index on grain yield.

Keywords: Brown top millet, Genetic divergence, Association studies, Path analysis, Cluster distance

Small millets are minute seeded crops and also known as minor millets, belong to the *Poaceae* family which are mainly cultivated as grain and fodder crops grown in dry areas of temperate, tropical and subtropical locations. Minor millets serve an important role as a main food for the poor and a healthy diet for city dwellers, highlighting the need for additional efforts in the research and development of these crops. These are crops of local preference that give consistent yields on marginal areas and play an important role in food security. Browntop millet (*Brachiaria ramosa* (L.) Stapf) is an annual/perennial warm-season grass which is used in forage/pasture management systems that originated in Southeast Asia (Sheahan, 2014). This crop is recently gained importance, familiar for climate resilience and its capacity to adapt to varied ecological circumstances, low water requirement, low incidence of insect pests and disease and low vulnerability to environmental pressures (Bandyopadhyay *et al.,* 2017). Currently, it is grown in a limited area due to the shift from traditional crops to commercial crops. The climate resilient aspects and increased interest among consumers regarding healthy consciousness necessitated more research and development in this crop. This millet has encountered minimal research attention in terms of the development of genetic and genomic resources and breeding for yield improvement. This might be due to low research priority for this crop and nearly all diverse genetic resources were lost in the shift to cash crops. In the browntop millet crop a very limited number of germplasm lines (< 1000) are conserved worldwide (Vetriventhan *et al.,* 2020). Diversity in crop cultivars is very important for sustainable agriculture. Germplasm provides the needed variability for crop development. A very few number of germplasm lines and inadequate information regarding the genetic diversity of browntop millet limit their effective utilization in crop improvement. Further, low yields in this crop are the major limitation which can cope up with genetic improvement of the crop.

The huge spectrum of genetic variability observed in segregating populations relies on the quantum of genetic diversity among parental genotypes. Genetic diversity is essential for any crop improvement plan as it helps in the occurrence of superior recombinants (Arunachalam, 1981). Among the multivariate procedures, Mahalonobis D^2 statistics suggested by Mahalanobis (1936) is the prime method in plant breeding and genetics for the estimation of genetic divergence. The D^2 statistic measures the cause of differentiation at inter and intra cluster levels and helps in the selection of genetically divergent parents for hybridization. Though numerous character relationships are useful in the selection, breeders should pay special attention to the links between yield and other component traits. Detected true associations among traits may be measured in terms of simple phenotypic and genotypic correlation coefficients (Sonnad, 2005). Yield, on the other hand, is a complicated feature that is influenced both directly and indirectly by its numerous components. Correlation coefficients alone are not sufficient to elucidate the complexity of the biological relationships between traits or how a change in a character affects an associated character (Dewey and Lu 1959). To overcome this dearth, path coefficient, a standardized regression coefficient developed by Wright (1921), helps in a partitioning of correlation into direct and indirect effects of different traits on the dependent variable and thus helps in judging the cause-effect relationship and aids in effective selection. Consequently, the present investigation was aimed at identifying genetically divergent browntop millet genotypes with desirable traits for hybridization and the contribution of traits for the total variability within the populations. Further, this analysis also aimed to determine the traits having a relationship with grain yield and interrelationships among different traits themselves.

The current study was carried out at Agricultural Research Station, Perumallapalle during *Kharif,* 2019. The experimental material constituted 25 browntop millet genotypes which were received from the Indian Institute of Millets Research, Hyderabad. This experiment was conducted as per Randomized Block Design with three replications and every entry was sown in three rows with a spacing of 45 cm x 10 cm. Timely management of recommended package was done during the crop period. Observations were noted for days to 50% flowering, days to maturity, plant height (cm), the number of productive tillers per plant, panicle length (cm), harvest index (%), fodder yield (t/ha) and grain yield (q/ha).

The data were subjected to the analysis of variance (Fisher and Yates, 1938) and further, biometrical procedures were followed to estimate genetic divergence by Mahalanobis (1936) D^2 statistic technique as described by Rao (1952). Phenotypic and genotypic correlations were estimated by using the formulae as suggested by Falconer (1964). Direct and indirect effects of different yield components on yield were calculated as per Dewey and Lu (1959).

In the present experiment, eight yield components were recorded for twenty five browntop millet genotypes. The mean values of eight quantitative traits and the location of collection of 25 browntop millet germplasm lines are presented in **Table 1**. The analysis of variance disclosed the presence of remarkable variation among the genotypes for the eight characters studied. Similar significant variability among the genotypes was earlier reported in browntop millet by Anuradha *et al.* (2020) in browntop millet and Singamsetti *et al.* (2018) in finger millet.

Early flowering (51 days) and maturity (81.5 days) were observed in BRO 29, while BRO 10 was the late flowering (61 days) and maturing (91.5 days) genotype. Short plant height was recorded in BRO 11 (127.1 cm) and tall plant height in BRO 19 (157.6 cm). More number of tillers was observed for BRO 15 and BRO 2 (13.9), while a lengthy panicle was observed in BRO 22 (20.9 cm). Harvest index was higher in BRO 14 which also recorded the highest grain yield (20.4 q/ha). Maximum fodder yield was recorded by BRO 23 (6.2 t/ha).

Among the eight yield components studied (**Table 2**) panicle length (23.67 %) contributed the maximum for divergence followed by fodder yield (14.33 %), harvest index (13.67%), the number of productive tillers per plant (12.33 %), plant height (11.67%) days to 50 % flowering (10.67 %) and days to maturity (7.67 %). The character grain yield per plant (6%) recorded the lowest contribution. Suryanarayana *et al.* (2019) found similar results for panicle length, Wonne Soe *et al*. (2022) and Bedis *et al.* (2007) for fodder yield and Shivangi negi *et al.* (2017) for harvest index.

Based on the Tocher clustering method, these genotypes were grouped into 7 clusters at Tocher cut-off value of 9.6363 (**Table 3**). Among seven clusters, cluster I was the largest having 11 genotypes after which came cluster II with 5 genotypes, cluster III with 3 genotypes, clusters IV and V with 2 genotypes and clusters VI and VII with one genotype each. The intra-cluster distance indicated the presence of variability among the genotypes grouped in the same cluster. The greatest intra cluster distance was noticed in cluster IV (8.0788) indicating the highest variability and followed by cluster I (7.1832). The two clusters *viz*., cluster VI and VII were solitary (**Table 4**). The maximum inter cluster distance was observed between cluster VI and Cluster VII (54.086) later came clusters V and VI (37.339), clusters II and VI (37.026), clusters I and VII (31.924) and clusters IV and VII (30.163) (**Table 4**).

Table 1. Mean performance of 25 browntop millet germplasm lines for eight quantitative characters

IIMR No.	NBPGR Acc.No	Location	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers / plant	Panicle length (cm)	Harvest index (%)	Fodder yield (t/ha)	Grain Yield (q/ha)
BRO 10	IC613554	Karnataka	61.0	91.5	144.9	10.4	16.4	9.1	3.9	12.3
BRO 11	IC613555	Karnataka	58.0	89.0	127.1	7.8	15.1	11.0	4.3	16.4
BRO 12	IC613556	Karnataka	59.0	90.0	139.8	9.6	16.4	9.7	3.9	13.5
BRO 13	IC613557	Karnataka	56.0	86.5	136.7	10.4	18.7	6.9	4.1	9.2
BRO 14	IC613558	Karnataka	54.0	84.5	138.6	11.3	17.4	11.9	5.0	20.4
BRO 15	IC613559	Andhra Pradesh	56.0	87.0	147.2	13.9	20.6	10.5	4.8	16.8
BRO 16	IC613560	Andhra Pradesh	54.5	85.5	147.7	7.9	18.6	11.4	4.6	18.1
BRO 17	IC613561	Andhra Pradesh	56.0	88.5	140.4	10.8	18.7	9.3	5.0	15.7
BRO 18	IC613562	Andhra Pradesh	53.0	85.5	148.2	10.0	19.6	5.5	5.5	9.4
BRO 19	IC617952	Karnataka	54.0	84.5	157.6	11.1	18.2	10.7	4.7	16.6
BRO 2	IC613546	Karnataka	52.5	84.0	149.4	13.9	18.2	10.1	4.8	15.8
BRO 20	IC617953	Karnataka	56.5	87.5	146.2	9.4	18.3	11.2	4.3	16.2
BRO 21	IC617954	Karnataka	59.5	90.0	141.5	11.1	16.6	8.9	4.1	12.3
BRO 22	IC617955	Karnataka	56.5	88.0	154.9	9.5	20.9	9.2	5.6	17.1
BRO 23	IC617956	Karnataka	56.0	88.0	130.2	7.6	16.6	7.9	6.2	16.0
BRO 24	IC617957	Karnataka	53.5	84.5	139.5	8.8	17.4	8.5	4.4	12.3
BRO 25	IC617958	Karnataka	55.0	87.5	143.5	10.5	18.5	8.5	6.1	17.3
BRO 27	IC617960	Karnataka	54.5	85.5	133.2	9.8	20.0	8.6	4.2	12.0
BRO 28	IC617961	Karnataka	53.5	83.5	142.5	13.8	17.2	8.8	4.4	13.1
BRO 29	IC617962	Andhra Pradesh	51.0	81.5	139.4	9.6	18.3	7.5	5.7	14.1
BRO 4	IC613548	Karnataka	53.5	85.5	140.4	11.9	13.1	10.9	3.8	14.3
BRO 5	IC613549	Karnataka	53.0	84.0	132.7	13.8	16.3	9.8	3.6	11.9
BRO 6	IC613550	Karnataka	56.5	89.0	152.5	9.1	20.0	9.2	5.0	15.2
BRO 8	IC613552	Karnataka	55.0	85.5	143.0	11.1	17.9	9.9	4.6	15.4
BRO 9	IC613553	Karnataka	54.0	85.0	147.2	11.4	17.8	8.3	5.1	14.3

Table 2. Contribution of different characters to divergence in browntop millet

Character	Number of times ranked 1st	Per cent contribution to divergence
Days to 50% flowering	32	10.67
Days to maturity	23	7.67
Plant height	35	11.67
Number of productive tillers / plant	37	12.33
Panicle length	71	23.67
Harvest index	41	13.67
Fodder yield	43	14.33
Grain Yield	18	6.00
	300	

Tocher cut off value: 9.6363

https://doi.org/10.37992/2022.1303.113

Table 3. Clustering of 25 browntop millet germplasm lines

Cluster	Number of genotypes	Name of genotype
I	11	BRO-10, 21, 12, 8, 19, 28, 20, 11, 9, 13, 14
II	5	BRO- 22, 6, 25, 17, 15
III	3	BRO-16, 24, 27
IV	2	BRO-2, 5
V	2	BRO-23, 29
VI	1	BRO-4
VII	1	BRO-18

Table 4. Average intra and inter cluster values in 7 clusters in browntop millet

Cluster	I	II	III	IV	V	VI	VII
I	7.1832	16.112	10.1735	12.7484	17.3071	19.0442	31.9247
II		6.6566	11.9052	18.8058	15.2238	37.0261	16.2492
III			6.1342	14.0437	10.978	24.8484	20.5099
IV				8.0788	21.7045	10.8278	30.1636
V					6.1029	37.339	11.3224
VI						0	54.0867
VII							0

The browntop millet genotypes grouped in the genetically diverse clusters might be used in hybridization for further crop improvement.

Genotypes present in cluster IV took less duration for days to flowering (52.8) and days to maturity (84.0). The maximum plant height (148.2 cm) was observed in cluster VII genotype, a higher tiller number (13.9) was noticed in cluster IV genotypes, lengthy panicle was observed in cluster II (19.7 cm) and cluster VII (19.6 cm). The cluster VI comprised of one genotype which had a better mean value for harvest index (10.9%). Fodder yield was higher in cluster V genotypes whereas more grain yield was recorded in cluster II genotypes (**Table 5**). In the present study, values of the phenotypic correlation coefficients among eight traits were given in **Table 6**. Correlation studies among the various traits revealed that plant height showed a significant positive correlation with panicle length. Days to 50 % flowering and days to maturity showed a significant negative correlation with the number of productive tillers per plant. Grain yield per plant was significantly positively correlated with harvest index and fodder yield. The findings were in line with the previous studies of Madhavilatha *et al.* (2021) in little millet and Anand *et al.* (2020) in foxtail millet for fodder yield.

The phenotypic correlations were separated into direct and indirect effects through path coefficient studies. It helps in separating the direct effect and their indirect effects through other traits by distributing the correlations (Wright, 1921) for a better understanding of the cause and effect relationship. The values of path coefficient analysis

Table 5. Cluster mean performance for yield and yield attributing traits in browntop millet

Cluster number	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of productive tillers / plant	Panicle length (cm)	Harvest index (%)	Fodder yield (t/ ha)	Grain Yield (q/ha)
I	56.4	87.1	142.3	10.7	17.3	9.7	4.4	14.5
II	56.0	88.0	147.7	10.8	19.7	9.3	5.3	16.4
III	54.2	85.2	140.1	8.8	18.7	9.5	4.4	14.1
IV	52.8	84.0	141.1	13.9	17.3	10.0	4.2	13.8
V	53.5	84.8	134.8	8.6	17.5	7.7	5.9	15.0
VI	53.5	85.5	140.4	11.9	13.1	10.9	3.8	14.3
VII	53.0	85.5	148.2	10.0	19.6	5.5	5.5	9.4

Table 6. Estimates of phenotypic correlations for grain yield and yield components in browntop millet

Character	Days to maturity	Plant height	Number of productive tillers / plant	Panicle length	Harvest index	Fodder yield	Grain Yield
Days to 50% flowering	0.956**	-0.261	-0.313*	-0.112	0.006	-0.295*	-0.147
Days to maturity		-0.218	-0.355*	-0.106	-0.071	-0.183	-0.144
Plant height			0.231	0.339*	0.041	0.162	0.134
Number of productive tillers / plant				-0.076	-0.007	-0.130	-0.092
Panicle length					0.016	0.110	0.061
Harvest index						-0.191	0.743**
Fodder yield							0.500**

** and * significant at 1 and 5 % level, respectively

Table 7. Estimates of direct and indirect effects of yield components on grain yield in browntop millet

Character	Days to 50% flowering	Days to maturity	Plant height	Number of productive tillers/ plant	Panicle length	Harvest index	Fodder yield	Correlation Value for grain yield
Days to 50% flowering	**-0.206**	0.138	-0.014	0.023	0.002	0.004	-0.094	-0.147
Days to maturity	-0.197	**0.144**	-0.012	0.026	0.002	-0.049	-0.058	-0.144
Plant height	0.054	-0.031	**0.055**	-0.017	-0.006	0.028	0.051	0.134
Number of productive tillers / plant	0.065	-0.051	0.013	**-0.073**	0.001	-0.005	-0.041	-0.092
Panicle length	0.023	-0.015	0.018	0.006	**-0.017**	0.011	0.035	0.061
Harvest index	-0.001	-0.010	0.002	0.001	0.000	**0.691**	0.061	0.743
Fodder yield	0.061	-0.026	0.009	0.010	-0.002	0.132	**0.317**	0.500

Residual effect = 0.31

were given for yield and yield component characters in **Table 7**. The results showed that the harvest index, fodder yield, plant height and panicle length showed a positive direct effect on grain yield per plant, whereas days to 50 % flowering, days to maturity and the number of productive tillers per plant manifested a negative direct effect on grain yield. Supported related findings were found in the studies by Bhuri Singh *et al.* (2014) in pearl millet, Lakshmi Prasanna *et al.* (2013) in foxtail millet and Rinkey Arya *et al.* (2017) in barnyard millet and partitioning of correlation values indicated that some of the characters did not produce significant correlation with grain yield; this may be due to very high negative direct effects. Understanding the results obtained from trait association and path analysis revealed positive association and high positive direct effects that fodder yield and harvest index on grain yield. To bring improvement in yield and yield components with respect to browntop millet selection should be based on fodder yield and harvest index.

Divergence analysis is executed to pick out the diverse genotypes for crossing programme. From the present investigation, it is evident that some variability is present for different traits hence selections based on these traits could improve productivity in browntop millet. Clusters II, V, VI and VII were very much diverse among themselves; hence genotypes present in these groups were recommended to make crosses which may create extensive variability in segregating generations.

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