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Evaluation of Genetic Diversity in Germplasm Accessions of Finger Millet [*Eleusine coracana* (L.) Gaertn.]

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Abstract

Finger millet [*Eleusine coracana* (L.) Gaertn.] is an annual herbaceous small millet crop with nutraceutical value grown in diverse environments. It is a crop of antiquity with great historical, cultural and nutritional importance, particularly in Asia and Africa. Utilization of diverse germplasm is important in breeding programme to improve the yield of the crop. In this regard, 224 finger millet germplasm accessions representing world collections were characterized for various quantitative traits adopting multivariate analysis. Wide variation was observed for most of the traits indicating their importance for direct selection. Among the quantitative traits evaluated, number of productive tillers had a significant positive association with grain yield per plant. Principal component analysis indicated that the first two principal components accounted 56.7 per cent of the total variability. Principal component analysis revealed that days to 50 per cent flowering, plant height, number of productive tillers, main ear length, number of fingers per ear and grain yield per plant contributed most to genetic diversity. Two hundred and twenty-four finger millet germplasm accessions evaluated for seven quantitative traits were grouped into 10 clusters. Thus, the grouping of accessions shall be of practical value to finger millet researchers to select and tap the genetic potential of elite accessions from different clusters as donor parents in crossing programmes.

Keywords : Finger millet, Germplasm, Principal component analysis, Cluster analysis, Genetic diversity

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an annual herbaceous small millet crop widely grown and consumed in Africa and Asia. It was domesticated around 5000 years ago in Eastern Africa and introduced in India about 3000 years ago (Hilu *et al*., 1979). It is an important staple food after rice, wheat, pearl millet and sorghum in India. Finger millet is grown throughout India and is cultivated over 0.97 million hectares with 1.68 mt production and 1662 kg/ha productivity during 2019-2020 (Dept. of Economics and Statistics, DAC & FW, Government of India, New Delhi). The major finger millet-growing states are Tamil Nadu, Karnataka, Orissa, Andhra Pradesh, Uttar Pradesh, Maharashtra, Bihar, Madhya Pradesh and Gujarat.

It serves as a food-security crop because of its high nutritional value and excellent storage qualities (Chandra and Sharma 2016; Ramashia *et al.,* 2019). Finger millet grain is gluten-free, rich in calcium, fiber, iron and essential amino acids, with excellent malting qualities and has low glycemic index (Bruntha Devi *et al*., 2011). More remarkably, finger millet grain contains higher calcium than other cereals (Kumar *et al*., 2016) and it is also endowed with abundant phytochemicals, with distinguished health-beneficial properties, making the crop reservoir of health-giving nutrients (Chandra and Sharma, 2016).

In any crop improvement programme genetic variability and diversity play very important roles. The higher diversity between parents shows the higher heterosis and more chance of getting transgressive segregation. To develop improved crop variety over existing cultivated variety breeder has to identify diverse parents having high genetic variability for combining desirable characters. Assessment of large number of germplasm accessions for genetic diversity is of immense help in the selection of diverse genotypes for hybridization programme (Reddy *et al.*, 2015). Multivariate hierarchical cluster analysis helps in the initial grouping of accessions. Principal Component Analysis is used to confirm the diversity pattern brought about by cluster analysis. Hence the present study was undertaken to characterize the germplasm accessions for yield and attributing traits by means of descriptive statistic and to understand the association of various characters, PCA and cluster analysis which would enable breeders to classify the available germplasm into distinct groups on the basis of genetic diversity.

Material and Methods

Experimental Material : The experimental material consisted 224 finger millet germplasm accessions representing collections across the world (Table 1) which are maintained at the National Active Germplasm Site, Project Coordinating Unit, AICRP on small millets, University of Agricultural Sciences, GKVK, Bengaluru.

Table 1

Details of 224 finger millet germplasm accessions evaluated in the experiment

Source	Number of accessions evaluated
Uganda	10
Kenya	5
Malawi	15
Ethiopia	4
Zambia	25
Zimbabwe	4
Tanzania	2
India	159
Total	224

Evaluation of Experimental material : The present experiment was conducted during *kharif* 2020 at the experimental farm of All India Coordinated Research Project on small millets, University of Agricultural Sciences, GKVK, Bengaluru located at 13^0 05" N latitude and 77^0 34" E longitudes. The center is at an altitude of 924 meters above mean sea level. The annual rainfall ranges from 528 mm to 1374.4 mm with the mean of 915.8 mm. 224 germplasm accessions consisted of indigenous collections, land races, exotic collections and white seeded accessions that were sown in a single row of 3m length and row to row spacing of 22.5cm. The experimental material was divided into 14 blocks; each block consisted of 16 accessions and 3 checks (KMR 340, GPU 66 and KMR 630) following the augmented design. The crop was supplied with recommended dose of fertilizers as per the package of practices. Observations were recorded from five randomly selected plants in each accession for seven quantitative characters *viz*., Days to 50 per cent flowering, Days to maturity, Plant height (cm), Number of productive tillers, main ear length (cm), number of fingers per ear and grain yield per plant(g).

Statistical analysis : Summary statistics like, mean, range, variances and standard deviation were estimated using Microsoft Excel. The data recorded on the quantitative traits was subjected to analysis of variance (Federer and Raghavarao, 1975). Phenotypic correlation coefficients were calculated as suggested by Johnson *et al.*, (1955). PCA was computed for 7 quantitative traits to find out the relative importance of different traits in capturing the variation in the entire germplasm set using OPSTAT statistical package as suggested by Johnson and Wichern (1988). The seven quantitative characters were subjected to diversity analysis to determine K means cluster using R software version 4.0.2.

Results and Discussion

Analysis of variance (Table 2) showed significant differences for all quantitative characters suggesting

TABLE 2

Analysis of variance (ANOVA) of yield in finger millet germplasm accessions

Source of Variation	DF	Sum of Squares	Mean Squares		Significance
Blocks (eliminating treatments)	13	22.192	1.707		0.0699
Treatment (ignoring blocks)	226	10,863.60	48.069	*	0
Checks	2	128.554	64.277		0
Accessions	223	10,735.03	48.139		0
Checks vs.accessions	1	0.022	0.022		0.87379
Error	26	22.643	0.871		
Total	265	10,908.44			

TABLE 3

Summery statistics of various quantitative traits evaluated in 224 finger millet germplasm accessions

Characters	Mean	Range	Variance	Standard division
Days to 50% flowering	72.112	58.00 - 88.00	35.66	5.972
Days to maturity	113.241	99.00 - 128.00	36.444	6.037
Plant height (cm)	96.882	65.0 - 133.00	124.871	11.175
No. of productive tillers	4.761	2.00 - 10.60	1.822	1.35
No. of fingers /ear	6.356	3.00 - 8.00	0.626	0.791
Main ear length (cm)	5.442	3.10 - 14.50	1.628	1.276
Grain yield per plant (g)	19.18	6.00 - 58.33	48.139	6.938

significant variability for all the traits. The mean, range, variance and standard deviation for all the seven quantitative traits are presented in Table 3. Days to 50 per cent flowering ranged from 58 days (GE 133) to 88 days (GE 4969) days with mean value of 71.11. Accessions GE 249, GE 289 and GE 68 were early to flower; hence these accessions could be utilized for developing early to medium duration varieties in finger millet. The accessions *viz*., GE 581 which is a land race called Nalla Gidda Ragi and GE 80 source from Africa were the most dwarf with height of 65 to 69 cm, while the accession GE 118 was the tallest with a height of 133 cm. These accessions can be utilized as a donor for breeding dwarf varieties. Wide range of variation was observed for number of productive tillers, main ear length and number of fingers per ear head. The accession GE 135 recorded a higher number of productive tillers among the accessions. The accession GE 4705 had higher number of fingers (8 no's), whereas GE 12 had longer ear head (14.50cm). The accession GE 135 expressed superior grain yield levels (58.33 g/plant) and produced numerous productive tillers (10 tillers). Most of the high yielding accessions were from Indian origin followed by Africa and Zambia. The landraces collected from India are low yielders. Most promising trait donors for various quantitative traits identified based on average are presented in Table 4.

Relationship Between Traits

The correlation coefficients between traits are presented in Table 5. The evaluation of data provides a valuable opportunity for assessing relationships among traits to test the similarity between different

TABLE 4

Identity of the promising finger millet trait donors with desirable quantitative traits

Characters	Promising accession
Days to 50% flowering (61-63) days), early duration	GE 249, GE 289, GE 68, GE 118,GE 155, GE 15, GE 31,GE 62, GE 100, GE 114, GE 117, GE 142, GE 157
More number of tillers (7-10)	GE 135, GE 274, GE 98, GE 59, GE 150, GE 153, GPU -W-1B, GE 15, GE 4801
Plant height (cm) (65-75 cm), dwarf accessions	GE 581,GE 80,GE 10,GE 6636, GE 4682, GE 170, GE 4706, GE 5155, GE 4895
Main ear length (8-14cm)	GE 12, GE 153, GE 69, GE 4, GE 86 ,GE 1324, GE 46, GE 169, GE 4805, GE 4808, GE 4902
More number of fingers per ear (7-8)	GE 4701, GE 5, GE 6, GE 26, GE 44, GE 133, GE 153, GE 198, GE 29
High yield (33-58g)	GE 135, GE 15, GE 1318, GE 249, VL356, GE 150, GE 4981, GE 67, GE 3371

TABLE 5

Phenotypic correlation co-efficient between 7 quantitative traits in 224 finger millet germplasm

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers	No. of fingers /ear	Main ear length (cm)	Grain yield per plant (g)
Days to 50% flowering	1	0.979	0.383	-0.312	-0.297	0.127	-0.17
Days to maturity		1	0.388	-0.3	-0.289	0.126	-0.179
Plant height (cm)			1	-0.246	-0.128	0.426	-0.101
No. of productive tillers				1	0.134	-0.078	0.382
No. of fingers /ear					1	0.128	0.013
Main ear length (cm)						1	-0.115
Grain yield per plant (g)							1

groups. This practice simplifies work and saves resources. Association studies among different characters are important for finger millet breeders in the effective selection of desirable genotypes. The knowledge on the association between grain yield and other attributing quantitative traits helps in improving the efficiency of selection. Number of productive tillers (0.382) had a significant positive association with grain yield per plant. This association suggests that number of productive tillers will be effective selection indices for grain yield. Similarly, Dagnachew *et al*., 2012, Kadam *et al.,* 2009 and Nandini *et al.,*2018, reported that number of productive tillers had significant positive association with grain yield per plant. Significant negative correlation was observed for days to 50 per cent flowering and days to maturity with grain yield per plant. This indicates that increase in one trait would lead to decrease in other trait. The negative association of days to 50 per cent flowering with grain yield is beneficial association because early maturing types are most preferred by farmers. Early duration types will escape from drought situations. Thippeswamy and Sajjanar, 2017, reported days to 50 per cent flowering have negative association with grain yield in foxtail millet and Nandini *et al,* 2018 in finger millet.

Principal Component Analysis (PCA)

PCA was applied as a reductionist approach to the multivariate data, to measure the importance and contribution of each component to the total variance.

TABLE 6

Vector loadings and percentage of variation explained by the first five principal components in 224 finger millet germplasm

	PC1	PC1	PC1	PC1	PC1
Eigen values	2.677	1.295	1.133	0.791	0.613
Variance explained (%)	0.382	0.185	0.162	0.113	0.088
Cumulative variance explained (%)	0.382	0.568	0.729	0.842	0.93
Eigen vectors					
Days to 50% flowering	0.547	-0.22	0.146	0.35	-0.039
Days to maturity	0.547	-0.214	0.148	0.359	-0.055
Plant height (cm)	0.381	0.355	0.301	-0.344	0.218
No. of productive tillers	-0.335	-0.108	0.546	0.191	-0.668
No. of fingers /ear	-0.234	0.508	-0.031	0.754	0.301
Main ear length (cm)	0.193	0.671	0.298	-0.149	-0.269
Grain yield per plant (g)	-0.228	-0.244	0.691	-0.054	0.582

The *per cent* variation explained by the first four principal components (PCs) and vector loadings for each trait is presented in Table 6. The first four PCs accounted to 84.2 *per cent* of the total variation and subsequent components contributed 5 per cent or less variation. Vaishali *et al*., (2021) reported that first five principal components explained 99.97 *per cent* of the entire variability in finger millet. Similarly, Patil *et al., 2019*, reported genetic diversity in finger millet using principal component analysis and found first three principal components showed 98.31 *per cent* of total variation. PC1 accounted to 38.2 per cent of the total variation. PC1 was attributed to days to 50 per cent flowering, days to maturity and plant height for largest positive loadings indicating its significant importance in these components. Number of productive tillers and number of fingers per ear and grain yield per plant had negative loadings. PC2 accounted for 18.5 per cent of the total variation and contributed to positive loadings for plant height, number of fingers per ear and main ear length whereas, all other traits contributed negatively. PC3 accounted for 16.2 per cent of the total variation. All the traits contributed to positive loadings except number of fingers per ear head.Similarly, PC4 accounted for 11.3 per cent of the total variation, the major traits that contributed highly to the variation include number of fingers per ear head, days to 50 per cent flowering and days to maturity, whereas, number of productive tillers contributed least to the variation. Similar findings with regard to grain yield per plant, plant height, days to 50 per cent flowering and productive tillers per plant were reported by Salini *et al*., 2010 in proso millet and Nandini *et al.,* 2018; Aradhana *et al.*, 2019 in finger millet. Principal component analysis revealed that days to 50 per cent flowering, plant height, number of productive tillers, main ear length, number of fingers per ear and grain yield per plant contributed most to genetic diversity.

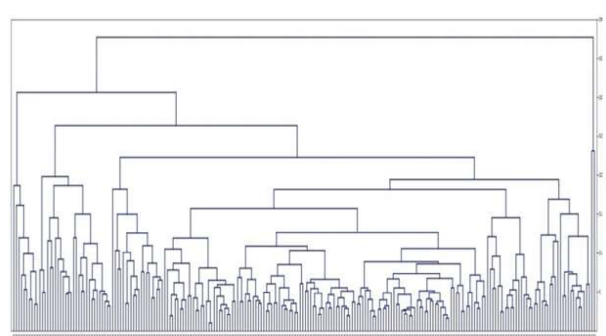

Fig. 1 : Hierarchical clustering pattern of 224 finger millet germplasm accessions

Cluster Analysis

K means cluster analysis based on agronomic traits grouped 224 finger millet germplasm into 10 clusters. Hierarchical clustering pattern of 224 finger millet germplasm accessions presented in Fig. 1. Cluster II, with highest number of germplasm accessions (49) was identified as the largest cluster, whereas clusters VII, VIII and X was with 10 germplasm accessions. The high grain yielding accessions (GE 135, GE 15 GE 249 and GE 150) and accessions with more number of productive tillers were registered in cluster I and are Indian origin. Cluster V comprised land races, whereas white seeded accessions registered in clusters VII and X. The dwarf accessions GE 4682, GE 6636 and GE 5155 were found in cluster II. This indicated that accessions in these clusters have wide diversity for various characters. Similar results have been reported by Nandini *et al.* (2020) in which the barnyard millet germplasm accessions used were grouped into 23 clusters and in foxtail millet, 23 clusters (Nandini *et al* 2018) have been made using 1312 foxtail millet germplasm accessions. Manimekalai *et al.,* 2018, grouped 61 genotypes of barnyard millet germplasm in 13 clusters based on the bouches clustering technique. Likewise, Sood *et al*., 2015 grouped 95 germplasm accessions of barnyard millet into two groups. Group A comprised of 43 accessions and Group B comprised of 51 accessions using two-way cluster analysis.

Cluster means of all seven quantitative traits are presented in Table 7. The accessions in the cluster I showed more mean grain yield followed by cluster III and IX. Accessions which are present in these diverse clusters can be utilized for hybridization to get transgressive segregants for that trait, which could be used for developing superior high grain yielding varieties. The dwarf accessions could be utilized in developing dwarf varieties in finger millet. Likewise, accessions in diverse clusters could be utilized in hybridization programme to develop high grain yielding, dwarf and high tillering ability types in finger millet.

Relationship among the accessions and assessment of genetic diversity among various accessions is fundamental importance to exploit the finger millet genetic resources. Multivariate statistical analysis provides a means for estimating morphological diversity between germplasm accessions. The potential breeding value of germplasm can be evaluated by these tools. The PCA and cluster analysis provided a simplified classification finger millet germplasm accessions for use in breeding. Principal component analysis revealed that days to 50 per cent flowering, plant height, number of productive tillers, main ear length, number of fingers per ear and grain yield per plant contributed most to genetic diversity. Number of productive tillers had significant positive association

TABLE 7

The average of 7 quantitative traits for each cluster in 224 finger millet germplasm

Cluster Number	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers	No. of fingers /ear	Main ear length (cm)	Grain yield per plant (g)
I	63.82	104.82	85.49	6.98	6.60	4.96	35.58
II	74.55	116.00	101.64	4.51	6.12	5.56	15.18
III	71.68	112.90	106.96	4.67	6.32	6.00	27.02
VI	65.80	106.70	77.80	4.71	6.48	4.57	17.43
V	65.00	106.10	94.62	4.87	6.70	5.28	17.00
VI	75.94	116.91	89.35	4.66	6.29	5.18	15.71
VII	81.50	122.30	114.08	3.43	6.09	5.65	16.20
VIII	72.20	113.20	122.03	4.52	6.28	7.12	15.07
IX	72.19	113.25	93.50	5.24	6.59	5.42	23.00
X	82.80	124.10	104.77	3.84	5.86	5.64	22.07

with grain yield per plant. This association suggests that number of productive tillers will be effective selection indices for grain yield. Hybridizing the accessions belonging to different clusters would maximize opportunities for transgressive segregation because of higher probability that unrelated genotypes will contribute unique desirable alleles at multiple loci (Beer *et al.,* 1993). Thus, the grouping of accessions by multivariate methods in present study will be of practical value to the finger millet breeders in allowing them to choose elite accessions from different clusters as parental line for hybridization programmes.

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