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Estimation of genetic diversity by using principal component analysis in genetic resources of foxtail millet (*Setaria italica* (L.) Beauv.)

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Abstract
Hundred foxtail millet genetic resources including four checks were evaluated for understanding the genetic divergence for 18 metric traits through Principal Component Analysis. The ANOVA revealed existence of highly significant variation for all the traits examined. In the present study 67.371 *per cent* of total variation accrued through Principal component analysis exhibited seven Principal components. The first, second and third roots accounted for 17.239, 10.406 and 10.030 per cent respectively to total variability. The remaining canonical roots *viz*., fourth, fifth, sixth and seventh contributed 9.264, 8.269, 6.557 and 5.606 per cent respectively towards the total variability. These seven canonical roots were retained based on the Scree plot and threshold eigen value greater than one (>1). The PCA analysis thus, identified that the maximum contributing traits towards the existing variability as plant height, 1000 grain weight, panicle length, days to maturity, grain yield/ plant, days to 50% flowering and zinc suggesting that these traits may be given top priority in future foxtail millet breeding programmes.

Keywords: Eigen value, foxtail millet, genetic divergence, principal component analysis

Introduction

Among the small millets, foxtail millet ranking second in global production, serves as an important staple food with good supplementary nutrients and protein for millions of people in Southern Europe and Asia, particularly in China and India (Marathee 1993) [3]. According to Vavilov, China is the considered as the centre of origin for this crop. Post green revolution, the cultivation of this small millet is slowly expanding owing to its distinct nutraceutical properties and ability to withstand biotic and abiotic stresses. Due to its geographically wide spread adaptation and wide gene base foxtail millet exhibits a wide range of genetic diversity and also provides ample scope for breeders to exploit through various breeding strategies and generate cultigens with promising traits suited to climate resilient agriculture. Moreover, estimates of genetic relationships can be useful for identification of parents for hybridization, and for reducing the number of accessions needed to maintain a broad range of genetic variability (Bezaweletaw, 2006) [1].

Exact information on the nature and degree of genetic diversity helps plant breeders in selecting the parents for targeted hybridization. Principal component analysis (PCA), a multivariate technique is used to classify the genetic relationships between the traits in multi-trait systems and for identifying the patterns of data by reducing the number of dimensions. This analysis provide information that could help in better selection of parental genotypes with specific traits and in devising breeding strategies for trait improvement. It also provides an insight into the process contributing differences in yield among genetic resources, a vital aspect in identification and selection of top ranking genetic resources out of diverse germplasm base. PCA results in generation of a 2D / 3D scatter plot of individuals and characters, whose geometrical distances helps in identification of correlated traits and identification of sets of genetically similar individuals (Mohammadi, 2003) [2].

Material and Methods

Hundred foxtail millet genetic resources obtained from Regional Agricultural Research Station, Nandyal, Andhra Pradesh were studied in a Augmented randomized complete block design (ARCBD) with four checks during *Kharif*, 2018 in order to estimate the principal component analysis. The experiment was carried out at an altitude of 211.3 m above mean sea level, latitude of 18.29°N and longitude of 78.29°E at RARS, Nandyal, A.P. The net plot size was 40 x 3 m^2 with a recommended spacing of 22.5 cm x 10 cm. The data was collected on five randomly selected plants per genetic resource for 18 metric traits *viz.*, SCMR at 30 DAS, SCMR at 45 DAS, days to 50% flowering, plant height, panicle length, number of productive tillers /plant, days to maturity, number of grains / ear head, 1000 grain weight, protein, carbohydrate, calcium, magnesium, iron, zinc, copper, manganese and grain yield/ plant. The data was subjected to statistical analysis for PCA using the software WINDOWSTAT of 9.2 version as per the procedure outlined by Rao (1952) [4].

Results and Discussion

The analysis of variance studies revealed high significant differences among the 100 foxtail millet genetic resources (Table 1) for all the 18 metric traits under study. This revealed that there is ample scope of variability existed in the experimental material and all the genetic resources of foxtail millet were genetically diverse, an important pre-requisite that paved way for further diversity analysis, thereby providing an opportunity for plant breeder to undertake further breeding activities like hybridization program. Seven canonical roots accounted for 67.371 per cent of total divergence (Table 2). The first, second and third roots accounted for 17.239, 10.406 and 10.030 per cent respectively to total variability. The remaining canonical roots *viz*., fourth, fifth, sixth and seventh contributed 9.264, 8.269, 6.557 and 5.606 per cent respectively towards the total variability. The mean values of canonical variates for three roots X, Y and Z were furnished in Table 2. Two dimensional (2D) and Three dimensional (3D)) pictures were constructed by plotting the mean values of vectors as in Fig 1 and Fig 2 respectively. These seven canonical roots were retained based on the scree plot and threshold eigen value greater than one (>1) (Fig 3). The amount of contribution of different traits towards canonical vectors total divergence was presented in Table 3.

In the vector Z_1, traits contributing towards total divergence positively were plant height (0.462), 1000 grain weight (0.379), panicle length (0.365), days to maturity (0.362), grain yield/ plant (0.322), days to 50% flowering (0.215), zinc (0.210), SCMR at 30 DAS (0.197), iron (0.193), magnesium (0.189), number of productive tillers /plant (0.163), manganese (0.162), copper (0.093), number of grains / ear head (0.067), carbohydrate (0.063) and protein (0.019). For the vector $Z_{2,}$ number of grains / ear head (0.438), copper (0.301), grain yield/ plant (0.233), iron (0.110), plant height (0.105), SCMR at 30 DAS (0.081), days to maturity (0.056) and panicle length (0.052). In the vector $Z_{3,}$ the traits *viz.*, SCMR at 45 DAS (0.423), 1000 grain weight (0.323), SCMR at 30 DAS (0.298), panicle length (0.244), carbohydrate (0.239), protein (0.129), grain yield/ plant (0.115), number of productive tillers /plant (0.095), calcium (0.067) and days to maturity (0.012) had contributed positively to diversity. Zinc (0.341) and manganese (0.337) together contributed positively maximum to the diversity in vector Z_4, followed by number of grains / ear head (0.322), SCMR at 45 DAS (0.315), grain yield/ plant (0.296), 1000 grain weight (0.145), SCMR at 30 DAS (0.084), magnesium (0.075), carbohydrate (0.058), iron (0.028) and calcium (0.024) towards total divergence positively. In the vector Z_5, traits contributing towards total divergence positively were carbohydrate (0.526), days to 50% flowering (0.251), SCMR at 30 DAS (0.228), grain yield/ plant (0.145), zinc (0.135), manganese (0.094), calcium (0.059), plant height (0.044) and number of grains / ear head (0.014). For the vector $Z_{6,}$ calcium (0.647), iron (0.468), copper (0.44), SCMR at 30 DAS (0.150), carbohydrate (0.106), grain yield/ plant (0.085), 1000 grain weight (0.062), number of productive tillers /plant (0.05), days to maturity (0.025) and manganese (0.009) contributed positively towards genetic diversity. In the vector $Z_{7,}$ traits contributing towards total divergence positively were magnesium (0.565), SCMR at 30 DAS (0.282), number of productive tillers /plant (0.233), grain yield/ plant (0.121), iron (0.088), calcium (0.052), panicle length (0.043) and SCMR at 45 DAS (0.039).

In the present study, the maximum contributing traits toward existing variability were identified *viz.*, plant height, 1000 grain weight, panicle length, days to maturity, grain yield/ plant, days to 50% flowering and zinc content. The seven PCs retained based on the scree plot and threshold eigen value greater than one (>1) reported about 67.371 *per cent* to total genetic divergence.

Table 1: ANOVA for grain yield and yield attributes in 100 foxtail millet genetic resources

Source of variation	d.f	SCMR at 30 DAS	SCMR at 45 DAS	Days to 50% flowering	Plant height	Panicle length	No. of productive tillers /plant	Days to maturity	No of grains / ear head	1000 grain weight
		Mean sum of squares								
Block	7	6.964	4.797	0.21	1.403	0.479	0.016	0.139	2523.687	0.008
Entries	99	19.742 **	19.519 **	15.182 **	161.298 **	5.727 **	1.231 **	32.266 **	18210.65 **	0.097 **
Checks	3	56.620 **	85.518 **	75.115 **	1036.958 **	36.288 **	0.859 **	334.115 **	132431.7 **	0.229 **
Varieties	95	18.556 **	17.366 **	12.252 **	121.583 **	4.787 **	1.165 **	19.052 **	14795.2 **	0.093 **
Checks vs. Varieties	1	21.788	26.042 *	113.753 **	1307.220 **	3.358 **	8.610 **	382.003 **	15.61	0.031
Error	21	5.239	4.24	0.257	1.087	0.288	0.007	0.234	1484.97	0.012

Sources of variations	d.f	Protein (g/100g)	Carbo-hydrate (g/100g)	Calcium (mg/100g)	Magnesium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Copper (mg/100g)	Manganese (mg/100g)	Grain yield/ plant (g)
		Mean sum of squares								
Block	7	0.588	0.546	0.122	0.16	0.104	0	0.001	0.027	0.747
Entries	99	2.922 **	57.173 **	34.524 **	43.080 **	42.754 **	1.437 **	0.452 **	0.233 **	14.513 **
Checks	3	5.320 **	4.716 **	336.718 **	311.224 **	250.694 **	0.726 **	1.195 **	0.784 **	23.160 **
Varieties	95	2.875 **	59.345 **	24.419 **	31.566 **	31.096 **	1.463 **	0.433 **	0.215 **	14.170 **
Checks vs. Varieties	1	0.202	8.184 **	87.879 **	332.457 **	526.524 **	1.184 **	0.062 **	0.214 **	21.188 **
Error	21	0.388	0.33	0.446	0.111	0.093	0	0.002	0.012	0.43

* Significant at 5% level
** Significant at 1% level

Table 2: Canonical root values, per cent of variation and cumulative variation explained for 100 foxtail millet genetic resources.

Parameter	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7
Eigene Value (Root)	3.103	1.873	1.805	1.668	1.488	1.180	1.009
% Var. Exp.	17.239	10.406	10.030	9.264	8.269	6.557	5.606
Cum. Var. Exp.	17.239	27.645	37.675	46.939	55.208	61.765	67.371

Table 3: Canonical vectors for 18 characters in 100 foxtail millet genetic resources

Character	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7
SCMR at 30 DAS	0.197	0.081	0.298	0.084	0.228	0.150	0.282
SCMR at 45 DAS	-0.024	-0.208	0.423	0.315	-0.297	-0.049	0.039
Days to 50% flowering	0.215	-0.144	-0.163	-0.478	0.251	-0.122	-0.119
Plant height (cm)	0.462	0.105	-0.101	-0.070	0.044	-0.131	-0.102
Panicle length (cm)	0.365	0.052	0.244	-0.078	-0.114	-0.172	0.043
No. of productive tillers /plant	0.163	-0.348	0.095	-0.334	-0.164	0.050	0.233
Days to maturity	0.362	0.056	0.012	-0.286	-0.023	0.025	-0.188
No. of grains / ear head	0.067	0.438	-0.150	0.322	0.014	-0.109	-0.180
1000 grain weight (g)	0.379	-0.050	0.323	0.145	-0.113	0.062	-0.083
Protein (g/100g)	0.019	-0.171	0.129	-0.002	-0.480	-0.043	-0.554
Carbohydrate (g/100g)	0.063	-0.118	0.239	0.058	0.526	0.106	-0.148
Calcium (mg/100g)	-0.037	-0.314	0.067	0.024	0.059	0.647	0.052
Magnesium (mg/100g)	0.189	-0.064	-0.246	0.075	-0.321	-0.170	0.565
Iron (mg/100g)	0.193	0.110	-0.383	0.028	-0.218	0.468	0.088
Zinc (mg/100g)	0.210	-0.403	-0.290	0.341	0.135	-0.118	-0.047
Copper (mg/100g)	0.093	0.301	-0.053	-0.088	-0.179	0.440	-0.188
Manganese (mg/100g)	0.162	-0.363	-0.337	0.337	0.094	0.009	-0.230
Grain yield/ plant (g)	0.322	0.233	0.115	0.296	0.145	0.085	0.121

Table 4: Mean values of canonical vectors for 100 foxtail millet genetic resources

S. No.	Genotype	X Vector	Y Vector	Z Vector
1	SiA 3222	224.579	777.792	-226.917
2	SiA 3323	254.342	784.604	-248.926
3	SiA 3657	266.393	789.259	-239.025
4	SiA 2745	268.821	791.530	-241.780
5	SiA 2579	270.778	791.081	-244.933
6	SiA 3627	249.883	696.322	-216.297
7	SiA 4061	247.416	788.775	-241.236
8	SiA 4036	245.757	672.076	-203.398
9	SiA 2662	262.225	788.507	-241.725
10	SiA 2737	266.601	790.869	-245.230
11	SiA 3611	271.025	791.388	-249.862
12	SiA 4155	268.880	787.866	-241.814
13	SiA 2849	251.919	676.679	-206.243
14	SiA 3577	264.389	738.860	-229.244
15	SiA 3701	257.113	787.894	-249.547
16	SiA 3559	259.145	785.238	-239.139
17	SiA 3851	269.522	788.578	-244.623
18	SiA 4016	247.912	692.668	-211.986
19	SiA 4179	259.526	790.696	-241.705
20	SiA 3498	262.575	789.923	-250.696
21	SiA 4107	274.271	792.971	-249.439
22	SiA 2674	259.497	783.367	-235.508
23	SiA 2697	259.454	775.244	-233.342
24	SiA 3516	239.343	672.101	-202.679
25	SiA 3496	258.832	790.848	-248.347
26	SiA 3580	247.212	682.505	-219.996
27	SiA 3971	238.096	672.222	-206.666
28	SiA 3038	235.240	669.956	-196.537
29	SiA 3588	249.003	674.444	-203.639
30	SiA 3737	261.997	781.631	-241.296
31	SiA 3462	243.165	674.380	-200.718
32	SiA 2671	262.374	784.046	-237.111
33	SiA 3492	265.338	787.285	-245.917
34	SiA 3429	241.528	687.215	-217.607
35	SiA 4063	254.364	783.831	-237.191
36	SiA 3793	243.634	673.021	-203.295
37	SiA 805	256.212	787.746	-243.582
38	SiA 3855	259.798	787.387	-239.830

39	SiA 3420	227.164	667.035	-196.377
40	SiA 4167	231.859	672.314	-203.478
41	SiA 2864	234.117	669.727	-198.974
42	SiA 3409	216.235	667.889	-205.558
43	SiA 4027	246.117	675.679	-210.138
44	SiA 3423	227.301	669.917	-205.010
45	SiA 4181	263.909	778.128	-235.763
46	SiA 1244	243.748	724.795	-218.279
47	SiA 4044	244.664	668.279	-214.885
48	SiA 3643	241.245	676.113	-196.937
49	SiA 2713	239.824	676.326	-202.768
50	SiA 2757	267.826	787.956	-237.201
51	SiA 2681	246.430	703.116	-209.561
52	SiA 3511	268.675	794.699	-251.397
53	SiA 3674	244.804	668.388	-207.676
54	SiA 3827	243.948	675.256	-195.615
55	SiA 3908	238.987	674.826	-198.210
56	SiA 3697	245.003	672.500	-199.571
57	SiA 4009	235.616	670.383	-198.472
58	SiA 3965	234.859	668.062	-202.074
59	SiA 3972	230.969	667.382	-199.954
60	SiA 3756	237.973	670.679	-208.664
61	SiA 4013	245.608	670.726	-210.653
62	SiA 3754	257.220	780.092	-236.463
63	SiA 3413	254.346	783.406	-247.267
64	SiA 3435	253.798	728.858	-224.791
65	SiA 4045	231.774	670.078	-200.924
66	SiA 3499	252.332	758.028	-234.650
67	SiA 3436	239.699	667.290	-199.927
68	SiA 3560	246.766	670.481	-204.260
69	SiA 4114	237.907	670.686	-193.722
70	SiA 3419	245.080	677.275	-202.981
71	SiA 3465	230.388	668.732	-194.305
72	SiA 4068	237.405	671.571	-197.100
73	SiA 3749	238.896	666.189	-192.649
74	SiA 4141	236.516	668.800	-194.475
75	SiA 2667	244.240	671.231	-193.569
76	SiA 3422	245.474	692.043	-210.878
77	SiA 3894	242.401	673.975	-199.044
78	SiA 3282	241.969	786.065	-236.933
79	SiA 3639	269.107	791.604	-240.181
80	SiA 2856	249.636	783.615	-235.097
81	SiA 3291	229.259	783.656	-240.843
82	SiA 3430	258.441	790.464	-242.172
83	SiA 4020	260.009	784.786	-235.350
84	SiA 2663	241.162	672.985	-197.123
85	SiA 3554	263.390	759.893	-233.366
86	SiA 3753	242.749	671.731	-203.416
87	SiA 2844	248.393	675.389	-207.203
88	SiA 4180	248.893	672.515	-195.753
89	SiA 4005	251.105	742.313	-229.605
90	SiA 2850	269.314	782.594	-239.365
91	SiA 3513	241.164	670.983	-199.657
92	SiA 3469	256.055	779.676	-241.392
93	SiA 3281	264.403	778.875	-243.146
94	SiA 1266	247.329	666.601	-198.675
95	SiA 4182	241.369	673.080	-204.112
96	SiA 3969	255.892	756.726	-227.761
97	Prasad (C)	244.823	781.937	-240.260
98	SiA 3085 (C)	262.958	765.049	-234.791
99	SiA 3156 (C)	241.268	678.535	-201.884
100	Suryanandi (C)	229.014	669.8	-2 04.238

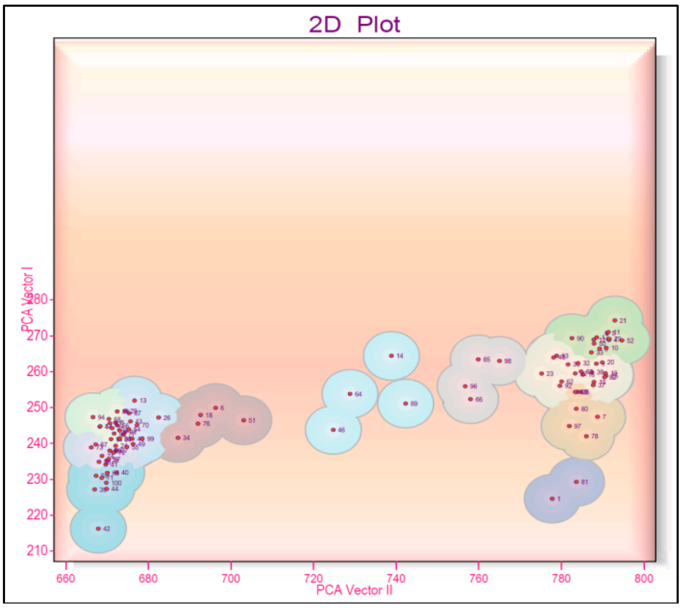

Fig 1: Two dimensional (2D) plot of canonical analysis

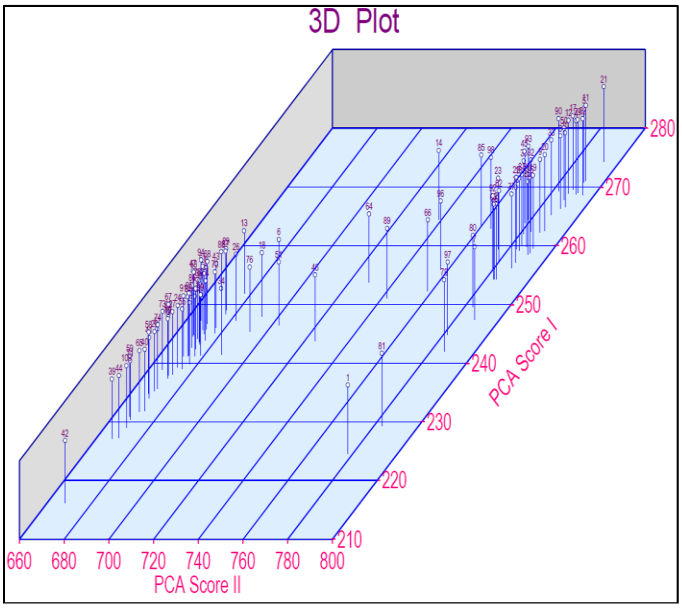

Fig 2: Three dimensional (3D) plot of Principal component analysis

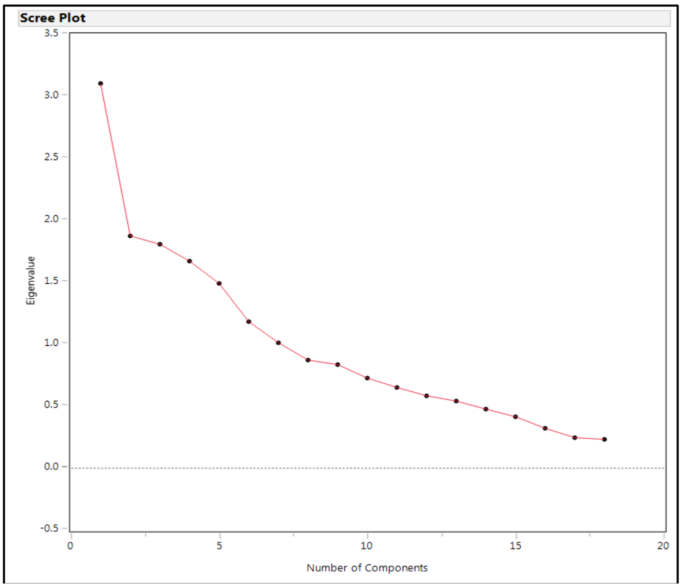

Fig 3: Scree plot showing the eigen value variation for 18 quantitaive traits in 100 foxtail millet genetic resources

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