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Estimation of genetic diversity in foxtail millet [*Setaria italica* (L.) Beauv.] Germplasm using principal component analysis

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Abstract
Fifty foxtail millet genotypes including three checks were evaluated for understanding genetic diversity of yield and yield attributing traits. In the present study first six principal components with eigen values more than one contributed 85.578 percent towards the total variability that comprised of 32.409 (PC 1), 16.931 (PC 2), 12.758 (PC 3), 9.875 (PC 4), 7.554 (PC 5) and 6.052 (PC 6). Ise-1419 and Ise-195 scored maximum in principal component analysis PCA 2 and PCA 3, respectively. PC1 contributed maximum towards the total variability (32.409), where characters *viz*., iron, phosphorus, fat and days to 50% flowering explained the maximum variance in this component.

Keywords: Diversity, Eigen value, principal component analysis, foxtail millet

Introduction
Millets are the cereals with small grains belonging to the family poaceae, and often termed as underutilised crops with local importance as a source of food. Foxtail millet commonly known a Italian millet or German millet or Chinese millet is one of the six small-grained cereals (small millets), which is grown as a food crop in Asia and for animal feed in the USA and Europe. Foxtail millet is taken as a significant cereal since old times and has important role in development of human civilization in Asia and Europe (Li *et al.*, 1996; Lu *et al.*, 2009) [3, 4]. It is one of the important ethnic small millet crops which provides staple food with good supplementary nutrients and protein. It is adapted for cultivation in dry climate with less resources. It ranks second in the world with respect to total millet production and serves as an important staple food for millions of people in Southern Europe and Asia, particularly in China and India (Marathee 1993) [5].
Due to its geographically wide spread adaptation, foxtail millet exhibits a wide range of genetic diversity. Collection, conservation and characterization of these genetic resources are a prerequisite for the genetic improvement of foxtail millet. Characterization of the accessions of foxtail millet can provide pivotal information for the breeding of crop and in the management of genetic resources. Characterization and evaluation of local foxtail millet landraces is necessary for the utilization in crop improvement. Precise information on the nature and degree of genetic diversity helps plant breeders in selecting the parents for targeted hybridization. Multivariate analysis such as principal component analysis (PCA) and cluster analysis serve as potential tools in evaluating the phenotypic diversity, identifying genetically distant clusters of genotypes and selecting important traits contributing to the total variation in the germplasm. These analyses provide information that could help in better selection of parental genotypes with specific traits and in devising breeding strategies for trait improvement. Multivariate analysis was effectively used for genetic diversity studies in many crops such as foxtail millet (Upadhyaya *et al.*, 2015) [10]. Multivariate analysis has been used frequently for genetic diversity analysis in many crops such as rice (Gana, 2013) [2] and millets (Ulaganathan and Nirmalakumari, 2015a,b) [8, 9]. Principal component analysis (PCA) allows natural grouping of the genotypes and is precise indicator of differences among genotypes. The main advantage of using PCA over cluster analysis is that each genotype can be assigned to one group only (Mohammadi, 2002) [6]. Principal component analysis (PCA) was used to identify redundancy of the genotypes with similar characters and their elimination (Adams, 1995) [1] While two-way cluster analysis for identification and separation of core subset of genotypes with distinct phenotypic traits. Principal component analysis

(PCA) allows natural grouping of the genotypes and is precise indicator of differences among genotypes. Principal component analysis (PCA) and two-way cluster analysis are two important statistical programs that aid in selecting elite germplasm lines for breeding program that meet the goal of a breeder for the development of improved varieties (Mohammadi and Prasanna, 2003) [7].

Material and Methods

Fifty germplasm collections of foxtail millet (Table 1) obtained from ICRISAT, Hyderabad were evaluated in Augmented Randomised Complete Block Design with three checks *viz*., korra local, Prasad and Suryanandi in each block during *Kharif*, 2017-18 at RARS, Lam, Guntur. Each genotype was raised in a single row of four meter length with a spacing of 22.5x10 cm between and within the rows, respectively. Standard agronomic practices and recommended fertilizer doses were applied for normal crop growth. Data recorded from the total thirteen traits including seven yield component characters and six grain quality parameters. Single plant observations were recorded on five plants selected at random per variety per replication and their means were used for the analysis. However, observations on test weight, days to 50% flowering and days to maturity were recorded on plot basis.

Table 1: Name and origin of foxtail millet germplasm employed in the present study

S. No.	Germplasm	Origin	S. No.	Germplasm	Origin
1.	Ise-31	India	28.	Ise-995	India
2.	Ise-144	India	29.	Ise-1000	India
3.	Ise-160	India	30.	Ise-1026	Lebanon
4.	Ise-179	India	31.	Ise-1059	India
5.	Ise-195	India	32.	Ise-1269	South Africa
6.	Ise-200	India	33.	Ise-1354	India
7.	Ise-254	India	34.	Ise-1402	India
8.	Ise-362	India	35.	Ise-1406	India
9.	Ise-364	India	36.	Ise-1408	India
10.	Ise-375	India	37.	Ise-1419	India
11.	Ise-458	Afghanistan	38.	Ise-1593	Republic of Korea
12.	Ise-507	Kenya	39.	Ise-1605	India
13.	Ise-525	Iran	40.	Ise-1629	India
14.	Ise-745	India	41.	Ise-1687	India
15.	Ise-769	India	42.	Ise-1780	India
16.	Ise-785	India	43.	Ise-1805	India
17.	Ise-795	India	44.	Ise-1806	India
18.	Ise-796	India	45.	Ise-1820	India
19.	Ise-813	India	46.	Ise-1846	India
20.	Ise-838	India	47.	Ise-1851	India
21.	Ise-840	India	48.	Ise-1881	India
22.	Ise-869	India	49.	Ise-1892	USA
23.	Ise-907	India	50.	Ise-1900	USA
24.	Ise-909	India	Checks		
25.	Ise-931	India	1.	Korra local	India
26.	Ise-936	India	2.	Prasad	India
27.	Ise-985	India	3.	Suryanandi	India

Results and Discussion

Variance studies revealed high significant differences among the genotypes for all characters under study. This indicates that there is considerable amount of variability existed in the experimental material and all the germplasm accessions of foxtail millet were genetically diverse thereby providing an opportunity for plant breeder to undertake further breeding activities like hybridization program. In the present study, the first six principal components contributed 85.578 percent towards the total variability (Table 2). The first principal component (PC 1) contributed 32.409 towards variability. Characters *viz*., iron, phosphorus, fat and days to 50% flowering explained the maximum variance in this component. The second principal component (PC 2) contributed 16.931 percent of total variance. Characters *viz*., days to 50% flowering, days to maturity, plant height, panicle length, number of productive tillers per plant, grain yield per plant and phosphorus. The third principal component (PC 3) was characterized by 12.758 percent contribution towards the total variability. Characters *viz*., fat, calcium, phosphorus, protein, plant height, days to 50 percent flowering, days to maturity, carbohydrate and test weight showed maximum loading. The fourth principal component (PC 4) was characterized by 9.874 percent contribution towards the total variability. Characters *viz*., iron, phosphorus, protein, days to maturity, days to 50 percent flowering, carbohydrate, test weight, panicle length and grain yield per plant showed maximum correlation towards the total diversity. The fifth principal component (PC 5) was characterized by 7.554 percent contribution towards the total variability. Characters *viz*., protein, fat, test weight, days to 50 percent flowering, days to maturity, iron and number of productive tillers per plant showed the maximum variance in this principal component. The sixth principal component (PC 6) was characterized by 6.052 percent contribution towards the total variability. Calcium, carbohydrate, days to 50 percent flowering, test weight, days to maturity, iron and protein showed maximum variability in this principal component. The PCA analysis thus identified that the maximum contributing traits towards the existing variability as panicle length, grain yield per plant, number of productive tillers per plant, test weight, carbohydrate and plant height. The PCA scores for 50 foxtail millet genotypes in the first three principal components were computed and were considered as three axes as X, Y and

Z and squared distance of each genotype from these three axes were calculated (Table 3). These three PCA scores for 50 genotypes were plotted in graph to get two dimensional scatter diagrams (Fig 1).

Table 2: Eigen values, proportion of the total variance represented by first six principal components, cumulative percent variance and component loading of different characters in foxtail millet

	PC I	PC II	PC III	PC IV	PC V	PC VI
Eigene Value (Root)	4.213	2.201	1.659	1.284	0.982	0.787
% Var. Exp.	32.409	16.931	12.758	9.875	7.554	6.052
Cum. Var. Exp.	32.409	49.340	62.098	71.973	79.527	85.578
Days to 50% flowering	0.019	0.633	0.104	0.199	0.087	0.176
Plant height (cm)	-0.293	0.169	0.279	-0.168	-0.042	-0.348
Panicle length (cm)	-0.442	0.081	-0.043	0.053	-0.157	-0.086
No. of prod. tillers/ Plant	-0.419	0.043	-0.141	-0.117	0.009	-0.101
Days to maturity	-0.010	0.633	0.087	0.234	0.086	0.123
Test weight (g)	-0.403	-0.081	0.049	0.137	0.116	0.174
Protein (g/100g)	-0.164	-0.185	0.366	0.296	0.577	0.004
Fat (g/100g)	0.078	-0.047	0.606	-0.194	0.209	-0.390
Carbohydrate (g/100g)	-0.366	-0.198	0.074	0.177	-0.191	0.197
Iron (mg/100g)	0.099	-0.263	-0.014	0.697	0.057	0.040
Phosphorus (g/100g)	0.087	0.004	0.369	0.343	-0.701	-0.243
Calcium (mg/100g)	-0.034	-0.097	0.474	-0.288	-0.183	0.727
Grain yield/ Plant (g)	-0.441	0.026	-0.108	0.001	-0.058	-0.070

Table 3: Means of Principal component variates/ Canonical variates of respective vectors of 50 foxtail millet [*Setaria italica* (L.) Beauv.] Genotypes

S. No.	Genotype	PC I X vector	PC II Y vector	PC III Z vector
1	Ise-31	-94.474	85.810	65.396
2	Ise-144	-81.969	84.156	66.876
3	Ise-160	-89.024	98.227	71.149
4	Ise-179	-77.330	80.988	69.740
5	Ise-195	-92.090	94.371	77.907
6	Ise-200	-95.149	96.422	71.486
7	Ise-254	-76.745	85.846	69.405
8	Ise-362	-81.491	92.549	65.865
9	Ise-364	-80.709	82.922	67.193
10	Ise-375	-79.150	91.334	68.920
11	Ise-458	-61.329	72.378	54.843
12	Ise-507	-83.576	94.733	67.057
13	Ise-525	-76.468	93.457	69.151
14	Ise-745	-76.197	79.377	54.179
15	Ise-769	-65.627	121.176	64.719
16	Ise-785	-58.061	83.921	64.629
17	Ise-795	-79.619	90.873	66.534
18	Ise-796	-77.718	90.813	69.778
19	Ise-813	-61.399	79.928	61.827
20	Ise-838	-70.673	77.723	68.734
21	Ise-840	-90.334	89.757	73.204
22	Ise-869	-80.704	93.702	71.048
23	Ise-907	-77.271	80.074	72.908
24	Ise-909	-80.541	87.397	62.224
25	Ise-931	-74.985	82.117	62.636
26	Ise-936	-70.236	82.122	60.467
27	Ise-985	-77.789	92.479	70.489
28	Ise-995	-71.480	85.309	59.308
29	Ise-1000	-82.105	92.511	62.680
30	Ise-1026	-50.119	75.716	45.788
31	Ise-1059	-86.145	90.496	77.497
32	Ise-1269	-79.167	87.943	72.397
33	Ise-1354	-74.823	78.067	62.465
34	Ise-1402	-80.213	79.596	64.253
35	Ise-1406	-80.092	87.704	63.726
36	Ise-1408	-68.225	78.416	56.601
37	Ise-1419	-74.575	123.089	65.677
38	Ise-1593	-71.157	72.840	66.786
39	Ise-1605	-99.488	86.874	64.954
40	Ise-1629	-79.249	85.855	62.265

41	Ise-1687	-78.420	90.388	70.303
42	Ise-1780	-78.410	87.476	67.711
43	Ise-1805	-86.838	88.566	65.688
44	Ise-1806	-83.161	84.814	59.739
45	Ise-1820	-84.144	86.237	58.307
46	Ise-1846	-74.344	81.449	61.537
47	Ise-1851	-86.089	83.445	64.588
48	Ise-1881	-92.070	88.943	67.943
49	Ise-1892	-89.675	89.093	63.410
50	Ise-1900	-85.252	90.456	69.305

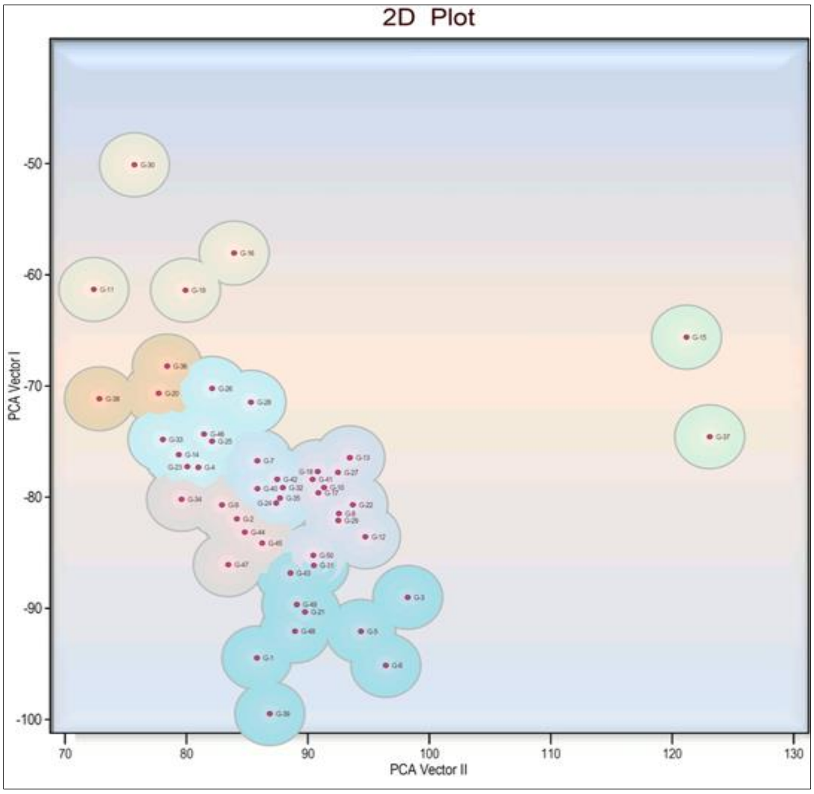

Fig 1: Two dimensional graph showing relative positions of 50 foxtail millet [*Setaria italica* (L.) Beauv.] Genotypes based on PCA scores

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