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Characterization of quality traits in foxtail millet germplasm [*Setaria italica* (L.) Beauv.]

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Abstract
Sixty foxtail millet germplasm were evaluated for protein, carbohydrate (CHO), calcium (Ca), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and phosphorus (P) in grain. The range of values of nutrients content for studied genotypes are 6.21g to 19.43 g/100g for protein, 43.25 g to 82.14 g/100g for carbohydrate, 10.20 mg to 22.60 mg/100g for calcium, 0.14 mg to 5.32 mg/100g for iron, 1.18 mg to 5.23 mg/100g for zinc, 0.12 mg to 2.43 mg/100g for copper, 0.26 mg to 1.55 mg/100g for Mn and 0.11g to 0.43 g/100g for P. The genotype, Ise 1209 has highest seed zinc, manganese, phosphorus contents. Ise 1563 is having highest seed calcium and iron contents whereas the other genotypes Ise 758, Ise 1511 and Ise 1454 are possessing maximum protein, carbohydrate and copper contents. The genotypes Ise 1209 and Ise 90 are nutritionally superior in almost all the parameters *viz.*, zinc, manganese, phosphorus, protein and iron contents followed by the genotypes Ise 238, Ise 1511 and Ise 1563, thereby inferring that these genotypes could be further utilized in breeding programmes for bio-fortification.

Keywords: Setaria, nutritional traits, quality traits

Introduction
Foxtail millet is self pollinating crop with chromosome number, 2n=2x=18, classified under the family Poaceae and subfamily Panicoideae. It is generally grown on marginal areas and lands having scarcity of water. It is grown in around 26 countries, ranks 2^{nd} in the world's total production of millets. Andhra Pradesh, Karnataka and Maharashtra are the Indian states in which this crop is raised. About six million tons of foxtail millet is produced globally; mainly in southern part of Europe, in temperate, subtropical and tropical Asia (Marathee, 1993) [12]. The foxtail millet is believed to have first domesticated in the central China (Chang, 1973 [4]; Ho, 1975) [6]. The naming of this taxon evolved as the millet having panicles resembling a fox tail in appearance *i.e.*, a long panicle with soft, long and erect hairs (Upadhaya, 2008) [19]. This millet grains offers an excellent source of quality proteins (leucine and methionine), β-carotene, minerals (Ca, Fe, K, Mg and Zn), antioxditants, dietary fibre, phytochemicals, vitamins (thiamine, riboflavin and niacin) and have low glycemic index, a requisite for healthy human diet (Murugan and Nirmalakumari, 2006) [13]. This crop is neglected in the past is being neglected even now inspite of having high health and nutritional benefits. In such situation, this study helps in identifying the genotypes with higher nutritional quality so that they can be employed in crop improvement.

Materials and methods
The experiment was conducted during *kharif*, 2018-19 at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, which is located at 16.10^0 N latitude, 28.29^0 E longitude and 31.5 m altitude. Sixty germplasm accessions of foxtail millet were laid out in Augmented Randomized Complete Block Design (ARCBD) and the seed samples of this germplasm was used for estimation of grain nutrients *viz.*, protein, carbohydrate, calcium, iron, zinc, copper, manganese and phosphorus content. Seed protein was estimated using Micro kjeldhal Distillation Method (Sadasivam and Manickam, 1996) [15]. Carbohydrate content was estimated using the procedure given by Sadasivam and Manickam (1997) [16]. Iron, Zinc, Copper and Manganese was estimated with the help of Atomic Absorption Spectrophotometer (AAS) as per Tandon (1999) [17]. Similarly seed phosphorus content was also estimated as per procedure given by Tandon (1999) [17]. While calcium content was estimated using Versanate titration method (Jackson, 1967) [7].

Results and Discussion

In the present screening experiment sixty accessions were assessed for differences in protein (g/100g), carbohydrate (g/100g), phosphorus (g/100g) and micronutrients like, zinc, calcium, iron, manganese and copper (mg/100g) in grain. Up on analyzing the variance, iron, zinc, copper, manganese and phosphorus content were found to be significantly different among the studied line (Table 1). The mean of all the quality traits are listed in Table 2 and are discussed hereunder.

Table 1: Analysis of variance for quality component characters in foxtail millet [*Setaria italica* (L.) Beauv.]

Sources of variations	d.f	Protein (g/100g)	Carbo-hydrate (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Copper (mg/100g)	Mangan-ese (mg/100g)	Phosph-orus (g/100g)
		Mean sum of squares							
Block	4	33.466	173.099	12.410	4.327	0.204	0.189	0.067	0.002
Entries	63	6.926	39.518	8.195	1.967**	0.530**	0.229**	0.093**	0.012**
Checks	3	0.837	4.262	0.249	0.179	0.068	0.036**	0.003	0.004
Genotypes	59	6.818	52.742	10.764	2.165**	0.396**	0.183**	0.086**	0.007**
Checks vs. Genotypes	1	31.582	0.617	2.738	4.327	9.807**	3.550**	0.760**	0.316**
Error	12	1.560	25.304	7.658	0.199	0.034	0.006	0.007	0.002

Table 2: Mean performance of 60 foxtail millet [*Setaria italica* (L.) Beauv.] Genotypes for nutritional traits under study

S. No	Geno-type	Protein (g/100g)	Carbo-hydrate (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Copper (mg/100g)	Mangan-ese (mg/100g)	Phosph-orus (g/100g)
1	Ise 2	12.86	69.56	14.40	3.74	2.44	0.74	0.81	0.28
2	Ise 18	12.69	67.62	16.60	3.85	2.23	0.58	0.56	0.20
3	Ise 49	9.54	78.81	20.80	3.29	1.97	0.52	0.71	0.22
4	Ise 90	15.23	59.68	11.20	5.29	2.93	0.76	0.44	0.41
5	Ise 96	14.35	71.89	11.00	3.37	1.88	1.34	0.70	0.12
6	Ise 132	12.08	63.71	12.80	5.18	2.29	0.77	0.70	0.14
7	Ise 156	12.34	59.64	13.20	1.68	1.55	0.56	0.44	0.29
8	Ise 238	6.21	79.51	20.60	5.20	1.87	0.42	1.12	0.38
9	Ise 267	14.70	56.29	15.60	5.07	2.33	0.51	0.61	0.37
10	Ise 289	8.05	74.23	18.40	5.25	2.63	0.94	0.84	0.22
11	Ise 302	11.29	64.90	10.40	2.78	1.86	1.24	0.33	0.26
12	Ise 388	12.43	70.18	15.20	5.30	3.15	1.02	0.53	0.24
13	Ise 398	11.38	67.83	10.20	4.87	2.22	0.47	0.57	0.40
14	Ise 480	10.85	68.56	17.20	5.29	2.06	1.08	0.75	0.35
15	Ise 663	9.54	71.49	19.80	2.26	2.28	0.80	0.92	0.29
16	Ise 717	7.88	68.97	14.60	4.56	2.56	0.66	0.67	0.34
17	Ise 719	9.89	54.83	16.20	4.94	2.73	1.66	0.50	0.37
18	Ise 746	12.25	61.11	20.80	4.64	2.86	1.02	1.27	0.27
19	Ise 751	9.80	56.89	11.88	5.00	2.86	1.08	0.61	0.22
20	Ise 758	19.43	67.73	19.00	1.87	2.21	1.22	0.35	0.31
21	Ise 771	16.80	62.94	14.60	4.75	2.27	0.86	0.82	0.16
22	Ise 828	14.53	60.03	18.40	1.82	2.22	0.65	0.73	0.26
23	Ise 842	12.08	66.62	17.80	4.87	2.42	0.86	0.66	0.28
24	Ise 846	12.25	72.64	12.80	3.43	1.89	0.67	0.48	0.32
25	Ise 900	11.20	65.82	17.60	3.20	3.01	0.61	0.71	0.40
26	Ise 946	13.04	60.28	17.00	2.00	2.24	0.69	1.07	0.18
27	Ise 956	14.26	60.28	18.40	1.70	2.06	1.05	0.54	0.39
28	Ise 969	12.95	63.15	21.20	1.96	2.50	0.76	0.87	0.14
29	Ise 983	9.71	69.21	16.40	0.96	2.25	0.74	0.94	0.16
30	Ise 999	6.56	59.44	17.00	0.14	2.30	1.61	0.67	0.11
31	Ise 1009	9.36	57.41	16.40	4.72	2.31	2.01	0.72	0.32
32	Ise 1037	11.73	56.81	16.60	5.03	1.84	1.51	0.74	0.30
33	Ise 1118	14.44	65.10	15.00	1.39	1.75	0.65	0.68	0.34
34	Ise 1119	14.88	61.80	19.00	4.70	1.99	1.22	0.83	0.31
35	Ise 1129	9.71	56.24	16.40	3.93	2.66	1.16	1.10	0.28
36	Ise 1134	10.15	56.91	19.00	1.80	2.01	1.04	1.25	0.32
37	Ise 1137	9.80	50.13	19.20	3.58	1.89	0.54	0.34	0.29
38	Ise 1151	10.06	64.43	17.60	5.17	1.63	1.01	0.26	0.25
39	Ise 1162	14.26	63.14	12.80	2.30	1.65	0.88	0.49	0.27
40	Ise 1187	12.43	63.85	12.40	1.77	1.32	0.81	0.36	0.27
41	Ise 1201	11.29	64.38	11.20	5.30	2.47	0.74	1.11	0.36
42	Ise 1209	9.80	52.69	13.80	5.15	3.69	1.02	1.36	0.43
43	Ise 1251	12.69	54.28	14.80	5.22	1.90	1.01	0.70	0.30
44	Ise 1254	6.48	66.72	18.40	2.98	2.13	0.71	1.11	0.34
45	Ise 1299	8.49	49.99	22.60	4.47	1.63	0.50	1.55	0.23
46	Ise 1312	11.38	56.32	12.60	1.15	2.48	0.91	0.54	0.29

47	Ise 1320	9.89	43.25	10.80	4.83	5.23	0.64	0.84	0.21
48	Ise 1335	16.01	69.27	18.60	4.96	2.00	0.49	1.41	0.26
49	Ise 1387	11.46	68.91	14.40	4.90	1.86	0.34	0.75	0.18
50	Ise 1400	11.20	69.21	14.20	2.55	1.95	0.65	0.85	0.39
51	Ise 1454	9.80	63.33	11.20	1.37	1.85	2.43	0.69	0.40
52	Ise 1458	10.06	63.82	10.40	4.92	1.18	0.12	1.06	0.18
53	Ise 1511	14.26	82.14	20.40	4.00	1.78	0.49	1.32	0.39
54	Ise 1563	12.43	60.83	21.20	5.32	1.44	0.60	0.53	0.14
55	Ise 1581	11.29	70.28	11.80	4.97	3.59	2.07	0.77	0.16
56	Ise 1610	9.80	71.56	12.80	2.66	2.15	0.79	0.34	0.11
57	Ise 1638	12.69	64.28	12.60	4.22	2.55	0.54	0.61	0.32
58	Ise 1647	6.48	65.82	14.40	5.24	2.09	0.90	0.96	0.30
59	Ise 1655	8.49	60.58	16.60	4.00	2.09	1.30	1.03	0.34
60	Ise 1664	11.38	65.70	16.20	5.27	1.55	0.63	0.58	0.31
Checks									
1	C1	8.75	66.88	16.35	2.42	2.42	1.24	0.82	0.13
2	C2	10.56	58.09	16.72	4.46	2.56	0.33	0.67	0.41
3	C3	12.44	62.35	16.74	3.23	1.54	0.41	0.54	0.15
4	C4	13.35	68.25	14.40	4.24	1.45	0.50	0.73	0.15
	Mean	**11.39**	**63.55**	**15.76**	**3.74**	**2.22**	**0.89**	**0.77**	**0.27**
	Std. Error	0.32	0.89	0.40	0.18	0.08	0.05	0.04	0.01
	Std. Dev	0.57	7.10	3.19	1.44	0.62	0.43	0.29	0.09
	CV%	10.90	7.90	17.50	12.00	8.50	9.20	11.50	16.90

The protein in the screened sixty genotypes varied from 6.21 g to 19.43 g/100 g of grain sample. High seed protein was observed in genotypes *viz.*, Ise 758 (19.43g), Ise 771, Ise 1335, Ise 90 and Ise 1119. Similar quantum of variability was found by Johar, 2015 [8] (4.55 g to 8.98 g), Kamatar *et al.*, 2015 [9] (8.98 g to 14.37 g), Brunda *et al.*, 2017 [3] (9.97 g to 13.12 g), Thippeswamy *et al.*, 2017 [18] (6.2 g to 10.89 g), Ayesha and Babu, 2018 [2] (6.01 g to 19.56 g), Kavya *et al.*, 2018 [10] (7.66 g to 13.49 g). A total of twelve genotypes were found superior to all the four checks (Suryanandi, Prasad, Co 7, Krishnadevaraya). The variability available for protein can act as source for either for direct exploitation using simple selection or by following population approach depending on the gene action.

For seed carbohydrate content, the values ranged from 43.25 g to 82.14 g/100g of seed sample. The genotype, Ise 1511 possessed highest carbohydrate (82.14 g) followed by Ise 238, Ise 49, Ise 289, Ise 846 and Ise 96. A total of seventeen genotypes recorded higher amount of carbohydrate than all the four checks. Different studies carried out by various researchers have reported the carbohydrate content up to 69.45 g (Lata and Rama, 1999) [11], 75.51 g (Abdoulaye and Jie, 2011) [1], 70.9 g to 74.63 g (Kamatar *et al.*, 2015) [9], 49.78 g to 73 g (Ayesha and Babu, 2018) [2], 56.2 g to 79.9 g (Kavya *et al.*, 2018) [10].

Calcium varied from 10.20 mg to 22.60 mg/100 g of seed sample. Ise 1299 recorded highest calcium content (22.6 mg) followed by Ise 969, Ise 1563, Ise 49, Ise 746 and Ise 238. A total of 23 lines are superior than all the four checks. Such ranges were earlier recorded by Thippeswamy *et al.*, 2017 [18] (1.99 mg to 22.69 mg), Ayesha and Babu, 2018 [2] (5.57 mg to 30.55 mg) and Doddamani and Yenagi, 2018 [5] (0.45 mg to 32.42 mg). However lesser range was indicated by Johar, 2015 [8] (1.6 mg to 7.72 mg).

Seed iron content ranged from 0.14 mg to 5.32 mg/100 g of sample. The genotype, Ise 1563 had possessed highest iron content (5.32 mg/100g) then by Ise 1201, Ise 480, Ise 388, Ise 90, Ise 289 and Ise 1664. A total of 30 genotypes were superior to all the four checks. These results are in concordance with Brunda *et al.*, 2017 [3] (1.08 mg to 2.54 mg) and Doddamani and Yenagi, 2018 [5] (0.04 mg to 5.75 mg). Still lesser range was observed by Thippeswamy *et al.*, 2017 [18] (0.33 mg to 16.26 mg) and Ayesha and Babu, 2018 [2] (1.22 mg to 27.73 mg).

Seed zinc content varied from 1.18 mg to 5.23 mg/100 g of seed sample. Highest zinc is found in genotypes *viz.*, Ise 1320 (5.23 mg) then by Ise 1209, Ise 1581, Ise 900, Ise 388 and Ise 90. A total of 11 genotypes were superior over the four checks. Similar variability was indicated by Brunda *et al.*, 2017 [3] (0.85 mg to 1.19 mg) and Doddamani and Yenagi, 2018 [5] (0.03 mg to 3.86 mg).

For seed copper values varied from 0.12 mg to 2.43 mg/100g of sample. Ise 1454 showed highest copper content (2.43 mg) followed by Ise1581, Ise 1009, Ise 719, Ise 999, Ise 1037, Ise 96 and Ise 1400. A total of 8 lines are superior to all the four checks. Different studies carried out by various researchers have reported the copper content existed between 2.44 mg to 3.37 mg (Brunda *et al.*, 2017) [3], 0.03 mg to 3.86 mg (Doddamani and Yenagi, 2018) [5].

For seed manganese the values ranged from 0.26 mg to 1.55 mg/100 g of sample. The genotype, Ise 1299 showed highest manganese content (1.55 mg) followed by Ise 1335, Ise 1209, Ise 1511, Ise 746, Ise 1134, Ise 238 and Ise 1201. A total of 21 genotypes were found superior to all the four checks. Similarly, Doddamaani and Yenagi, 2018 [5] reported manganese content among the selected genotypes ranged from 0.04 mg to 1.58 mg.

For seed phosphorus content, the values ranged from 0.11g to 0.43 g/100g of seed sample. Highest phosphorus was seen in Ise 1209 (0.43g) then by Ise 90, Ise 398, Ise 900, Ise 1454, Ise 956, Ise 1400 and Ise 1511. Ise 1209 is the genotype that was found to be superior to all the four checks. Similar results were obtained by Ravindran, 1991 [14] (0.27g/100g) and Ayesha and Babu, 2018 [2] (0.11 g to 0.43 g).

Conclusion

Among the analyzed 60 foxtail millet lines, the highest quantum of zinc, manganese, phosphorus in seed were present in genotype Ise 1209. The highest seed calcium and iron contents were seen in genotype Ise 1563 whereas the genotypes Ise 758, Ise 1511 and Ise 1454 possessed maximum protein, carbohydrate and copper contents. However, the genotypes Ise 1209 and Ise 90 was nutritionally superior in almost all the nutrients *viz.*, zinc, manganese, phosphorus, protein and iron contents followed by the genotypes Ise 238, Ise 1511 and Ise 1563,thereby inferring that these lines could be further utilized in breeding programmes for bio-fortification

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