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Genotype×Environment Interaction and Stability Analysis for Quality Parameters in Little Millet (*Panicum sumatrense* L.)

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Abstract

The present study was conducted to evaluate Genotype×Environment interaction and stability analysis for quality parameters for 9 observations in 50 little millet genotypes under three environments i.e.Waghai, Vanarasi and Navsari locations under Gujarat, India during the year *kharif*-2020. Stability analysis revealed that G×E interaction was significantly differed for all the characters except calcium content (mg 100 g^{-1}) and ash content (mg 100 g^{-1}) indicated that different genotypes reacted differently to different environmental conditions. Estimates of environmental indices indicated that Waghai location was favourable for yield contributing characters along with quality parameters followed by Navsari and Vanarasi. The results of present study revealed that none of the genotypes exhibited average stability for all the characters. Among the genotypes, WV 262, WV 258, WV 256, WV 293 and WV 273 were found average stable over environments for grain yield plant^{-1} with quality parameters. So, these genotypes may be used in further breeding programme in little millet.
Keywords: Little millet, Stability, Genotype×Environment interaction, Grain yield.

Keywords: Genotype×Environment interaction, stability analysis, yield and quality traits, little millet

1. Introduction

Little millet is one of the coarse cereals consumed in the form of rice. It is self-pollinated crop with a chromosome number of 2n=4x=36. Little millet belongs to the family Poaceae, sub-family Panicoideae and the tribe Paniceae (Rachie, 1975). Little millet's inflorescence is a panicle, contracted or thyrsiform and 15–45 cm long and 1–5 cm in wide (Seetharam et al., 2003). The spikelet is persistent and 2–3.5 mm long. Panicle branches are scabrous and drooping at the time of maturity. Spikelets were produced on unequal pedicels but solitary at the end of the branches. Each spikelet consisted of 2 m flowers. The lower one is sterile; the upper one is fertile or bisexual without rachilla extension (Sundararaj and Thulasidas, 1976). The lateral vein is absent in lower glume and its apex is acute. The upper glume is ovate and without keel but larger than lower glume (Nanda and Agrawal, 2008).The flowering progressed from the top to the bottom of the panicle. The anthesis occurred between 9.30–10.30 a.m. (Jayaraman et al., 1997). The glumes open for a short while and self-pollination is the rule. The whole process of the anthesis is very rapid and is completed within 2–5 m.

Little millet (*Panicum sumatrense*L.) is grown in India under various agro-ecological situations and commonly known as *samai, samo, moraio, vari* and *kutki*. Little millet is an important crop grown in the tribal belt of Madhya Pradesh, Chhattisgarh, Gujarat, Maharashtra, Odisha and Andhra Pradesh in India. In India, little millet having 1.42 lt of production. In Gujarat, little millet is cultivated in an area of 10,634 ha with 9,526 t of production having the productivity of 896 kg ha^{-1} (Anonymous, 2021). The area under this crop is mainly concentrated in the districts of Dangs, Valsad and Narmada of South Gujarat and Panchmahal of middle Gujarat.

Little millet is better as comparable to other cereals in terms of fiber, fat, carbohydrates, protein, calcium, iron and rich in phytochemicals included phenolic acids, flavonoids, tannins and phytate (Patil et al., 2019). Therefore, it could address nutritional sensitive agriculture, which aimed at nutritional enhancement to combat the present scenario of micronutrient malnutrition. Little millet is known for its drought tolerance and considered as one of the least waters demanding crop. Crop improvement work carried out so far in this crop has thrown some success. In the recent past some improved cultivars were developed but have limited yield potential. The potentiality of little millet has not been exploited in India and the yield levels were very low there by indicated a greater scope for exploitation of little millet under Indian condition. Phenotype is defined as a linear function of Genotype (G), Environment (E) and G×E interaction effects. Relative importance of main and interaction effects might vary from genotype to genotype (Eberhart and Russell, 1966, Finley and Wilkinson, 1963, Perkins and Jinks, 1968). The study of G×E interaction served as a guide for various environmental niches. It is possible to identify genotypes with stability for high yield, through the stability for yield character as well as for quality traits.

2. Materials and Methods

The experiment was conducted during *kharif*-2020 having 50 little millet genotypes, viz.,WV 254, WV 255, WV 256, WV 257, WV 258, WV 259, WV 260, WV 261, WV 262, WV 263, WV 264, WV 265, WV 266, WV 267, WV 268, WV 269, WV 270, WV 271, WV 272, WV 273, WV 274, WV 275, WV 276, WV 277, WV 278, WV 279, WV 280, WV 281, WV 282, WV 283, WV 284, WV 285, WV 286, WV 287, WV 288, WV 289, WV 290, WV 291, WV 292, WV 293, WV 294, WV 295, WV 296, WV 297, WV 298, WV 299, WV 300, WV 301, WV 302 and WV 303 were evaluated in randomized block design atHill Millet Research Station, Navsari Agricultural University, Waghai, Gujarat, India; Niger Research Station, Navsari Agricultural University, Vanarasi, Gujarat, India and College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India during *kharif*-2020.The seedlings were planted at 22.5×10 cm^2 spacing. All recommended practices were followed and timely plant protection measures were taken to avoid damage through insect-pests and diseases.

The observations on five randomly selected plants were recorded for 9 characters viz., hulling (%), chlorophyll content (mg 100 g^{-1} fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg 100 g^{-1}), iron content (mg 100 g^{-1}), calcium content (mg 100 g^{-1}) and ash content (mg 100 g^{-1}). Estimation of stability parameters evaluated by the Eberhart and Russell (1966) model.

3. Results and Discussion

The analysis of variance for stability (Table 1) revealed that, the differences among the genotypes and environments were also significant for all the traits when tested against pooled deviation as well as pooled error. The environments+(genotypes×environments) interaction was observed to be significant for all traits when tested either against pooled deviation or pooled error. Further partitioning of environments+(genotypes×environments) component of variation revealed that the environments (linear) components of variation as well as genotypes×environments (linear) component except for calcium content (mg 100 g^{-1}) were observed to be significant for all the characters under study. The G×E interaction was significant for all characters except calcium content (mg 100 g^{-1}) and ash content (mg 100 g^{-1}). So, these traits were not considered for further analysis. The variance due to pooled deviation was found significant for hulling (%), chlorophyll content (mg 100 g^{-1} fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg 100 g^{-1}), iron content (mg 100 g^{-1}), calcium content (mg 100 g^{-1}) and ash content (mg 100 g^{-1}). Highly significant differences among genotypes, environments and G×E interaction were reported by Fentie et al. (2013), Soodet al. (2018) and Kandel et al. (2020).

Table 1: Analysis of variance for stability parameters with regards to different quality characters in little millet

Source of variation	Df	Hulling (%)	Chlorophyll content (mg 100 g^{-1} fresh weight)	Leaf area (cm^2)	Protein content (%)	Crude fiber (%)	Mineral matter (mg 100 g^{-1})	Iron content (mg 100 g^{-1})	Calcium content (mg 100 g^{-1})	Ash content (mg 100 g^{-1})
Genotype (G)	49	56.43***	72.77***	6074.21***	2.05***	0.71***	0.17***	1.53***	0.84***	0.11***
Environment (E)	2	1224.21***	1651.92***	139918.90***	45.44***	16.96***	4.01***	30.98***	16.23***	2.48***
Env.+(Gen.× Env.)	100	36.24***	51.00***	4156.08***	1.39***	0.51***	0.12***	0.97***	0.51***	0.08***
G×E	98	12.00*	18.33*	1385.41*	0.49*	0.17*	0.04*	0.36*	0.19	0.03
Environment (Linear)	1	2448.42***	3303.85***	279837.90***	90.88***	33.93***	8.03***	61.96***	32.46***	4.96***
G×E (Linear)	49	16.02**	25.12**	1946.74**	0.69**	0.24**	0.06***	0.50**	0.23	0.04*
Pooled deviation	50	7.81*	11.30***	807.60***	0.30***	0.11***	0.02***	0.21***	0.15***	0.02***
Pooled error	294	5.03	1.36	316.91	0.02	0.008	0.002	0.01	0.06	0.003

*, ** and *** significant at 5, 1 and 0.1% levels, respectively.

Table 2: Estimation of environment index (Ij) for various quality characters under different environments in little millet

Sl. No.	Characters	Environmental index		
		Waghai (E1)	Vanarasi (E2)	Navsari (E3)
1.	Hulling (%)	5.54	-1.57	-3.98
2.	Chlorophyll content (mg 100 g^{-1} fresh weight)	6.35	-1.51	-4.84
3.	Leaf area (cm^2)	59.01	-15.85	-43.17
4.	Protein content (%)	1.06	-0.27	-0.79
5.	Crude fiber (%)	0.65	-0.16	-0.49
6.	Mineral matter (mg 100 g^{-1})	0.32	-0.10	-0.22
7.	Iron content (mg 100 g^{-1})	0.88	-0.24	-0.64

The environmental indices computed for the quality characters studied were presented in Table 2 indicating both the favourable and unfavourable environments for all the component characters. Estimates of environmental indices indicated that Waghai location was favourable for most of the yield contributing characters along with quality parameters followed by Navsari and Vanarasi. It was also realized that among all the characters, leaf area (cm^2) was the most vulnerable to environmental fluctuations.

The environmental indices calculated as the deviation of the mean of all the genotypes at a particular environment from the grand mean of all the genotypes revealed that in E_1 (Waghai) increased values in the environmental index for traits viz., grain yield plant^{-1} (g), harvest index (%), hulling (%), chlorophyll content (mg 100 g^{-1} fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg 100 g^{-1}) and iron content (mg 100 g^{-1}). The environmental index was observed to be congenial as well as poorest in environment E_2 (Vanarasi) for none of the traits. In E_3 (Navsari) environment index obtained poorest value for hulling (%), chlorophyll content (mg 100 g^{-1} fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg 100 g^{-1}) and iron content (mg 100 g^{-1}).

When environmental indices of the different characters are studied, the most fluctuating traits observed were hulling (%), chlorophyll content (mg 100 g^{-1} fresh weight) and leaf area (cm^2). It indicated the vulnerability of these traits to the variation in the environment. It was also realized that among all the characters, leaf area (cm^2) was the most vulnerable to environmental fluctuations. The protein content (%) was moderately affected by environmental changes. While, the grain yield plant^{-1} (g), crude fiber (%), mineral matter (mg 100 g^{-1}) and iron content (mg 100 g^{-1}) were less influenced by environmental fluctuations as compared to those listed before.

Patel et al. (2019) reported the G×E interaction was significant for iron content.Patil (2007) reported the genotypes viz., RPSP 742, EC 138375 and RPSP 732 were high yielder with average stability of genotypes.Kandel et al. (2020) reported significant genotypes and genotypes and their interaction for plant height along with genotype CO-4656 which had mean yield that was higher than the overall mean (0.429 t ha^{-1}) with parameter of response (b_i)=1.16 and parameter of stability (S^2di)=0.05.

When genotypes with higher mean performance and non-significant deviation from regression (S^2d_i=0) were tested for the significance of regression coefficient from unity,6 genotypes viz., WV 262, WV 258, WV 256, WV 293, WV 294 and WV 273for grain yield plant^{-1} (g); ten genotypes viz., WV 256, WV 291, WV 263, WV 286, WV 288, WV 299, WV 293, WV 259, WV 282 and WV 296 for hulling (%); three genotypes viz., WV 289, WV 286 and WV 302for chlorophyll content (mg 100 g^{-1} fresh weight); eight genotypes *viz.*, WV 289, WV 272, WV 288, WV 286, WV 263, WV 303, WV 296 and WV 282for leaf area (cm^2); one genotype WV 286for protein content (%); three genotypes viz., WV 263, WV 286 and WV 303for crude fiber (%); none of genotypefor mineral matter (mg 100 g^{-1}) and three genotypes viz., WV 263, WV 287 and WV 303for iron content (mg 100 g^{-1}) showed a regression coefficient nearly equal to unity (b_i=1), which demonstrated good general adaptation of character under various environments (Table 3, 4, 5 and 6).

Four genotype viz., WV 302, WV 303, WV 301 and WV 272for grain yield plant^{-1} (g); one genotype WV 303for hulling (%); three genotypes *viz.*, WV 297, WV 265 and WV 263 for chlorophyll content (mg 100 g^{-1} fresh weight); one genotype WV 297 for leaf area (cm^2); two genotypes viz., WV 297 and WV 273 for protein content (%); two genotypes viz., WV 297 and WV 302 for crude fiber (%); two genotypes viz., WV 297 and WV 303 for mineral matter (mg 100 g^{-1}) and one genotype WV 274 for iron content (mg 100 g^{-1}) which had a higher mean value, regression coefficients below unity (b_i<1) and non-significant deviation from regression (S^2d_i=0) was considered as only adapted to poor environment.

While four genotypes viz., WV 259, WV 288, WV 269 and WV 296 for grain yield plant^{-1} (g); two genotypes viz., WV 260 and WV 273for hulling (%); three genotypes viz., WV 288, WV 294 and WV 260for chlorophyll content (mg 100 g^{-1} fresh weight); five genotypes viz., WV 256, WV 260, WV 294, WV 273 and WV 291 for leaf area (cm^2); three genotypes viz., WV 263, WV 256 and WV 260 for protein content (%); two genotypes viz., WV 256 and WV 260for crude fiber (%); two genotypes viz., WV 286 and WV 256for mineral matter (mg 100 g^{-1}) and one genotype WV 286 for iron content (mg 100 g^{-1})were regarded as specifically adapted to a favourable environment because they had a higher mean value, a regression coefficient above unity (b_i>1), and a non-significant deviation from regression (S^2d_i=0).

Table 3: Estimation of mean and stability parameter for hulling (%) and chlorophyll content (mg 100 g^{-1} fresh weight) in little millet

Sl. No.	Genotypes	Hulling (%)			Chlorophyll content (mg 100 g^{-1} fresh weight)		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
1.	WV 254	52.83	0.51^{**+}	-3.09	23.54	0.43^{**++}	-1.15
2.	WV 255	53.71	0.90^{*}	0.99	24.56	0.79^{*}	5.61^{*}
3.	WV 256	59.34	1.38^{**}	0.30	29.85	1.56^{**++}	0.98
4.	WV 257	57.91	1.19^{**}	-1.22	27.38	1.45^{**}	4.34^{*}
5.	WV 258	58.80	1.37	21.36^{*}	29.17	1.49^{*}	23.33^{***}
6.	WV 259	66.12	1.63^{**}	7.13	39.27	1.74^{**}	12.84^{**}
7.	WV 260	58.77	1.90^{**++}	-4.89	30.00	1.85^{**++}	-0.88
8.	WV 261	65.53	0.90	40.96^{**}	38.24	0.94	65.67^{***}
9.	WV 262	60.57	1.13	22.79^{*}	31.63	1.29	49.24^{***}
10.	WV 263	59.97	0.93^{**}	-4.23	32.12	0.84^{**++}	-1.11
11.	WV 264	52.58	0.72^{**++}	-4.76	24.89	0.30^{**++}	-1.36
12.	WV 265	56.85	0.79^{**+}	-4.49	30.27	0.47^{**++}	-1.32
13.	WV 266	55.96	1.13^{**}	-3.37	26.28	1.12^{**}	1.81
14.	WV 267	54.60	0.85^{*}	2.66	25.12	0.83^{*}	8.24^{**}
15.	WV 268	64.40	0.07	6.72	36.57	0.17	25.23^{***}
16.	WV 269	57.56	1.91^{**}	5.74	28.41	2.01^{**+}	14.22^{***}
17.	WV 270	56.22	1.26^{**++}	-5.04	27.63	1.29^{**++}	-1.27
18.	WV 271	52.26	0.05^{++}	-0.24	22.44	-0.12^{++}	2.52
19.	WV 272	58.38	1.49^{**}	-1.82	29.61	1.65^{**++}	4.37^{*}
20.	WV 273	58.76	2.00^{**++}	-3.49	29.90	2.07^{**++}	8.96^{**}
21.	WV 274	58.39	0.94^{**}	-3.25	29.26	0.78^{**}	0.70
22.	WV 275	50.64	-0.05^{++}	-4.53	22.10	-0.11^{**++}	-1.37
23.	WV 276	55.00	1.16^{**}	-2.56	25.58	1.09^{**}	5.11^{*}
24.	WV 277	57.72	-0.08^{++}	2.82	29.11	-0.05^{+}	10.31^{**}
25.	WV 278	51.69	0.48^{**++}	-3.77	23.51	0.28^{**++}	-0.97
26.	WV 279	55.23	1.24^{**}	-2.17	27.20	1.25^{**}	3.01
27.	WV 280	54.23	0.93^{**}	-4.98	24.82	0.75^{**++}	-1.00
28.	WV 281	53.41	0.43^{**++}	-4.67	23.47	0.49^{**++}	-0.63
29.	WV 282	66.33	1.57^{**}	5.24	39.22	1.57^{**}	13.06^{**}
30.	WV 283	56.36	1.27^{**++}	-5.04	27.01	1.26^{**}	0.24
31.	WV 284	59.68	1.11	22.62^{*}	31.75	1.05	23.56^{***}
32.	WV 285	57.11	1.38^{**++}	-4.69	28.14	1.46^{**++}	-1.30
33.	WV 286	60.64	1.07^{**}	-4.91	32.38	1.03^{**}	-0.64
34.	WV 287	56.50	1.67^{**}	13.64	28.18	1.56^{*}	28.57^{***}
35.	WV 288	60.67	1.68^{**}	3.33	32.87	1.58^{**+}	3.31
36.	WV 289	58.31	1.06^{**}	-0.44	31.55	1.19^{**}	1.18
37.	WV 290	57.47	0.50	41.66^{**}	29.60	0.31	53.73^{***}
38.	WV 291	59.37	1.75^{**}	3.77	30.09	1.92^{**+}	12.69^{**}

Table 3: Continue...

Sl. No.	Genotypes	Hulling (%)			Chlorophyll content (mg 100 g^{-1} fresh weight)		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
39.	WV 292	54.53	1.04^{**}	-2.43	27.59	1.00^{**}	-0.23
40.	WV 293	64.55	1.39^{**}	3.42	37.84	1.30^{**}	13.25^{**}
41.	WV 294	57.89	2.04^{**++}	-3.78	30.64	1.79^{**++}	-0.97
42.	WV 295	56.28	0.41^{**++}	-4.80	25.59	0.38	19.30^{***}
43.	WV 296	67.39	1.46^{**}	7.02	41.22	1.47^{**}	17.14^{***}
44.	WV 297	58.17	-0.43^{**++}	-4.91	32.19	-0.28^{**++}	-1.35
45.	WV 298	61.41	0.95	22.70^{*}	34.30	1.00	34.74^{***}
46.	WV 299	61.99	0.72^{*}	0.01	31.97	-0.06^{++}	0.76
47.	WV 300	55.96	0.72	8.23	27.12	0.61	12.05^{**}
48.	WV 301	55.79	0.55	-3.32	27.06	0.51^{**++}	-0.96
49.	WV 302	66.15	0.21^{++}	-3.34	39.82	1.30^{**}	1.66
50.	WV 303	69.59	0.68^{**++}	-4.37	40.01	1.42^{*}	31.73^{***}
	General mean	58.39			29.96		
	±SEbi		0.40			0.41	

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively; * and ** significant at 5 and 1% levels, respectively when Ho: b_i=0; + and ++ significant at 5 and 1% levels, respectively when Ho: b_i=1

Table 4: Estimation of mean and stability parameter for leaf area (cm^2) and protein content (%) in little millet

Sl. No.	Genotypes	Leaf area (cm^2)			Protein content (%)		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
1.	WV 254	481.49	0.48^{**++}	-228.62	7.91	0.52^{**++}	0.01
2.	WV 255	491.52	0.82^{*}	348.32	8.02	0.92^{*}	0.20^{**}
3.	WV 256	544.21	1.53^{**++}	-166.23	9.04	1.62^{**++}	0.03
4.	WV 257	516.56	1.53^{**++}	-185.08	8.53	1.61^{**++}	0.04^{**}
5.	WV 258	527.43	1.69^{**}	471.09	8.76	1.83^{**+}	0.18^{**}
6.	WV 259	625.27	1.57^{**}	1029.65^{*}	10.63	1.73^{**}	0.31^{***}
7.	WV 260	540.16	1.87^{**++}	-309.03^{***}	9.04	1.96^{**++}	-0.01
8.	WV 261	617.36	0.87	5083.20^{***}	10.46	0.94	1.90^{***}
9.	WV 262	563.23	1.08	2678.83^{**}	9.44	1.19	1.06^{***}
10.	WV 263	564.49	1.08^{**}	-276.51	9.61	1.28^{**++}	-0.02
11.	WV 264	483.21	0.64^{**++}	-276.93	7.85	0.67^{**++}	-0.01
12.	WV 265	522.86	0.74^{**}	-236.00	8.70	0.80^{**}	0.07
13.	WV 266	516.26	1.12^{**}	-67.97	8.36	1.31^{**++}	-0.01
14.	WV 267	500.84	0.89^{**}	243.47	8.25	0.84^{*}	0.31^{***}
15.	WV 268	604.18	0.02	1904.76^{**}	10.18	0.12	0.66^{***}
16.	WV 269	525.52	2.02^{**++}	111.35	8.76	2.13^{**++}	0.30^{***}
17.	WV 270	522.20	1.14^{**++}	-309.80	8.53	1.36^{**++}	-0.01
18.	WV 271	472.44	0.01^{++}	229.21	7.63	-0.10^{++}	0.27^{***}
19.	WV 272	540.21	1.61^{**}	295.49	9.16	1.46^{**}	0.17^{**}
20.	WV 273	543.57	2.05^{**++}	139.11	10.74	0.67^{**++}	-0.01
21.	WV 274	535.27	0.79^{**}	-25.06	8.93	0.87^{**}	0.06

Table 4: Continue...

Sl. No.	Genotypes	Leaf area (cm^2)			Protein content (%)		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
22.	WV 275	472.59	-0.08^{++}	-305.40	7.46	-0.07^{++}	-0.01
23.	WV 276	504.84	1.06^{**}	-52.69	8.31	1.17^{**}	0.08^{*}
24.	WV 277	533.19	-0.10^{+}	1284.54^{*}	8.87	-0.12^{+}	0.43^{***}
25.	WV 278	474.88	0.43^{**++}	-244.04	7.68	0.50^{**++}	0.01
26.	WV 279	505.82	1.34^{**}	70.67	8.53	1.26^{**}	0.11^{*}
27.	WV 280	498.20	0.77^{**++}	-279.48	8.48	0.57^{**++}	-0.02
28.	WV 281	481.26	0.49^{**++}	-245.30	7.91	0.52^{**++}	0.01
29.	WV 282	654.31	0.87^{**}	-78.30	10.56	1.62^{**}	0.37^{***}
30.	WV 283	509.54	1.37^{**++}	-316.87	8.48	1.39^{**++}	-0.02
31.	WV 284	555.49	1.03	3076.11^{**}	9.27	1.19	1.07^{***}
32.	WV 285	531.14	1.39^{**++}	-291.85	8.87	1.19^{**++}	-0.02
33.	WV 286	562.84	1.06^{**}	-302.63	9.55	1.02^{**}	-0.02
34.	WV 287	514.86	1.70^{**}	1860.26^{**}	8.59	1.74^{*}	0.82^{***}
35.	WV 288	560.14	1.66^{**}	883.99	9.44	1.73^{**}	0.31^{***}
36.	WV 289	539.79	1.13^{**}	-12.66	9.04	1.09^{**}	0.15^{**}
37.	WV 290	524.00	0.72^{**++}	-269.80	8.87	0.42	1.64^{***}
38.	WV 291	536.86	2.11^{**++}	163.79	9.04	2.03^{**++}	0.26^{**}
39.	WV 292	500.53	0.83^{**}	-254.48	8.36	0.97^{**}	0.04
40.	WV 293	611.96	1.36^{**}	1207.67^{*}	10.35	1.36^{**}	0.34^{***}
41.	WV 294	540.37	1.91^{**++}	41.14	8.99	1.93^{**+}	0.22^{**}
42.	WV 295	496.23	0.65	672.41	8.42	0.37	0.24^{**}
43.	WV 296	640.86	1.47^{**}	813.78	10.86	1.54^{**}	0.41^{***}
44.	WV 297	543.93	0.08^{**++}	-316.54	9.21	-0.10^{**++}	-0.02
45.	WV 298	576.80	0.81	3115.11^{**}	9.61	0.89	1.32^{***}
46.	WV 299	549.95	0.11^{++}	-238.04	9.21	0.02^{++}	-0.01
47.	WV 300	517.60	0.52	2550.98^{**}	8.53	0.70	0.57^{***}
48.	WV 301	514.23	0.52^{*}	81.55	8.48	0.52^{*+}	0.08^{*}
49.	WV 302	507.99	0.19	1751.35^{*}	8.48	0.22	0.02
50.	WV 303	634.63	1.03^{**}	-293.06	8.53	0.59^{**+}	0.05
General mean		536.66			8.93		
$\pm SEb_i$			0.40			0.41	

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively; * and ** significant at 5 and 1% levels, respectively when Ho: b_i=0; + and ++ significant at 5 and 1% levels, respectively when Ho: b_i=1

The Table 7 indicates the classification of genotypes by number based on their adaptation in different environments in little millet while, Table 8 indicates the classification of genotypes by name based on their adaptation in different environments in little millet. In general, the numbers of genotypes identified for average stability and wide/general adaptability were higher as compared to stable and adapted to poor environment or stable and adapted to better environment.

Patel et al. (2019) noted significant G×E interaction for yield and quality traits in pearl millet. Madhavilatha et al. (2020) reported among the tested genotypes that PR-1041 recorded average stability for grain yield indicated the wide adoptability of this genotype for important traits.Also, found out significant G×E interaction for grain yield plant^{-1}. Kandel et al. (2020) reported that the genotype CO-4656 had mean yield which was higher than the overall mean (0.429 t ha^{-1}), parameter of response (b)=1.16 and parameter of stability (S^2d_i)=0.05.

Table 5: Estimation of mean and stability parameter for crude fiber (%) and mineral matter (mg 100 g^{-1}) in little millet

Sl. No.	Genotypes	Crude fiber (%)			Mineral matter (mg 100 g^{-1})		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
1.	WV 254	4.70	0.50^{**++}	0.002	1.66	0.48^{**++}	0.002
2.	WV 255	4.80	0.85^{**}	0.035^{*}	1.68	0.92^{**}	0.013^{**}
3.	WV 256	5.37	1.54^{**++}	0.015	1.98	1.60^{**++}	0.001
4.	WV 257	5.07	1.54^{**++}	0.015	1.85	1.54^{**++}	0.004^{*}
5.	WV 258	5.33	1.47^{*}	0.246^{***}	1.97	1.55^{**}	0.045^{***}
6.	WV 259	6.30	1.66^{**}	0.103^{***}	2.48	1.88^{**}	0.035^{***}
7.	WV 260	5.37	1.88^{**++}	-0.001	1.92	2.05^{**++}	0.022^{***}
8.	WV 261	6.20	0.91	0.651^{***}	2.42	1.00	0.172^{***}
9.	WV 262	5.60	1.14	0.360^{***}	2.12	1.05	0.088^{***}
10.	WV 263	5.57	0.86^{**}	-0.001	2.08	0.87^{**}	0.003^{*}
11.	WV 264	4.67	0.64^{**++}	-0.002	1.67	0.57^{**++}	-0.002
12.	WV 265	5.17	0.76^{**}	0.026^{*}	1.88	0.79^{**}	0.004^{*}
13.	WV 266	4.97	1.26^{**+}	-0.001	1.80	1.23^{**+}	0.002
14.	WV 267	4.90	0.81	0.109^{***}	1.75	0.85^{*}	0.022^{**}
15.	WV 268	6.03	0.12	0.228^{***}	2.32	0.09	0.059^{***}
16.	WV 269	5.20	2.04^{**+}	0.113^{***}	1.96	2.02^{**++}	0.021^{***}
17.	WV 270	5.06	1.27^{**++}	-0.005	1.83	1.31^{**++}	-0.002
18.	WV 271	4.53	-0.09^{++}	0.093^{***}	1.63	-0.23^{++}	0.002
19.	WV 272	5.70	0.97^{**}	0.088^{***}	1.95	1.66^{**+}	0.012^{**}
20.	WV 273	5.40	2.09^{**++}	0.037^{*}	2.02	2.05^{**++}	0.022^{***}
21.	WV 274	5.30	0.83^{**}	0.020	1.97	0.77^{**}	0.004^{*}
22.	WV 275	4.42	-0.06^{++}	-0.001	1.63	-0.10^{**++}	-0.002
23.	WV 276	4.93	1.11^{**}	0.031^{*}	1.79	1.08^{**}	0.006^{**}
24.	WV 277	5.27	-0.12^{+}	0.149^{***}	1.93	-0.15^{+}	0.037^{***}
25.	WV 278	4.57	0.47^{**++}	0.005	1.58	0.50^{**++}	0.002
26.	WV 279	5.09	1.16^{**}	0.058^{**}	1.77	1.46^{**}	0.008^{**}
27.	WV 280	4.90	0.78^{**++}	-0.007	1.72	0.90^{**}	-0.001
28.	WV 281	4.70	0.50^{**++}	0.002	1.67	0.44^{**++}	-0.001
29.	WV 282	6.27	1.57^{**}	0.119^{***}	2.45	1.68^{**}	0.042^{***}
30.	WV 283	5.10	1.19^{**}	0.012	1.83	1.30^{**++}	-0.002
31.	WV 284	5.50	1.14	0.360^{***}	2.12	0.85	0.044^{***}
32.	WV 285	5.20	1.40^{**++}	-0.007	1.93	1.30^{**++}	-0.002
33.	WV 286	5.60	1.07^{**}	-0.007	2.10	1.10^{**++}	-0.001
34.	WV 287	5.10	1.66^{*}	0.294^{***}	2.05	1.28^{*}	0.050^{***}
35.	WV 288	5.60	1.66^{**}	0.103^{***}	2.10	1.68^{**}	0.042^{***}
36.	WV 289	5.40	0.97^{**}	0.088^{***}	1.98	1.09^{**}	0.009^{**}
37.	WV 290	5.21	0.47	0.635^{***}	1.93	0.47	0.135^{***}
38.	WV 291	5.50	2.21^{**++}	0.091^{**}	1.97	2.05^{**++}	0.022^{***}
39.	WV 292	5.00	0.95^{**}	-0.004	1.75	1.06^{**}	0.003

Table 5: Continue...

Sl. No.	Genotypes	Crude fiber (%)			Mineral matter (mg 100 g^{-1})		
		Mean	b_i	S_2d_i	Mean	b_i	S_2d_i
40.	WV 293	6.10	1.38^{**}	0.154^{***}	2.38	1.29^{*}	0.059^{***}
41.	WV 294	5.27	1.99^{**++}	0.027^{*}	1.98	1.85^{**+}	0.017^{***}
42.	WV 295	4.83	0.62	0.080^{**}	1.83	0.25	0.041^{***}
43.	WV 296	6.43	1.47**	0.136^{***}	2.57	1.61^{**}	0.031^{***}
44.	WV 297	5.47	-0.09^{**++}	-0.008	2.03	-0.10^{**++}	-0.002
45.	WV 298	5.70	0.86	0.449^{***}	2.20	0.66	0.113^{***}
46.	WV 299	5.47	0.02^{++}	-0.002	2.03	0.03^{++}	0.001
47.	WV 300	5.10	0.59	0.254^{***}	1.83	0.72	0.043^{***}
48.	WV 301	5.17	0.40^{**}	0.007	1.81	0.57^{**++}	0.003
49.	WV 302	6.00	0.62^{**++}	-0.008	1.78	0.37^{**++}	-0.001
50.	WV 303	6.20	0.95^{**}	-0.004	2.38	0.70^{**++}	0.002
	General mean	5.33			1.96		
	±SEb_i		0.41			0.40	

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively; * and ** significant at 5 and 1% levels, respectively when Ho: b_i=0; + and ++ significant at 5 and 1% levels, respectively when Ho: b_i=1

Table 6: Estimation of mean and stability parameter for iron content (mg 100 g^{-1}) in little millet

Sl. No.	Genotypes	Iron content (mg 100 g^{-1})			Sl. No.	Genotypes	Iron content (mg 100 g^{-1})		
		Mean	b_i	S_2d_i			Mean	b_i	S_2d_i
1.	WV 254	8.86	0.51^{**++}	0.01	21	WV 274	9.81	0.68^{**++}	-0.01
2.	WV 255	8.95	0.92^{**}	0.12^{**}	22	WV 275	8.49	-0.07^{++}	-0.01
3.	WV 256	9.79	1.60^{**++}	0.01	23	WV 276	9.15	1.18^{**}	0.08^{*}
4.	WV 257	9.37	1.60^{**++}	0.01	24	WV 277	9.65	-0.14^{+}	0.29^{***}
5.	WV 258	9.75	1.54^{**}	0.41^{***}	25	WV 278	8.77	0.40^{**++}	0.01
6.	WV 259	11.10	1.71^{**}	0.26^{***}	26	WV 279	9.28	1.36^{**}	0.07^{*}
7.	WV 260	9.79	1.94^{**++}	-0.01	27	WV 280	9.09	0.84^{**++}	-0.01
8.	WV 261	10.96	0.91	1.35^{***}	28	WV 281	9.05	0.23^{++}	0.01
9.	WV 262	10.21	1.02	0.51^{***}	29	WV 282	11.05	1.61^{**}	0.29^{***}
10.	WV 263	10.07	0.88^{**}	0.01	30	WV 283	9.47	1.21^{**++}	-0.01
11.	WV 264	8.91	0.57^{**++}	-0.01	31	WV 284	9.98	1.16	0.78^{***}
12.	WV 265	9.51	0.79^{**}	0.04	32	WV 285	9.75	1.38^{**++}	-0.02
13.	WV 266	9.23	1.31^{**++}	-0.01	33	WV 286	10.12	1.11^{**++}	-0.02
14.	WV 267	9.23	0.70	0.36^{***}	34	WV 287	10.24	1.18^{**}	0.03
15.	WV 268	10.73	0.11	0.45^{***}	35	WV 288	10.12	1.71^{**}	0.26^{***}
16.	WV 269	9.61	2.05^{**+}	0.23^{***}	36	WV 289	10.11	1.42^{*}	0.36^{***}
17.	WV 270	9.37	1.35^{**++}	0.01	37	WV 290	9.61	0.47	1.33^{***}
18.	WV 271	9.05	-0.76^{**++}	0.07^{*}	38	WV 291	9.89	1.93^{**++}	0.11^{**}
19.	WV 272	9.89	1.46^{**}	0.09^{*}	39	WV 292	9.23	0.96^{**}	0.02
20.	WV 273	9.81	2.05^{**++}	0.14^{**}	40	WV 293	10.82	1.41^{*}	0.36^{***}

Table 6: Continue...

Sl. No.	Genotypes	Iron content (mg 100 g^{-1})			Sl. No.	Genotypes	Iron content (mg 100 g^{-1})		
		Mean	b_i	S_2d_i			Mean	b_i	S_2d_i
41.	WV 294	9.71	1.98^{**++}	0.07^{*}	47	WV 300	9.37	0.70	0.36^{***}
42.	WV 295	9.05	0.60	0.33^{***}	48	WV 301	9.51	0.32^{++}	0.02
43.	WV 296	11.29	1.51^{**}	0.33^{***}	49	WV 302	11.33	0.76^{**}	0.07^{*}
44.	WV 297	9.70	0.17^{**++}	-0.01	50	WV 303	11.52	0.68^{**}	0.03
45.	WV 298	10.31	0.96	0.88^{***}	General mean		9.79		
46.	WV 299	9.93	0.03	0.01	±SEbi			0.41	

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively; * and ** significant at 5 and 1% levels, respectively when Ho: b_i=0; + and ++ significant at 5 and 1% levels, respectively when Ho: b_i=1

Table 7: Classification of genotypes by number based on their adaptation in different environments in little millet

Sl. No.	Quality characters	Number of genotypes suitable for		
		Average stability and wide/ general adaptability	Stable and adapted to poor environment	Stable and adapted to better environment
1.	Hulling (%)	10	1	2
2.	Chlorophyll content (mg 100 g^{-1} fresh weight)	3	3	3
3.	Leaf area (cm^2)	8	1	5
4.	Protein content (%)	1	2	3
5.	Crude fiber (%)	3	2	2
6.	Mineral matter (mg 100 g^{-1})	-	2	2
7.	Iron content (mg 100 g^{-1})	3	1	1

Table 8: Classification of genotypes by name based on their adaptation in different environments in little millet

Sl. No.	Quality Characters	Name of genotypes suitable for		
		Average stability and wide/ general adaptability	Stable and adapted to poor environment	Stable and adapted to better environment
1.	Hulling (%)	WV 256, WV 291, WV 263, WV 286, WV 288, WV 299, WV 293, WV 259, WV 282 and WV 296	WV 303	WV 260 and WV 273
2.	Chlorophyll content (mg 100 g^{-1} fresh weight)	WV 289, WV 286 and WV 302	WV 297, WV 265 and WV 263	WV 288, WV 294 and WV 260
3.	Leaf area (cm^2)	WV 289, WV 272, WV 288, WV 286, WV 263, WV 303, WV 296 and WV 282	WV 297	WV 256, WV 260, WV 294, WV 273 and WV 291
4.	Protein content (%)	WV 286	WV 297 and WV 273	WV 263, WV 256 and WV 260
5.	Crude fiber (%)	WV 263, WV 286 and WV 303	WV 297 and WV 302	WV 256 and WV 260
6.	Mineral matter (mg 100 g^{-1})	-	WV 297 and WV 303	WV 286 and WV 256
7.	Iron content (mg 100 g^{-1})	WV 263, WV 287 and WV 303	WV 274	WV 286

Madhavilatha et al. (2020) reported average stability for grain yield was found in VR 990 which revealed the wide adaptability of the genotype across different locations. Kandel et al. (2022) studied genotypes viz., GE-0382, KLE-216, NE-94 and KLE-559 that were found environmentally sensitive producing higher grain yield throughout the environments.

Patel et al. (2019) reported significant G×E interaction for leaf area when tested against pooled error in pearl millet.

Chavan et al. (2018) recorded average stability for protein content (%) for genotypes viz., GE-1680, Kanika Reddy, IVT-25, NagliDapoli 1 which indicated wider adoptability of these genotypes under all environments.Chavan et al. (2018) found out general stability for iron content (mg 100 g^{-1}) in the genotypes viz., MR-6, PEH-1201 and IVT-11. Also, recorded average stability for protein content (%) for genotypes viz., GE-1680, Kanika Reddy, IVT-25, Nagli Dapoli 1 which indicated wider adoptability of these genotypes under all environments.

Saritha et al. (2018) noted that the genotypes viz., VR-1034, GPU-71, DHWFM 11-3, OUAT-2 and JWM-1 were consistently stable across the environments whereas VR-936, GE-728, GE-6834-1, WFM-10, KMR-344, DHWFM 2-3 and GPU-67 were poorly adapted across the environments for their grain iron content.In general, the numbers of genotypes identified for average stability and wide/general adaptability were higher as compared to stable and adapted to poor environment or stable and adapted to better environment.

As the genotype WV 294 was found to be stable over environment for grain yield per plant but with none of the yield contributing characters. Hence, it was suggested that in order to identify stable genotypes, actual testing under variable environments including favourable and unfavourable would be advantageous. During selection, the attention should be paid to the phenotypic stability of characters directly related to grain yield per plant in little millet. Estimates of environmental indices indicated that Waghai location was favourable for most of the yield contributing characters along with quality parameters followed by Navsari and Vanarasi. Estimates of environmental indices indicated that Waghai location was favourable for most of the yield contributing characters along with quality parameters followed by Navsari and Vanarasi.

4. Conclusion

The overall picture of stability of genotypes to different characters, it could be concluded that, genotypes viz., WV 262, WV 258, WV 256, WV 293 and WV 273 were found to be average stable over environments for grain yield per plant with one or more yield contributing characters. The protein content (%) was moderately affected by environmental changes. While, the grain yield $plant^{-1}$ (g), crude fiber (%), mineral matter (mg 100 g^{-1}) and iron content (mg 100 g^{-1}) were less influenced by environmental fluctuations.

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