Original Research Article

Genotype × Environment interaction and stability analysis for grain yield and yield related traits in little millet (*Panicum sumatrense* L.)

Abstract

The present study was conducted to evaluate Genotype × Environment interaction and stability analysis for grain yield, its components in 50 little millet genotypes under three environments *i.e.* Waghai, Vanarasi and Navsari locations (Gujarat, India) in year *Kharif*-2020. Stability analysis revealed that G x E interaction was significantly differe~~nt~~ntd for all the characters except calcium content (mg/100g) and ash content (mg/100g), indicat~~ed~~ing that different genotypes reacted differently to different environmental conditions. 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. The results of the 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 per plant with one or more yield contributing characters and quality parameters. So, these genotypes may be used in further breeding programmes in little millet.

Key words: Little millet, Stability, Genotype × Environment interaction, Grain yield

Introduction

Little millet (*Panicum sumatrense* L.) is one of the coarse cereals consumed in the form of rice. It is a 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 two-minute 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 the lower glume (Nanda and Agrawal, 2008). The flowering progressed from the top to the bottom of the panicle. The anthesis occurred between 9.30 to 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 min.

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 lakh tones of production. In Gujarat, little millet is cultivated in an area of 10,634 hectares with 9,526 tonnes of production having the productivity of 896 kg/ha (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~~when compared to other cereals in terms of fiber, fat, carbohydrates, protein, calcium, iron and rich in phytochemicals includ~~ed~~ing phenolic acids,

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flavonoids, tannins and phytate. Therefore, it could address nutritional sensitive agriculture, which is 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 water~~s~~-demanding crops. Crop improvement work carried out so far in this crop has ~~thrown~~ yielded some success. In the recent past some improved cultivars were developed but they have limited yield potential. The potential~~ity~~ of little millet has not been exploited in India and the yield levels were very low there~~-~~by ~~indicated~~ indicating 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 x 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 x E interaction served as a guide for various environmental niches. It is possible to identify genotypes with stability for high yield over various environments, through the stability for yield and yield component characters.

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 at Hill 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 x 10 cm^2 spacing. All recommended practices were followed and timely plant protection measures were taken to avoid damage through insect-pests and diseases.

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The observations on five randomly selected plants were recorded for 19 characters *viz*., days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, panicle length (cm), spikes per panicle, 1000 grain weight (g), grain yield per plant (g), fodder yield per plant (g), harvest index (%), hulling (%), chlorophyll content (mg/100g fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg/100g), iron content (mg/100g), calcium content (mg/100g) and ash content (mg/100g). Estimation of stability parameters was evaluated by the Eberhart and Russell (1966) model.

Results and Discussions

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 x environments) interaction was observed to be significant for all traits when tested either against pooled deviation or pooled error. Further partitioning of environments + (genotypes x environments) component of variation revealed that the environments (linear) components of variation as well as genotypes x environments (linear) component except for calcium content (mg/100g) were observed to be significant for all the characters under study. The G x E interaction was significant for all characters except calcium content (mg/100g) and ash content (mg/100g). So, these traits were not considered for further analysis. The variance due to pooled deviation was found significant for days to 50% flowering, productive tillers per plant, spikes per panicle, hulling (%), chlorophyll content (mg/100g fresh weight), leaf area (cm^2), protein content (%), crude fiber (%), mineral matter (mg/100g), iron content (mg/100g), calcium content (mg/100g) and ash content (mg/100g). Highly significant differences among genotypes, environments and G x E interaction were reported by Fentie *et al.* (2013), Sood *et al*. (2018), Ataei and Reza (2020) and Kandel *et al.* (2020).

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The environmental indices computed for the seventeen 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.

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Table ~~1~~2. Estimation of environment index (Ij) for various characters under different environments in little millet.

Sr. No.	Characters	Environmental index		
		Waghai (E_1)	Vanarasi (E_2)	Navsari (E_3)
1.	Days to 50% flowering	6.53	-1.81	-4.71
2.	Days to maturity	6.51	-1.79	-4.71
3.	Plant height (cm)	6.78	-1.47	-5.31
4.	Productive tillers per plant	0.64	-0.18	-0.46
5.	Panicle length (cm)	2.59	-0.69	-1.90
6.	Spikes per panicle	0.64	-0.18	-0.47
7.	1000 Grain weight (g)	0.05	-0.01	-0.04
8.	Grain yield per plant (g)	0.62	-0.08	-0.55
9	Fodder yield per plant (g)	0.93	-0.18	-0.75
10.	Harvest index (%)	0.44	0.03	-0.47

When genotypes with lower mean performance and non-significant deviation from regression (S^2d_i=0) were tested for the significance of regression coefficient from unity, five genotypes *viz.*, WV 265, WV 270, WV 276, WV 292 and WV 267 for days to 50% flowering; six genotypes *viz.*, WV 265, WV 270, WV 287, WV 276, WV 292 and WV 267 for days to maturity and seven genotypes *viz.*, WV 265, WV 287, WV 283, WV 276 WV 292, WV 279 and WV 255 for plant height (cm) showed a regression coefficient nearly equal to unity (b_i=1), which demonstrated good general adaptation of character under various environments.

The seven genotypes *viz.*, WV 275, WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280 for days to 50% flowering; seven genotypes *viz.*, WV 275, WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280 for days to maturity and six genotypes *viz.*, WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280 for plant height (cm) which had a lower 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 environments.

While seven genotypes *viz.*, WV 283, WV 266, WV 279, WV 285, WV 257, WV 294 and WV 269 for days to 50% flowering; seven genotypes *viz.*, WV 283, WV 266, WV 279, WV 285, WV 257, WV 294 and WV 269 days to maturity and seven genotypes *viz.*, WV 270, WV 285, WV 266, WV 294, WV 269, WV 257 and WV 273 for plant height (cm) were regarded as specifically

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Nagaraja *et al*. (2015) reported that the genotype HR374 showed greater variation for days to 50 ~~per cent~~% flowering. Patel *et al*. (2019) reported the G × E interaction was significant for days to 50% flowering.

Patil (2007) reported the genotypes *viz*., RPSP 742, EC 138375 and RPSP 732 were early maturing with average stability of genotype. Kandel *et al*. (2020) reported the significant genotypes and genotypes and their interaction were observed for day to maturity.

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Patel *et al*. (2019) reported that the G × E interaction was significant for plant height. Kandel *et al*. (2020) reported significant genotypes and genotypes and their interaction for plant height along with genotype CO4656 which had mean yield that was higher than the overall mean (0.429 t/ha) with parameter of response (b_i)=1.16 and parameter of stability (S^2di)=0.05.

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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, four genotypes *viz*., WV 274, WV 289, WV 286 and WV 296 for productive tillers per plant; ten genotypes *viz*., WV 274, WV 258, WV 289, WV 272, WV 288, WV 286, WV 293, WV 259, WV 282 and WV 296 for panicle length (cm); ten genotypes *viz*., WV 274, WV 258, WV 289, WV 272, WV 288, WV 286, WV 293, WV 282, WV 259 and WV 296 for spikes per panicle; three genotypes *viz*., WV 272, WV 262 and WV 293 for 1000 grain weight (g); six genotypes *viz*., WV 262, WV 258, WV 256, WV 293, WV 294 and WV 273 for grain yield per plant (g); eight genotypes *viz*., WV 257, WV 288, WV 269, WV 293, WV 260, WV 273, WV 282 and WV 259 for fodder yield per plant (g); three genotypes *viz*., WV 291, WV 301 and WV 273 for harvest index (%); 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 302 for chlorophyll content (mg/100g fresh weight); eight genotypes *viz*., WV 289, WV 272, WV 288, WV 286, WV 263, WV 303, WV 296 and WV 282 for leaf area (cm^2); one genotype WV 286 for protein content (%); three genotypes *viz*., WV 263, WV 286 and WV 303 for crude fiber (%); none of genotype for mineral matter (mg/100g) and three genotypes *viz*., WV 263, WV 287 and WV 303 for iron content (mg/100g) showed a regression coefficient nearly equal to unity ($b_i=1$), which demonstrated good general adaptation of character under various environments.

Genotype WV 263 for productive tillers per plant; two genotypes *viz*., WV 297 and WV 263 for panicle length (cm); two genotypes *viz*., WV 297 and WV 263 for spikes per panicle; two genotypes *viz*., WV 297 and WV 263 for 1000 grain weight (g); four genotypes *viz*., WV 302, WV 303, WV 301 and WV 272 for grain yield per plant (g); five genotypes *viz*., WV 303, WV 301, WV 258, WV 272 and WV 262 for fodder yield per plant (g); three genotypes *viz*., WV 302, WV 303 and WV 254 for harvest index (%); one genotype WV 303 for hulling (%); three genotypes *viz*., WV 297, WV 265 and WV 263 for chlorophyll content (mg/100g 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/100g) and one genotype WV 274 for iron content (mg/100g) 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 environments.

While four genotypes *viz*., WV 256, WV 260, WV 291 and WV 273 for productive tillers per plant; four genotypes *viz*., WV 256, WV 260, WV 291 and WV 273 for panicle length (cm); three genotypes *viz*., WV 256, WV 260 and WV 273 for spikes per panicle; six genotypes *viz*., WV

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296, WV 288, WV 295, WV 259, WV 282 and WV 257 for 1000 grain weight (g); four genotypes *viz.*, WV 259, WV 288, WV 269 and WV 296 for grain yield per plant (g); one genotype WV 296 for fodder yield per plant (g); seven genotypes *viz.*, WV 258, WV 259, WV 294, WV 288, WV 293, WV 269 and WV 296 for harvest index (%); two genotypes *viz.*, WV 260 and WV 273 for hulling (%); three genotypes *viz.*, WV 288, WV 294 and WV 260 for chlorophyll content (mg/100g 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 260 for crude fiber (%); two genotypes *viz.*, WV 286 and WV 256 for mineral matter (mg/100g) and one genotype WV 286 for iron content (mg/100g) 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).

Patel *et al*. (2019) noted significant G × E interaction for number of effective tillers per plant. Madhavilatha *et al.* (2020) reported among the tested genotypes that PR-1041 recorded average stability for number of productive tillers per plant ~~indicated~~ indicating the wide adoptability of this genotype for number of productive tillers per plant.

Table 2: Analysis of variance for stability parameters with regards to grain yield and its component characters in little millet.

Source of variation	Df	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Spikes per panicle	1000 grain weight (g)	Grain yield per plant (g)	Fodder yield per plant (g)	Harvest index (%)
Genotype (G)	49	67.90***	68.57***	81.02***	0.68***	10.95***	0.69***	0.01***	6.01***	9.03***	6.90***
Environment (E)	2	1702.52***	1694.20***	1908.77***	16.52***	270.03***	16.58***	0.10***	17.29***	36.63***	10.30***
Env. + (Gen. x Env.)	100	53.12***	53.14***	61.01***	0.52***	8.47***	0.52***	0.004***	0.73***	1.28***	1.02**
G x E	98	19.46*	19.65*	23.30*	0.19*	3.13*	0.19*	0.002**	0.39**	0.56*	0.83*
Environment (Linear)	1	3405.05***	3388.41***	3817.55***	33.04***	540.06***	33.17***	0.21***	34.59***	73.27***	20.61***
G x E (Linear)	49	26.81**	27.31**	33.49***	0.27**	4.33**	0.27**	0.003***	0.61***	0.78**	1.14**
Pooled deviation	50	11.86***	11.75	12.85	0.12***	1.90	0.12**	0.001	0.18	0.33	0.51
Pooled error	294	5.38	11.83	27.21	0.04	2.26	0.07	0.004	0.16	0.97	1.94

Table 3. Estimation of mean and stability parameter for days to 50% flowering, days to maturity, Plant Height and Productive tillers per plant in little millet.

Sr. No.	Genotypes	Days to 50% flowering						Days to maturity						Plant height (cm)						Productive tillers per plant					
		Mean	b_i			S^2d_i		Mean	b_i			S^2d_i		Mean	b_i			S^2d_i		Mean	b_i			S^2d_i	
1	WV 254	68.67	0.56	**	+	-2.41		108.67	0.57	**	+	-8.89		163.67	0.56	**	+	-23.74		4.49	0.54	*	+	-0.008	
2	WV 255	70	0.78			15.46		110	0.78			9.15		158.33	2.09	**		7.86		4.6	0.78			0.207	*
3	WV 256	75.67	1.55	**	++	-4.19		115.67	1.55	**	++	-10.58		170.67	1.45	**	+	-24.47		5.18	1.55	**	++	-0.026	
4	WV 257	72.33	1.62	**	++	-5.13		112.33	1.62	**	++	-11.54		163.67	2.26	**	+	-7.56		4.87	1.53	**	++	-0.036	
5	WV 258	75.33	1.49	**		15.93	*	115.33	1.49	**		9.75		170	1.41	*		-4.36		5.15	1.48	**		0.159	*
6	WV 259	85	1.65	**		9.1		125	1.66	**		2.4		180	1.56	**		-19.79		6.11	1.72	**		0.143	*
7	WV 260	76	1.81	**	++	-4.55		116	1.81	**	++	-10.93		171	1.68	**	++	-22.94		5.2	1.84	**	++	-0.034	
8	WV 261	84.33	0.8			55.27	**	124.33	0.81			48.57	*	179.33	0.79			27.88		6.04	0.8			0.614	***
9	WV 262	78.33	1.05			28.37	*	118.33	1.05			21.68		173.33	1.03			0.15		5.42	1.07			0.273	**
10	WV 263	78.67	0.64	**	++	-4.98		118.67	0.65	**	++	-11.41		174	0.57	**	+	-23.7		5.49	0.68	**	++	-0.039	
11	WV 264	68.67	0.64	**	++	-4.98		108.67	0.65	**	++	-11.41		163.67	0.57	**	++	-26.41		4.49	0.68	**	++	-0.039	
12	WV 265	74	0.7	**		-0.51		114	0.7	**		-6.9		169	0.63	**		-23.03		5	0.67	**		-0.007	
13	WV 266	71.33	1.33	**	++	-5.37		111.33	1.33	**	++	-11.83		164.33	1.53	**	+	-23.87		4.75	1.32	**	++	-0.04	
14	WV 267	71	0.82	*		4.83		111	0.82	*		-1.52		166	0.69			-15.23		4.73	0.83	*		0.059	
15	WV 268	82.33	0.1			18.59	*	122.33	0.1			12.12		177.33	0.11			-5.6		5.84	0.08			0.181	*
16	WV 269	73.67	2.12	**	++	-0.06		113.67	2.13	**	++	-6.31		168.33	2.03	**	++	-17.7		4.98	2.13	**	++	0.016	
17	WV 270	73	1.28	**		-2.58		113	1.28	**		-9.11		166.67	1.47	**	+	-23.22		4.84	1.33	**		-0.013	
18	WV 271	67.67	-0.01		++	3.28		107	-0.2		++	-0.59		160.33	0.2			4.62		4.27	-0.19		+	0.103	
19	WV 272	76.33	1.33	*		19.58	*	116.33	1.33	*		13.4		171.33	1.21			5.29		5.22	1.37	*		0.183	*
20	WV 273	75	2.26	**	++	-4.08		115	2.27	**	++	-10.43		168	2.54	**	++	-26.39		5.11	2.27	**	++	-0.026	
21	WV 274	75	0.83	**		-1.76		115	0.83	**		-8.27		170	0.82	**		-24.54		5.11	0.83	**		0.008	
22	WV 275	66	-0.17	**	++	-5.24		106	-0.17	**	++	-11.69		160	-0.06		++	-26.05		4.13	-0.11	**	++	-0.04	
23	WV 276	71.33	1.12	**		-2.67		111.33	1.13	**		-9.04		166.67	1.01	**		-18.92		4.76	1.04	**		0.004	
24	WV 277	74.33	-0.06			15.01		114.33	-0.06			8.57		169.33	-0.02		+	-8.95		5.04	-0.04			0.157	*
25	WV 278	67.33	0.51	*	+	-2.14		107.33	0.51	*	+	-8.55		162	0.53	**	++	-24.89		4.33	0.58	**	++	-0.027	
26	WV 279	71	1.48	**	+	-2.58		111	1.48	**	+	-8.93		166	1.41	**		-21.98		4.73	1.5	**	+	-0.015	
27	WV 280	70.67	0.81	**	++	-5.32		110.67	0.81	**	++	-11.76		165.67	0.7	**	++	-26.94		4.69	0.7	*		0.043	
28	WV 281	69.33	0.43	**	++	-5.07		109.33	0.43	**	++	-11.53		164.33	0.44	**	++	-27.16		4.55	0.4	**	++	-0.037	
29	WV 282	84.67	1.55	**		10.69		124.67	1.56	**		3.99		179.67	1.51	**		-20.3		6.09	1.54	**		0.132	*
30	WV 283	72.67	1.26	**	++	-5.15		112.67	1.26	**	++	-11.58		168	1.15	**		-26.56		4.89	1.29	**	++	-0.036	
31	WV 284	77	1.12			35.49	**	117	1.12			28.76		172	1.1			6.15		5.29	1.1			0.384	**
32	WV 285	73.33	1.54	**	+	-1.95		113.33	1.54	**	+	-8.51		168.33	1.48	**	++	-26.98		4.93	1.5	**	+	-0.008	
33	WV 286	78.33	1	**		-4.95		118.33	1	**		-11.37		173.33	0.93	**		-26.35		5.42	0.98	**		-0.038	
34	WV 287	73	1.68	**		19.84	*	113	1.69	**		13.72		168.33	1.54	*		1.8		4.87	1.7	*		0.25	**
35	WV 288	77.67	1.72	**		13.88		118	1.66	**		2.4		172.67	1.68	**		-15.88		5.36	1.77	**		0.178	*
36	WV 289	75.67	1.05	**		-0.4		115	1.2	**		-10.65		170.67	0.98	**		-19.4		5.18	1.1	**		0.009	
37	WV 290	74.33	0.46			63	***	114.33	0.46			56.7	*	169.67	0.35			48.14		5.04	0.41			0.617	***
38	WV 291	74.67	2.12	**	++	-0.06		114.67	2.13	**	++	-6.31		169.67	1.99	**	+	-13.41		5.09	2.18	**	++	-0.001	
39	WV 292	71	1.03	**		-3.29		111	1.03	**		-9.68		166.33	0.9	**		-22.83		4.71	1.02	**		-0.016	
40	WV 293	83	1.36	*		14.11		123	1.37	*		7.42		178	1.34	**		-12.38		5.89	1.35	*		0.166	*
41	WV 294	74.33	2.07	**	++	-4.84		114.33	2.08	**	++	-11.23		169	2.01	**	++	-26.13		5.04	2.08	**	++	-0.034	
42	WV 295	69.67	0.68			13.65		109.67	0.68			7.32		164.67	0.63			-8.95		4.58	0.74			0.114	
43	WV 296	87	1.32	**		3.89		127	1.32	**		-2.72		182	1.27	**		-22.97		6.31	1.36	**		0.026	
44	WV 297	76.33	-0.03		++	-4.76		116.33	-0.03		++	-11.21		171.67	-0.12	**	++	-27.1		5.27	-0.08		++	-0.037	
45	WV 298	79.33	0.93			40.84	**	119.33	0.93			34.14	*	174	0.78			14.28		5.47	0.92			0.367	**

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46	WV 299	76.67	0.03 ++	-4.76	116.67	0.03 ++	-11.21	171.67	-0.03 ++	-26.41	5.29	0.04 ++	-0.03
47	WV 300	72.67	0.68	13.65	112.67	0.68	7.32	168	0.54	-8.85	4.87	0.7	0.146 *
48	WV 301	73.67	0.23	11.71	113.67	0.23	5.3	168.67	0.18	-9.16	4.98	0.21	0.146 *
49	WV 302	72.33	0.22 ++	-3.96	112.33	0.22 ++	-10.4	167.33	0.14 ++	-25.92	4.84	0.21 ++	-0.032
50	WV 303	73	0.5 ** ++	-4.08	113	0.5 ** ++	-10.55	168	0.46 ** ++	-27.03	4.91	0.49 ** ++	-0.02
	General mean	**74.65**			**114.63**			**169.29**			**5.07**		
	±SEb$_i$		**0.42**			**0.4**			**0.4**			**0.43**	

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

Table 4. Estimation of mean and stability parameter for panicle length (cm), spikes per panicle 1000 grain weight (g) and grain yield per plant (g) in little millet

Sr. No.	Genotypes	Panicle length (cm)			Spikes per panicle			1000 Grain weight (g)			Grain yield per plant (g)		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1	WV 254	29.45	0.54 ** +	-1.8	6.18	0.6 ** +	-0.04	1.96	1.37 ** ++	-0.004	7.84	0.45 ** ++	-0.15
2	WV 255	29.97	0.76	1.01	6.29	0.75	0.13	2.01	1.89 **	-0.002	7.29	0.76 **	-0.13
3	WV 256	32.21	1.52 ** ++	-2.06	6.87	1.53 ** ++	-0.06	2.1	1.71	0.003	10.23	0.87 **	-0.14
4	WV 257	30.97	1.63 ** ++	-2.2	6.53	1.64 ** ++	-0.07	2.16	2.4 ** ++	-0.003	8.74	0.95 **	-0.08
5	WV 258	32.11	1.46 *	1.37	6.84	1.54 **	0.15	2.17	0.65	-0.003	9.95	1.01 **	-0.16
6	WV 259	35.81	1.63 **	-0.12	7.8	1.67 **	0.07	2.21	1.73 ** ++	-0.004	12.3	1.46 ** ++	-0.14
7	WV 260	32.44	1.82 ** ++	-2.05	6.89	1.82 ** ++	-0.07	2.1	1.59 ** +	-0.004	10.14	0.22	0.3
8	WV 261	35.76	0.82	6.93 *	7.73	0.76	0.51 **	2.24	0.18	0.001	10.66	0.34	1.14 **
9	WV 262	33.36	1.06	3.01	7.15	1.07	0.23 *	2.15	0.86 **	-0.004	9.23	1.08 **	-0.16
10	WV 263	33.61	0.55 ** ++	-1.98	7.2	0.58 ** ++	-0.06	2.15	0.62 ** ++	-0.004	8.65	1.63 ** ++	-0.13
11	WV 264	29.37	0.74 ** ++	-2.26	6.18	0.63 ** ++	-0.06	2.07	0.34	-0.003	8.09	0.87 ** +	-0.16
12	WV 265	31.64	0.7 *	-1.37	6.69	0.73 **	-0.03	2.05	-0.27 +	-0.002	8.13	0.25 +	-0.07
13	WV 266	30.56	1.34 ** ++	-2.27	6.42	1.32 ** ++	-0.07	2.07	1.55 ** +	-0.003	8.47	0.5	0.01
14	WV 267	30.37	0.81 *	-0.64	6.4	0.83 *	0.03	2.05	1.22 **	-0.003	8.03	-0.35	0.61 *
15	WV 268	34.94	0.13	1.55	7.53	0.06	0.2	2.14	1.08	-0.001	10.22	-1.05 ++	0.19
16	WV 269	31.5	2.13 ** ++	-1.31	6.67	2.11 ** ++	-0.03	2.09	1.53 ** ++	-0.004	10.08	1.96 ** +	-0.04
17	WV 270	31.01	1.36 ** ++	-2.12	6.53	1.39 ** +	-0.05	2.08	1.47 **	-0.004	8.36	1.2 **	-0.1
18	WV 271	28.71	-0.09 +	0.28	5.98	-0.14 +	0.11	2.05	-0.87 * ++	-0.003	7.66	0.69 ** ++	-0.16
19	WV 272	32.56	1.33 *	2.08	6.93	1.3 *	0.15	2.12	1.94 **	-0.002	9.8	0.54 * +	-0.12
20	WV 273	32.02	2.28 ** ++	-1.98	6.8	2.25 ** ++	-0.06	2.1	2.8 ** +	-0.001	11.15	0.95 **	-0.13
21	WV 274	32.03	0.83 **	-1.78	6.8	0.78 **	-0.04	2.25	0.19	-0.003	8.04	1.38 ** +	-0.14
22	WV 275	28.23	-0.08 ++	-2.24	5.84	-0.09 ++	-0.06	2.01	-0.08 ++	-0.003	7.52	1.09 **	-0.13
23	WV 276	30.69	1.06 **	-1.28	6.49	1.03 **	-0.02	2.07	0.6 ** +	-0.004	7.61	1	0.19
24	WV 277	31.75	-0.04	1	6.75	-0.09	0.14	2.09	-0.36	-0.001	8.49	1.6 ** ++	-0.16

25	WV 278	28.87	0.55	**	++	-2.1		6	0.58	**	++	-0.06		2.03	0.36			-0.002	7.14	0.67	**	++	-0.16	
26	WV 279	30.41	1.47	**	+	-1.69		6.4	1.5	**	+	-0.04		2.06	1.98	**	+	-0.003	8.45	1.3	**		-0.01	
27	WV 280	30.25	0.81	**	++	-2.25		6.38	0.85	**	++	-0.07		2.05	1.22	**	++	-0.004	7.42	0.68	**	++	-0.16	
28	WV 281	29.72	0.41	**	++	-2.24		6.24	0.46	**	++	-0.07		2.04	0.66	*		-0.003	7.16	0.63	**	++	-0.16	
29	WV 282	35.88	1.56	**		0.1		7.78	1.61	**		0.08		2.2	1.89	**	++	-0.004	11.25	1.93			0.92	**
30	WV 283	31.05	1.27	**	++	-2.24		6.58	1.27	**	++	-0.07		2.08	1.42	**		-0.003	8.37	1.32	**		-0.12	
31	WV 284	32.72	1.15			4.59		7.02	1.1			0.34	*	2.16	0.43			-0.003	8.46	2.38	*		0.45	
32	WV 285	31.34	1.56	**	++	-1.78		6.62	1.57	**	++	-0.05		2.1	1.23	**		-0.003	8.03	2.28	**		0.15	
33	WV 286	33.31	1.01	**		-2.18		7.15	0.98	**		-0.07		2.16	1.07			-0.001	8.56	2.32	**		0.16	
34	WV 287	31.21	1.7	**		2.2		6.62	1.67	**		0.18		2.11	2.02	**		-0.002	8.58	2.58	**	++	-0.1	
35	WV 288	33.07	1.76	**		0.62		7.07	1.7	**		0.15		2.15	1.67	**	++	-0.004	10.01	1.84	**	+	-0.08	
36	WV 289	32.24	1.08	**		-1.53		6.87	1.08	**		-0.04		2.13	0.6			-0.003	8.55	1.59	**		-0.07	
37	WV 290	31.76	0.43			8.9	*	6.73	0.46			0.62	**	2.04	1.95	**	++	-0.004	8.08	0.54			0.18	
38	WV 291	31.89	2.12	**	++	-1.2		6.76	2.17	**	++	-0.02		2.23	0.03		+	-0.003	10.52	2.08			0.89	*
39	WV 292	30.42	1.05	**		-1.9		6.42	1.06	**		-0.05		2.11	2.18	**	+	-0.002	7.28	0.87	**		-0.15	
40	WV 293	35.21	1.39	**		0.44		7.58	1.42	**		0.11		2.18	1.68	**		-0.003	10.53	2.13	**		0.13	
41	WV 294	31.78	2.07	**	++	-2.12		6.75	2.12	**	++	-0.07		2.1	2.55	**	++	-0.003	10.71	1.11	*		0.04	
42	WV 295	30.54	0.57	**	++	-2.24		6.27	0.69			0.12		2.12	1.67	**	++	-0.004	7.56	0.89	**		-0.15	
43	WV 296	36.82	1.32	**		-0.93		8	1.34	**		0.02		2.23	1.54	**	++	-0.004	10.97	3.57	**	++	-0.08	
44	WV 297	32.6	-0.07	*	++	-2.26		7.02	-0.16	*	++	-0.07		2.13	-0.38	*	++	-0.004	8.23	0.23	**	++	-0.16	
45	WV 298	33.65	0.84			6.58	*	7.22	0.83			0.49	**	2.19	-0.15		++	-0.003	9.24	1.11			0.19	
46	WV 299	32.67	0.03		++	-2.17		7.02	-0.08		++	-0.05		2.11	0.35	**	++	-0.004	8.07	0	**	+	-0.16	
47	WV 300	31.05	0.69			0.56		6.6	0.69			0.12		2.11	-0.09			0.005	7.79	0.86	**		-0.15	
48	WV 301	31.51	0.19			0.62		6.69	0.25			0.09		2.1	-0.01			-0.002	10.97	0.52	**	++	-0.16	
49	WV 302	30.91	0.23		++	-2.07		6.55	0.23		++	-0.05		2.09	0.19		++	-0.003	10.9	-1.98	**	++	-0.16	
50	WV 303	31.22	0.5	**	++	-2.07		6.62	0.51	**	++	-0.06		2.16	-0.22		++	-0.004	12.51	-0.83	**	++	-0.15	
General mean		**31.86**						**6.77**						**2.11**					**9.04**					
±SEb$_i$			**0.42**						**0.43**						**0.53**					**0.51**				

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively.

* and ** significant at 5 and 1 per cent levels, respectively when Ho: $b_i = 0$

+ and ++ significant at 5 and 1 per cent levels, respectively when Ho: $b_i = 1$

Table 5. Estimation of mean and stability parameter for fodder yield per plant (g) and harvest index (%) in little millet

Sr. No.	Genotypes	Fodder yield per plant (g)				Harvest index (%)				
		Mean	b_i		S^2d_i	Mean	b_i			S^2d_i
1	WV 254	16.76	0.85	*	-0.82	31.96	-0.58	**	++	-1.93

2	WV 255	16.76	1.36	*		-0.43	30.36	-0.18			-1.54
3	WV 256	18.57	2.46	**	+	-0.22	35.65	-2.43			1.53
4	WV 257	19.54	0.91	**		-0.94	30.97	1.26			-1.69
5	WV 258	20.59	0.61	**	++	-0.96	32.58	1.61	**	++	-1.93
6	WV 259	22.60	0.74	**		-0.92	35.29	1.86	**	++	-1.92
7	WV 260	21.01	0.78	**		-0.91	32.56	-0.57			-0.11
8	WV 261	21.22	0.61			-0.81	33.53	0.58			2.49
9	WV 262	19.90	0.83	**	++	-0.97	31.65	1.75	**	++	-1.93
10	WV 263	19.19	1.23	**	++	-0.97	30.97	2.59	**		-1.58
11	WV 264	18.16	1.13	**		-0.91	30.79	0.52			-1.62
12	WV 265	18.68	0.22			-0.71	30.41	0.33			-1.87
13	WV 266	18.72	0.70			-0.37	31.21	0.23		++	-1.92
14	WV 267	18.36	-0.02			2.03	30.39	-0.76		++	-1.87
15	WV 268	20.69	-0.48		++	-0.80	33.05	-2.03		+	-0.96
16	WV 269	20.66	1.16	**		-0.76	32.78	3.27	**	++	-1.92
17	WV 270	18.85	0.97	**		-0.94	30.73	1.62			-1.60
18	WV 271	17.47	0.76	**		-0.94	30.51	0.84	**		-1.93
19	WV 272	20.46	0.65	**	++	-0.96	32.42	0.36			-1.55
20	WV 273	21.61	0.82	**		-0.96	34.07	0.79	*		-1.87
21	WV 274	18.07	1.38	**	++	-0.95	30.81	1.55	*		-1.75
22	WV 275	17.38	1.78	**		-0.48	30.27	-0.30		++	-1.91
23	WV 276	17.35	1.43			0.46	30.56	0.44	**	++	-1.93
24	WV 277	18.92	1.34	**		-0.81	31.04	2.15	**	++	-1.86
25	WV 278	16.35	0.85	**	++	-0.97	30.44	0.52	**	+	-1.92
26	WV 279	18.83	1.25			-0.25	30.87	1.49	**	++	-1.93
27	WV 280	16.75	1.03	**		-0.97	30.66	-0.13		++	-1.93
28	WV 281	16.46	0.58	*		-0.90	30.36	0.93			-1.77
29	WV 282	21.94	1.22	**		-0.84	33.85	2.11			1.32
30	WV 283	18.78	1.22	**		-0.69	30.84	1.66	**	+	-1.90
31	WV 284	18.56	2.49			2.13	31.29	2.28	**	++	-1.93
32	WV 285	17.91	2.29	**	++	-0.84	30.89	2.60			-0.61
33	WV 286	18.98	1.94	**	++	-0.91	31.02	3.02			-0.35
34	WV 287	18.86	2.27	**	++	-0.85	31.18	3.01			-0.89
35	WV 288	20.56	1.10	**		-0.97	32.72	2.89	**	+	-1.63
36	WV 289	19.08	1.27	**	+	-0.95	30.94	2.43			-1.21
37	WV 290	17.62	1.54	*		-0.23	31.52	-1.55	**	++	-1.88
38	WV 291	21.11	1.17			-0.23	33.18	3.70	*		-0.83
39	WV 292	16.90	1.40	**	++	-0.97	30.13	-0.17		++	-1.93
40	WV 293	20.87	1.23	*		-0.49	33.50	3.10	**	++	-1.71
41	WV 294	21.22	0.53			-0.76	33.53	1.97	**	+	-1.85

42	WV 295	17.51	1.48	**		-0.82	30.17	0.11			-1.81
43	WV 296	21.29	2.54	**	++	-0.50	33.94	4.59	**	++	-1.81
44	WV 297	18.42	-0.12	**	++	-0.97	30.90	1.00	**		-1.88
45	WV 298	20.01	0.58			-0.68	31.63	2.40	*		-1.37
46	WV 299	18.66	-0.18		++	-0.96	30.25	0.40			-1.88
47	WV 300	17.66	0.77	**		-0.90	30.70	1.04			-1.51
48	WV 301	21.38	0.31	**	++	-0.98	34.04	0.89	**		-1.91
49	WV 302	21.82	-0.36		++	-0.62	33.24	-4.29	**	++	-0.85
50	WV 303	22.95	-0.61	**	++	-0.94	35.32	-0.91	**	++	-1.93
	General mean	**19.24**					**31.83**				
	$\pm SEb_i$		**0.48**					**1.11**			

Where, b_i and S^2d_i were regression coefficient and deviation from regression, respectively

* and ** significant at 5 and 1 per cent levels, respectively when Ho: $b_i = 0$

+ and ++ significant at 5 and 1 per cent levels, respectively when Ho: $b_i = 1$

Jawale *et al*. (2017) reported the genotypes showing better performance under favourable environments were DPI 20114, DPI 20132, L 48, MR 34, DM 4, DM 7, GPU 58 and VR 847 for length of finger. Chavan *et al.* (2018) evaluated genotypes which were showing better performance under favourable performance, and they were PEH-1201, VL-149 and NDS-1 for length of finger. Chavan *et al.* (2018) evaluated genotypes which were showing better performance under favourable environment, they were GE-1680, Kanika Reddy, IVT-25, Nagli Dapoli-1 for number of fingers per ear, indicat~~ed~~ing wider adoptability of these genotypes under all environments.

Patel *et al*. (2019) found ~~out~~ significant G × E interaction for grain yield per plant. Kandel *et al*. (2020) reported that the genotype CO-4656 had mean yield which was higher than the overall mean (0.429 t/ha), parameter of response (b)=1.16 and parameter of stability (S2di)=0.05. 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.

Shanthakumar and Lohithaswa (2004) reported that the genotype PPR-2614 was also found stable for fodder yield per plant with higher mean value. Ataei and Reza (2020) found out environment, genotype and interaction effects that were accounted for 76.38, 6.97 and 8.92 percent of the total forage yield variation, respectively.

Patel *et al*. (2019) reported significant G × E interaction for harvest index when tested against pooled error. Patel *et al.* (2019) reported significant G × E interaction for leaf area when tested against pooled error. 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.

Comment [IG9]: adaptability?

Chavan *et al.* (2018) found ~~out~~ general stability for iron content (mg/100g) in the genotypes *viz.*, MR-6, PEH-1201 and IVT-11. 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. The genotypes studied in the present investigation have been classified on the basis of their stability performance, which are ~~and were~~ presented in table 6. 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.

Table 6. Classification of genotypes by number-wise based on their adaptation in different environments in little millet.

SI. No.	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	Days to 50% flowering	5	7	7
2	Days to maturity	6	7	7
3	Plant height (cm)	7	6	7
4	Productive tillers per plant	4	1	4
5	Panicle length (cm)	10	2	4
6	Spikes per panicle	10	2	3
7	1000 grain weight (g)	3	2	6
8	Grain yield per plant (g)	6	4	4

9	Fodder yield per plant (g)	8	5	1
10	Harvest index (%)	3	3	7

Table 7. Classification of genotypes by name-wise based on their adaptation in different environments in little millet.

Sr. No	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	Days to 50% flowering	WV 265, WV 270, WV 276, WV 292 and WV 267	WV 275, WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280	WV 283, WV 266, WV 279, WV 285, WV 257, WV 294 and WV 269
2	Days to maturity	WV 265, WV 270, WV 287, WV 276, WV 292 and WV 267	WV 275, WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280	WV 283, WV 266, WV 279, WV 285, WV 257, WV 294 and WV 269
3	Plant height (cm)	WV 265, WV 287, WV 283, WV 276 WV 292, WV 279 and WV 255	WV 281, WV 303, WV 278, WV 254, WV 264 and WV 280	WV 270, WV 285, WV 266, WV 294, WV 269, WV 257 and WV 273
4	Productive tillers per plant	WV 274, WV 289, WV 286 and WV 296	WV 263	WV 256, WV 260, WV 291 and WV 273
5	Panicle length (cm)	WV 274, WV 258, WV 289, WV 272, WV 288, WV 286, WV 293, WV 259, WV 282 and WV 296	WV 297 and WV 263	WV 256, WV 260, WV 291 and WV 273
6	Spikes per panicle	WV 274, WV 258, WV 289, WV 272, WV 288, WV 286, WV 293, WV 282, WV 259 and WV 296	WV 297 and WV 263	WV 256, WV 260 and WV 273
7	1000 grain weight (g)	WV 272, WV 262 and WV 293	WV 297 and WV 263	WV 296, WV 288, WV 295, WV 259, WV 282 and WV 257
8	Grain yield per plant (g)	WV 262, WV 258, WV 256, WV 293, WV 294 and WV 273	WV 302, WV 303, WV 301 and WV 272	WV 259, WV 288, WV 269 and WV 296
9	Fodder yield per plant (g)	WV 257, WV 288, WV 269, WV 293, WV 260, WV 273, WV 282 and WV 259	WV 303, WV 301, WV 258, WV 272 and WV 262	WV 296
10	Harvest index (%)	WV 291, WV 301 and WV 273	WV 302, WV 303 and WV 254	WV 258, WV 259, WV 294, WV 288, WV 293, WV 269 and WV 296

Conclusion

From the preceding discussion and overall picture of stability of genotypes to overall character, 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. As 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.

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