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Assessment of G × E Interactions and Stability Parameters for Quality Traits, Grain Yield and Its Components in Finger Millet [*Eleusine coracana* (L.) Gaertn.]

V. L. Ladumor [a++], Harshal E. Patil [b*] and Ketan G. Kanjariya [b]

[a] N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India.
[b] AICRP-SM, Hill Millet Research Station, Navsari Agricultural University, Waghai (Dangs), Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted on G × E interactions and stability analysis in thirty-five finger millet genotypes under three environments i.e. Waghai, Vanarasi and Navsari locations in year *kharif*-2020-21. Observation were recorded for days to 50% flowering, days to maturity, plant height

++ *PG Student;*
**Corresponding author: E-mail: harshalpatil@nau.in;*

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(cm), productive tillers per plant, fingers per ear, finger width (cm), main ear head length (cm), finger length (cm), 1000 seed weight (g), grain yield per plant (g), fodder yield per plant (g), harvest index (%), leaf area (cm^2), chlorophyll content (SPAD value), fiber content (%), calcium content (mg/100g), iron content (mg/100g) and zinc content (mg/100g). The genotypes and environmental analysis of variance for stability revealed that, the differences among them were significant for all the characters when tested against pooled deviation and pooled error. The G x E interaction was significant for all the characters except fingers per ear and iron content. Mean squares due to environment (linear) were high and significant for all the characters except fiber content and iron content when tested against pooled deviation and/or pooled error. The stability parameters revealed that, the genotypes Dapoli-1, Dapoli-2, KOPN-235, VR-708, VR-847, GPU-67, KMR-340, KMR-204, KMR630, GN-5, GNN-6, GNN-7 and GN-8 were found to be average stable over environments for grain yield per plant with one or more yield contributing characters and quality parameters. So, these genotypes were used in future hybridization programme in finger millet.

Keywords: Finger millet; stability; G × E interaction and grain yield per plant.

1. INTRODUCTION

Millets are some of the oldest important nutri-cereal crop and cultivated under high rainfall receiving hilly land as well as dry land agriculture. Due to their unique adaptation properties for poor degraded lands and ability to tolerate abiotic stress, millet crops have a long history of cultivation of more than 5000 years [1]. Millets belongs to the grass family Poaceae with small edible seeds which do not shatter readily at maturity and also refers to a group of annual grasses and mainly found in the arid and semi-arid regions [2]. These grasses family produce small seed and are often cultivated as cereals.

The most important small millet crops of India *viz*., finger millet, barnyard millet, foxtail millet, proso millet, kodo millet and little millet. Small millets are generally considered as minor crops except in part of Asia, Africa and former USSR. Most of the small millets have their origin in Asia and Africa. The most important domestication areas are East Asia, Indian sub-continent and regions from southern margin of Sahara to the Ethiopian high lands of Africa [3].

Finger millet [*Eleusine coracana* (L.) Gaertn.] belongs to family Poaceae with species corocana. The cultivated *E. coracana* is a tetraploid (2n = 4X = 36); has morphological similarities to both *E. indica* (L.) Gaertn. (2n = 18) and *E. africana* (O.) Byrne (2n = 36). It is an important cereal crop amongst the small millets and third in importance among millets in the country in area and production after sorghum and pearl millet. Finger millet is a valued food grain crop and mostly cultivated in rainfed condition in India. Finger millet is more versatile crop due to its adaptability to wide range of geographical areas and agro-ecological diversity. Finger millet is a tufted annual crop, growing to a height of 30-150 cm and maturing in 75-160 days. Finger millet leaves are grass-like, narrow and capable of producing nodal branches and many tillers. The group of digitally arranged spikes on the panicle referred to as fingers. The 4–10 florets arranged serially on the finger is referred to as spikelets. All florets are perfect flowers with the exception of the terminal ones which may sometimes be infertile. The grain is oblong to round and oval, reddish brown in colour with the grains surface finely corrugated. Finger millet is a rainfed crop, tropical and one of the most suitable for dry farming. The most important tropical cereals among finger millet is very adaptable and thrives at higher elevations. (Vilas et al*.,* 2015)

Finger millet is an important cereal because of its excellent storage properties and the nutritive value of the grains. Finger millet is a good source of calcium and dietary fiber and consumed both in native and processed form [4,5]. For famine-prone areas, finger millet grain can be stored for years without storage pest infestation which makes it a perfect food grain commodity. The finger millet crop residues are excellent source of dry matter for livestock especially in dry season so, its grains are used for human consumption. Finger millet straw contains up to 61 per cent total digestible nutrients makes good fodder.

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 may vary from genotype to genotype [6,7, 8]. Among the different stability models, Eberhart and Russell [6] model was the most exploited model for the identification of stable genotypes over locations. The objective of the present study of G × E interaction serves as a guide for various environmental niches. It is possible to identify genotypes with stability for high yield, through the stability for yield and yield component characters.

2. MATERIALS AND METHODS

The experiment was conducted during *kharif*-2020-21 having 35 finger millet genotypes, *viz*., VL-352, VL-315, VL-149, VL-324, VL-376, VL-314, Dapoli-1, Dapoli-2, KOPN-235, KOPN-942, Phule Nachni, VR-708, VR-847, VR-936, PR-202, GPU-66, GPU-28, GPU-45, GPU-67, MR-6, KMR-340, KMR-204, KMR-630, OEB-532, Indira Ragi-1, Chhattisgarh Ragi-2, RAU-8, GN-1, GN-2, GN-3, GN-4, GN-5, GNN-6, GNN-7 and GN-8 were evaluated in a RBD at Hill Millet Research Station, NAU, Waghai, Niger Research Station, NAU, Vanarasi and College Farm, N. M. College of Agriculture, Navsari Agriculture University, Navsari. The genotypes were sown on raised bed for nursery and transplanted after 25-30 days after sowing. The seedlings were planted at 22.5 × 7.5 cm^2 spacing. The observations on five randomly selected plants were recorded for 18 characters *viz*., days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, fingers per ear, finger width (cm), main ear head length (cm), finger length (cm), 1000 seed weight (g), grain yield per plant (g), fodder yield per plant (g), harvest index (%), leaf area (cm^2), chlorophyll content (SPAD value), fiber content (%), calcium content (mg/100g), iron content (mg/100g) and zinc content (mg/100g). Estimation of stability parameters described by the Eberhart and Russell [6] model.

3. RESULTS AND DISCUSSION

The analysis of variance presenting the mean squares due to different sources of variation as per stability model of Eberhart and Russell [6] is presented in Table 1. The analysis of variance for stability revealed that, the environments + (genotypes x environments) interaction was observed to be significant for all traits except iron content when tested either against pooled deviation or pooled error. The mean squares due to G x E interaction was found significant for all the characters except fingers per ear and iron content so, these traits were not considered for further analysis. Mean squares due to environment (linear) were high and significant for all the characters except fiber content and iron content. This indicated that, considerable differences among environment and their predominant effects on almost all these traits. The mean squares due to genotype x environment linear when tested against pooled error and/or deviation were significant for all characters except iron content. This indicated preponderance of linear component in these traits and hence predication appeared possible. Almost identical results have been reported by Shanthakumar and Lohithaswa [9] Mishra et al. [10] Sood et al. [11] Patel et al. [12] Kandel et al. [13] and Madhavilatha et al. [14].

Eberhart and Russell [6] defined a stable genotype as one which showed high mean yield, regression coefficient (b_i) around unity and deviation from regression (S^2d_i) equal to zero. The genotypes having less than average stability when bi is more than unity and the genotypes having more than average stability when bi is less than unity. The estimates of stability parameters computed to evaluate relative stability of different genotypes over three environments *viz.,* Waghai, Vanarasi and Navsari are presented in Tables 2 to 5. Top most genotypes for earliness were VL-352, VL-149, VL-376, OEB-532 and GN-8. The genotypes, VL-315, VL-324, VL-376, VL-314, Indira Ragi-1, GN-2 and GN-4 exhibited bi value near to unity and least deviation from regression hence it may be considered as stable for early maturity. For plant height, eleven genotypes *viz*., VL-352, VL-324, VL-376, VL-314, Dapoli-2, KOPN-942, OEB-532, Indira Ragi-1, Chhattisgarh Ragi-2, RAU-8 and GN-1 exhibited lower mean value than general mean (desirable for dwarfness) with non significant regression coefficient and least deviation from regression indicating the average stability for dwarfness. Same result have been reported by Ashalatha et al. [15] Asfaw et al. [16] Nagaraja et al. [17] and Kandel et al. [13].

For productive tillers per plant, seven genotypes *viz.*, VL-315, VL-149, VR-847, PR-202, GN-2, GN-4 and GN-8 responded consistently well to the varying environmental conditions, as possessed non significant b_i value as well as least deviations from regression accompanied by higher mean. For finger width, PR-202 and GN-4 were found to be most stable for this trait across locations. Only two genotypes MR-6 and OEB-532 exhibited higher mean value coupled with regression coefficient significantly higher than unity and non-significant S^2d_i indicating its stability for rich environment *i.e*. below average stability. Six genotypes expressed average stability across the environment for main ear head length.

Table 1. Analysis of variance for stability parameters with regards to different characters in finger millet

Source of variation	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers per plant	Fingers per ear	Finger width (cm)	Main ear head length (cm)	Finger length (cm)	1000 seed weight (g)
Genotype (G)	34	114.10***	124.44***	335.26***	1.07***	2.77***	2.34***	8.58***	6.19***	0.46***
Environment (E)	2	1052.44***	995.93***	760.64***	4.85***	6.44***	5.96***	9.17***	31.23***	0.22***
Env. + (Gen. x Env.)	70	30.43***	29.97***	23.22***	0.14***	0.19***	0.19***	0.28***	0.95***	0.02**
G x E	68	0.37**	1.56***	1.53**	0.006*	0.005	0.02***	0.01**	0.06***	0.02*
Environment (Linear)	1	2104.88***	1991.86***	1521.28***	9.70***	12.88***	11.91***	18.34***	62.45***	0.44***
G x E (Linear)	34	0.56***	2.80***	2.35***	0.009***	0.006*	0.03***	0.02***	0.12***	0.03**
Pooled deviation	35	0.17	0.31	0.69	0.00	0.00	0.00	0.01	0.01	0.01***
Pooled error	204	1.78	1.21	1.07	0.01	0.01	0.01	0.01	0.01	0.00

Source of variation	df	Grain yield per plant (g)	Fodder yield per plant (g)	Harvest index (%)	Leaf area (cm^2)	Chlorophyll content (SPAD value)	Fiber content (%)	Calcium content (mg/100gm)	Iron content (mg/100g)	Zinc content (mg/100g)
Genotype (G)	34	0.54***	3.31***	33127.88***	13.07***	31.32***	0.05***	10814.53***	0.58***	0.18***
Environment (E)	2	0.13***	0.12***	1212.57***	0.24***	0.51***	0.00	984.88***	0.002	0.004***
Env. + (Gen. x Env.)	70	0.004***	0.004***	35.30***	0.11***	0.08***	0.004***	42.70***	0.01	0.00***
G x E	68	0.0001**	0.00006**	0.68*	0.10***	0.06***	0.004***	14.99***	0.01	0.00**
Environment (Linear)	1	0.26***	0.24***	2425.14***	0.48***	1.01***	0.00	1969.77***	0.003	0.007***
G x E (Linear)	34	0.0002***	0.00001***	0.99**	0.21***	0.11***	0.007***	24.65***	0.001	0.0003***
Pooled deviation	35	0.00	0.00	0.36	0.001***	0.01	0.001***	5.19***	0.02***	0.00*
Pooled error	204	0.00	0.00	1.10	0.00	0.06	0.00	1.10	0.00	0.00

, ** and * Significant at 5 and 1 per cent levels, respectively*

Table 2. Estimation of mean and stability parameter for days to 50% flowering, days to maturity, plant height and productive tillers per plant in finger millet

Sr. No.	Varieties	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	VL-352	65.33	0.82	-1.92	102.67	1.20	-0.25	99.33	0.97	-1.10	2.93	1.21	-0.01
2	VL-315	72.67	0.91	-1.61	112.0	0.97	-1.08	107.67	0.96	-0.16`	3.26	1.04	-0.01
3	VL-149	64.33	1.0	-1.94	102.67	1.19	-1.02	100.33	0.75	-1.12	3.03	0.94	-0.01
4	VL-324	66.67	1.0	-1.55	107.0	0.82	-1.04	101.67	0.87	-1.03	3.16	0.77*	-0.01
5	VL-376	62.67	0.91	-1.61	101.33	1.08	-1.05	98.0	0.76	-0.53	2.88	1.13*	-0.01
6	VL-314	71.67	1.10	-1.66	111.33	1.09	-0.17	107.33	0.97	-1.10	3.29	1.01	0.00
7	Dapoli-1	75.33	0.82	-1.92	113.33	1.08	-1.05	110.0	0.76	-0.53	3.31	1.01	-0.01
8	Dapoli-2	79.0	1.09	-1.90	117.67	1.19	-1.02	113.0	1.19	-0.86	3.47	1.09	-0.01
9	KOPN-235	80.11	1.06	-1.95	120.33	0.92	-1.07	111.0	2.10	12.68**	3.34	1.42	-0.01
10	KOPN-942	82.67	0.91	-1.61	122.0	0.97	-1.08	116.33	1.18	-1.04	3.11	1.11	-0.01
11	Phule Nachani	81.67	1.10	-1.66	121.33	1.08	-1.05	131.33	0.75*	-1.12	3.93	1.21	-0.01
12	VR-708	84.33	1.0	-1.94	123.33	1.08	-1.05	132.67	0.87	-1.03	4.12	0.89	-0.01
13	VR-847	86.67	0.82	-1.60	123.0	1.30	-0.98	133.33	0.97	-1.10	4.0	1.23	-0.01
14	VR-936	83.33	1.19*	-1.95	122.67	1.20	-0.25	132.33	0.97	-1.10	4.02	1.06	-0.01
15	PR-202	82.0	1.09	-1.90	122.0	0.97	-1.08	129.67	0.99	1.0	4.86	1.04	-0.01
16	GPU-66	78.67	1.0	-1.55	118.67	0.86	-1.11	127.0	0.85	-0.86	4.81	0.75	-0.01
17	GPU-28	70.0	1.09	-1.90	112.0	0.65	-1.15	118.33	0.97	-1.10	4.40	0.97	-0.01
18	GPU-45	71.67	0.91	-1.61	111.67	0.86	-1.11	119.33	0.97	-1.10	4.54	0.72*	-0.01
19	GPU-67	72.0	1.09	-1.90	111.0	1.14	-1.12	120.33	0.88	0.12	4.60	0.80	-0.01
20	MR-6	80.0	1.09	-1.90	119.33	1.08	-1.05	128.0	1.07	-0.72	4.04	0.72*	-0.01
21	KMR-340	77	0.91	-1.92	117.33	0.76	-1.13	123.67	1.08	-1.09	3.83	0.84	-0.01
22	KMR-204	75.0	1.09	-1.90	117.67	0.55	0.27	122.33	1.09	-0.15	3.82	0.89	-0.01
23	KMR-630	76.67	1.10	-1.66	119.67	0.54*	-1.17	124.67	1.08	-1.09	3.94	0.72*	-0.01
24	OEB-532	67.0	0.91	-1.92	107.33	0.76	-1.13	103.67	0.87	-1.03	3.11	1.01	-0.01
25	Indira Ragi-1	68.33	1.0	-1.94	108.67	0.86	-1.11	104.0	1.19	-0.86	3.27	0.72	-0.01
26	Chhattisgarh Ragi-2	70.0	1.09	-1.90	108.0	1.30	-0.98	107.33	0.97	-1.10	3.22	1.16	-0.01
27	RAU-8	74.33	1.0	-1.94	112.67	1.20	-0.25	110.67	1.08	-1.09	3.33	1.21	-0.01
28	GN-1	70.67	1.0	-1.55	108.67	1.19	-1.02	106.33	1.18	-1.04	3.22	1.16	-0.01
29	GN-2	72.67	1.0	-1.55	112.67	0.86	-1.11	121.67	0.87	-1.03	3.77	0.82	-0.01
30	GN-3	76.0	0.91	-1.92	117.67	0.54*	-1.17	124.33	0.97	-1.10	3.73	1.11	-0.01
31	GN-4	73.67	1.10	-1.66	113.33	1.09	-0.17	122.0	1.19	-0.86	4.30	1.23	-0.01
32	GN-5	74.67	1.0	-1.55	112.67	1.19	-1.02	123.33	0.97	-1.10	4.37	1.09	-0.01
33	GNN-6	76.33	1.0	-1.94	116.67	0.86	-1.11	125.67	0.96	-0.16	4.76	0.77*	-0.01
34	GNN-7	71.33	0.82	-1.92	107.67	1.36	-1.16	123.0	0.98	-0.71	4.60	0.97	-0.01

Sr. No.	Varieties	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
35	GN-8	64.33	1.0	-1.94	102.67	1.20	-0.25	118.33	0.75	-1.12	4.29	1.18	-0.01
	General Mean	74.52			113.68			117.08			3.79		
	SE±		0.05			0.10			0.10			0.10	

**, ** significant at 5 and 1 per cent levels, respectively*

Table 3. Estimation of mean and stability parameter for finger width, main ear head length, finger length and 1000 seed weight in finger millet

Sr. No.	Varieties	Finger width (cm)			Main ear head length (cm)			Finger length (cm)			1000 seed weight (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	VL-352	3.29	1.33	-0.01	9.38	1.06	-0.01	5.34	1.28	0.00	2.72	0.61*	0.00
2	VL-315	3.09	1.0	-0.01	11.23	1.06	-0.01	7.0	1.33	-0.01	2.98	0.76*	0.00
3	VL-149	2.76	1.44	0.00	9.31	0.70	-0.01	5.98	0.72	0.00	2.71	0.67	0.00
4	VL-324	3.50	1.25	-.001	9.89	-0.43	0.11**	6.52	0.62	0.00	2.88	0.66*	0.00
5	VL-376	2.64	1.02	-0.01	9.18	0.56	0.01	4.84	1.38	-0.01	2.55	0.55*	0.00
6	VL-314	3.12	1.0	-0.01	11.23	0.95	0.00	7.23	1.08	-0.01	3.39	0.63*	0.00
7	Dapoli-1	3.23	0.88	-0.01	11.73	0.99	0.00	7.60	1.12*	-0.01	3.06	0.63*	0.00
8	Dapoli-2	3.53	1.0	0.00	11.91	1.09	-0.01	8.08	0.90	-0.01	3.35	0.57*	0.00
9	KOPN-235	3.59	1.42*	-0.01	11.84	1.06	-0.01	8.38	0.80*	-0.01	3.72	0.70	0.00
10	KOPN-942	2.93	0.82*	-0.01	10.48	0.85	-0.01	6.08	1.36*	-0.01	3.02	0.77	0.00
11	Phule Nachani	4.53	1.0	-0.01	10.93	1.09	-0.01	7.61	0.49	0.03	3.26	0.71*	0.00
12	VR-708	4.71	0.98	-0.01	11.27	1.01	-0.01	7.27	1.06	-0.01	3.39	0.60	0.00
13	VR-847	4.66	0.91	-0.01	11.44	1.18*	-0.01	7.84	0.66	0.00	3.45	0.63*	0.00
14	VR-936	4.58	1.09	-0.01	11.20	1.26	-0.01	7.30	1.02	-0.01	3.37	0.85	0.00
15	PR-202	4.72	1.23	-0.01	10.94	0.81	-0.01	7.64	0.56	-0.01	3.32	0.66	0.00
16	GPU-66	4.10	1.0	-0.01	10.03	1.11	-0.01	6.37	0.78*	-0.01	2.94	0.00	0.002*
17	GPU-28	3.57	1.14	-0.01	8.86	1.22*	-0.01	5.12	0.88*	-0.01	2.43	0.71	0.00
18	GPU-45	3.72	1.18	-0.01	8.97	1.05	-0.01	5.0	1.12*	-0.01	2.49	0.63*	0.00
19	GPU-67	5.20	0.81	-0.01	12.71	1.11	-0.01	8.74	0.48	0.01	3.09	6.65	0.22***
20	MR-6	4.32	0.82*	-0.01	10.78	1.19	-0.01	6.63	1.03	-0.01	3.11	0.68	0.00
21	KMR-340	4.08	0.81	-0.01	11.61	1.26	-0.01	7.54	0.92	-0.01	3.45	0.57*	0.00
22	KMR-204	4.12	0.53	0.01	11.62	1.05	-0.01	7.29	1.0	-0.01	3.39	0.53*	0.00
23	KMR-630	4.22	1.07	-0.01	11.63	1.05	-0.01	7.80	0.84*	-0.01	3.52	0.61*	0.00
24	OEB-532	2.90	0.39	0.05*	8.34	0.87	-0.01	4.24	0.92	-0.01	2.09	0.63*	0.00
25	Indira Ragi-1	3.04	1.07	-0.01	8.36	0.89*	-0.01	4.46	1.04	-0.01	2.23	0.66*	0.00
26	Chhattisgarh Ragi-2	3.16	0.88	-0.01	8.86	0.94	-0.01	4.70	1.12*	-0.01	2.35	0.72	0.00
27	RAU-8	3.30	1.23	-0.01	9.24	1.11	-0.01	5.48	0.98	-0.01	2.62	0.64	0.00
28	GN-1	3.09	0.81	-0.01	10.23	1.06	-0.01	6.47	0.80	0.01	2.95	0.63*	0.00

Sr. No.	Varieties	Finger width (cm)			Main ear head length (cm)			Finger length (cm)			1000 seed weight (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
29	GN-2	4.01	1.0	0.00	11.81	1.01	-0.01	8.48	1.34	0.00	2.99	0.51*	0.00
30	GN-3	4.14	1.11	-0.01	12.27	1.13	-0.01	8.30	1.48	-0.01	2.97	0.57*	0.00
31	GN-4	5.22	1.04	-0.01	13.24	1.29	-0.01	8.59	1.18	-0.01	2.93	0.88	0.00
32	GN-5	5.26	1.02	-0.01	13.88	1.18*	-0.01	8.71	1.14*	-0.01	2.97	0.76*	0.00
33	GNN-6	5.86	0.93	0.00	14.59	1.03	0.00	9.42	1.24	0.00	2.56	7.37	0.12***
34	GNN-7	5.61	1.0	-0.01	14.13	1.25	-0.01	9.07	1.24	-0.01	3.12	0.68	0.00
35	GN-8	5.22	0.82*	-0.01	14.18	0.95	0.00	8.41	1.12	0.01	2.89	0.59*	0.00
	General Mean	3.97			11.07			7.02			2.98		
	SE±		0.13			0.11			0.06			0.88	

, ** and * significant at 5 and 1 per cent levels, respectively*

Table 4. Estimation of mean and stability parameter for grain yield per plant, fodder yield per plant, harvest index and leaf area in finger millet

Sr. No.	Varieties	Grain yield per plant (g)			Fodder yield per plant (g)			Harvest index (%)			Leaf area (cm^2)		
		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	VL-352	3.61	0.95	0.00	9.49	0.82	0.00	1048.56	0.82	-1	9.86	-0.48*	0.00
2	VL-315	4.81	0.93	0.00	10.97	1.02	0.00	1196.67	1.02	-1	6.98	-0.24*	0.00
3	VL-149	3.92	0.79	0.00	10.26	0.90	0.00	1126.22	0.90	-1	10.0	16.18*	0.001***
4	VL-324	4.08	0.94	0.00	10.70	0.90	0.00	1170.44	0.90	0	6.50	0.02	0.00
5	VL-376	3.73	1.05	0.00	9.81	1.11	0.00	1081.0	1.11	-1	5.49	-0.48*	0.00
6	VL-314	4.58	1.0	0.00	12.0	1.10	0.00	1300.33	1.10	0	6.96	-0.46	0.00
7	Dapoli-1	4.25	0.98	0.00	11.16	0.81	0.00	1215.89	0.81	0	5.84	-0.24*	0.00
8	Dapoli-2	4.54	0.93	0.00	11.89	1.24	0.00	1289.22	1.24	0	9.90	-0.14*	0.00
9	KOPN-235	4.90	1.15	0.00	12.88	1.13	0.00	1388.44	1.13	-1	4.97	-0.35	0.00
10	KOPN-942	4.22	1.17	0.00	11.09	1.04	0.00	1209.33	1.04	-1	4.91	-0.24*	0.00
11	Phule Nachani	4.43	1.38	0.00	11.70	1.11	0.00	1270.0	1.11	-1	7.71	-0.22	0.00
12	VR-708	4.58	1.01	0.00	12.0	1.04	0.00	1300.33	1.04	-1	5.42	-0.11	0.00
13	VR-847	4.63	1.08	0.00	12.16	0.99	0.00	1316.56	0.99	-1	5.75	-0.15	0.004**
14	VR-936	4.56	1.27	0.00	11.99	1.16	0.00	1299.78	1.16	0	6.48	-0.16*	0.00
15	PR-202	4.51	1.02	0.00	11.85	1.01	0.00	1285.22	1.01	-1	7.59	-0.13	0.00
16	GPU-66	4.08	1.01	0.00	10.73	1.02	0.00	1173.67	1.02	-1	5.36	-0.16*	0.00
17	GPU-28	3.62	1.10	0.00	9.54	0.95	0.00	1054.0	0.95	-1	5.17	-0.35	0.00
18	GPU-45	3.69	0.82	0.00	9.69	1.02	0.00	1068.67	1.02	-1	8.47	-0.09*	0.00
19	GPU-67	4.63	0.98	0.00	12.13	0.95	0.00	1313.00	0.95	-1	12.60	-0.02	0.00
20	MR-6	4.31	0.86	0.00	11.29	0.82	0.00	1229.56	0.82*	-1	9.70	-0.12*	0.00
21	KMR-340	4.64	0.92	0.00	12.18	0.89	0.00	1317.56	0.89	-1	8.62	-0.13	0.00
22	KMR-204	4.58	0.95	0.00	11.99	1.08	0.00	1298.89	1.08	-1	10.50	0.02	0.00

Sr. No.	Varieties	Grain yield per plant (g)			Fodder yield per plant (g)			Harvest index (%)			Leaf area (cm^2)		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
23	KMR-630	4.71	0.98	0.00	12.33	1.04	0.00	1333.33	1.04	-1	10.73	13.32*	0.002*
24	OEB-532	3.29	0.89	0.00	8.65	1.04	0.00	965.11	1.04	-0.06	9.92	12.12*	0.00
25	Indira Ragi-1	3.41	1.02	0.00	8.99	1.08	0.00	998.89	1.08	1.08	7.50	0.02	0.00
26	Chhattisgarh Ragi-2	3.55	0.96	0.00	9.34	0.99	0.00	1033.78	0.99	0	4.91	0.13	0.00
27	RAU-8	3.81	1.12	0.00	10.02	1.07	0.00	1102.44	1.07	-1	8.05	-0.35*	0.00
28	GN-1	4.12	1.12	0.00	10.87	0.82	0.00	1187.56	0.82*	-1	5.69	-0.13	0.00
29	GN-2	4.14	1.28	0.0003*	10.93	1.07	0.00	1193.44	1.07	-1	4.81	0.13	0.00
30	GN-3	4.15	1.10	0.00	10.92	0.95	0.00	1192.0	0.95	-1	7.84	-0.14*	0.00
31	GN-4	4.17	0.72	0.00	10.87	1.17	0.00	1187.22	1.17	-1	4.90	0.02*	0.00
32	GN-5	4.48	0.73	0.00	10.93	1.13	0.00	1192.67	1.13	0	7.95	-0.48*	0.00
33	GNN-6	4.82	0.90	0.00	11.62	0.75	0.00	1261.89	0.75	-1	5.69	-0.01	0.004**
34	GNN-7	4.52	0.90	0.00	11.32	0.90	0.00	1232.44	0.90	0	7.90	-0.33	0.00
35	GN-8	4.64	0.95	0.00	10.98	0.87	0.00	1198.33	0.87	-1	9.54	-0.40	0.00
	General Mean	4.23			11.001			1200.93			7.43		
	SE±		0.07			0.08			0.10			0.33	

, ** and * significant at 5 and 1 per cent levels, respectively*

Table 5. Estimation of mean and stability parameter for chlorophyll content, fiber content, calcium content and zinc content in finger millet

Sr. No.	Varieties	Chlorophyll content			Fiber content (%)			Calcium content (mg/100g)			Zinc content (mg/100g)		
		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	VL-352	19.30	2.58	0.01	4.04	-4.47	0.00	395.22	0.94	-0.36	2.95	2.94	0.00
2	VL-315	28.57	4.69	0.02	4.0	-22.15	0.00	392.0	-0.38*	-1.07	2.91	2.08	0.00
3	VL-149	20.72	-0.05	0.00	3.99	1.66	0.00	382.67	2.66	4.73*	2.92	-1.40	0.001***
4	VL-324	16.22	-0.34	0.12	4.05	-3.59	0.00	388.67	1.40	9.88**	3.02	-0.45	0.00
5	VL-376	26.33	0.01*	0.00	4.12	0.52	0.00	398.0	0.93	6.49**	3.01	2.53	0.00
6	VL-314	25.72	0.15*	0.00	4.05	-5.51	0.00	390.0	1.68	7.89**	2.82	1.0	0.003**
7	Dapoli-1	18.63	4.69	0.02	3.82	-11.65	0.00	374.67	0.77	8.04**	2.46	0.72	0.00
8	Dapoli-2	18.71	-0.22	0.00	4.05	0.52	0.00	379.67	1.60	-0.22	2.50	0.30	0.00
9	KOPN-235	24.78	0.71	0.00	4.10	-3.59	0.00	329.67	0.35	16.56***	3.08	1.72	0.00
10	KOPN-942	24.65	0.62	0.00	4.07	0.00	0.00	336.0	-0.01	4.91**	3.30	2.28	0.00
11	Phule Nachani	23.06	1.03	0.05	4.01	0.00	0.00	395.67	0.44	28.67***	2.97	-0.96*	0.00
12	VR-708	15.77	1.45	0.00	4.49	99.32	0.03***	396.67	0.40	8.79**	2.87	-0.45	0.00
13	VR-847	22.47	0.06	0.00	4.09	1.92	0.00	389.33	1.60*	-1.07	2.91	1.26	0.00
14	VR-936	25.60	0.26	0.00	4.11	-0.78	0.00	397.33	1.02	4.56*	2.97	2.08	0.00
15	PR-202	26.03	0.91	0.02	4.16	3.33	0.00	400.67	-0.01	1.58	2.78	0.72	0.00
16	GPU-66	19.13	-0.48	0.03	3.79	-5.51	0.00	593.0	1.23	-0.39	2.84	0.21	0.00

Sr. No.	Varieties	Chlorophyll content			Fiber content (%)			Calcium content (mg/100g)			Zinc content (mg/100g)		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
17	GPU-28	20.40	-0.20	0.00	3.94	3.85	0.00	490.33	1.79*	-1.05	3.20	1.32	0.00
18	GPU-45	18.93	0.02*	0.00	3.80	-4.99	0.00	395.67	1.02	9.09**	2.73	2.08	0.00
19	GPU-67	21.07	0.93	0.00	3.82	0.00	0.00	490.67	1.70*	-1.01	2.57	-0.45	0.00
20	MR-6	24.82	0.88	0.00	4.04	-0.26	0.00	493.0	1.23	-0.39	2.89	1.36	0.00*
21	KMR-340	22.72	1.28	0.00	4.03	-4.99	0.00	435.0	0.68	10.88**	2.41	-0.36	0.00
22	KMR-204	26.60	1.19	0.00	4.0	0.52	0.00	393.33	1.14	0.52	2.47	1.32	0.00
23	KMR-630	22.77	0.66	0.00	4.08	3.33	0.00	449.67	1.89*	-1.04	2.48	3.55*	0.00
24	OEB-532	20.76	1.08	0.00	3.99	-4.47	0.00	362.0	1.25	9.65**	2.81	0.00*	0.00
25	Indira Ragi-1	22.91	0.63	0.00	3.96	-0.52	0.00	392.67	1.24	1.62	2.43	0.25	0.00
26	Chhattisgarh Ragi-2	22.01	0.43	0.01	3.85	-0.26	0.00	473.67	1.05	1.83	2.88	0.41	0.00
27	RAU-8	29.51	0.85	0.02	4.10	-4.99	0.00	396.67	0.48	2.48	2.66	1.57	0.00
28	GN-1	20.13	-0.48	0.03	4.0	2.55	0.00	4.93.33	1.23*	-1.08	2.37	0.45	0.00
29	GN-2	24.50	0.01*	0.00	3.82	-6.66	0.00	396.0	0.49	11.3***	2.40	-1.17	0.00
30	GN-3	22.73	0.20	0.00	3.99	4.73	0.00	496.33	0.75	0.04	2.56	1.77	0.00
31	GN-4	21.90	0.79	0.00	4.03	-4.26	0.00	302.33	-0.47*	-0.77	2.50	2.43*	0.00
32	GN-5	20.41	-0.15*	0.00	3.95	-3.85	0.00	492.33	1.24	4.97*	2.88	2.0	0.00
33	GNN-6	19.22	1.28	0.00	3.88	0.00	0.00	493.0	1.23	-0.39	2.93	-0.09	0.00
34	GNN-7	20.77	9.98	0.14	4.0	-0.26	0.00	396.0	0.75	-1.02	2.92	2.89	0.00
35	GN-8	23.24	-0.46*	0.00	4.02	5.51	0.00	480.67	1.70*	-1.01	2.96	1.11	0.00
	General Mean	22.32			4.01			418.91			2.78		
	SE±		0.70			7.11			0.30			0.62	

, ** and * significant at 5 and 1 per cent levels, respectively*

Table 6. Most widely adapted genotypes identified on the basis of grain yield per plant along with their stability traits in finger millet

Sr. No.	Genotypes	Stable yield and quality attributes
1	Dapoli-1	Grain yield per plant (g)
2	Dapoli-2	Plant height (cm), Finger length(cm), 1000 seed weight (g), Grain yield per plant (g), Fodder yield per plant (g) and Fiber content (%)
3	KOPN-235	Main ear head length (cm), 1000 seed weight (g), Grain yield per plant (g), Fodder yield per plant (g), Harvest index (%), Chlorophyll content and Zinc content (mg/100g)
4	VR-708	Main ear head length (cm), Grain yield per plant (g), Fodder yield per plant (g), Harvest index (%),Fiber content (%)and Zinc content (mg/100g)
5	VR-847	Productive tillers per plant, Finger width (cm), Main ear head length (cm), Grain yield per plant (g), Fodder yield per plant (g), Harvest index (%),Fiber content (%)and Zinc content (mg/100g)
6	GPU-67	Days to 50% flowering and Grain yield per plant (g)
7	KMR-340	Finger width (cm), Finger length (cm), 1000 seed weight (g), Grain yield per plant (g), Leaf area (cm^2), Chlorophyll content and Fiber content (%)
8	KMR-204	Finger width (cm), Finger length (cm), 1000 seed weight (g), Grain yield per plant (g), Harvest index (%),Leaf area (cm^2) and Chlorophyll content,
9	KMR-630	Finger width (cm), Grain yield per plant (g), Fodder yield per plant (g), Harvest index (%),Chlorophyll content and Fiber content (%)
10	GN-5	Finger width (cm), Main ear head length (cm), Grain yield per plant (g) and Zinc content (mg/100g)
11	GNN-6	Finger length (cm), Grain yield per plant (g), Harvest index (%),Calcium content (mg/100g) and Zinc content (mg/100g)
12	GNN-7	Days to 50% flowering, Main ear head length (cm), Finger length (cm), 1000 seed weight (g), Grain yield per plant (g), Fodder yield per plant (g), Leaf area (cm^2) and Zinc content (mg/100g)
13	GN-8	Days to 50% flowering, Productive tillers per plant, Grain yield per plant (g), Leaf area (cm^2), Fiber content (%) and Zinc content (mg/100g)

Among the 35 genotypes, 16 genotypes *viz*., VL-314, Dapoli-2, Phule Nachni, VR-708, VR-847, VR-936, PR-202, GPU-67, KMR-340, KMR-204, GN-2, GN-3, GN-4, GNN-6, GNN-7 and GN-8 indicating higher mean than population mean and non-significant regression coefficient as well as deviation from regression values indicating its average stability across the environments for finger length. Same results have been reported by Jawale et al. [18]. Ten genotypes viz., VL-324, Dapoli-2, Phule Nachni, KOPN-235, VR-936, MR-6, KMR-340, KMR-204, GN-2 and GNN-7 had higher mean than general mean, non-significant b_i as well as S^2d_i values indicating its average stability across the environments. While, three genotypes GPU-66, GPU-67 and GNN-6 exhibited significant values of S^2d_i indicating their unpredictability for 1000 seed weight.

The 13 genotypes, *viz*., Dapoli-1, Dapoli-2, KOPN-235, VR-708, VR-847, GPU-67, KMR-340, KMR-204, KMR630, GN-5, GNN-6, GNN-7 and GN-8 were found to be most stable genotypes for grain yield per plant as their regression values were unity or close to unity. One genotype, GN-2 recorded significant deviation from zero and were considered as unpredictable. This type of result was reported by Ashalatha et al*.* [15] Shanthakumar [19] Shanthakumar and Lohithaswa (2004), Patil [20] Asfaw et al*.* [16] Nagaraja et al*.* [21] Jawale et al. [18] Sood et al. [11] Chavan et al. [22] Kandel et al. [13] and Madhavilatha et al*.* [14].

10 genotypes *viz.,* VL-314, Dapoli-2, KOPN-235, KOPN-942,VR-708, VR-847, VR-936, PR-202, KMR-630 and GNN-7 exhibited higher mean than general mean, non significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments. This type of result also reported the genotype PPR-2614 was also found stable for fodder yield per plant with higher mean, Shanthakumar and Lohithaswa (2004). The eleven genotypes *viz.,* KOPN-235, KOPN-942, Phule Nachni, VR-708, VR-847, PR-202, GPU-67, KMR-204, KMR-630 and GNN-6 exhibited higher mean than population mean, non-significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments. On other hand genotype MR-6 and GN-1 exhibited higher mean value coupled with regression coefficient significantly lower than unity and non-significant S^2d_i indicating its stability for poor environment *i.e*. above average stability for harvest index. For the leaf area, 8 genotypes *viz*., Phule Nachni, PR-202, GPU-67, KMR-340, KMR-204, Indira Ragi-1, GNN-7 and GN-8 exhibited higher mean than general mean, non-significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments.

The eleven genotypes displayed higher mean performance than that of general mean (22.32) coupled with non-significant b_i and S^2d_i values, thus appeared as a stable genotype across the environments. On other hand four genotypes *viz*., VL-376, VL-314, GN-2 and GN-8 exhibited higher mean value coupled with regression coefficient significantly lower than unity and non-significant S^2d_i indicating its stability for poor environment *i.e*. above average stability for chlorophyll content. For fiber content, 17 genotypes viz., VL-352, VL-324, VL-376, VL-314, Dapoli-2, KOPN-235, KOPN-942, Phule Nachni, VR-708, VR-847, VR-936, PR-202, MR-6, KMR-340, KMR-630, RAU-8, GN-4 and GN-8 exhibited higher mean than general mean, non significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments. Only four genotypes exhibited higher mean than general mean, non-significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments for calcium content. For zinc content, 16 genotypes *viz.*, VL-352, VL-315, VL-324, VL-376, VL-314, KOPN-235, KOPN-942, VR-708,VR-847, VR-936, GPU-66, GPU-28, Chhattisgarh Ragi-2, GN-5, GNN-6, GNN-7 and GN- 8 exhibited higher mean than general mean, non significant regression of coefficient as well as deviation from regression values indicating its average stability across the environments. This type of result was reported by Saritha et al. [23].

Stability of the genotypes for grain yield per plant has been characterized with respect to yield attributing characters and quality parameters information is presented in Table 6.

4. CONCLUSION

In this study, 13 best high yielding and stable genotypes were identified *viz*., Dapoli-1, Dapoli-2, KOPN-235, VR-708, VR-847, GPU-67, KMR-340, KMR-204, KMR-630, GN-5, GNN-6, GNN-7 and GN-8 which were also showed stable for most of the yield attributing traits, quality parameters and could be utilized for further breeding programme for improvement of yield in finger millet.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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