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Short Communication

Stability of finger millet genotypes under diverse environments

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Abstract

The present study aimed at deciphering the stability and patterns of genotype × environment interaction (GEI) in finger millet genotypes tested in All India Coordinated Trials using GGE biplot technique. The combined ANOVA for grain yield of five finger millet cultivars at four environments showed that environments (E), genotypes (G) and GEI were highly significant (P<0.01). GGE biplot grouped the four environments into two mega environments with GPU 67 and VR 990 as winning genotypes. VL 376 was found to be an ideal genotype in terms of high yield and stability followed by VR 990 as desirable genotype.

Key words: Finger millet, GEI, GGE biplot, stability

Finger millet [*Eleusine coracana* (L.) Gaertn. subsp. *coracana*] is one of the oldest cultivated crop in India and East Africa (Hilu and DeWet 1976). Although previously neglected, the value of small millets including finger millet in modern agriculture has been identified due to their stress tolerance and nutritional qualities. However, breeding efforts in finger millet have been limited and farmers still grow low yielding cultivars (Neves 2011). The current average national productivity of the crop is 1661 kg ha^{-1} (Directorate of Economics and Statistics, 2013-14), which is quite low mainly due to lack of stable high yielding and adapted improved varieties and poor crop management. The data from All India Coordinated Finger Millet Varietal Trials was taken to determine the stability and yield performance of advanced finger millet genotypes at multiple locations using GGE biplot analysis.

Thirty finger millet genotypes including four checks *viz*., VR 708, VL 352, GPU 45 and GPU 67 were grown at four locations representing diverse environmental conditions (Tables 1 and 2). The crop was raised in the rainy season of Almora, Uttarakhand (E1), Jagdalpur, Chhattisgarh (E2), Viziaragaram, Andhra Pradesh (E3) and Kolhapur, Maharashtra (E4) in 2013 from June to November. Five rows (10 rows at Kolhapur) of each genotype were planted in RCBD with three replications in 3 m rows at 22.5 cm apart. Plots were initially over-planted and thinned later during first weeding to maintain plant to plant spacing of 10 cm within the rows. All standard package and practices were followed to raise the crop.

Data on grain yield were recorded on plot basis and converted into quintals per hectares for statistical analyses. The GGE Biplot analysis was done for visual examination of the genotype by environment interaction (GEI) as per Yan et al. (2000). The GGE biplot was constructed using first two principal components (PC1 and PC2) derived from subjecting environment centered yield data. All the statistical analyses were performed using R software version 3.1.2 (R Core Team 2014).

Combined analysis of variance showed significant GEI (P<0.001), exhibiting the influence of changes in environment on grain yield performance of genotypes. Similarly, the environmental factor i.e. years and the genotype main effect was also significant (P<0.001). The relative magnitudes of G, E and G×E variances accounted for 24.90, 48.87 and 26.24%,

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Table 1. Mean grain yield (q ha^{-1}) of the finger millet genotypes at four different locations

Codes	Genotypes	Locations (environments)				Mean
		Almora E1	Jagdalpur E2	Vizianagram E3	Kolhapur E4	
V1	KRI 013-11	19.87	21.23	23.70	8.02	18.21
V2	VR 990	45.45	24.44	33.94	18.59	30.61
V3	GPU 91	33.80	24.68	37.75	17.86	28.52
V4	BR 45	35.34	22.96	35.07	13.54	26.73
V5	IGRFM 08-4	29.89	24.19	27.73	26.15	26.99
V6	KRI 013-18	38.14	23.45	16.28	13.74	22.90
V7	GPU 88	22.12	20.24	46.01	12.41	25.20
V8	BR 90	12.68	18.51	25.04	18.34	18.64
V9	TNEC 1234	30.26	23.20	28.00	16.78	24.56
V10	KMR 344	28.44	18.76	20.79	11.64	19.91
V11	DHFMV10-2-1	36.78	24.19	29.59	19.52	27.52
V12	GK 1	41.30	24.93	31.22	16.07	28.38
V13	VL 376	41.30	25.42	33.82	19.69	30.06
V14	GPU 92	37.14	23.70	32.40	15.58	27.21
V15	TNEC 1256	32.69	18.27	19.07	18.73	22.19
V16	PPR 1044	23.25	19.75	19.01	14.13	19.04
V17	OEB 265	40.30	23.94	30.52	13.38	27.04
V18	KMR 316	36.60	27.40	40.35	10.73	28.77
V19	VL 384	36.94	24.93	28.27	11.70	25.46
V20	PPR 1040	25.46	24.19	25.60	13.44	22.17
V21	GPU 90	13.12	17.03	21.03	10.28	15.37
V22	GK 2	39.01	26.90	25.15	16.29	26.84
V23	WN 259	44.03	21.97	33.31	19.29	29.65
V24	KMR 228	24.24	25.42	17.20	10.05	19.23
V25	DHFMV78-3-1	40.49	27.15	28.38	10.61	26.66
V26	KOPN 939	23.13	24.44	19.64	12.01	19.81
C1	VR 708 (Early)	19.89	21.72	29.52	12.31	20.86
C2	VL352 (Early)	30.03	23.94	33.17	18.73	26.47
C3	GPU 45 (Medium)	21.67	20.24	25.18	13.67	20.19
C4	GPU 67 (Late)	38.20	31.1	39.88	24.46	33.41
	Mean	31.44	23.14	28.18	14.91	
	SE (m)	2.33	1.90	3.18	1.14	
	CD	6.58	5.38	8.98	3.21	

Table 2. Brief description of experimental sites

Trial sites	Soil type	Date of sowing	Altitude*	Annual rainfall (mm)	Average temp. (°C)		Global position	
					Min.	Max.	Latitude	Longitude
Almora (E1)	Sandy Loam	14-06-2013	1250	1012	10	26	25°35'N	79°39'E
Jagdalpur (E2)	Sandy Loam	29-06-2013	554	1405	18	31	19°05'N	81°57'E
Vizianagram (E3)	Red Sandy Loam	22-06-2013	63	1100	27	33	18°7'N	83°25'E
Kolhapur (E4)	L. T. Shallow	29-06-2013	574	1015	20	32	16°43'N	74°14'E

*amsl (in meter) = above mean sea level; Min. = Minimum; Max. = Maximum; LT = Light textured respectively. Although the genotypes contributed significantly, major part of the variation was explained by environments. This indicated that grain yield was affected due to diverse environments. GEI significantly explained 26.24 % of the treatments variation in grain yield. Similar results of high variance for environment component, followed by GEI and least variance for genotypes in finger millet were earlier reported (Adugna et al. 2011; Lule et al. 2014).

GGE biplot defines an ideal genotype, based on both mean performance and stability across environments. Visualization of the "which-won-where" pattern of MET data is important for studying the possible existence of different mega-environments (Fig. 1) in a region (Yan et al. 2000). The polygon view

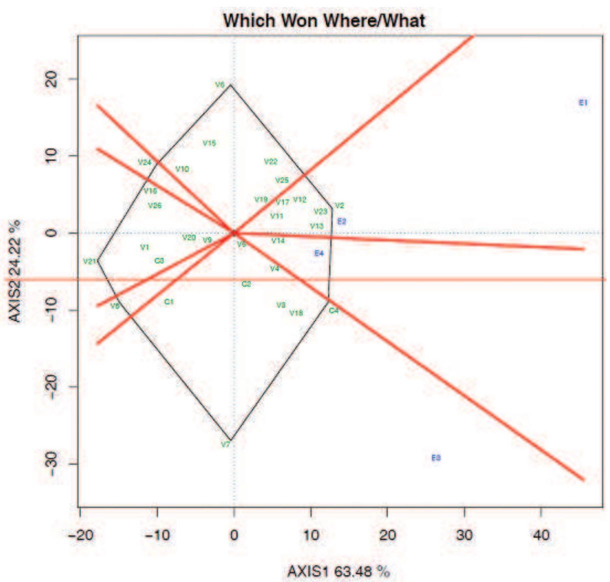

Fig. 1. GGE biplot exhibiting grain yield performance of finger millet genotypes across environments. SVP-GH-(Column Metric Preserving); Centred by-2. Tester-Centered G+GE; Scaled by-0. No scaling

of a biplot is the best way to visualize the interaction patterns between genotypes and environments and to effectively interpret a biplot (Yan and Kang 2003). The genotypes, VR 990 (V2), GPU 67 (C4), GPU 88 (V7), BR 90 (V8), GPU 90 (V21), KMR 228 (V24) and KRI 013-18 (V6) were vertex genotypes. The vertex genotype for each sector is the one that give the highest yield for the environments that fall within that sector. The four environments considered in present study were falling in two sectors only, E1 and E2 in one sector and E3 and E4 in second sector. The angles created by the environment vectors indicate their correlations, it is acute environment, it is highly correlated, if obtuse they show opposite relationship (Yan and Tinker 2006). In present study, they show acute angle indicating crossover GEI is less prevalent. The environments E1 and E2 comprise one mega environment and E3 and E4 represent another mega environment, and the vertex genotypes VR 990 (V2) and the check variety GPU 67 (C4) were the winning genotypes for these two mega environments, respectively. The reason for grouping of E2 and E4 may be similarity in their geographical position, rainfall and temperature, however, it is difficult to explain the grouping of E1 and E3 together. Mean performance and stability of genotypes view of GGE biplot showed that the check variety GPU 67 (C4) had the highest mean yield followed by test genotypes VR 990 (V2), WN 259 (V23), VL 376 (V13), KMR 316 (V18), and the test genotype GPU 90 (V21) had the poorest mean yield. In terms of mean grain yield and stability, GPU 67 (C4) followed by VL 352 (C2) were the best checks, whereas, among top five genotypes for grain yield VL 376 (V13) was the most stable, followed by WN 259 (V23) and VR 990 (V2) (Fig. 2).

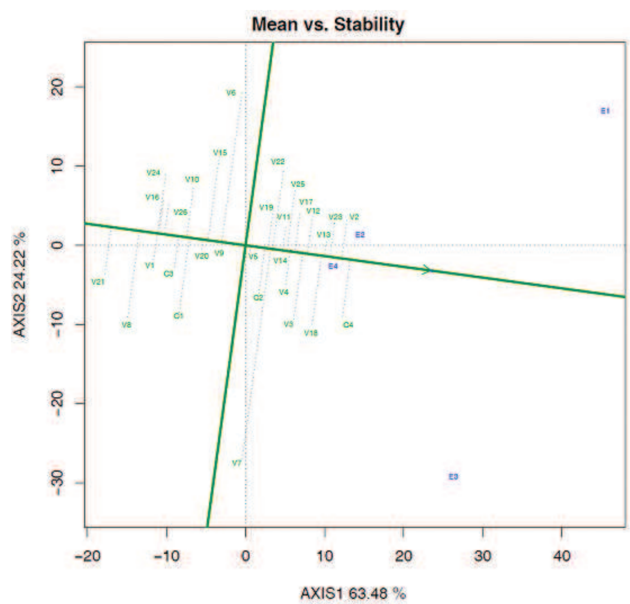

Fig. 2. Average environment coordination (AEC) view of the GGE biplot based on environment- focused scaling for the means performance and stability of genotypes

The overall desirability of a genotype is a combination of high yield and stability in performance. An ideal genotype is one that has the highest yield and an absolute stability (Yan and Kang 2003), however, the genotypes closer to the ideal genotype are the most desired ones (Yan et al. 2007; Yan and Kang 2003). Concentric circles rippling around the average environmental coordinate (AEC) of a genotype focussed GGE biplots encompass genotypes that are relatively similar in their overall desirability (Yan and Kang 2003). Therefore, genotype VL 376 (V13) which fell into the centre of concentric circles was ideal genotypes in terms of higher yield ability and stability, compared with the rest of the genotypes. In addition VR 990 (V2) and WN 259 (V23) may be regarded as desirable genotypes GK1 (V12), GPU 92 (V14) and GPU67 (C4) falling on the next concentric circle (Fig. Supplementary 1; available online: http://www. isgpb. co.in).

Author's contribution

Conceptualization of research (SS); Designing of the experiments (SS, TSSKP, SK, AS); Contribution of experimental materials (SS, SK, TSSKP, AS); Execution of field/lab experiments and data collection (SS, TSSKP, SK, AS); Analysis of data and interpretation (SS); Preparation of the manuscript (SS).

Declaration

The authors declare no conflict of interest.

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Figure S1. Based on average grain yield the ideal and stable finger millet genotypes across environments