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Research Article

Comparison and association of parametric and non-parametric measures for identification of stable genotypes in finger millet

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Abstract
A study of phenotypic stability of 13 finger millet genotypes was conducted to assess genotype-environment interaction (GEI) and identify stable finger millet (*Eleusine coracana* (L.) Gaertn. subsp. *coracana*) genotypes for grain yield across four diverse locations in India. Both parametric and non-parametric stability statistics were used to identify stable finger millet genotypes. The parameters Wi^2, σi^2, $Si^{(1)}$, $Si^{(2)}$ identified similar stable genotypes, while different stable genotypes were identified by other measures. High correlation among non-parametric and parametric measures showed that these measures can be used alternatively. Only two stability measures, Ysi and YSI showed significant association with mean grain yield and Ysi was better choice for screening of genotypes for both yield and stability. The stable high yielding genotypes PPR 2773, VL 368, KOPN 942, VR 988, TNAU 1214 and GPU 45 can be deployed or included in breeding program for enhancing the finger millet productivity.

Keywords
Finger millet , genotype-environment interaction, stability, correlation

Introduction

Finger millet (*Eleucine coracana* L. Gaertn) is a crop of subsistence farming in India and Africa. It is present in archaeological records of early African agriculture in Ethiopia that date back 5000 years, and it probably originated somewhere in the area that today is Uganda. It is highly adaptable crop and even grown in higher elevations up to 2400 m above mean sea level in the Himalayas. It is one of the main ingredients of the staple food in South Indian State, Karnataka, which is also the major producer of finger millet in India. The yield levels in finger millet are lower in comparison to major cereal crops and require attention of plant breeders for concerted efforts towards development of high yielding stable varieties.

Genotype-by-environment interactions (GEI) are important sources of variation in any crop, and the term stability is used to characterize a genotype, which shows a relatively constant yield, independent of changing environmental conditions. There are two major approaches (Parametric and Non-parametric) to study GEI and determine the adaptation of genotypes (Truberg and Huehn 2000). Parametric methods for estimating phenotypic stability are widely used in plant breeding and they were mostly related to the variance components and related statistics. Nonparametric stability measures based on ranks provide a viable alternative to present parametric measures based on absolute data (Nassar and Huehn 1987).

Therefore, we intend to study the interrelationship among various parametric and nonparametric phenotypic stability statistics, to evaluate the similarity between these methods, and to determine the most suitable methods for assessing the finger millet genotypes grain yield stability.

Materials and Methods

Thirty finger millet genotypes including four national check varieties viz., VL 352 (early Duration), VR 708 (Early Duration), GPU 45 (Medium Duration) and GPU 67 (Late Duration) were grown in the rainy season 2013 at four locations. The first location (L1) was ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand (79°39'E longitude and 25°35'N latitude, 1250 m above msl), L2 was Jagdalpur, Chattisgarh ($81^0$57' E longitude and $19^0$05' N latitude), L3 was Vizianagram, Andhra Pradesh (83°25'E longitude and 18°7'N latitude) and L4 was Kolhapur, Maharashtra ($74^0$14'E longitude and $16^0$43'N latitude). These four locations represent Northern, Central, Western and Southern regions of India. Five rows (10 rows at Kolhapur) of each genotype were planted in randomized complete block design with three replications. The row length was 3 m with row

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to row spacing of 22.5 cm. Plots were initially over-planted and thinned later during first weeding to maintain plant to plant spacing of 7.5 cm within the rows. The crop was raised in rainfed condition without pre-sown irrigation and sowing dates changed as per the onset of rain. Fertilizers were applied at the rate of 50:40:25 (N: P: K) Kg/ha, where the entire amount of phosphorus, potash and half of the nitrogen was applied as basal dose during field preparation. The remaining half of the nitrogen was applied as top dressing after 45 days of sowing after second weeding. Manual weeding was done twice during the crop season, 20 and 40 days after sowing.

Data on grain yield and component traits were recorded. The grain yield data recorded on plot basis, converted into quintals per hectares was only considered for statistical analyses.

Combined analysis of variance was done across the test locations. The parametric stability parameters were performed in accordance to Wricks's (1962) ecovalance (W_i^2), and Shukla's (1972) stability variance (σi^2), and Shukla's squared hat (s^2). Another parametric measure AMMI stability value (ASV) for each genotype was calculated as suggested by Purchase et al. (2000). Among non-parametric statistics to estimate stability $Si^{(1)}$ and $Si^{(2)}$ (Nassar and Huehn 1987) was used. Simultaneous selection of yield and stability (Ysi) is another non-parametric stability procedure used in the study, where both yield and Shukla's (1972) stability variance were used as selection criteria (Kang 1993). Another non parametric stability measure known as Yield Stability Index (YSI) was calculated by the following formula:

YSI = RASV + RY

where RASV is the rank of AMMI stability value and RY is the rank of mean grain yield of genotypes (RY) across environments. YSI incorporate both mean yield and stability in a single criterion. Low value of this parameter shows desirable genotypes with high mean yield and stability.

Besides, the stability parameters were compared using Spearman's rank correlation (Steel and Torrie 1980). All analyses were performed using R software version 3.1.2 (R Core Team 2014). Stability analysis in R was performed using Agricolae package (Mendiburu 2014).

Results and Discussion

Combined analysis of variance (Table 2) over locations resulted in highly significant differences (P<0.01) in the interaction of genotypes × environments. The significant interactions of genotypes × environments suggest that grain yield of genotypes varied across environments. Significant differences for genotypes, environments and GE interaction indicated the effect of environments in the GE interaction, genetic variability among the entries and possibility of selection for stable genotypes. The relative magnitudes of G, E and G×E variances accounted for 10.64, 66.23 and 23.13 per cent, respectively. Genotypic rank differences over environments showed the existence of crossover GEIs (Crossa 1990). This was fitted by the significant effect of GEI in the joint analysis of variance (Table 2) and showed the necessity to assess the response of the genotypes to environmental variation.

Evaluation of genotypes based on four parametric and four non parametric stability parameters with mean yield are presented in Table 3. According to Wricke (1962) ecovalance (Wi^2), genotypes with the smallest ecovalance (Wi^2) values are considered stable. The Wi^2 was lowest for PPR 2773 (29.90) followed by KOPN 942 (75.05), TNAU 1214 (104.43) and VL 352 (104.76). The stability variance (σi^2) revealed that the same genotypes (PPR 2773, KOPN 942, TNAU 1214 and VL 352) had the smallest variance across the environments. Similarly, according to the Sukla's squared cap (s^2), PPR 2773 (-6.73), KOPN 942 (-2.99), KRI 007-01 (-1.25), TNAU 1214 (0.92) and VL 368 (23.23) were stable genotypes. ASV indicated PPR 2773 (0.46) as highly stable genotype across environments followed by TNAU 1214 (0.59), KRI 007-01 (0.85), KOPN 942 (1.40), VL 352 (1.76) and GPU 45 (1.76).

According to Kang (1993) stability statistic (YSi), another parametric stability analysis, genotypes with greater than the mean YSi (9.8 in our case) are considered stable. Thus, the genotypes in the order PPR 2773 (13), VL 368 (8), KOPN 942 (8), VR 988 (6), TNAU 1214 (5) and GPU 45 (4), were stable across the locations for grain yield.

According to Yield Stability Index (YSI), the genotype with least value is considered most stable with high grain yield. Based on YSI the most stable genotypes with high grain yield were TNAU 1214 (3.5, 26.30), PPR 2773 (4, 26.85), VL 368 (8.5, 28.78), GPU 45 (9, 26.54) and KOPN 942 (10, 26.32). Stability *per se* should not be the only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance (Mohammadi and Amri 2008). Two rank stability measures ($Si^{(1)}$ and $Si^{(2)}$) from Nassar and Huehn (1987) based on ranks of genotypes across environments are presented in Table 3. Zero variance is an indication of maximum stability. Thus, $Si^{(1)}$ and $Si^{(2)}$ of the tested genotypes showed that genotypes PPR 2773 (1.33, 1.33), KOPN 942 (3.17, 6.92), GPU 45 (3.67, 8.67) and TNAU 1214 (4.0, 11.0) had the lowest values and can be regarded as the most stable genotypes according to $Si^{(1)}$ and $Si^{(2)}$. However, for each genotype, $Zi^{(1)}$ and $Zi^{(2)}$ values were calculated based on the rank of the corrected data and summed over genotypes to obtain Z values; $Zi^{(1)}$sum = 14.58 and $Zi^{(2)}$ sum = 15.96. Since both of these statistics were less than the critical value $\chi2_{0.05, df=12}$ = 22.36, therefore no significant differences were found in rank stability among the 13 genotypes grown in four different environments. The individual Z values were also smaller than the critical value $\chi2_{0.05, df=1}$ = 8.36, which inferred that these two non parametric stability statistics ($Si^{(1)}$, $Si^{(2)}$) could not differentiate the stability of different genotypes.

Spearman's rank correlation (Steel and Torrie 1980) was determined for each pair of mean yield and stability statistics (Table 4). Mean yield showed highly significant (P<0.01) positive rank correlation with Ysi and negative significant correlation with YSI. The parametric stability measures, Shukla (σi^2) and Wricke (Wi^2) had a total correspondence (r =1.00). This indicates that these procedures are equivalent for ranking purposes. These parametric stability measures along with s^2 and ASV were also in total correspondence with non parametric stability measures $Si^{(1)}$, $Si^{(2)}$ and YSI. The lower values indicating higher stability for all these parameters and significant positive correlation between these parameters suggest that they can be used as an alternative to each other and consequently as a useful index for selecting stable genotypes in crops. All the studied stability parameters except Ysi and YSI did not show significant correlation with mean grain yield and therefore, could be compromise methods to select genotypes with high grain yield and stability. Significant negative rank correlation between mean yield and YSI showed that lower value of this parameter is related to higher yield. While, Ysi had nearly perfect positive correlation with mean grain yield which inferred that Ysi is more suitable stability parameter in finger millet for selection of genotypes with wide adaptability and higher yield.

All four parametric stability measures (σi^2, s^2, Wi^2, ASV) identified similar stable genotypes namely PPR 2773, KOPN 942, TNAU 1214, KRI 007-01, VL 368, VL 352 and GPU 45. All these stability measures were significantly positively associated with each other and can be used alternatively. However, these parameters did not consider the grain yield along with stability. Among non parametric statistic, only two statistical measures (Ysi and YSI) could differentiate the genotypes for stability. These two stability measures showed significant association with mean grain yield and were important in identification of stable genotypes (PPR 2773, VL 368, KOPN 942, VR 988, TNAU 1214 and GPU 45) without compromise for grain yield. Among all the stability measures, simultaneous selection for yield and stability (Ysi) was found to be the better choice for screening of genotypes for both yield and stability.

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Table 1. Pedigree and maturity duration of genotypes taken in present study.

Codes	Genotypes	Pedigree	Maturity Duration	Origin place
V1	PR 10-30	(GE 4971/ GPU 26)/GE 559	114	Peddapuram, AP
V2	VL 368	VL 326/VL 328	106	Almora, UK
V3	TNAU 1226	Co (Ra) 14/GPU 48	112	Coimbatore, TN
V4	VR 988	GE 3076/VR 855	115	Vizianagaram, AP
V5	VL 352*	VR 708/ VL 149	107	Almora, UK
V6	VL 348	VL 146/ VL 149	105	Almora, UK
V7	PPR 2773	Satagiri/Gauthami	114	Perumallapalle, AP
V8	TNAU 1214	CO 12/KM 232	108	Coimbatore, TN
V9	GPU 45*	GPU 26/ L5	112	Bengaluru, KAR
V10	KRI 007-01	CO 12/GPU28	116	Coimbature, TN
V11	VL 369	VL 315/ VL 329	106	Almora, UK
V12	KOPN 942	Selection from IEC 190	108	Kolhapur, MH
V13	VR 708*	Selection from VMEC 36	104	Vizianagaram, AP

Table 2. Combined analysis of variance for grain yield (q ha^{-1}) of 13 finger millet genotypes evaluated in four locations

Source of variation	Degree of freedom	Mean Squares	F value	Pr (>F)	Per cent of total# sum of squares
Environment (E)	3	3473.1	839.89***	2.47e^{-10}	66.23
Replications (Environment)	8	4.1	0.47	0.873	
Genotypes (G)	12	139.4	15.92***	2.2e^{-10}	10.64
G × E	36	101.1	11.54***	2.2e^{-10}	23.13
Error	96	8.8			

***-Significant at the 0.1% probability level; #- Total is G+E+G×E

Table 3. Mean grain yield values (q ha^{-1}) and stability parameters of thirteen finger millet genotypes across four environments

Codes	Genotypes	Mean	Parametric				Non-parametric					
			σi^2	**s^2**	**Wi^2**	**ASV**	**Ysi**	**$Si^{(1)}$**	**$Zi^{(1)}$**	**$Si^{(2)}$**	**$Zi^{(2)}$**	**YSI**
V1	**PR 10-30**	23.15	427.24**	640.55**	1108.52	5.59	-4	6	1.31	25.33	1.80	24
V2	**VL 368**	28.78	61.52**	23.23ns	180.14	2.08	8	5.17	0.34	18.92	0.34	8.5
V3	**TNAU 1226**	23.27	65.66**	102.35**	190.65	2.26	-3	4.17	0.01	10.92	0.13	17
V4	**VR 988**	27.68	122.43**	186.92**	334.75	2.91	6	6.83	2.91	30.92	4.02	16
V5	**VL 352***	23.14	31.83*	41.68*	104.76	1.76	-1	5.17	0.34	16.25	0.07	14
V6	**VL 348**	20.92	93.66**	125.22**	261.72	2.74	-8	6.33	1.87	26.00	2.02	19
V7	**PPR 2773**	26.85	2.34	-6.73ns	29.90	0.46	13	1.33	4.03	1.33	2.25	4
V8	**TNAU 1214**	26.30	31.69*	0.92ns	104.43	0.59	5	4.0	0.04	11.00	0.13	3.5
V9	**GPU 45***	26.54	42.06**	42.14*	130.74	1.76	4	3.67	0.19	8.67	0.40	9
V10	**KRI 007-01**	21.61	39.45**	-1.25ns	124.11	0.85	-7	4.83	0.13	14.92	0.01	15
V11	**VL 369**	25.51	119.91**	68.46**	328.36	2.83	0	6.50	2.19	27.58	2.59	17
V12	**KOPN 942**	26.32	20.12	-2.99ns	75.05	1.40	8	3.17	0.59	6.92	0.71	10
V13	**VR 708***	16.19	292.49**	242.02**	766.43	4.16	-10	5.50	0.65	24.25	1.48	25
	Sum								**14.58**		**15.96**	
	Mean	**24.32**					**0.84**	**11.57**	**0.97**	**94.78**	**1.04**	**31.0**
								Test statistics				
							E(Si(1)) = 4.31			E(Si(2))=14		
							V(Si(1)) = 2.19			V(Si(2))= 71.17		
							$\chi 2$ Sum = 22.36			$\chi 2$ Z1Z2 = 6.64		

σi^2- stability variance of Shukla; s^2- Shukla's squared hat; Wi^2-Wricke´s ecovalence; ASV-AMMI stability value; Ysi- simultaneous selection for yield and stability; Si(1)- mean of absolute rank difference of a genotype over environments; Si(2)- sum of square deviations of the rank; YSI-Yield stability index; V(Si(1)) and V(Si(2)) are variance for Si(1) and Si(2), respectively; Z-statistics- measures of stability; Z1 and Z2 are the standard values of Si (1) and Si (2) respectively, for $\chi 2$ test; $\chi 2$ Sum is the chi-square value at 13 degree of freedom and p at 0.05; $\chi 2$ Z1Z2 is chi-sqaure value at 1 degree of freedom and p at 0.01.

Table 4. Spearman rank correlation between mean yields and stability parametric and non-parametric measures for five genotypes across six environments.

	σi^2	s^2	Wi^2	ASV	Ysi	$Si^{(1)}$	$Si^{(2)}$	YSI
MGY	-0.31	-0.38	-0.31	-0.29	0.92**	-0.27	-0.24	-0.68*
σi^2		0.95**	1**	0.97**	-0.57*	0.83**	0.81**	0.84**
s^2			0.95**	0.94**	-0.61*	0.76**	0.73**	0.83**
Wi^2				0.97**	-0.57*	0.83**	0.81**	0.84**
ASV					-0.5	0.82**	0.79**	0.85**
Ysi						-0.45	-0.41	-0.79**
$Si^{(1)}$							0.99**	0.68*
$Si^{(2)}$								0.63*

* and **: significant at the 0.05 and 0.01 level of probability, respectively MGY - Mean grain yield
σi^2- stability variance of Shukla; s^2- Shukla's squared hat; Wi^2-Wricke´s ecovalence; ASV-AMMI stability value; Ysi-simultaneous selection for yield and stability; Si(1)- mean of absolute rank difference of a genotype over environments; Si(2)- sum of square deviations of the rank; YSI-Yield stability index.