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Evaluation of finger millet (*Eleusine coracana* (L.) Gaertn.) Varieties at Different Locations of Southwestern Ethiopia

Tegegn Belete[1]*, Leta Tulu[2] and Tsegau Senbetay[3]
[1]Ethiopian Institute of Agricultural Research, Jimma Research Center, P.O.Box 192, Jimma, Ethiopia
[2]Holeta Agricultural Research Center; P.O.Box: 31; Holetta, Ethiopia
[3]Mehoni Agricultural Research Center; Mehoni, Ethiopia
***Corresponding author: tegegnbelete2011@gmail.com**

Abstract
The objectives of this study was (i) to evaluate grain yield of finger millet varieties across different environments at southwestern part of Ethiopia (ii) to identify and recommend varieties with improved yield and stable performance using different stability parameters. Ten finger millet varieties which were for the experiment. The experiment was laid out using Randomized Complete Block Design with four replications in all testing sites. The plot size was four harvestable rows and spacing between rows was 40cm with the length of 5m long. All management practices such as cultivation, fertilization and weeding were done based on the recommendations for each test sites. Data for all relevant agronomic traits were collected, but only plot yield data converted to qt/ha was subjected to statistical analysis. Result Revealed that the combined ANOVA for grain yield revealed highly significant ($p<0.01$) variations among the genotypes, environments and GEI. The total variation explained was 78.7% for environment,1.5% for genotype and 9.8% for GEI. Several univariate and AMMI model were used to identify high yielding and stable varieties. The most stable finger millet varieties according to the eco-valence method were G10, G3,G7 and G8.Lin and Binns cultivar superiority measure (Pi) the most stable varieties were G7, G5,G4 and G1. According to the stability variance, the most stable varieties were G2, G4, G1 and G10.Francis and Kannenberg (CV) identified varieties G4, G10, G2,G3 and G7 as stable. In AMMI analysis, the first two IPCAs were highly significant and captured 76.1% of GEI of variance. AMMI analysis identified variety Gudetu as high yielding and stable variety. BD19 and OM19 were close to the origin and contributed less to the GEI, considered as relatively high yielding and stable environments. In conclusion, variety G7 and G4 could be suggested to be stable and high yielding than others and relatively low contribution to GEI. Therefore, these varieties were recommended for commercial use at different locations of Southwestern Ethiopia.

Keywords: AMMI model, Genotype by environment interaction, Stable varieties, Stability parameters.

Introduction
Ethiopia is a country which is known for its rich biodiversity and being a centre of origins for many crop species and diversities due to its wide range of altitudes, temperature extremes, huge amounts of rainfall and different soil characteristics. Therefore, due to this variation in the environment, it has evolved and gave a great opportunity for the existence of diverse vegetation types, crop species, and landrace varieties of crops that have been used for generations, conserved by farmers in their fields (Vavilov, 1951).

Finger millet (*Eleusine coracana* (L.) Gaertn) is an annual cereal crop and an allotetraploid (2n = 4× = 36) that includes two distinct subspecies: subsp. *coracana* (cultivated finger millet) and subsp. *africana* (wild finger millet) (Hilu,1994) is preferred as potentially a climate-resilient and nutritious crop, having antioxidant properties (Kumar *et al*., 2017).Finger millet grain is gluten-free, rich in calcium, fiber and iron; and with excellent malting qualities (Pradhan *et al*., 2010).

Finger millet in Ethiopia has a variety of uses. It is used for making injera, a thin, pancake-like bread, commonly served in the national dishes, bread and porridge. It is also used for making traditional alcoholic beverages such as 'tella', the local beer and 'arakie', local sprit. The straw is used for animal feed and for thatching roofs. The grains fetch better price than maize (Chimdo *et al*. 2006). Most of the finger millet produced in the country are consumed locally or sold in local markets for traditional uses. The crop is considered as nutritious cereal with enhanced levels of essential nutrients compared to rice, maize or sorghum (Hulse *et al*.,1980). Oil from finger millet is considered to be good quality (polyunsaturated); that it provides health benefits to humans through reducing cholesterol levels (National Research Council 1996).Finger millet, commonly called

"Dagussa" in Ethiopia, is an important staple food crop, widely grown in the country (CSA, 2016). The productivity of this crop is limited by shortage of stable and high yielding finger millet varieties.

In plant breeding programs, genotypes are evaluated in METs by testing their performance across environments and selecting the best genotypes in specific environments. However, selection of superior genotypes in METs usually results in GEIs that often complicate the interpretation of results obtained and reduce efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994). This interaction is the result of changes in genotype's relative performance across environments, due to differential responses of the genotypes to various abiotic and biotic factors (Dixon and Nukenine, 1997). Thus, a significant GEI for a quantitative trait such as grain yield can complicate the identification of superior genotypes for both improved crop development and new crop introduction. Choice of appropriate statistical models and their validation are fundamental steps which should precede any study of GEI and analysis of stability.

Many methods of analysis for stability have been proposed. Wricke (1962) ecovalence measures the contribution of a genotype to the GEI. The ecovalence (Wi) or stability of the genotype is its interaction with the environments, squared and summed across environments. The genotypes with the lowest ecovalence have fewer fluctuations across the environments and therefore it is considered to be more stable than others. Shukla (1972) proposed the stability variance (σi^2), the amount of genotype by environment variance associated with genotypes i. This stability variance is a linear function of with the wricke's ecovalence (Wricke and Weber 1980).However, Shukla's model differs in the ranking of the genotypes from Wricke (1962) when covariates (locations means) were considered. A genotype is described as stable if the stability variance (σi^2) is the environmental variance (σe^2) which means that $\sigma i^2 = 0$. The relatively large value of σi^2 indicates greater instability of genotype i.

Francis and Kannenberg (1978), used the coefficient of variation (CVi), according to Francis *et al*. (1978), stable genotype is the one that provides a high yield performance and consistent low CV and Pinthus (1973), used coefficients of determination (Ri^2) of each genotype as stability parameter. Cultivar Performance Measure (Pi) is the method of Lin and Binns (1988) has the great advantage of a directed recommendation of more stable and adapted genotypes, due to the uniqueness of the parameter, the evaluation of genotype performance according to the environmental variation and the fact that the genotypes identified among the most stable and adapted are generally the most productive. According to Lin and Binns (1988) for cultivar superiority measure (Pi) analysis, the genotype with low or small Pi value is considered to be the more stable.

Eberhart and Russell (1966) procedure involves the use of joint linear regression where the yield of the genotype is regressed on the environmental mean yield. In this model, the SS due to the environments and GEI is partitioned into environments (linear), GEI (linear) and deviation from the regression (pooled deviations overall the genotypes).They recommended that the genotype stability is expressed in terms of three empirical parameters: the mean performance, the slope of regression line (bi), and the sum of squares of deviation from regression (S^2di). Therefore, a genotype with high mean yield over the environment, unit regression coefficient (b=1) and deviation from regression equal to zero ($S^2di = 0$) will be a better choice as a stable genotype.

The AMMI model ensures a multivariate analytical parameter for interpreting GEI (Crossa *et al* 1990).When main effects and interaction are both important; AMMI is the model of first choice to improve accuracy of yield estimates (Zobel *et al.,* 1988). AMMI method combines ANOVA and principal component analysis (PCA) into a united approach. The most important feature of this analysis is that adjustment is carried out using information from other locations to refine the estimates within a given location (Sadeghi *et al*., 2011). It removes residual or noise variation from GEI (Crossa *et al*., 1990).The objectives were (i) to evaluate grain yield of finger millet varieties across different environments at southwestern part of Ethiopia (ii) to identify and recommend varieties with improved yield and stable performance using different stability parameters.

Materials and Methods

Experimental Materials: Ten finger millet varieties which were obtained from Melkassa and Bako (regional) Agricultural Research Center were used for the experiment (Table 1).The experiment was conducted in southwestern part of Ethiopia and the environments descriptions was in table 2.

Experimental Design and field layout: The experiment was laid out using randomized complete block design (RCBD) with four replications in all testing sites. The plot size was four harvestable rows and spacing between rows was 40cm with the length of 5m long. All management practices such as cultivation, fertilization and weeding were done based on the recommendations for each test sites.

Data collection

Days to flowering (DTF): This parameter was recorded as number of days from sowing to stage when ears emerged from 50% of the tillers per plot.

Days to Physiological Maturity (DPM): It was recorded as number of days from sowing to stage when 50% of the tillers per plot had matured ears (detected by yellowing of leaves).

Plant Height (PH) (cm): It was recorded by measuring the height of plants from ground level to the tip of inflorescence (ear), at dough stage.

Number of Tillers per Plant (NOT): The number of tillers per plant was number of basal tillers that bear mature ears and recorded from five randomly taken plants of each plot at harvest.

Number of Ears per Plant (NOE): The number of ears per plant was recorded as the total number of ears produced from all tillers and recorded from five randomly taken plants of each plot at harvest.

Number of Fingers per Ear (NOF): The number of fingers per ear was recorded from five randomly taken plants at harvest.

Finger Length (FL) (cm): The finger length was recorded from the base of the ear to the tip of the finger at each five randomly taken plants of main tillers, at dough stage.

Biomass Yield/plot (BMY) (kg): The biomass yield was recorded from weight of the aboveground parts (stem + leaves + seed) by sensitive balance at harvest after sun drying.

Grain Yield (GY) (kg/plot): The weight of grains harvested in grams from each plot. Grains were weighed by sensitive balance and approximately adjusted to 10% moisture content by drying in the sun.

Data for all relevant agronomic traits were collected, but only plot yield data converted to qt/ha was subjected to statistical analysis.

Statistical Analysis: Primary statistical analysis (such as an Anderson-Darling normality test and the Levine homogeneity test of variances) was performed. An analysis of variance was conducted for individual environments to plot the residuals and identify outliers; the homogeneity of residuals variance was determined using Bartlett's homogeneity test. Comparison of treatment means was done using fischer's least significant difference (LSD) test at 5% probability levels. In performing the combined analyses of variance genotypes were assumed to be fixed while environments were assumed random.

The following statistical model was used for combined analysis of variance over environments:

Yijk = μ + Gi + Ej + GEij + Bk(j) + ϵijk ,where, Yijk, Observed value of genotype i in block k of environment (location) j; μ, grand mean; Gi, effect of genotype I; Ej, environment or location effect; GEij, the interaction effect of genotype i with environment j; Bk (j), The effect of block k in location (environment) j and ϵijk, error (residual) effect of genotype i in block k of environment j.The combined analysis of variance was carried out to estimate effects of environment (E), genotype (G) and GEI. Levels of significance of these variables were determined by using F-test.

Different stability parameters were applied to assess stability performance of genotypes and to identify superior genotypes; Coefficient of variation (CV %),Wricke's ecovaence,Cultivar superiority index, stability variance and regression analysis (Ebrehart and Russel,1963),Coefficient of determination (R^2) and multivariate analysis was done using AMMI model. All analysis was performed using the statistical package G-EAR (Genotype by environment interaction with R) and Genstat version 18th software. Spearman's coefficient of rank correlation was computed for each pair of the possible pair-wise comparison of the stability parameters by SAS software and the significance of the rank correlation coefficient was tested according to Steel and Torrie (1980).

Table 1: Finger millet varieties evaluated across different locations

Common name	Variety name	Year of release	Altitude (m.a.s.l.)	Maturity date
Boneya	(KNE#411)	2002	1400-1600	145
Bareda	(BRC-356-1)	2009	1200-1900	146-169
Tessema	ACC#229469	2014	1600 -1900	145-150
Wama	(KNE#392)	2007	1400-1900	145-150
Padet	KNE #409	1999	1600-1900	NA
Tadesse	(KNE #1098)	1999	1600-1900	NA
Gudetu	(Acc.215990)	2014	1400-1900	145-150
Addis 01	Acc. 203544)	2015	1400-2200	145-155
Axum	NA	NA	NA	NA
Meba	NA	NA	NA	NA

NA=not available

Table 2: Environmental sites, Altitude, Rainfall and Temperature.

No.	Environments	Env.code	Altitude (m.a.s.l.)	Rainfall (mm)	Temp (0C)
1.	Bedele	#BD	2087	1700	18
2.	Omonada	#ON	1975	1600	20
3.	Limu kosa	#LK	NA	NA	NA
4.	Gooma	#GM	1,560	1764	19.7

NA=not available

Results and Discussion

Mean performance: The mean grain yields of ten varieties tested across different locations were presented in Table 3.The mean grain yield of the varieties was ranged from 18.9qt/ha to 15.3qt/ha.The highest mean was harvested from the variety Gudetu (18.9qt/ha) and the lowest from variety Meba (15.3qt/ha).Out of ten varieties, six varieties had grain yield below the average. Among the environments, the LK2017 and GM2019 had below the mean average yields. The highest yield were recorded in the environment BD2018 and BD2017 with mean yields of 25.6 and 24.5qt/ha respectively.

The combined analysis of variance was presented in Table 4. Genotype, environment and interaction were highly significant ($p<0.01$).Such statistical interaction results from the changes in the relative ranking of the genotypes from one environment to another. The significant genotype by environment interaction effects showed that varieties responded differently to the variations in environmental conditions indicating the necessity of testing varieties at multiple locations.

Partitioning of the sum of squares of the components indicated the contribution of locations to be 78.7% (Table 4) of the total variation which is in agreement with Yan and Kang (2003) as stated the environmental portion of the sum of squares in the multi-environmental trail has been usually known to be the largest among all sources of variation. The remaining 1.55, 9.86, 8.51 and 1.31% were contributed due to genotype, GEI, pooled error and replication within locations, respectively. The large sum of square of environment suggested that the big influence of environment on yield performance of finger millet varieties in southwestern Ethiopia.

Table 3: Mean grain yield (qt/ha) of ten finger millet varieties across different locations and years.

	Locations and years							
Varieties	BD 2017	BD 2018	BD 2019	LK 2017	GM 2019	ON 2019	Overall Mean	Overall Rank
Boneya	20.4	25.8	25.8	6.6	12.1	19.1	18.3	2
Bareda	25	20.9	14.5	9.4	10.4	16.6	16.1	9
Tesema	24.5	24.9	15.1	6.8	5.8	19.7	16.1	8
Wama	22	27.9	20	7.5	12.5	16.2	17.7	3
Padet	33.3	23.7	17.9	6.5	5	19.3	17.6	4
Tadesse	24.5	29.2	16.6	7.2	9.6	11.6	16.5	7
Gudetu	26.2	28.5	22.9	6.2	10.8	18.5	18.9	1
Addis01	26.5	23.6	15.4	7.6	5.8	20	16.5	6
Axum	22.1	28.9	13.3	7.2	12.1	15.8	16.6	5
Meba	22.5	22.5	15.8	5.6	6	19.1	15.3	10
Mean	**24.5**	**25.6**	**17.7**	**7.1**	**9**	**17.6**	**16.9**	
CV (%)	**15.5**	**10.7**	**14.9**	**13.6**	**13.3**	**11.6**		
LSD at 5%	**5.5**	**4**	**3.8**	**1.4**	**1.7**	**2.9**		

Where, BD=Bedele, LK=Limu kosa, GM=Gooma, ON=Omonada

Table 4.Combined ANOVA for grain yield (Qt/ha) and the percentage sum of squares of the 10 finger millet varieties tested at different locations during 2017 to 2019 cropping season

Source of variation	d.f	SS	%SS	MS
Environment	5	13032.8	78.77	2606.56**
Genotype	9	256.6	1.55	28.5**
Rep (location)	18	217.3	1.31	12.1
Interaction	45	1631.6	9.86	36.2**
Residuals	162	1407.9	8.51	8.7
Total	239	16546.4		
CV (%) = 14.4		**R^2= 0.93**		

**,* Significant difference at $p<0.01$ and $p<0.05$ respectively, df= degree of freedom, SS = sum square, MS=mean square

Stability of tested varieties

Stability of varieties by Univariate Stability parameters

The relatively large proportion of genotype environment variance, more than double, when compared to that of genotypes as main effect is very important consequence. The presence of significant GEI indicated the inconsistency in performance of finger millet varieties across environments. According to Ghaderi *et al*. (1980) standard analysis of variance procedure is useful for estimating the magnitude of GEI, but fails to provide more information on the contribution of individual genotypes to GEI. To tackle the problem, different statistical procedures have been developed. Therefore, the different stability parametric procedures were used to evaluate and describe finger millet performance and their result presented in Table 5.

The lower the Wi value of a genotype, the smaller is its fluctuations from the predictable response in different environments so that the genotype with the least ecovalence is considered to be ideal from the point of view of yield stability. The four most stable finger millet varieties according to the eco-valence method of Wricke's (1962) were G10, G3,G7 and G8 (Table 5).Lin and Binns cultivar superiority measure (Pi) the most stable varieties were G7,G5,G4 and G1. According to this stability variance, the most stable varieties were G2, G4, G1 and G10.Francis and Kannenberg (CV) identified varieties G4, G10, G2,G3 and G7 as stable.

According to Eberhart and Russel's (1966) model, regression coefficients (bi) approximately 1.0 coupled with s^2di of zero indicate an average stability. When this is associated with high mean grain yield, genotype had general adaptability and when associated with low mean grain yield, genotypes are poorly adapted to all environments. Regression values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability), and greater specificity of adaptability to high yielding environments. Regression coefficient decreasing below 1.0 provide a measure of greater resistance to environmental change (above average stability), and thus increasing specificity of adaptability to low yielding environments. The values of regression coefficients ranged from 0.74 to 1.31 (Table 5) .This variations in regression coefficient indicate that genotypes had different responses to environmental changes.

The two varieties (Bareda and Meba) which were relatively low yielders and had regression coefficients approaching to one (0.74 and 0.97) respectively, suggesting that the varieties are stable, but poorly adapted to all environments (Table 5). An ideal genotype has highest average grain yield, regression coefficient (bi) value of approximately one and a mean square deviation from regression (s^2di) value close to zero (Eberhart and Russel, 1966, Becker and Leon,1988).Coefficients of determination (R^2) is the predictability of response estimates response (R^2=1), ranged from 0.7 to 0.9 in which variation of mean grain yield was explained by genotype response across environments. None of values of coefficient of determination (R^2) was significantly different from 1.0.In regard to this parameter; all of varieties could be considered a stable for grain yield (Table 5). Generally, univariate stability parameters identified different superior and stable varieties across locations. On average, the two high yielding and stable varieties were variety Gudetu and Wama.

Table 5: Results of various stability parameters for grain yield

Varieties	GY	Pi	Wi	σ^2	CV (%)	bi	S^2di	R^2	IPCA1
G1	18.3	15.55	84.72	58.69	41.8	0.850	18.024	0.9027	-1.67085
G2	16.1	23.21	37.45	36.39	37.2836	0.742	2.9385	0.734	0.48583
G3	16.1	21.89	18.97	71.2	52.2208	1.065	2.9332	0.9585	0.83901
G4	17.7	14.93	28.3	52.43	40.8525	0.892	4.7285	0.9524	-1.38667
G5	17.6	13.3	95.16	115.78	61.2086	1.312	15.056	0.8436	2.30383
G6	16.5	20.37	48.55	76.58	53.1308	1.061	10.370	0.9277	-0.83305
G7	18.9	6.18	20.81	78.43	46.8681	1.123	2.582	0.9503	-0.54825
G8	16.5	19.65	26.11	70.43	50.9509	1.047	4.874	0.8761	1.23647
G9	16.6	25.32	49.03	60.68	46.9606	0.927	10.371	0.9052	-0.928
G10	15.3	26.59	14.37	59.84	50.6719	0.978	2.0704	0.8857	0.50168

G1=Boneya,G2=Bareda,G3=Tesema,G4=Wama,G5=Padet,G6=Tadesse,G7=Gudetu,G8=Addis 01,G9=Axum and G10=Meba,CV=Francis and Kannenberg's (1978) coefficient of variability,Pi=Lin and Binns's (1988) cultivar performance measure; σ^2i= Shukla's (1972) stability variance; Wi=Wricke's (1962) ecovalence; bi= regression coefficient; S^2di= Eberhart and Russell's' (1966) deviation from regression. R^2=Coefficient of determination, IPCA=Interaction principal component analysis,GY=grain yield

Multivariate Stability Analysis

AMMI Analysis

The AMMI analysis of variance for grain yield (qt/ha) of ten finger millet varieties tested in four environments were presented in table 6.

Combined Analysis of variance revealed highly significant (p<0.01) variations among environments, GEIs and IPCAs (Table 6).This result revealed that there was differential yield performance among finger millet varieties across testing environments and strong GEI.The result was in agreement with previous reports on finger millet (Dagnachew,2014) and (Misra *et al*., 2009). Substantial percentage of GEI was explained by IPCA1 (50.29%) followed by IPCA2 (25.8%) and IPCA3 (15.17%) (Table 6).The most accurate model for AMMI can be predicted by using the first two IPCAs (Gauch and Zobel, 1996).This suggestion was later modified such that factors like type of crop, diversity of germplasm and range of environmental conditions affect the degree of complexity of the best predictive model and hence the number of IPCAs to be used (Crossa *et al*.,1990).

Table 6: ANOVA table for AMMI model

Source	df	SS	MS	%SS explained	%GXE
Total	239	14980	62.7		
Genotypes	9	271	30.1**	1.8	
Environments	5	11915	2383**	79.5	
Block	18	136	7.6	0.9	
Interactions	45	1694	37.6**	11.3	
IPCA 1	13	852	65.6		50.3
IPCA 2	11	438	39.8		25.8
IPCA 3	9	257	28.6		15.17
IPCA 4	7	124	17.7		7.3
Error	162	964	5.9	6.43	

**,* Significant difference at p<0.01 and p<0.05, respectively, df= degree of freedom, SS = sum square, MS=mean square,GXE=genotype by environment interaction,IPCA=Interaction Principal Component Analysis

Table 7: AMMI selections of stable genotypes per environments

			Four AMMI selections			
EVT code	**Mean**	**Scores**	1	2	3	4
BD17	24.7	2.59	G5	G8	G7	G2
OM19	17.64	1.32	G8	G3	G5	G1
LM17	7.05	0.25	G2	G8	G4	G6
BD19	17.74	-1.16	G1	G7	G4	G5
BD18	25.64	-1.21	G6	G9	G7	G4
GM19	9.01	-1.79	G4	G1	G9	G7

EVT=Environmnet,BD=Bedele,OM=Omonada,LM=Limukosa,GM=Gooma,G1=Boneya,G2=Bareda,G3=Tesema,G4=Wama,G5=Padet,G6=Tadesse,G7=Gudetu,G8=Addis 01,G9=Axum and G10=Meba

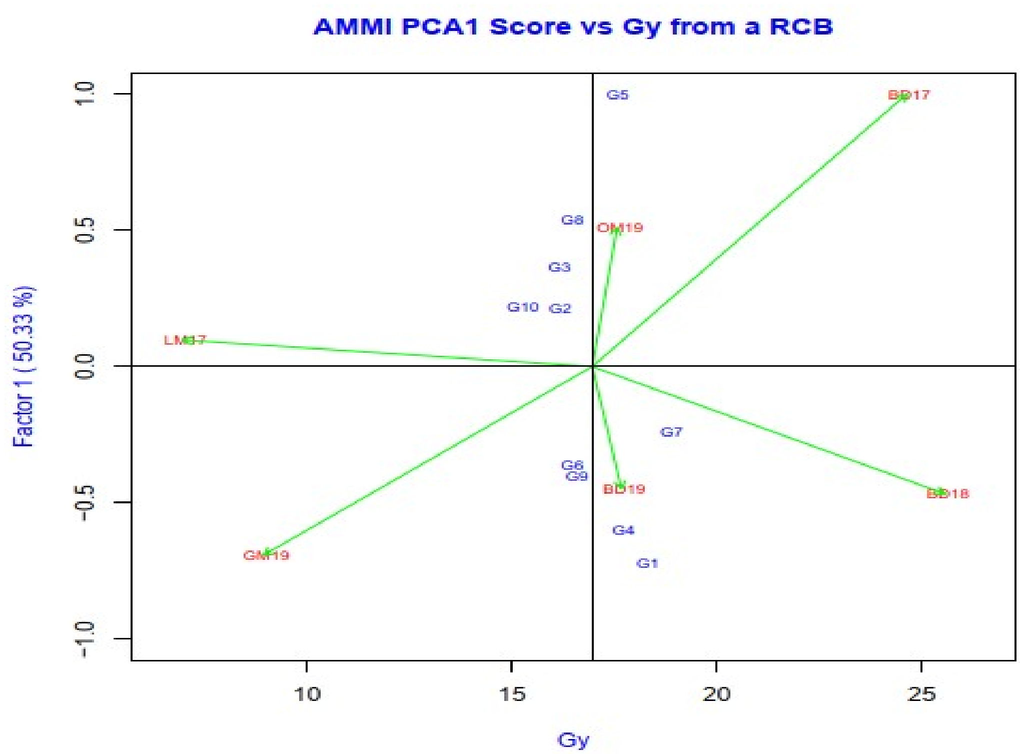
According to AMMI analysis variety padet (IPCA=0.48) and Tesema (IPCA=0.5) showed the least GE interaction as measured by first IPCA which took 50.29% of the GE interaction sum square and were the most stable in across all environments, but the yield performance of the variety padet and Tesema was below the average grain yield. On the other hand, variety Bareda (IPCA=2.3) and Boneya (IPAC= -1.67) had the largest interaction and thus,the most variable hence indicating their specific adaptation to certain environments. Both of these varieties had grain yield above the average.AMMI analysis also showed that the least IPCA score was observed at environment LM17 (IPCA=0.25) with mean yield of 7.05qt/ha and BD19 (IPCA= -1.16) with 17.7qt/ha while, the highest IPCA value (IPCA=2.59) was observed for BD17 (Table 5).

Despite its below average yield, low interaction of the climatic conditions in LM17,may enable it to be more stable and desirable environment for evaluating the performance of the finger millet varieties where as BD17 was found to be unstable environment. BD19 and OM19 were close to the origin and contributed less to the GEI, considerd as relatively high yielding and stable environments. According to Yan *et al*.(2000) for environment to become desirable it should have more discriminating ability of the genotypes in terms of genetic main effects and high stability index, which implies more representativeness of the overall environment. In addition, the AMMI analysis selected variety Gudetu (G7),Boneya (G1),Wama (G4) and Padet (G5) with mean average grain yield of 18.9,18.3,17.7 and 17.6qt/ha as the most stable varieties and high yielding across locations (Table 7).

AMMI biplot Analysis

In bi-plot analysis the relative magnitude and direction of varieties along the abscissa and ordinate axis is important to understand the response pattern of genotypes across locations. The best genotype should combine high yield and stable performance across range of production environments (Ebdon and Gauch, 2002).In the figure 1 of AMMI bi plot, the Y-axis represents the IPCA1 score, while the X-axis represents the yield of the variety which is the main effect of the genotype. The variety G2 and G10 were stable across locations, but they had yield below the average (figure 1).G1,G4 and G5 were relatively above average in yield, but all of them were unstable indicating that they are responsive to environmental change.G7 was the most stable and grain yield above the average indicating less interaction of the variety with the environment to hinder the yield as shown in IPCA score of relatively near to zero (figure 1) suggesting that the variety can be cultivated in any of the four locations.

Genotypes that were grouped together had similar adaptation while environments which were grouped together influences the genotypes in the same way.In the AMMI biplot,if genotypes had zero or nearly zero IPCA-1 scores, then they are stable across their testing sites.However,if a genotype is further from zero,it is highly responsive and does not perform consistently across environments (Samonte *et al.*,2005). Also AMMI biplot graph revealed location BD17 as high yielding but unstable location. Locations BD18 and BD19 were above average in yield and relatively more stable.LM17 was the most stable location but had yield below the average.



BD=Bedele,OM=Omonada,LM=Limukosa,G=Gooma,G1=Boneya,G2=Bareda,G3=Tesema,G4=Wama,G5=Padet,G6=Tadesse,G7=Gudetu,G8=Addis 01,G9=Axum and G10=Meba

Figure 1: AMMI Bi-plot of IPCA 1 against grain yield of 10 finger millet varieties across four enviroments

Correlation of stability parameters: Correlation analysis was used to study the relationship between mean yield and stability parameters, as well as between studied stability parameters. Table (8) shows the spearman's correlation coefficient by using ranking of ten finger millet varieties, after applying the methods of stability analysis. Mean grain yield was statistically significant ($p<0.05$) and positively correlated with Wi and s^2di. This finding indicated that using Wi and s^2di to evaluate the performance stability of finger millet varieties in future selection programs would favor the simultaneous development of stable and high yielding varieties. Stability parameter with grain yield revealed strong negative correlation coefficients between Cultivar superiority index (Pi) parameter and mean grain yield. Thus, selection of stable genotypes based on the stability parameter may not enable finger millet breeders to identify genotypes that are both high-yielding and stable. Dissimilar results reported by Alberts (2004) and Abdurhaman (2009) that high rank correlation between grain yield and Pi.Pi was showed negative and weak correlation with all stability parameters. Coefficeint of variance was positively correlated with σ^2 and regression coefficient (bi**)**.The significant positive correlation between these stability parameters suggests that these parameters would play similar roles in stability ranking of genotypes as previously reported Kilic, (2012)**.**Negative correlation between stability parameters indicate that separate use of the stability parameters to measure stability of genotypes.

Table 8. Spearman's rank correlation coefficients for different GEI stability statistical methods for mean grain yield of 10 finger millet varieties grown in four environments of Ethiopia.

	GY	σ^2	CV	Pi	R^2	S^2di	Wi	bi
GY								
σ^2	0.213							
CV	-0.232	0.806**						
Pi	-0.823**	-0.43*	-0.03					
R^2	0.256	0.164	0.018	-0.176				
S^2di	0.433*	0.079	0.176	-0.248	-0.248			
Wi	0.451*	0.067	0.067	-0.273	-0.358	0.927		
bi	0.116	0.964	0.794**	-0.418*	0.224	-0.115	-0.127	

**,* Significant difference at $p<0.01$ and $p<0.05$,CV=Francis and Kannenberg's (1978) coefficient of variability,Pi=Lin and Binns's (1988) cultivar performance measure; σ^2i= Shukla's (1972) stability variance; Wi=Wricke's (1962) ecovalence; bi= regression coefficient; S^2di= Eberhart and Russell's' (1966) deviation from regression. R^2=Coefficient of determination,GY= grain yield

Conclusion

This study revealed that GEI is a significant source of variation in the finger millet multi-environment trial. The observed pattern of GE interaction for grain yield of finger millet suggests that genotypes respond differently in different environments. Several univariate parametric and AMMI model stability statistics employed in the present study to quantify stability of grain yield. BD19 and OM19 were close to the origin and contributed less to the GEI, considered as relatively high yielding and stable environments. Variety Gudetu (G7) and Wama (G4) were likely to be stable and high yielding and may be recommended for cultivation for different locations.

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Conflict of Interest

The authors have not declared any conflict of interests.

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