Evaluation of Yield Performance of Intermediate Altitude Sorghum (*Sorghum bicolor* (L.) Moench) Genotypes Using Genotype x Environment Interaction Analysis and GGE Biplot in Ethiopia

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Abstract: In Ethiopia, sorghum is grown as one of the major food cereals, is the third major cereal crop in area coverage next to tef and maize and the second in terms of productivity next to Maize. In spite of biotic and a biotic stress tolerant , is largely affected by genotype ×environment interaction (GE) making it difficult and expensive to select and recommend new sorghum genotypes for different environments . Yield stability is one of the setbacks facing sorghum breeders in developing widely adapted varieties with superior yield. The objectives of this study was to assess the nature and magnitude of GEI and determine the response of advanced genotypes to varying environments and to identify high yielding and stable sorghum genotypes for intermediate altitude of Ethiopia. The grain yield of 24 genotypes along with one standard check were evaluated for 3 years (2010, 2011 and 2012 cropping seasons) at seven location(enviroment) in Ethiopia. Combined analyses of variance displayed highly significant variation for Genotype (P<0.01), Location (L) (P<0.001), Year(Y) (P<0.001), and GenotypexLocation (GxL)(P<0.01), GenotypexYear(GxY)(P<0.001),LocationxYear(LxY)(P<0.001)andGenotypexLocationxYear(GxYxL) (P<0.001) . This finding indicated that mean grain yield (kg/ha) was significantly influenced by Year(Y), Environment (Y x L) and Genotype(G) which accounted for 37.57 % , 16.92% and 13.22% of the total variation, while Location(L) and Genotype by location (G x L) displayed 8.92 % and 4.62 % of the variation, respectively. Genotype 10, Genotype 3, Genotype 4, Genotype 7, Genotype 15 and Genotype 2 respectively displayed 17.9%, 15.31 %, 14.77%, 14.53%, 13.60% and 12.19% yield advantage over the popular standard check Geremew. These genotypes are the most ideal and stable genotypes across the testing environment and will be advanced to variety verification trail for evaluation and verification by variety verification committee in the coming cropping season. Whereas ,Mechara Jimma and Bako respectively has been identified as the ideal testing site for intermediate altitude sorghum testing environment in Ethiopia .By and large, the information from this finding could be useful for breeders who are interested to develop high yielding , leaf and grain disease resistant Sorghum varieties adapted to the intermediate agro-ecology of Ethiopia.

Keywords: *G; GxE; GEI; Stability;Ideal Environment; GE biplot ; Ideal Genotype;*

I. INTRODUCTION

Globally Sorghum[*Sorghum bicolor* (L.) Moench] 2n = 20) is the fifth most important cereal crop worldwide after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (*Hordeum vulgare*). Sorghum is a monocotyledon crop belonging to the family Gramineae. Sorghum is one of the most important cereal crops with a high rate of photosynthetic activity leading to high grain and biomass yield potential called C4 grain crop. It is naturally self pollinated short day plant with the degree of spontaneous crosspollination, in some cases, reaching up to 30% depending on panicle types (Poehlman and Sleper, 1995).Sorghum grain is as nutritious as other cereal grains; contains about 11% water, 340 k/cal of energy, 11.6% protein, 73% carbohydrate and 3% fat by weight (Hiebsch and O' Hair, 1986). In Ethiopia, sorghum is grown as one of the major food cereals. It is utilized in various forms such as for making local bread , Injera and for preparation of local alcoholic beverages (tela and areke). It is also consumed as roasted and boiled grain. Sorghum is leading cereal grain worldwide with area coverage of about 42.70 million ha and total production of 56.96 million metric tons (FAO,2004). In Africa, the area under sorghum production is about 24.44 million ha and total production and average yield being 20.84 million metric tons and 0.85 ton/ha, respectively (FAO, 2004). Ethiopia is third largest sorghum producer in Africa next to Nigeria and Sudan (FAO, 2004).In sub-Saharan Africa, over 100 million people depend on sorghum as staple (Serna-Saldivar and Rooney, 1995; Smith and Frederiksen, 2000). Sorghum is the third major cereal crop in Ethiopia in area coverage next to tef (*Eragrostis tef*) and maize (*Zea mays*) and the second in terms of yield kg/ha next to maize (*Zea mays*).

Agriculture constitutes the largest economic sector in Ethiopia and contributes 48% of the nation's GDP, generates 85 percent of the foreign currency flow into Ethiopia and employing about 83 percent of the total population of Ethiopia (Rashid, 2010). Cereals are the major food crops in Ethiopia and cover 82 % of the total land area covered by grain crops (cereals, pulses and oil seeds) and contributes 87% of the total grain production. Cereal production and marketing represent the single largest sub-sector in the Ethiopian economy, which accounts for roughly 60% of rural employment (Rashid, 2010). Sorghum is the third most important crop after teff and maize in terms of sown area and it is the second in total production next to maize (CSA, 2012). Currently sorghum is produced by 5 million holders and its production is estimated to be 4 million metric tons from nearly 2 million hectares of land giving the national average grain yield of around 2 tons per hectare (CSA, 2012). It covers 16% of the total area allocated to grains (cereals, pulses, and oil crops) and 20% of the area covered by cereals (CSA, 2012). Sorghum is cultivated in all regions of Ethiopia between 400m and 2500m altitude. According to Gorfu and Ahmed 2009, EIAR 2011; Sorghum is produced in AEZ of dry lowland, the intermediate and high land altitudes vernacularly named *Kolla,* Woina and *Dega* respectively with altitude ranging from 500 to 2,500 masl. The national average sorghum productivity in Ethiopia is 2.369 tons/ha (CSA, 2014/15) which is far below the global average of 3.2 tons/ha (FAO, 2005). This is because of a number of factors. Several production constraints were identified as hindrance for sorghum production and productivity enhancement. These include the lack of stable, well-adapted , disease and insect pests' tolerant varieties.

The concepts of GxE and yield stability have been issues to the breeders and biometricians for a long of time. A significant GxE for a quantitative trait is known to reduce the usefulness of the genotype means over all locations or environments for selecting and advancing superior genotypes to the next stage of selection (Pham and Kang, 1988). If there were no GxE associated with the genotype environment system relevant to a breeding objective, selection would be greatly simplified because the 'best' genotype in one environment would also be the 'best' genotype for all target environments (Basford and Cooper, 1998). Furthermore, variety trials would be conducted at only one location to provide universal results (Assefaw, 2007).

The basic cause for difference in the performance of genotypes over environments is the occurrence of genotype-environment interaction (GEI). To overcome GEI problem, trials are usually conducted over several locations and years to ensure that the selected genotypes have a high and stable performance over a wide range of environments. The data generated in these trials are analyzed for GEI by various methods. The most recent method GGE biplot model [6], provides breeders with a complete and visual evaluation of all aspects of the data by creating a biplot that simultaneously represents both mean performance and stability, optimized environments for specific genotypes and identifies mega-environments.

Yield stability is one of the setbacks facing plant breeders in developing widely adapted varieties with superior yield. To enhance superior and stable variety development information on nature and magnitude of genotype by environment interaction of advanced sorghum genotypes using a GGE Biplot analysis is extremely important. However, there is no information on genotype by environment interaction of advanced sorghum genotypes of the twenty four pedigree lines used in this study. Therefore; the objectives of this study was to assess the nature and magnitude of GEI and determine the response of different genotypes to varying environments to identify high yielding stable sorghum genotypes for Intermediate altitude of Ethiopia.

II. MATERIALS AND METHODS

Originally the materials were crossed at Melkassa agricultural research center , then outstanding lines have been evaluated and advanced to F_6 stage of through pedigree selection of lines at Bako, Jimma and Mechara by the Ethiopian national Sorghum breeding program. Promising lines at F_6 stage were selected and advanced to preliminary variety trial and tested for 1 year across 3 location , then the best and superior genotypes were selected and advanced to organize intermediate altitude Sorghum national variety trail at three location and 7 environment .The parental lines were developed from germplasm collection and characterization and were crossed for grain yield and resistance to various biotic and a biotic stresses. The most important stresses against which the parental lines were selected include susceptibility to various grain and leaf diseases.

A. Experimental Materials

The current study consisted of 24 genotypes and one popular released variety, Geremew (a standard Check), adapted to the mid altitude areas of Ethiopia). All genotypes used in this study were advanced from pedigree breeding at Ethiopian Institute of Agricultural research, based at Melkassa agricultural research center by breeders who works in the National Sorghum Improvement program.

Table 1: Description of the test environments of the field experiment

Location	Year	Geographical Location	Altitude (m.a.s.l)	Soil type	Seasonal R.F mm
Jimma	2010,2011	7˚46'0"N & 36'0″E	1753	Fluvisol	1432
Bako	2010,2011,2012	11˚18'0"N& 36˚24'0″E	1550	Nitosol	1178mm
Mechara	2010,2012	40˚19'0"N& 08˚35'0″E	1700	Sandy loam	1200mm

Table.2: list of Sorghum genotypes used in the study

Entry #	Genotype	Pedigree
1	07MW 6001	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
2	07MW 6002	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
3	07MW 6009	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
4	07MW 6013	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
5	07MW 6031	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
6	07MW 6033	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
7	07MW 6035	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
8	07MW 6036	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
9	07MW 6040	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
10	07MW 6052	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
11	07MW 6054	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
12	07MW 6061	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
13	07MW 6064	(89 MW 4122 x 85 MW 5552) x 85 MW 5340
14	07MW 6073	97 BK 6129 x 85 MW 5340
15	07MW 6085	97 BK 6129 x 85 MW 4138
16	07MW 6092	97 BK 6129 x 85 MW 4138
17	07MW 6097	IS 9302 X 85 MW 5340
18	03 MW 6125	ICRISAT 76 T4 # 432 X NES 635 X 80 ESIP-11 X (IS-9302 X ICSV 745) X (9327 X IS-10485)-4
19	97 MW 5044-2	85 MW 5325 X (IS-158 X ETS 2113)4
20	97 MW 6141	IS-158 X M-66145 X 84 MW 4141 X RS/R-20-8614-2) X IS-9379
21	E 237	Kaffir sor,66
22	03 MW 6135	87 BK 4134 x Jimma local-1
23	02 BK 7072	89 MW 4112 x (Rs/R-20-8614-2) x IS-13958
24	03 MW 6120	ICRISAT 76 T4 # 432 X NES 635 X 80 ESIP-11 X (IS-9302 X ICSV-745) X (9327 XIS-10485)-4
25	Geremew (Standard check)	87 BK 4122

B. Experimental Design and Trial Management

The trial was conducted in the main season for three consecutive years 2010,2011 and 2012 at three major intermediate altitude Sorghum testing locations (Bako, Jimma and Mechara) in a total of 7 environments (location x year combinations). For all trials the design used was RCBD with four replications. Planting was done on may in plots of 5 m × x 0.75 m x 3rows ($11.25m^2$). Sowing was by hand drilling in rows, fertilizer and Management practices were uniformly applied at all locations x years following standard agronomic recommendation for sorghum in Ethiopia. Data were recorded for grain yield plot-1, which was latter, converted to ha-1.

C. Analysis of variance (ANOVA)

Analysis of variances (ANOVA) was conducted using PROC MIXED procedure of SAS 9.1 version (SAS, 2008) and Genstat 17th ed.(Genstat,2014) . LSD was used for mean separation. The locations were considered as random and genotypes as fixed effects, and a mixed effect model ANOVA was used for statistical analysis. In the ANOVA, sources of partitioned variances include blocks, treatments and error terms. The treatment was broken down into three components: G, E and GEI effects in the following equation (Ding *etal*.2007) **$Y_{ijr} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + b_j + \varepsilon_{ijr}$ (1)** where *yijr*, is the average value of the dependent variable of genotype *i* in environment *j* and block *r*, *μ* is a grand mean, *αi* is the effect of the *ith* genotype. *βj*, is the effect of the *jth* environment, *αβij* is the effect of the *ith* genotype by the *jth* environment, *bj* is the block effect at the *jth* environment and *ijr* ε , is the residual error term.

D. Stability Analysis

GE interaction analysis was done by GGE biplot, which uses singular value decomposition (SVD) to decompose GGE into two or more principal components. Each principal component consisted of a set of genotype scores multiplied by a set of environment scores, to generate a two-dimensional biplot (Ding *etal*.2007). In GGE biplots genotype plus genotype × environment (G + GE) interaction was studied together and to achieve this G + GE effect is separated out from the observed mean from Equation (1) (by omitting random error and block effect) and eventually model becomes as **$Y_{ij} - \mu - \beta_j = \alpha_i + \alpha\beta_{ij}$ (2)** The GGE (G + GE) effect was partitioned into multiplicative terms by using SVD. The model based on singular value decomposition (SVD) of first two principal components is: **$Y - \mu - \beta = \lambda \xi \eta + \lambda \xi \eta + \varepsilon$ (3)** where *Yij* is the measured mean of genotype *i* in environment *j*, μ is the grand mean, is the main effect of environment *j*, *j* β being the mean yield across all genotypes in environment *j*, 1 λ and 2 λ are the singular values (SV) for the first and second principal components (PC1 and PC2), respectively, and 1*i* ξare eigenvectors of genotype *i* for PC1 and 2 *i* ξ for PC2, respectively, 1 *j* η and 2 *j* η are eigenvectors of environment *j* for PC1 and PC2, respectively, *ij* ε is the residual associated with genotype *i* in environment *j* (Ding *etal*.2007)

III. RESULTS AND DISCUSSION

A. Analysis of Variance

The analysis of variance for grain yield (kg/ha)presented (Table 3) years(2010&2012) displayed the highest contribution of genotype followed by location was the most important source of grain yield(GY kg/h) variation that accounted 60,95%, 31.48% in 2010 and 49.37%, 38.09% in 2012. Where as in 2011 location followed by genotype expressed the highest source of grain yield (GY kg/h)variation 42% and 34.68% respectively. On the other hand the contribution of genotype by environment interaction was 7.57% , 23.56% and 12.54% in 2010, 2011 and 2012 respectively which indicated the minimal contribution of GE to the total variation for grain yield(GY kg/h).

Combined analysis of variance over three years and seven location revealed highly significant variations for the location, genotype, year and genotype by environment interaction effect (Table 3).The result indicated that mean grain yield (GY kg/ha) was significantly influenced by Year(Y), Environment (Y x L) and Genotype(G) which accounted for 37.57 % , 16.92% and 13.22% of the total variation, while Location(L) and Genotype by location (G x L) displayed 8.92 % and 4.62 % of the variation, respectively. Differences among the environments were significant indicating that they were diverse (Table 3). The GxE was significant showing variable performance of the genotypes in the various environments. The result indicated that there was highest variation in grain yield (GY kg/ha) due to inconsistence in rain fall pattern, distribution and temperature across each location in each year. In line with the current study (Assefaw ,2007 and Gasura *etal*.,2015) reported significant variation in GE and GEI. Generally this research finding gives an information to the breeders who intended to work on intermediate altitude sorghum improvement that to consider the impact of rain fall patter, distribution and temperature as well as location in their future pedigree breeding and evaluation.

Table 3: Analysis of variance for grain yield involving 25 genotypes evaluated at Bako, Jimma and Mechara in 2010, 2011 and 2012.

Year/s	Source of variation	DF	Sum of square(SS)	Mean square(MS)	% Contribution of (L + G + GL)
2010	Location(L)	1	143074919.0	143074919.0**	31.48
	Genotype(G)	24	277044706.5	11543529.4**	60.95
	Genotype x Location(GL)	24	34396237.6	1433176.6**	7.57
	Error	147	85077662.9	578759.6	
2012	Location(L)	1	89458995.6	89458995.6**	38.09
	Genotype(G)	24	115926717.9	4830279.9**	49.37
	Genotype x Location(GL)	24	29433794.4	1226408.1**	12.54
	Error	147	104405387.2	710240.7	
2011	Location(L)	2	90319433.17	45159716.59**	42.06
	Genotype(G)	24	74475979.81	3103165.83**	34.68
	Genotype x Location(GL)	48	49942601.05	1040470.86**	23.26
	Error	222	110390776.6	497255.8	
					% Contribution of (L + G + Y + GL + GY + GYL)
Combined	Location(L)	2	120634997.5	60319748.7**	8.92
	Genotype(G)	24	178965839.1	7456910.0**	13.22
	Year(Y)	2	508617481.3	254308740.6**	37.57
	Genotype x Location(GL)	48	62561572.3	1303366.1**	4.62
	Genotype x Year(GY)	48	228909422.4	4768946.3**	16.92
	Location x Year(LY)	2	202213850.4	101106925.2**	14.92
	Genotype x Location x Year(GLY)	48	51211060.8	1066897.1**	3.83
	Error	522	310204167	5942261	

** Highly significant at(p<0.01)

B. Mean Performance of Genotypes

The overall mean performance of the 24 genotypes entries along with the one standard check evaluated for grain yield and related agronomic traits evaluated at Jimma, Bako and Mechara were given in Table 4. In the current findings of seven environment and threes location combined analysis of data (Table 4) indicated significant effect of genotypes for most grain yield(kg/ha) . Genotype10 (4308.25kg/ha), Genotype 3 (4176.44 kg/ha), Genotype 4 (4150.07kg/ha), Genotype 7(4138.24 kg/ha), Genotype 15(4093.84 kg/ha) and Genotype 2 (4027.76 kg/ha) respectively expressed higher grain yield, while Genotype 20(2431 kg/ha) Genotype 13(2648.93 kg/ha) and Genotype17 (2757.44kg/ha) showed lower grain yield kg/ha . In agreement with this study many researchers (Taye,2006; Girma, 2006; Dagne *et al*., 2010; Zerihun, 2011; Alemenesh, 2012 and Nigus, 2012) in their studies reported that experimental varieties showed better performance than the best check for most of yield and other traits.

In the current finding, Genotype 10, Genotype 3, Genotype 4, Genotype 7, Genotype 15 and Genotype 2 are displayed 17.9%, 15.31 %, 14.77%, 14.53%, 13.60% and 12.19% yield advantage over standard check Geremew respectively. Hopefully, these outstanding candidate will be submitted as candidate genotypes for variety verification trail to be evaluated by variety verification committee and to be released for commercial production purpose in the 2016/17 cropping season.

The mean performance of tested genotypes across testing years and locations ranged from 3536.976 Kg/ha ranging from 2431.94 kg/ha to 4308.25 kg/ha. Genotype 2 had superior grain yield (kg/ha) at Bako and Jimma in 2010, while inferior at Jimma in 2011 and at Bako in 2012. This expressed the presence of cross over interaction across the testing site and years. Mean grain yield (kg/ha) of testing environments varied from 1996.67 kg/ha for Jimma 2011 to 4663.04 kg/ha for Jimma 2010 . This result displayed that the impact of year after year variation of rainfall pattern, distribution etc on grain yield. The highest yield difference of grain yield due to Location(testing site) and years, which is irrelevant to genotypes evaluation and mega environment investigation (Yan *etal*.2000) justifies selection of site regression as the appropriate model for analyzing the multi-environment trials' data. Hence, the grain yield (kg/ha) data of Intermediate altitude pedigree sorghum genotypes was subjected to GGE biplot analysis.

Table 4: Estimates of mean values for grain yield

Genotype code	Genotype	During 2009 GY(kg/ha)		During 2010 GY(kg/ha)			During 2011 GY(kg/Ha)		Combined GY(kg/ha)
		Bako	Jimma	Bako	Jimma	Mechara	Bako	Mechara	
1	07MW 6001	4488.89	6869.57	2522.22	2255.56	3111.11	1883.78	3988.75	3588.55
2	07MW 6002	4955.56	6673.91	3077.78	1802.22	4066.67	2722.44	4895.75	4027.76 6th
3	07MW 6009	5133.33	7521.74	3000.00	2377.78	4000.00	2944.22	4258.00	4176.44 2nd
4	07MW 6013	3088.89	5739.13	4477.78	2716.67	4088.89	3777.11	5162.00	4150.07 3rd
5	07MW 6031	3666.67	5652.17	2111.11	1644.44	2600.00	1452.22	3893.50	3002.87
6	07MW 6033	3622.22	6391.30	2644.44	1888.89	3600.00	1711.56	2248.75	3158.17
7	07MW 6035	4200.00	7521.74	3100.00	2226.67	4044.44	3399.56	4475.25	4138.24 4th
8	07MW 6036	4666.67	6326.09	3533.33	1866.67	2688.89	3723.33	4366.50	3881.64
9	07MW 6040	3600.00	5739.13	2422.22	2004.44	2644.44	1583.33	4191.25	3169.26
10	07MW 6052	3777.78	6173.91	4333.33	2344.44	4555.56	4046.22	4926.50	4308.25 1st
11	07MW 6054	4555.56	4652.17	3255.56	1813.33	2755.56	2399.11	4766.50	3456.83
12	07MW 6061	4533.33	5739.13	2977.78	2204.44	3688.89	4022.67	4019.75	3883.71
13	07MW 6064	438.11	354.35	3855.56	1522.22	3488.89	4016.67	4866.75	2648.93
14	07MW 6073	4311.11	6043.48	3844.44	3037.78	3200.00	1570.67	3944.25	3707.39
15	07MW 6085	4311.11	5304.35	4877.78	2733.33	4044.44	2616.89	4769.00	4093.84 5th
16	07MW 6092	4066.67	5750.00	3166.67	2462.22	3288.89	2970.44	4289.00	3713.41
17	07MW 6097	1288.89	2586.96	2677.78	1377.78	2600.00	3578.67	5192.00	2757.44
18	03 MW 6125	4044.44	6500.00	3177.78	2004.44	3177.78	2494.22	3795.75	3599.20
19	97 MW 5044-2	3600.00	5782.61	2266.67	2404.44	3311.11	3323.33	4375.50	3580.52
20	97 MW 6141	3355.56	5032.61	1300.00	1411.11	2333.33	1969.00	1622.00	2431.94
21	E 237	4355.56	5206.52	2788.89	1655.56	3377.78	1539.56	2929.00	3121.84
22	03 MW 6135	3733.33	5402.17	3088.89	2268.89	2266.67	2632.22	3795.75	3312.56
23	02 BK 7072	4311.11	5239.13	4100.00	1255.56	2888.89	1728.11	3318.00	3262.97
24	03 MW 6120	4266.67	6173.91	2166.67	2211.11	3155.56	2850.44	4091.00	3559.34
25	Geremew(standardcheck)	4377.78	4663.04	4211.11	1966.67	2933.33	3742.67	3958.00	3693.23
	R Square	**0.748113**	**0.82582**	**0.708984**	**0.572452**	**0.596622**	**0.542111**	**0.702213**	**0.816571**
	P level	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.0001**	**<.0001**	**<.0001**	**<.0001**
	LSD Value	**989.46**	**1139.9**	**1072.4**	**633.93**	**990.13**	**1391.8**	**943.47**	**404.74**
	CV	**18.14**	**14.54**	**24.08**	**21.85**	**21.44**	**35.93**	**16.38**	**21.74**
	Mean	**3869.969**	**5561.565**	**3159.111**	**2058.267**	**3276.444**	**2747.938**	**4085.540**	**3536.976**

C. Stability Analysis

1. Comparison Biplot of 7 Test Environments: The average environments coordinate (AEC) is a line that pas through the average environment (represented by small circle) and biplot origin. A test environment that has a small angle with the AEC is more representative of other test environments (Yan *etal*.2000 and Yan *etal*.2006). Thus, Mechara 2010 were more representative testing location followed by Jimma 2010 and Bako 2010. Since MH10, JM10 and BK10 respectively had better discriminating power (Figure 1) as well as representativeness, it was identified as good testing environment for selecting widely adaptable and high yielding Intermediate altitude Sorghum genotypes in Ethiopia. In agreement with this finding Gasura etal(2015)) in their finding reported the existence of a good testing environment for selecting widely adaptable and high yielding cultivar.

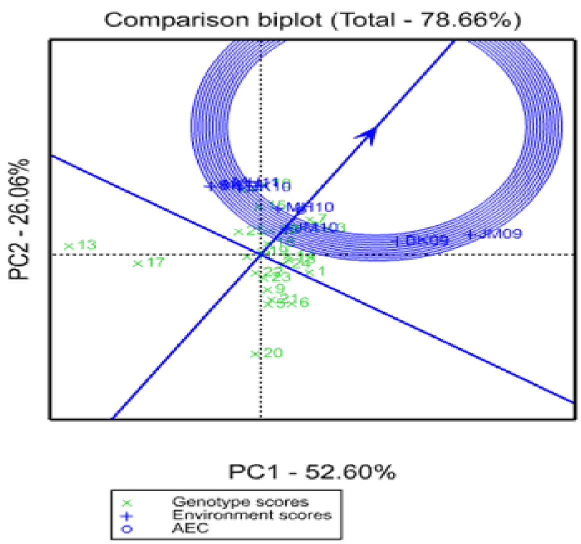

Figure 1: GGE-biplot showing a comparison of 7 testing environments with in **ideal environment** for grain yield (kg/ha)

2. Mean Performance and Stability of Genotypes Using Biplot: The Biplot analysis indicated that the AEC view of the GGE biplot. The average tester coordinate (ATC) separates genotypes with above average mean from below average means. Thus, genotypes with above average means were G10, G3, G4,G7,G15 and G2, while G20,G17 and G20 were genotypes which had below average mean performance (Figure 2). The shorter the genotype vector is more stable it is than others. Thus, among tested genotypes G10,G3,G4,G7,G15 and G2 were identified as high yielder and stable genotype while G20, G17 and G13 were identified as low yielding with poor stability (long vector length). In agreement with this finding (Gasura *etal*.2015) in their finding reported high yielder and stable genotype as well as low yielding and poorly stable genotypes.

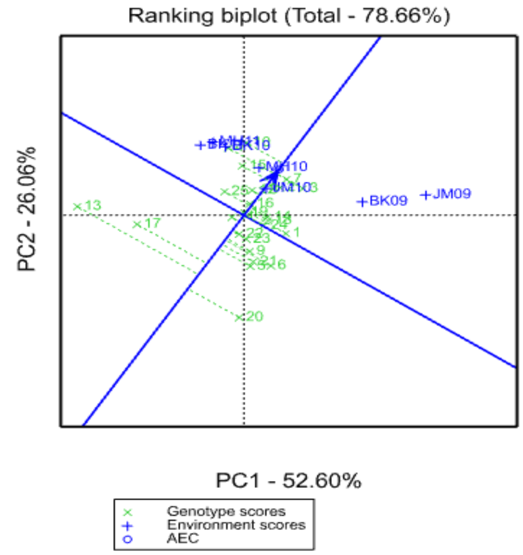

Figure 2: GGE ranking biplot indicates the mean grain yield and stability performance of 25 tested genotypes.

3. Comparison of genotypes with ideal genotypes using biplot:

An ideal genotype should have both high mean yield performance and high stability across environments. It is a genotype to be on average environmental coordinate (AEC) on positive direction and has vector length equal to the longest vector of the genotype and indicated by a arrow pointed to it(Yan *etal*.2006 and Kaya *etal*.2006). The Biplot indicated that G10 is the most ideal genotypes, where as G3,G4,G7,G15 and G2 respectively were nearest to the ideal genotype (the center of concentric circles) so these genotypes are more desirable and ideal genotypes than other tested genotypes. In line with this finding (Gasura *etal*.2015) in their finding found the presence of that ideal genotype.

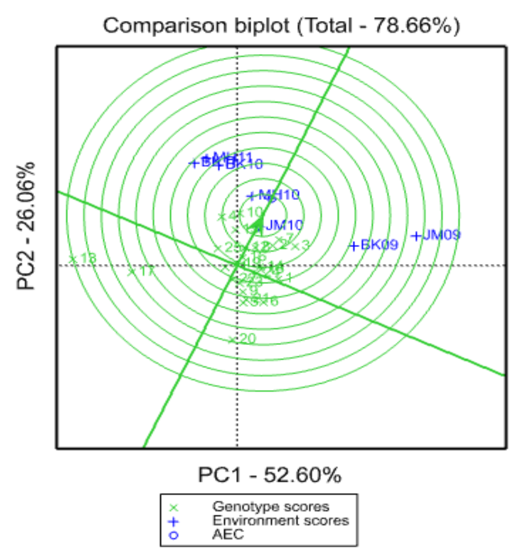

Figure 3: GGE-biplot showing a comparison of all genotypes with in ideal **genotypes** for grain yield (kg/ha)

CONCLUSION AND RECOMMENDATION

The present study consisted of 24 genotypes along with one popular standard check were evaluated at Jimma, Bako and Mechara in Ethiopia during the 2010,2011 and 2012 cropping season with the objective of assessing the nature and magnitude of GEI and determine the response of different genotypes to varying environments to identify high yielding stable sorghum genotypes for intermediate altitude of Ethiopia. Combined analysis of variance for grain yield (kg/ha) over three years and seven location revealed highly significant variations for the location, genotype, year and genotype by environment interaction effect. The analysis of variance(Table 3) based on years displayed the highest contribution of genotype followed by location was the most important source of grain yield(GY kg/h) variation that accounted 60,95%, 31.48% in 2010 and 49.37%, 38.09% and in 2012. Where as in 2011 location followed by genotype expressed the highest source of grain yield (GY kg/h)variation 42% and 34.68% respectively. On the other hand the contribution of genotype by environment interaction was 7.57% , 23.56% and 12.54% in 2010, 2011 and 2012 respectively which indicated the minimal contribution of GE to the total variation for grain yield(GY kg/h).

In the current study , of seven environment and three locations combined analysis of data (Table 4) indicated significant effect of genotypes for most grain yield(kg/ha) . Genotype10 (4308.25kg/ha), Genotype 3 (4176.44 kg/ha), Genotype 4 (4150.07kg/ha), Genotype 7(4138.24 kg/ha), Genotype 15(4093.84 kg/ha) and Genotype 2 (4027.76 kg/ha) respectively expressed higher grain yield, while Genotype 20(2431 kg/ha) Genotype 13(2648.93 kg/ha) and Genotype17(2757.44kg/ha) showed lower grain yield kg/ha . From the current finding, Genotype 10, Genotype 3, Genotype 4, Genotype 7, Genotype 15 and Genotype 2 were displayed 17.9%, 15.31 %, 14.77%, 14.53%, 13.60% and 12.19% yield advantage over standard check Geremew respectively. Hopefully, these outstanding candidate will be submitted as candidate genotypes for variety verification trail to be evaluated by variety verification committee and to be released for commercial production purpose in the 2016/17 cropping season.

Mechara 2010 was more representative testing location(Envoronment) followed by Jimma 2010 and Bako 2010. MH10, JM10 and BK10 had better discriminating power (Figure 1) as well as representativeness, it was identified as good testing environment for selecting widely adaptable and high yielding Intermediate altitude Sorghum genotypes in Ethiopia.

Genotypes with above average means were G10, G3, G4,G7,G15 and G2, while G20,G17 and G20 were genotypes which had below average mean performance (Figure 2). The shorter the genotype vector is more stable it is than others. Thus, among tested genotypes G10, G3, G4, G7, G15 and G2 were identified as high yielder and stable genotype while G20, G17 and G13 were identified as low yielding with poor stability (long vector length). The biplot indicated that G10 is the most ideal genotypes, where as G3, G4, G7, G15 and G2 respectively were nearest to the ideal genotype (the center of concentric circles) so these genotypes are more desirable and ideal genotypes than other tested genotypes.

From these finding ideal genotype and ideal environment for grain yield were successfully identified. These germplasm constitute a source of valuable genetic material that could be used for future Intermediate altitude Sorghum breeding program. Generally, the results of this study could be useful for researchers who need to develop high yielding, grain and leaf disease resistant variety of Sorghum adapted to intermediate agro-ecology of Ethiopia.

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