

Evaluation of Sorghum (Sorghum bicolor (L) Moench) Varieties and Environments for Yield Performance and Stability

Kinde Lamessa* Gebeyehu Chala Abubeker Tarbush Dadi Gudeta Shanene Haile Abdela Usmael
Oromia Agricultural Research Institute (IQQO), Mechara Agricultural Research Center (McARC), P.O. Box: 19, Mechara, Ethiopia

Abstract
Sorghum is a major food crop grown in Western Hararghe, accounting for 59.3% followed by maize 32.8%, and tef 4.15% of the total cultivated areas. The objectives of this study was to evaluate the adaptability and stability of released sorghum (Sorghum bicolor (L) Moench)) varieties at three location in West Hararghe, Ethiopia. Five sorghum varieties (Mesay, ESH-1, Meko, Chare and Girana-1) were planted in Randomized Complete Block design (RCBD) in three locations, with three replications. The AMMI analysis of variance for grain yield showed that the main effect of Variety (V), environment (E), and G X E account for 4.5, 86.9 and 2.3 % of the total variation, respectively. The variety ESH-1 (38.67 Qut ha^{-1}) produced the highest grain yield than other varieties while the lowest grain yield was recorded in Mako variety (28.89 Qut ha^{-1}). ESH -1 resulted in higher yield advantage than Girana-1 (13.21%), Mesay (22.4%), Chare (24.4%) and Mako (25.29%). Environments were positively correlated one another. Miesso and Hawi Gudina were moisture stress area and suitable environment for sorghum production than Mechara. The result clearly indicated that ESH-1 and Girana-1 were the tolerable variety than other variety at all locations. Finally ESH-1 and Girana-1 was preferred for further demonstration and promotion in low moisture stress area of West Hararghe to contribute to food security in the area.
Keywords: AMMI model, Environment X variety interaction, Sorghum variety

INTRODUCTION

Genotype X environments interaction continue to be a challenging issue among plant breeder, geneticists, and production agronomists who conduct crop performance trials across diverse environments. Yield stability influenced by genotype X environments interaction (Asfaw, 2007a). The phenotypic performance of a genotype is not always the same in different locations as it is influenced by abiotic and biotic environmental factors. Some genotypes may perform well in one environment, but, fail in several others. Yield and quality traits are influenced by genotype (G) , environmental factors (E) and the interaction between genotype and environment (Alberts, 2004).

Sorghum (*Sorghum bicolor (* L).*Moench*) is a monocotyledon crop belonging to the family Gramnieae. It is naturally self pollinated short day plant with the degree of spontaneous cross pollination, in some cases, reaching up to 30% depending on panicle types. Sorghum is a viable food grain for many of the world's mostly for food insecure people who live in marginal area with poor and erratic rains and often poor soils (AATF, 2011). Sorghum is among the most important grain crops in the world including Ethiopia. Because of its multiple purposes and ability to cope up with unfavorable growing conditions. Sorghum will continue to feed the world's expanding populations. Moreover sorghum will be the crop of the changing global climatic trends and increase in use of marginal lands for agriculture (Paterson *et. al*., 2008).

Sorghum is cultivated both in tropical and temperate climates, it is best known for its adaptation to the drought prone semi-arid tropical (SAT) regions of the world. 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. It serves as a staple food for more than 500 million people in the semi arid tropics of Africa and Asia. It is also used for preparing traditional beverages. It is a highly reliable crop that that grows well in hot, dry environments . It is climate change ready and provides food security and income for farmers.

Sorghum (*Sorghum bicolor* (L) *Moench*) is the fifth most important cereal crop in the world (FAO, 2005). It is cultivated in wide geographical area . Sorghum is a viable food grain for many of the world's most food insecure people who live in marginal areas with poor and erratic rains and often poor soil. In Ethiopia , sorghum is the third most important crop after tef and maize in terms of area coverage and the second most important cereal crop in total production next to maize (CSA, 2012). Sorghum production is estimated to be four million metric tons from tons from two million hectares of land, giving the average grain yield of two tons per hectare. It accounts for 16% of the total area allocated to grain crops such as cereals , pulses and oil crops and it also accounts for 20% of the area covered by cereals (CSA, 2015). In Ethiopia, sorghum was cultivated on 1.78 million hectare with a production of 3.47 million metric tons and the average yield of 1.95 ton ha^{-1} during 2010-2011 (CSA, 2012). The livelihood millions of Ethiopians depends on this staple food crop. It remains to be primary source of food in Ethiopia (Asfaw, 2007b). Besides, it has tremendous uses for the Ethiopia farmers and no parts of the plant are ignored. Sorghum is a major food crop grown in Western Hararghe, accounting for 59.3% followed by maize 32.8%, and tef 4.15% of the total cultivated areas (CSA, 2012).

The area of sorghum in Africa has steadily increased over the years but the average yield trends are downwards. Paramount among the yield reducing factors are predominant cultivation of inherently low yielding varieties, poor soil fertility, drought, Striga, pests and diseases. In spite of the importance of the crop farmers in the region grow local cultivar which is low yielder and susceptible to disease. With the frequent and cyclical occurrence of drought and erratic rainfall, it could be an insurance crop to the small-scale resource-poor farmers constituting the majority of the rural farming community in Ethiopia. The objectives of this study was to evaluate the adaptability and stability of released sorghum *(Sorghum bicolor (L) Moench))* varieties at three location in West Hararghe, Ethiopia

MATERIALS AND METHODS

Experimental materials

Four released sorghum varieties (Chare, ESH-1, Meko and Mesay) and one standard check (Girana-1) were introduced from Melkasa and Sirnka Agricultural Research Center and one adaptable and recommended variety (Girana-1) as standard check (Table 1).

Table 1. Description of variety

S.N	Name of variety	Year of release	Breeding location
1	Chare	2011	Debre Birhan Agricultural Research Center
2	ESH-1	2009	Melkasa Agricultural Research Center
3	Girana-1	2007	Sirnka Agricultural Research Center
4	Meko	1997	Melkasa Agricultural Research Center
5	Mesay	2011	Sirnka Agricultural Research Center

Description of study site

The evaluation of improved (early maturing) sorghum varieties were done in three locations, namely, Mechara, Miesso and Hawi Gudina. Mechara is found at an altitude of 1700 m.a.s.l at 40^{o} 19' North latitude and 08^{o} 35' East longitude. The major soil type of the center is sandy clay with reddish color. Mechara is located in Daro Labu district of West Hararghe Zone, Oromia Regional State and 12% of its area lies in the high land, 44% in the mid-high land and 44% in the low land agro ecological zones. The rainfall in this area is usually irregular; there is also rainfall variability in the onset and cessation of the main rainfall. Farming systems of Daro Labu district constitute complex production units involving a diversity of interdependent mixed cropping and livestock activities. The area is predominantly cereal producing with sorghum and maize as staple food crops; the major annual crops grown include sorghum, maize, ground nuts, sweet potato, wheat, common beans and barley. In addition, the major cash crops, like chat and coffee, have a long-standing tradition in the district (Kinde *et.al.,* 2015). Miesso is found at an altitude of 1570 m.a.s.l. The major soil type of Miesso is dominated by silt clay loam soil texture. The farming system of Miesso is dominated by crop production; the major annual crops grown include sorghum, maize, sesame and haircot bean as staple and cash crops (Kidane *et al*., 2006). Hawi Gudina is located at an altitude of 1430 M.a.s.l at 7^{o} 52' 15" North latitude and 43^{o} 34' 13" East longitude. The rainfall distribution and amount is of the area is erratic. Livestock production is one of the major components of farming system. In addition crop like sorghum, maize, coffee, groundnut, are major crop produced in the area. Coffee and groundnut are the major cash crops in the district (Fekede *et.al.,* 2016) All these areas are major part of sorghum production in West Hararghe zone.

Crop husbandry

The varieties were planted in four rows of 5m length with an inter-row spacing of 75cm and with an intar row spacing of 30cm. Sorghum seed were drilled at seed rate 10 kg ha^{-1} in the row and were later thinned at three weeks after planting (WAP) at appropriate spacing. The plot size 15.30 m^{2} (4 rows x 75cm row spacing x 5m length and 30cm spacing between plants) with standard check (Girana-1) was employed for the study. 100/100 kg ha^{-1} urea/DAP (urea in two splits application, half at planting and half at 45 days weeks after planting) was applied. Other agronomic management were applied as per recommendation.

Experimental design, data collection and analysis

Yield and yield component data were collected. The five varieties were evaluated in randomized complete block design (RCBD) with three replications**.** The analysis of variance (ANOVA) was carried out using statistical packages and procedures out lined by Gomez and Gomez (1984) appropriate to randomized complete block design using GenStat computer software version 13.3 and meta analysis used for AMMI model. Mean separation was carried out using least significant difference (LSD) at 5% probability. Combined analysis was done in order to determine the difference between genotype across location during 2013 cropping season.

RESULT AND DISCUSSION

Yield Qut ha^{-1}: The analysis of variance (ANOVA)showed that yield was significantly ($P \leq 0.05$) affected due to main effect of variety and location. The highest yield was recorded in ESH-1 variety (38.67 Qut ha^{-1}) and the lowest was recorded in Mako variety (28.89 Qut ha^{-1}) (Figure 1).The highest (54.93 Qut ha^{-1}) and lowest (19.27 Qut ha^{-1}) yield was recorded at Miesso and Mechara respectively (Table 2). The interaction of variety with location was not significant due to interaction effect. Similar result was reported by (Tekle and Zemach, 2014) sorghum grain yield was influenced by variety. In agreement with the finding of Hussain *et.al*, (2011) different sorghum variety has different grain yield weight than other. Also in line with the work of (Abush *et.al*, 2001) grain yield was significant difference due to variety, location and the interaction of variety with location.

Stand count at harvest : The analysis of variance (ANOVA) showed that stand count at harvest was significantly ($P \leq 0.05$) affected by main effect of variety and location. The highest stand count was recorded in ESH-1 variety (80 plant plot $^{-1}$) while the lowest was recorded in Chare variety (59 plant plot^{-1}) but statistical non significant from other variety. The highest stand count was recorded at Mechara (71 plant plot $^{-1}$) while the lowest and similar result was recorded at Miesso and Hawi Gudina (63 plant plot $^{-1}$) . The result clearly indicated that at moisture stress area influence stand count at harvest of sorghum and decreases plant population per plot. The interaction of variety with location plays significant role in stand count at harvest. The result in agreement with the findings of result (Abush *et.al.,* 2001) location significantly affected stand count at harvest.

Days to 75% flowering: The analysis of variance (ANOVA) showed that days to 75 % flowering was significantly ($P \leq 0.05$) different due to main effect variety and location. This in agreement with the finding of different result (Tekle and Zemach, 2014; Hussain *et.al*., 2011) days to flowering was affected due to variety and location. This might be due to genetic difference of the genotype in response to flowering and location also shows significantly difference on days to flowering. Late days to 75% flowering was recorded due to Mechara but not significantly difference due to Miesso and Hawi Gudina.

Plant height: The analysis of variance (ANOVA) showed that plant height was significantly ($P \leq 0.05$) different due to main effect variety and location. The highest plant height was recorded in Girana-1 variety (163cm) and the lowest was recorded in Mako variety (148 cm). The highest (175cm) and lowest (141cm) plant height was recorded at Miesso and Hawi Gudina respectively. The interaction of variety with location was not significant due to interaction effect.

Days to maturity : The result showed that days to maturity was not significantly different due to main effect of variety but it was significantly affected ($P \leq 0.05$) days to maturity. The highest days to maturity was recorded at Mechara (140 days)and the lowest was recorded at Miesso (112 days). The interaction of variety with location was not significant on days to maturity. Similar result was reported by (Tekle and Zemach, 2014) days to maturity was influenced by variety. In agreement with the finding of Hussain *et.al*, (2011) different sorghum varieties had different days to maturity; this might be the genotype /variety has different growth degree days. Also in line with the work of (Abush *et.al*, 2001) days to maturity was significantly affected by variety, location and the interaction of variety with location.

Head weight per plant : The result of the analysis also showed that head weight per plant was significantly ($P \leq 0.05$) different due to main effect variety and location. The interaction of variety with location was not significant due to head weight per plant.

Diseases : The analysis of variance (ANOVA) showed that diseases was significantly ($P \leq 0.05$) affected due to main effect of variety and location. The interaction of variety with location was highly significant role diseases occurs. The result in agreement with the findings of result (Abush *et.al.,* 2001) mean square due to variety, location and location x variety were significant grain mould, and anthracnose diseases.

Table 2. Main effect of variety and location on yield and yield components of sorghum.

Treatments	Yield Qt ha^{-1}	Days to 75% Flowering	Plant Height	Number of head per plant	Days to maturity	Head weight per plant	Diseases	Stand count at harvest
Variety (V)								
Mesay	30.00	72.0	153.0	85.2	122.0	74.6	1.44	64
Chare	29.22	79.0	154.0	82.4	123.0	64.7	2.667	59
Mako	28.89	67.0	148.0	87.1	121.0	58.1	1.44	63
ESH-1	38.67	67.0	159.0	100.9	122.0	81.3	1.33	80
Girana-1	33.56	76.0	163.0	92.2	125.0	76.9	1.11	63
LSD(5%)	5.33	24.0	8.6	13.67	NS	16.56	0.2493	13
Location (L)								
Mechara	19.27	77.0	150.0	78.3	140.0	54.2	1.4	71
Miesso	54.93	70.0	175.0	116.1	112.0	80.9	1.2	63
Hawi Gudina	22.00	69.0	141.0	74.7	117.0	78.2	2.2	63
LSD(5%)	4.13	1.9	6.64	10.59	5.96	12.83	0.193	10.39
V* L	NS	NS	NS	*	NS	NS	**	*
CV(5%)	17.2	3.5	11.7	15.8	6.5	24.1	16.1	21.2

*LSD= Least significant difference; CV= Coefficient of variation; NS= Not significant; *= significant at ($P \leq 0.05$) **= significant at ($P \leq 0.01$*

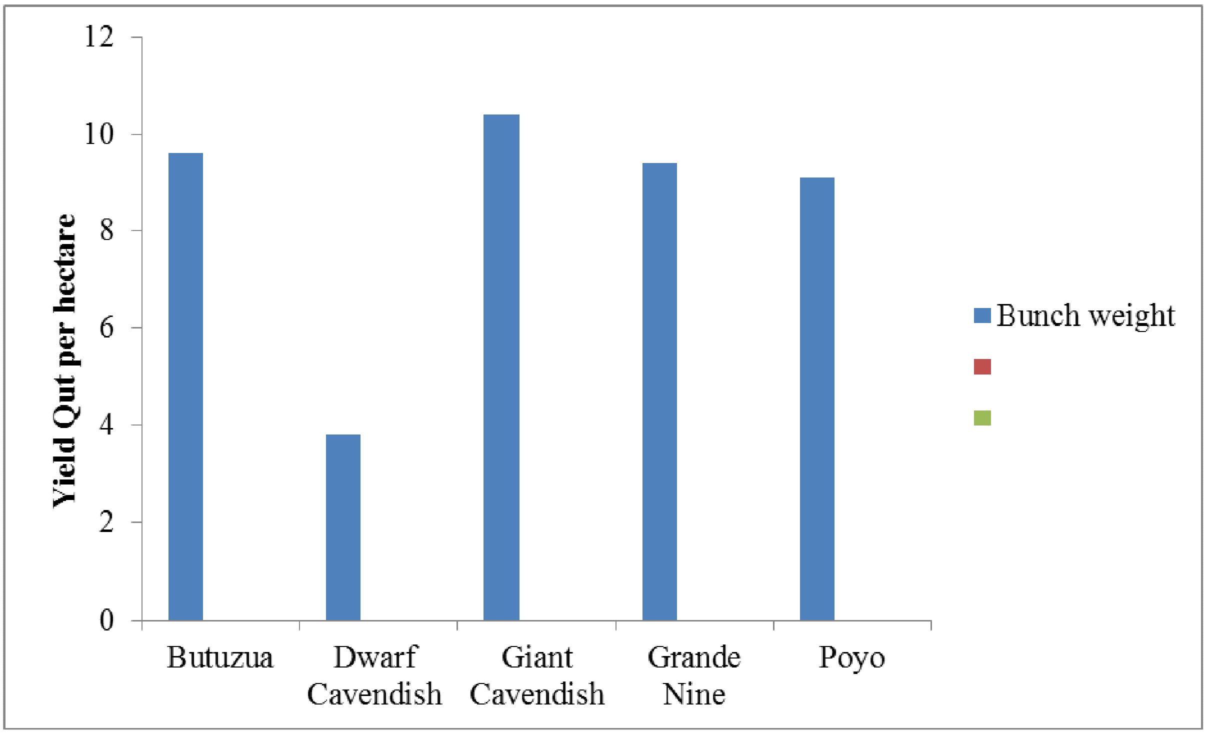

Figure 1. The grain yield of the sorghum variety in three location of west Hararghe.

Table 3. AMMI analysis by variety and environment mean score

Variety(v)	Variety mean	IPCAv(1)	IPCAv(2)
Mesay	30	1.6245	-0.328
Chare	29.22	-1.19993	1.56022
Mako	28.89	1.3189	0.6936
ESH-1	38.67	-1.8056	-1.2464
Girana-1	33.56	0.0622	0.0517
Environment(e)	Environment mean	IPCAe(1)	IPCAe(2)
Mechara	19.27	-2.14325	0.85845
Miesso	54.93	0.02463	1.74719
Hawi Gudina	22.00	2.11862	0.88874

Table 4. Analysis of variance table from AMMI model showing the effect of variety , environments and their interaction on grain yield performance of sorghum and interaction principal components in 2013 at three locations of West Hararghe, Ethiopia

Source of variation	**DF**	**SS**	**Ms**	**Explained SS(%)**
Variety (V)	4	614	153.5	4.53
Environment (E)	2	11821	5910.5	86.89
Treatment	14	12745	910.4	
VXE interaction (VEI)	8	310	38.8	2.28
Block	6	230	38.3	1.69
IPCA1	5	247	49.5	1.82
IPCA2	3	3	21.0	
Error	24	627	26.1	4.60
Total	44	13603	309.2	

The meta analysis indicated that variety ESH-1 (38.67 Qut ha^{-1}) was highest grain yielder than other varieties while the lowest grain yielder was recorded in Mako variety (28.89 Qut ha^{-1}). ESH -1 has high yield advantage than Girana-1 (13.21%), Mesay (22.4%), Chare (24.4%) and Mako (25.29%) (Table 3). The principal component (PC1) explained 82.01% of the total variation; while the principal component (PC2) explained 16.4% . Finally, these two principal components summed up to 98.2% which accounted for the total variation in grain yield. The AMMI analysis of variance for grain yield of variety tested in three environments showed that the main effect of V and E account for 4.53% and 86.89 variation respectively and VXE interaction effect represents 2.28% of the total variation for grain yield (Table 4). The analysis revealed that variance due to environment and variety was significant while VXE interaction was not significant. The small sum of square of variety indicated that the Variety were not diverse , the environment where the variety tested was very diverse. Large difference among environment means causing most of the variation in grain yield , which is in line with the findings of (Molla *et.al*., 2013; Maqsood and Ali, 2007; Mahto *et.al.,* 2006) in finger millet production. This result also indicated the overpowering influence of those environments have on the yield performance of sorghum variety in West Hararghe.

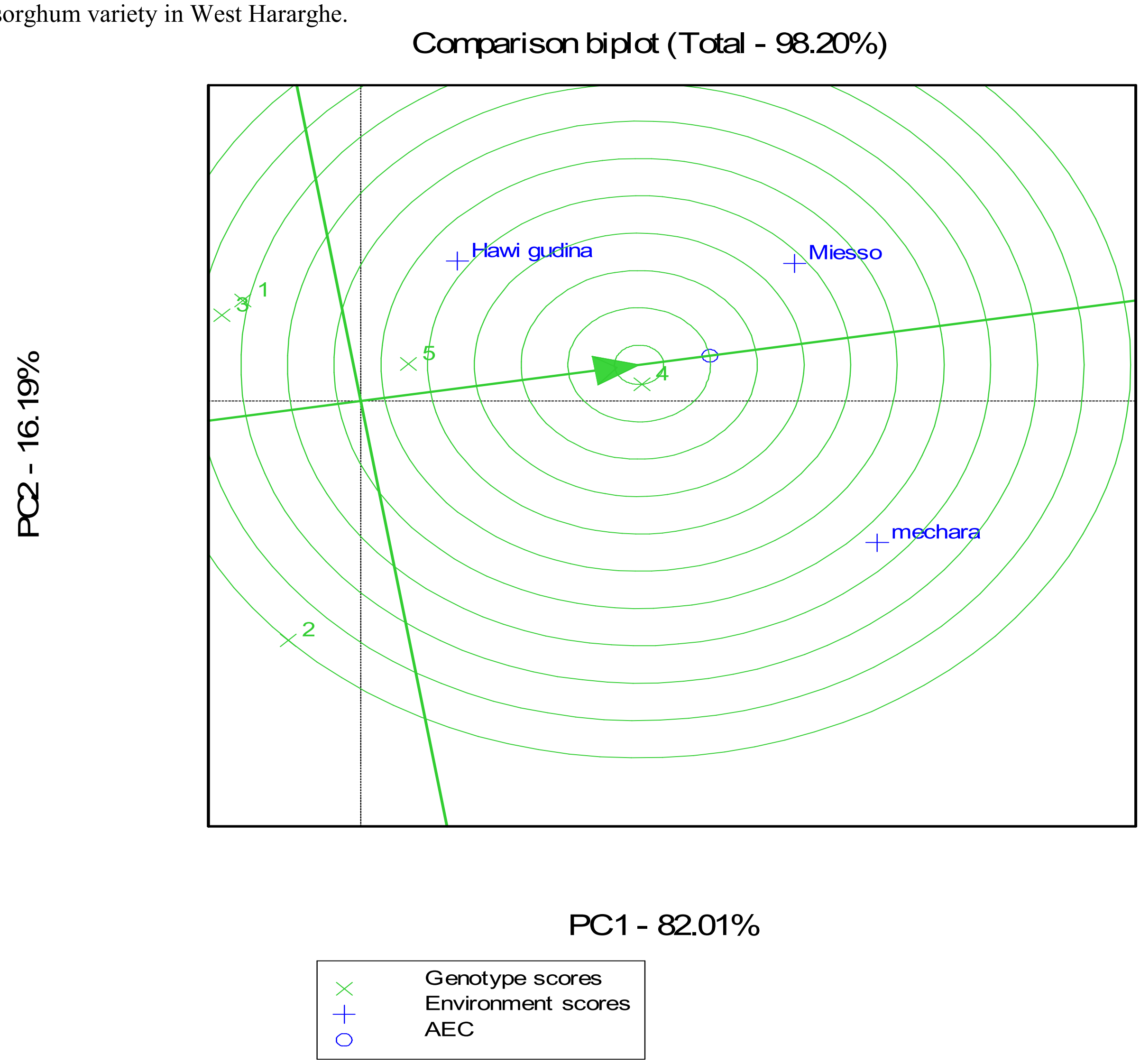

Figure 2. GGE Biplot for which won where pattern of variety by environment in grain yield of sorghum in West Hararghe

Genotype 4 (G4) / ESH -1 and genotype 5 (G5) Girana-1 was the winning genotype in all locations . This pattern suggests that G4 and G5 being the winning genotype , it would be selected for further demonstration and promotion in moisture stress areas of West Hararghe zone. However, genotype 5 (Girana-1) was less responsive than ESH-1. Genotype 1, genotype 2 and genotype 3 were indicating that they were low yield genotype as compared to Genotype 4. Variety showed consistent performance across all environments (Figure 3).

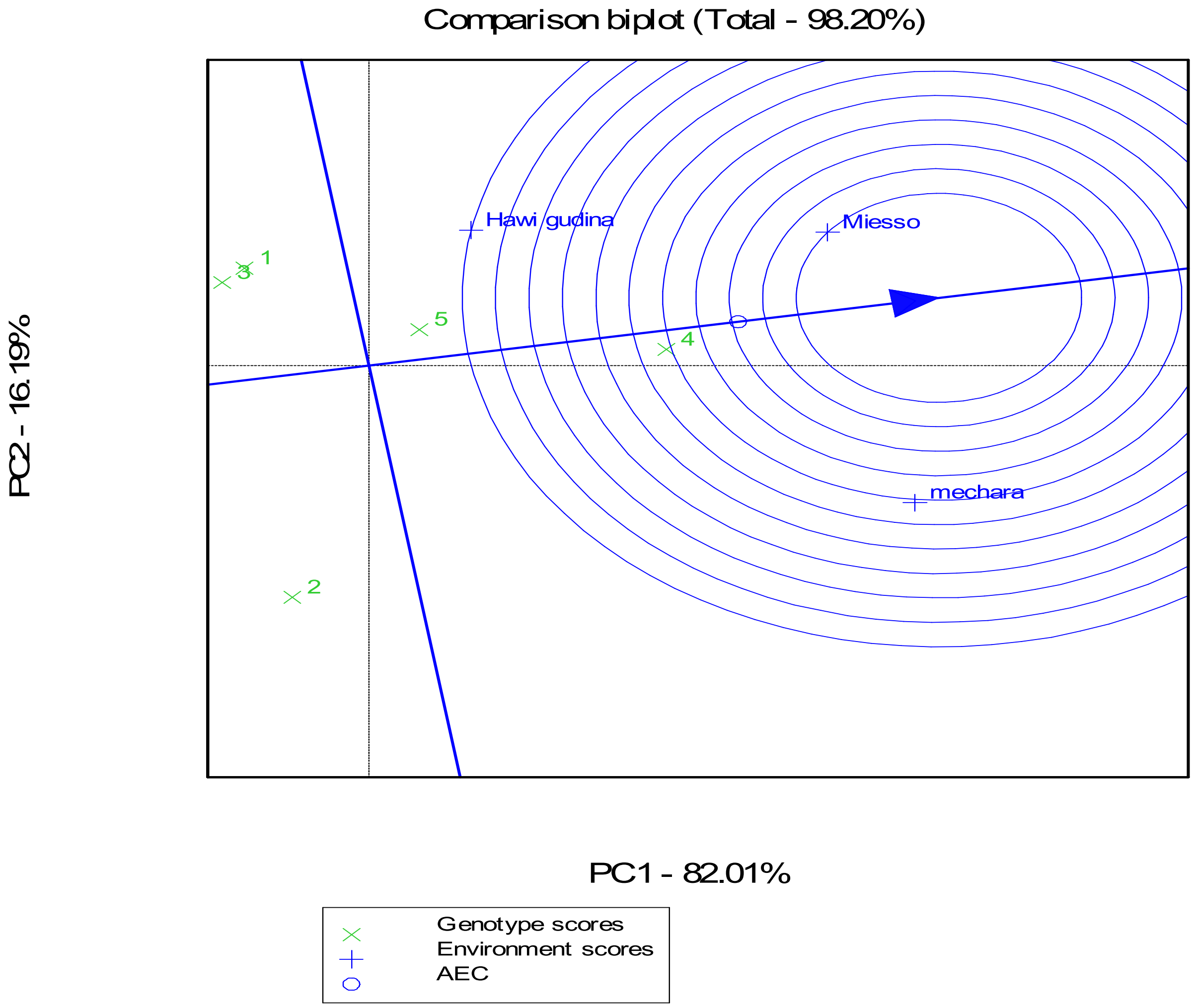

Figure 3. GGE Biplot of the relationship among three environment in grain yield of sorghum in West Hararghe

Miesso and Hawi Gudina were best locations for genotype 4 and 5 than Mechara. Environments were positively correlated with one another. Miesso and Hawi Gudina were moisture stress areas than Mechara. The result clearly indicated that ESH-1 and Girana-1 were the tolerable genotypes than other varieties at all locations (Figure 2).

CONCLUSION

The result indicated that the yield performance of sorghum was highly influenced by GE interaction effects ; the magnitude of environment greater than variety effect . Genotype 4 (G4) / ESH -1 followed by genotype 5 (G5) Girana-1 were the winning genotypes and the highest grain yielder for the three locations. These will be selected for further demonstration and promotion in low moisture stress areas of West Hararghe. However, genotype 5 (Girana-1) was less responsive than ESH-1. The result shows that Chare, Mako and Mesay were low yielding varieties as compared to ESH-1. Variety showed consistent performance across all environments. The highest grain yield was recorded at Miesso and Hawi Gudina than Mechara ; the location were favorable for variety ESH-1 and Girana-1 sorghum variety. Finally ESH-1 and Girana-1 were recommended for further demonstration and promotion in Moisture stress area of West Hararghe to contribute towards food security in the area.

ACKNOWLEDGEMENT

I would like to thank Oromia Agricultural Institute (IQQO) , Mechara Agricultural Research Center for financial support.

REFERENCE

AATF (African Agricultural Technology Foundation) (2011). Feasibility study on Striga Control in Sorghum Nairobi, *African Agricultural Technology* . ISBN 9966-775-12-19.
Abush Tesfaye, V.P Gupt and Ketema Belete (2001) . Genotype X environment interaction land race derived

Advanced Line of Sorghum (*Sorghum bicolor* L Moench). *Alemaya university* M.Sc thesis.
Alberts, M.J.A., 2004. A comparison of Statistical Methods to describe Genotype x Environment Interaction and Yield Stability in Multi Location Maize trials. PhD Thesis department of Plant sciences (Plant breeding), *Faculty of Natural and Agricultural Sciences of the University of the Free State*, Bloemfontein, South Africa, pp: 7-35.
Asfaw Adunga (2007a). Assessment of Yield Stability in Sorghum, *African Crop Science Journal* , vol.15,No, 2 pp 83-92.
Asfaw Adugna. (2007 b). The Role of Introduced Sorghum and Millets in Ethiopian Agriculture. Melkasa Agricultural Research Center. *An Open Access Journal Published by ICRISAT*. Volume 3 Issues 1, ICRISAT, India 1-3.
CSA (Central Statistics Agency) (2012). Report on Area and Crop Production Forecast for Major Crops. Statistical Bulletin. V.505. Addis Ababa, Ethiopia, pp.12-17.
CSA (Central Statistics Agency) (2015). Report on Area and Crop Production Forecast for Major Crops. Statistical Bulletin. Volume. I. Addis Ababa, Ethiopia, pp.12-50.
FAO. (2005). FAO STAT statistical data base for agriculture.
Fekede Gemechu. Lemma Zemedu and Jema Yousuf (2016). Determinants of Farm House Hold food security in Hawi Gudina District West Hararghe Zone, Oromia Regional National State Ethiopia. Journal of Agricultural Extension and Rural Development Vol8 (2), pp 12-18: DOI : 10.5897/JAERD 2014.0660
Gomez, K.A. and A.A. Gomez, (1984). Statistical Procedures for Agricultural Research. 2nd Edition. John Wiley and Sons Inc. Inter-Science Publications .New York. pp. 180-225.
Kidane G, Abebe T, Degefie T (2006). Estimating Crop Water Use and Simulating Yield Reduction for Maize and maize and Sorghum in Adama and Miesso districts using the cropwat model, Ethiopia Agricultural Research Institute , 1-14 p.
Kinde .L, Sharma JJ, Tessema T (2015). Influence of cowpea and Soybean Intercropping Pattern and Time of Planting on Yield and GMV of sorghum Based intercropping system . *International Journal of Plant Breeding and Crop Science*, 2(2): 043-045.
Mahto, R.N., Karmaker, S and Haider, Z.A. (2006). Genotype x Environment interaction study in finger millet. Zonal Research Station, Darisai, Birsa Agricultural University, Barakhursi, Singhbhum (East) 832304 India.
Maqsood, M. and Ali ,S.N. (2007). Effect of environmental stress on Growth, Radiation use efficiency and yield of finger millet. Pakistan Journal Botany, 39(2): 463-474.
Molla F, Alemayehu A, Ketema B (2013). AMMI Analysis of Yield Performance and stability of finger millet genotype Across Different Environments. *World Journal of Agricultural Science* 9 (3): 231-237: ISSN 1817-3047.
Paterson, A.H., Bowers. J.E. and Feltus .F.A. (2008). Genomics of sorghum, a semi-arid cereal and emerging model for tropical grass genomics, In: Paul H. Moore Ray Ming (Eds) Genomics of tropical crop plants. Springer Science + Business Media, LLc.233 spring street, New York , NY10013, USA, pp.469-482.