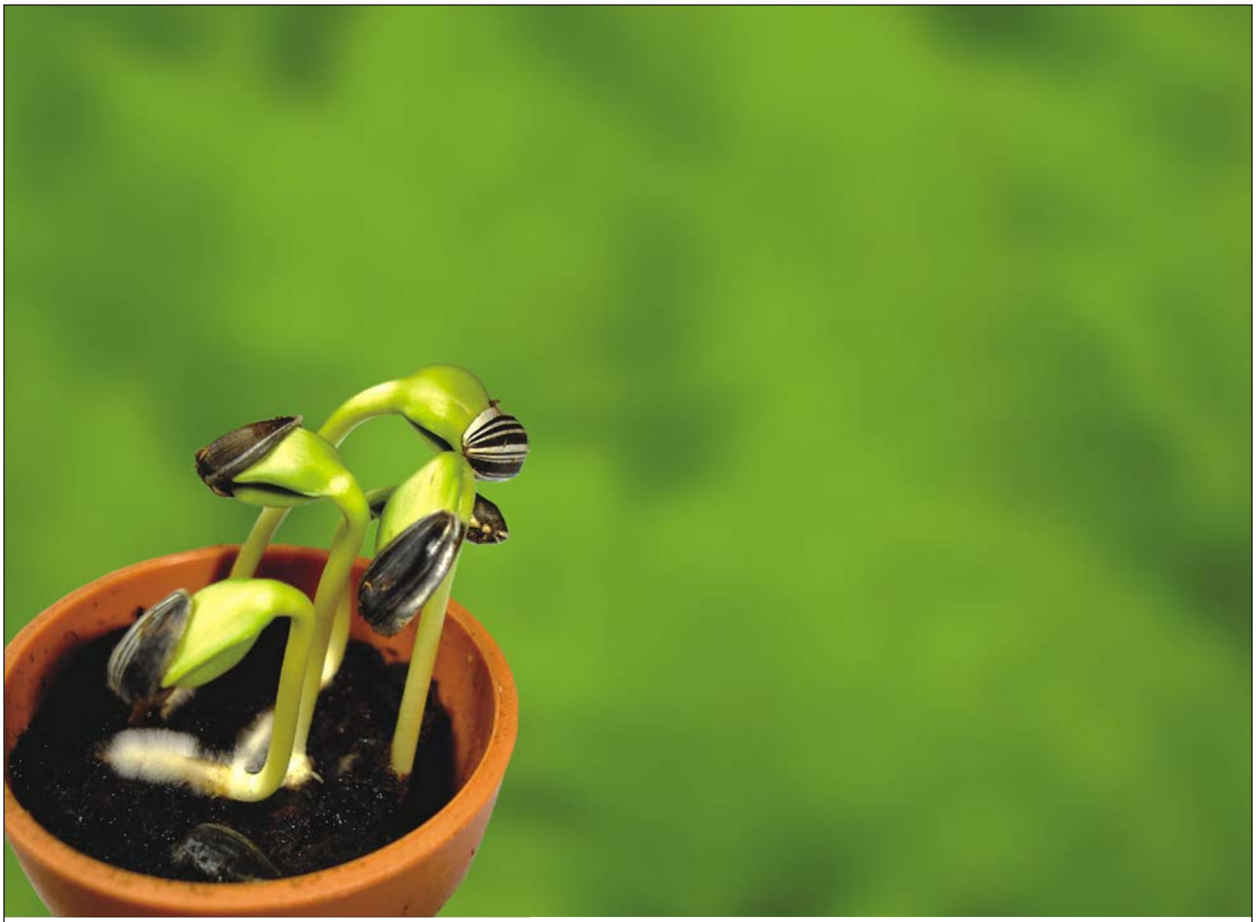

International Journal of
Plant Breeding and Genetics

ISSN 1819-3595

Academic Journals Inc.

www.academicjournals.com

International Journal of Plant Breeding and Genetics 9 (4): 247-254, 2015
ISSN 1819-3595 / DOI: 10.3923/ijpbg.2015.247.254

Genotype-Environment Interaction and Stability Analysis of Hybrid Maize Varieties in North West Ethiopia

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ABSTRACT

Maize (*Zea mays* L.) is one of the principal food crops in Amhara region of Ethiopia. A project on SIMLESA is aimed at increasing the range of maize varieties available for small holder farmers of Amhara region. In this study, eight improved maize hybrid varieties were evaluated across ten environments of Jabitehinan and South Achefer districts. Combined analysis of variance for grain yield across test environments indicated that the mean squares for environments, genotypes and genotype by environment interaction were highly significant and accounted for 66.73, 5.04 and 12.17% of treatment combination sum of squares, respectively. Based on the grain yield performance of the tested varieties, AMH-851(Jibat), BH-661 and PHB-3253 (Jabi) were identified as the three high yielding varieties across the testing environments. GGE biplot analysis identified that AMH-851 (Jibat) was the most stable and desirable hybrid followed by hybrids BH-661 and PHB-3253. Compared with other tested varieties, BHQPY-545 and PHB-3253 were selected as early maturing varieties with 156 and 149 days to maturity, respectively. Therefore, AMH-851 (Jibat) as a potential variety, BHQPY-545 and PHB-3253(Jabi) as early maturing varieties, are recommended for Jabitehinan and South Achefer districts.

Key words: GE interaction, GGE, stability, mega environment

INTRODUCTION

Maize (*Zea mays* L.) is originated in Central America and was introduced to Africa in the early 1500s by the Portuguese traders (Dowswell *et al*., 1996). It is one of the well known cereal crop that can be successfully grown in many parts of the world over a wide range of environmental conditions and ranked third after wheat and rice in terms of cultivation area, total production and consumption (IITA., 2007). The crop is used as source of food for human beings and feed for animals, for production of biofuel as well as manufacturing of industrial products like starch, syrup, alcohol, acetic acid and lactic acid.

In Ethiopia, maize has been growing from moisture stress areas to high rainfall areas and from lowlands to highlands of the country. At national level around 2.01 million ha of land was covered by maize with 6.2 million t of total production (CSA., 2012). From this total maize production of the country, 0.56 million t was obtained in the west Gojam zone of Amhara region but now a day due to the current global climate change these maize growing areas were commonly experienced with terminal moisture stress as well as uneven distribution of rain fall. As a result, long maturing maize varieties had showed inconsistence and low grain yielding performance. In a similar fashion, Akcura *et al*. (2011) reported that changes of environmental conditions aggravate the effect of genotype environment interaction that often hampers the identification of high yielding and stable maize hybrids. Besides, Sibiya *et al.* (2012) also declared that effect of GEI makes genotypes to perform differently in different environments especially on those environments which have highly variable weather conditions.

Large magnitude of GEI variation usually hinders the accuracy of yield estimation and reduces the relationship between genotypic and phenotypic values of plants (Ssemakula and Dixon, 2007). Moreover, GE interaction reduces the genetic progress in plant breeding programs through minimizing the association between phenotypic and genotypic characteristic of plants (Comstock and Moll, 1963). Therefore, GEI must be exploited by either selecting superior genotypes for each specific targeted environment or by selecting widely adapted and stable genotypes across a wide range of environments. Hence, more attention should be paid on the identification of maize varieties which able to give best yield across different environments; on the effect of genotype, environment and GE interaction on grain yield performance of the tested varieties and on the investigation of mega environments that are important for current as well as future maize improvement research program. Therefore, this study was conducted with the following objectives:

- To evaluate the grain yield performance of each tested varieties across the testing environments
- To identify high yielding stable maize varieties and recommend for commercial production across west Gojam zone of Amhara region
- To examine the possible existence of mega environments in maize growing areas of west Gojam zone, Amhara region

MATERIALS AND METHODS

Experimental materials and testing locations: A total of eight improved hybrid maize varieties: BHQPY-542, BHQPY-545, BH-660, BH-661, BH-670), PHB-3253, AMH-850 and AMH-851 (Table 1) were collected from Bako and Ambo, Agricultural Research Centers as well as Pioneer seed enterprise. During 2012 and 2013, main cropping seasons, these varieties were evaluated across ten environments of Jabitenahin and South Achefer districts (Table 2).

Table 1: Code, cropping season, locations, altitudes and districts of experimental locations

Codes	Cropping season	Locations	Altitude (masl)	Districts
E1	2012	Mekelamo	1700-1800	Jabitenahin
E2	2012	Tikurwuha	1700-1800	Jabitenahin
E3	2012	Aferefida	1800-1948	South Achefer
E4	2012	Sibit	1800-1948	South Achefer
E5	2013	Mekelamo	1700-1800	Jabitenahin
E6	2013	Tikurwuha	1700-1800	Jabitenahin
E7	2013	Leza	1700-1800	Jabitenahin
E8	2013	Aferefida	1800-1948	South Achefer
E9	2013	Sibit	1800-1948	South Achefer
E10	2013	Sefera	1800-1948	South Achefer

Table 2: Description of the tested hybrid maize varieties and their adaptations

Codes	Hybrids	Maize type	Source	Adaptation (masl)
G1	BHQPY-542	QPM	Bako ARC	1000-1800
G2	BHQPY-545	QPM	Bako ARC	1000-2000
G3	BH-660	Non-QPM	Bako ARC	1600-2200
G4	BH-661	Non-QPM	Bako ARC	1600-2200
G5	BH-670	Non-QPM	Bako ARC	1700-2400
G6	PHB-3253	Non-QPM	Pioneer seed	1000-2000
G7	AMH-850	Non-QPM	Ambo ARC	1800-2400
G8	AMH-851	Non-QPM	Ambo ARC	1800-2600

QPM: Quality protein maize

Field experiments: By considering farmers site as replication, a randomized complete block design with three replications was used to evaluate the performance of the tested varieties. Each tested varieties was planted on a plot size of 19.125 m^2 (5.1×3.75 m), in five rows with 75 and 30 cm inter and intra row spacing, respectively. Spacing between the two adjacent blocks was 1 m. Recommended seed rate (25 kg ha^{-1}) and fertilizer rates (138/180 kg ha^{-1} P and N) were used at each location. The whole amount of DAP was applied at planting, while Urea was split in to half at planting and the remaining half at knee high stage. The other agronomic practices were done as required.

Data collection and analysis: Both plot base and plant base techniques were used to collect data from the central four harvestable rows. Data, that collected, based on plot base techniques includes; grain yield, days to tasseling, days to silking, days to maturity, plant aspect and ear aspect, while the other remaining data (plant height and ear height) were collected from five randomly selected plants of each experimental plot (plant base techniques). Grain yield data was converted in t ha^{-1} at 12.5% moisture content and subjected to combined analysis of variance (ANOVA) using SAS version 9.0 and the least significant differences among means were calculated to identify differences among treatments. Besides, the mean performance of each tested varieties on yield related traits was done for both individual and combined locations. Decomposition of GE interaction and stability analysis of the tested hybrids were also done using Gene stat software 12th edition (Payne *et al*., 2009).

RESULTS AND DISCUSSION

Since, yield is the final result of many plant characters, which are interacting with numerous external factors during the life span of plants, evaluation of hybrid maize varieties based on grain yield may be considered as a reliable measure for genotypic performance. Accordingly, the mean grain yield of eight hybrid maize varieties evaluated across ten environments of Jabitehinan and South Achefer districts (Table 3). In Jabitehinan district, the highest and the lowest mean grain yield performance were obtained on hybrid maize varieties AMH-851 and BH-542 with the grain yield of 6.51 and 3.93 t ha^{-1}, respectively. Hybrid maize variety BH661 was identified as the second high yielding variety with mean grain yield of 6.28 t ha^{-1}. The BHQPY-545 was also identified as the third high yielding hybrid with better number of cobs/plant, good disease tolerance and early maturing character (Table 4), which is important to safeguard the farmers from the risks of unexpected climate uncertainty (moisture stress at end of cropping season).

Table 3: Mean grain yield (t ha^{-1}) of eight hybrid maize varieties in 2012 and 2013 crop seasons

	Jabitenahin			South Achefer			
Varieties	2012	2013	Mean	2012	2013	Mean	Mean grain yield
BH-542	3.90	3.94	3.93	5.54	8.65	7.41	5.67
BHQPY-545	7.33	4.83	5.83	8.85	8.19	8.46	7.14
BH-660	5.03	4.21	4.54	7.51	9.72	8.84	6.69
BH-661	5.99	6.48	6.28	7.51	9.27	8.57	7.43
BH-670	4.60	4.74	4.69	6.59	11.37	9.46	7.07
PHB-3253	5.19	5.80	5.56	6.67	11.02	9.28	7.42
AMB-850	4.76	6.25	5.66	6.63	10.63	9.03	7.35
AMB-851	5.62	7.10	6.51	6.84	10.60	9.10	7.80
Mean	5.30	5.42	5.33	7.02	9.93	8.77	7.07
CV	18.00	17.70	17.95	19.31	12.02	13.14	15.03
LSD (0.05)	1.13	0.91	0.70	1.59	1.13	0.84	0.54
R^2	0.73	0.85	0.83	0.71	0.76	0.87	0.91

Table 4: Combined analysis of variance for grain yield of eight hybrid maize varieties across 10 environments

Sources	DF	TSS	MS	F-value	TSS (%)
Total	239	177799.53			
Environments	9	118642.51	13182.51**	116.76	66.73
Block (environments)	20	12757.84	637.89**	5.65	7.18
Genotypes	7	8961.43	1280.20**	11.34	5.04
GE interaction	63	21631.14	343.35**	3.04	12.17
Residual	140	15806.62	112.90		

**Indicates highly significant

Table 5: Mean of yield related traits and disease scores of the tested hybrid maize varieties

	Combined mean of yield related traits (2012 and 2013)							Diseases score (%) in 2013					
								Jabitanahin			South Achefer		
Varieties	PH (cm)	EH (cm)	DT	DS	DM	PAS	EAS	G	B	R	G	B	R
BH-542	210.80	93.40	84.50	87.30	154.00	2.80	2.69	31.10	41.10	12.00	14.00	28.00	-
BHQPY-545	208.40	100.00	84.40	87.70	156.00	2.47	2.75	23.30	25.50	8.00	6.00	12.00	-
B-660	265.90	159.20	95.10	100.80	174.00	3.55	3.16	20.00	26.70	6.00	8.00	14.00	-
BH-661	268.40	151.50	97.50	102.10	178.70	2.44	2.83	22.20	26.70	8.00	6.00	8.00	-
BH-670	273.40	166.10	96.50	100.90	174.70	2.60	2.83	24.40	27.80	10.00	10.00	22.00	-
PHB-3253	221.90	101.60	77.60	81.10	149.30	2.16	2.31	28.90	36.60	8.00	10.00	26.00	-
AMB-850	197.50	93.10	89.20	92.90	169.10	2.33	2.27	25.60	34.40	8.00	10.00	24.00	-
AMB-851	227.00	113.20	86.40	90.40	171.60	2.22	2.19	27.80	26.70	6.00	10.00	20.00	-
Mean	234.20	122.30	88.90	92.90	165.90	2.46	2.63	25.40	30.70	8.30	8.50	19.30	-
CV	6.45	9.37	2.67	2.01	1.03	17.13	15.24	20.60	17.00	17.00	25.60	28.10	-
LSD (0.05)	7.70	5.84	1.21	0.95	0.87	0.27	0.26	4.90	4.90	4.10	5.20	6.30	-
R^2	0.90	0.93	0.96	0.98	0.99	0.65	0.86	0.72	0.79	0.58	0.58	0.71	-

PH: Plant height, EH: Ear height, DT: Days to tasseling, DS: Days to silking, DM: Days to maturity, PAS: Plant aspect, EAS: Ear aspect, G: Gray leaf spot, B: Blight and R: Rust

Similarly, in South Achefer district significant differences was observed among the grain yield performance of the hybrid maize varieties. Among the tested varieties, Hybrid BH-670 had showed the highest yield performance (9.46 t ha^{-1}) while BH-542 gave the lowest yield (7.41 t ha^{-1}). Besides Hybrids; PHB-3253, AMH-851 and AMH-850 were also identified as the second, third and fourth high yielding hybrids with non significant mean grain yield performance of 9.28, 9.10 and 9.03 t ha^{-1}, respectively. Combined mean grain yield of the tested hybrids across the two districts (ten environments) indicated that the presence of non significant grain yield performance among the first three high yielding hybrids: AMH-851, BH-661 and PHB-3253 with mean grain yield value of 7.80, 7.43 and 7.42 t ha^{-1}, respectively.

The combined analysis of variance for grain yield showed highly significant difference among environments, genotypes and GE interaction with a contribution of 66.73, 5.04 and 12.17% of the total variation, respectively (Table 5). This indicates that the test environments were highly variable and have high influence on the yield performance of the tested hybrid maize varieties. The significant GEI indicated that a particular genotype may not exhibit the same phenotypic performance under different environmental conditions or different genotypes may respond differently to a specific environment. Similar results reported by Payne *et al*. (2009) and Munawar *et al*. (2013).

Among the tested hybrids, PHB-3253 and BHQPY-545 were identified as early maturing varieties with 149 and 156 days to maturity, respectively (Table 5), which suit for maize growing areas that are commonly experienced terminal moisture stress. While, hybrids AMH-851 and BH-661 were identified as medium and late maturing high yielding hybrids which best fit for maize growing areas that have adequate amount of rainfall throughout the growing season.

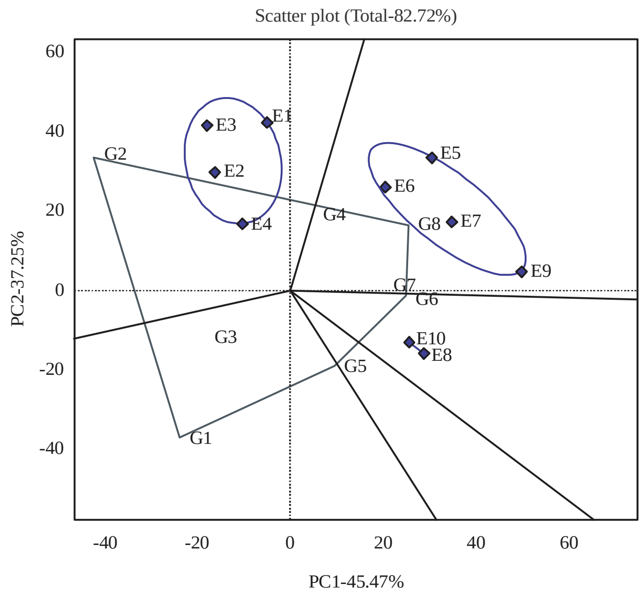

Fig. 1: Polygon view of GGE biplot based on grain yield of eight maize genotypes tested in ten environments

In GGE biplot analysis the first Principal Component (PC) axis explained 45.47% of total variation; while the second Principal Component (PC) axis explained 37.25% and thus, these two axes collectively accounted for 82.72% of the total variation of GEI (Fig. 1). These results suggest that the biplot of PC1 and PC2 adequately approximated the environment centered data. The GGE biplot graphically displays GEI of a multi environment trial and facilitates visual genotype evaluation and mega- environment identification (Yan *et al*., 2000). In the GGE biplot grain yield performance was represented by a polygon with five vertex hybrids and the remaining three inside the polygon (Fig. 1). These vertex hybrids are supposed to be the most responsive since they have the longest distance from the biplot origin (Yan and Rajcan, 2002). Responsive hybrids are either the best or the poorest at one or all locations. Therefore, AMH-851 was identified as the best high yielding hybrid, as compared to the rest tested hybrids.

The Average Environment Coordinator (AEC) or line that passes through the biplot origin with an arrow indicating the positive end of the axis, ranked the genotypes based on their mean performance across all environments (Fig. 2). The average yield of the hybrids is estimated by the projections of their markers to the AEC X-axis (Yan and Tinker, 2005). Thus, hybrid AMH-851 had the highest mean grain yield followed by hybrids BH-661 and PHB-3253 while the lowest mean grain yield was recorded by BH-542. The AEC Y-axis or the stability axis passes the plot origin and perpendicular to the AEC X-axis. The stability of the hybrids is measured by their projection onto the AEC Y-axis. The greater the absolute length of the projection of a hybrid, the less stable it is (Yan *et al*., 2010). Therefore; Among high yielding hybrids AMH-851 and BH-661 were identified as the most stable hybrids. Besides, AMH-850 also showed a medium stability performance as compared to hybrids BHQPY-545, BH-670 and PHB-3253, which were identified as the most unstable hybrids. Among these unstable hybrids maize varieties, BHQPY-545 and PHB-3253 had showed high performance in grain yield, which is above the mean grain yield of the tested hybrids.

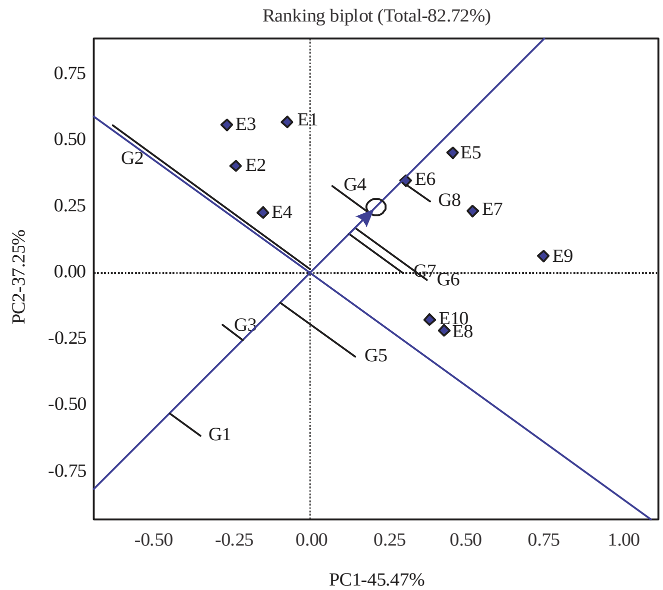

Fig. 2: AEC views of GGE-biplot based on genotype focused scaling which shows the mean yield performance and stability of genotypes

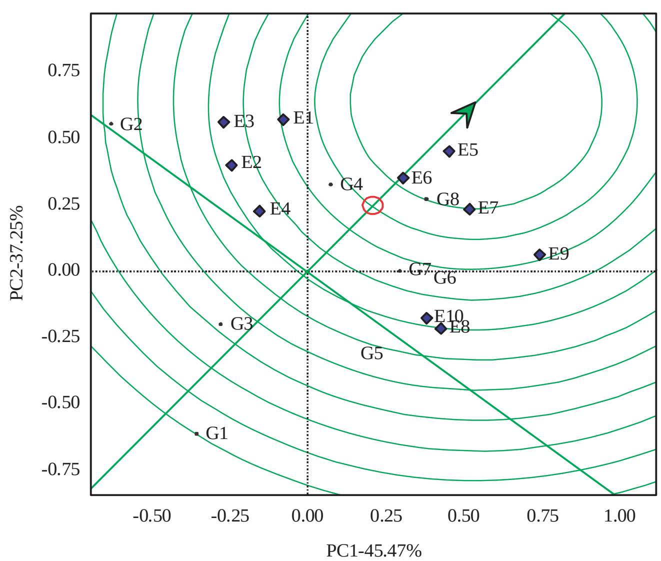

Fig. 3: GGE-biplot based on genotype-focused scaling for comparison the genotypes with the ideal genotype

An ideal hybrid is the one, that has high mean grain yield (PC1) and less GE interaction (high stability). The center of the concentric circles represents the position of an ideal hybrid (Fig. 3), which is defined by a projection onto the mean-environment axis that equals the longest vector of the hybrids that had above-average mean yield and by a zero projection onto the perpendicular line (zero variability across environments). A hybrid is more desirable if it is closer to the ideal hybrid. Although, such an ideal hybrid may not exist in reality, it can be used as a reference for evaluation of the tested hybrids (Yan and Kang, 2003). Hence, hybrid AMH-851 which found closer to the center of concentric circles was identified as an ideal hybrid. Besides, hybrids BH-661 and PHB-3253 were also identified as the second and the third desirable hybrid maize varieties, respectively.

CONCLUSION

Combined analysis of variance indicated that the grain yield was greatly influenced by the environment while genotypes and GEI contributed the least phenotypic variation. The GGE biplot identified three distinct mega environments (ME1, ME2 and ME3) and best varieties for each of mega environments. Accordingly, AMH-851 was identified as the best performing variety in ME2; BHQPY-545 and BH-661 in ME1 and PHB-3253 in ME3. The GGE biplot also identified variety AMH-851 as the most desirable variety for maize growing areas of Jabitehinan and South Achefer districts and other areas with similar agro ecology. Besides, early maturing varieties: BHQPY-545 and PHB-3253 were specifically identified for maize growing areas which commonly experienced with terminal moisture stress.

ACKNOWLEDGMENTS

Authors are gratefully acknowledged CIMMYT and ACIAR for financial support through SIMLESA project to reduce the problem associated with monocropping. Adet maize research team is appreciatively acknowledged for their active participation for trial management, follow up and data collection. Authors are also indebted to Amhara Agricultural Research Institute and Adet Agricultural Research Center for providing technical assistance during the work.

REFERENCES

Akcura, M., S. Taner and Y. Kaya, 2011. Evaluation of bread wheat genotypes under irrigated Multi-environment conditions using GGE biplot analyses. Agriculture, 98: 35-40.

CSA., 2012. Area and production of major crops. Agricultural Sample Survey, Central Statistics Authority (CSA), Addis Ababa, Ethiopia.

Comstock, R.E. and R.H. Moll, 1963. Genotype x environment interactions. Proceedings of the Symposium on Statistical Genetics and Plant Breeding, (SSGPB'63), National Academy Science National Research Council, Washington, D.C., pp: 164-196.

Dowswell, C.R., R.L. Paliwal and R.P. Cantrell, 1996. Maize in the Third World. West View Press, Colorado, USA., ISBN-13: 9780813389639, Pages: 268.

IITA., 2007. Maize. International Institute of Tropical Agriculture. http://www.iita.org/maize.

Munawar, M., G. Hammad and M. Shahbaz, 2013. Evaluation of maize (*Zea mays* L.) hybrids under different environments by GGE biplot analysis. Am.-Eur. J. Agric. Environ. Sci., 13: 1252-1257.

Payne, R.W., D.A. Murray, S.A. Harding, D.H. Baird and D.M. Soutar, 2009. GenStat for Windows Introduction. 12th Edn., VSN International, Hemel Hempstead.

Sibiya, J., P. Tongoona, J. Derera and N. van Rij, 2012. Genetic analysis and genotype x environment (G x E) for grey leaf spot disease resistance in elite African maize (*Zea mays* L.) germplasm. Euphytica, 185: 349-362.

Ssemakula, G. and A. Dixon, 2007. Genotype x environment interaction, stability and agronomic performance of carotenoid-rich cassava clones. Scient. Res. Essay, 2: 390-399.

Yan, W., L.A. Hunt, Q. Sheng and Z. Szlavnics, 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci., 40: 597-605.

Yan, W. and I. Rajcan, 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. Crop Sci., 42: 11-20.

Yan, W. and M.S. Kang, 2003. GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists and Agronomists. 1st Edn., CRC Press, Boca Raton, FL., USA., ISBN-13: 9781420040371, Pages: 288.

Yan, W. and N.A. Tinker, 2005. An integrated biplot analysis system for displaying, interpreting and exploring genotype x environment interaction. Crop Sci., 45: 1004-1016.

Yan, W., J. Fregeau-Reid, D. Pageau, R. Martin and J. Mitchell-Fetch *et al*., 2010. Identifying essential test locations for oat breeding in eastern Canada. Crop Sci., 50: 504-515.