



CGBPB 033

GENOTYPE × ENVIRONMENT INTERACTION OF WHITE MAIZE HYBRIDS IN SOUTHERN GUINEA SAVANNA ECOLOGY OF NIGERIA

Aboderin O.S.¹, Bankole F.A.²

¹Department of Agronomy, University of Ilorin, Ilorin, Nigeria

Corresponding Author: olawaleaboderin@yahoo.com, +2348032161832

ABSTRACT

A proper understanding of the effects of $G \times E$ interactions on variety evaluation is vital for cultivar recommendations. This study was conducted to determine the grain yield performance, stability and adaptability of white maize hybrids in the Southern Guinea savanna of Nigeria. Seven maize hybrids were evaluated at six locations in the southern Guinea savanna (SGS) ecology of Nigeria in 2015 and 2016. The mean square from analysis of variance showed that significant differences ($p \leq 0.01$) existed across environment and genotypes for grain yield and other measured traits. Genotype by environment effect was also significant ($p \leq 0.05$) for grain yield and days to anthesis only. The yield of the hybrid ranged from 3.25 (EEWH) to 5.98 t/ha (EEWH-59). The analysis of GGE biplot showed that EEWH-59 and EEWH-48 were not only the highest yielders but also were the most stable across the environments except in Ballab where EEWH-43 performed better than the rest of the genotypes. Mokwa based on discriminating and representative effect of the GGE biplots appears to be the ideal test environment for selecting adapted genotypes while Omu-Aran and Ballab were highly discriminating but non-representative and are therefore useful for selecting specifically adapted genotypes. EEWH-59 and EEWH-48 were the closest to the ideal genotype and may be considered as superior hybrids for further testing in farmers' fields for the purpose of registration and release for the southern Guinea Savanna.

Keywords: Cattle, breeds, genetic, resources, variatio- Genotype × environment interaction, GGE biplot, *Zea mays* L., grain yield, Southern Guinea Savanna, Stability.

Introduction

Maize (*Zea mays* L.) is the third most important crop after wheat and rice in terms of production in the world (IITA, 2009). It is not only an important source of human nutrition but also a basic element of animal feed and raw material for manufacture of many industrial products which include corn starch, maltodextrins, corn oil, corn syrup etc. Maize is a versatile crop grown over a range of agro-climatic zones with an unmatched sustainability in diverse environments (Downsell, 1996). It is grown from 58°N to 40°S, from below sea level to altitudes higher than 3000 m, and in areas with 250 mm to more than 5000 mm of rainfall per year (Downsell *et al.*, 1996) and

with a growing cycle ranging from 3 to 13 months (CIMMYT, 2000).

Grain yield is the most important trait because it is the one that gives an economic benefit to the consumers. Hence, good varieties should give high yield and should be stable across different environments in which they are grown (Finlay and Wilkinson, 1963). However, the quantitative nature of grain yield predisposes it to the effect of genotype × environment interaction (GEI) which is the differential response of cultivars across two or more environments. The effect of GEI often cause complications in varietal selection activities and identification of genotypes for wide adaptation in most



breeding programmes (Magari and Kang, 1993, Badru-Apraku *et al.*, 2011). A large portion of the observed GEI in grain yield responses of maize genotypes in multilocal trials may be due to varying environmental conditions prevailing at the different agroecological zones where maize

is grown, which often hampers the identification of high yielding genotypes.

Numerous studies have shown that a proper understanding of the environmental and genetic factors causing the interactions as well as an assessment of their importance in the relevant GEI system could have a large impact on plant breeding (Magari and Kang, 1993; Basford and Cooper, 1998, Badru-Apraku *et al.*, 2011). GEI occurs universally when genotypes are evaluated in several different environments (Becker and Léon, 1988; Magari, 1989; Kang, 1990, Badru-Apraku *et al.*, 2003). The study of the GEI allows the classification of genotypes by their behaviour into two different situations, either stable or adapted to a particular environment in terms of their yield or some other interesting agronomic features. Generally, the term stability refers to a genotype's ability to perform consistently, whether at high or low yield levels, across a wide range of environments. On the other hand, adaptability refers to the ability of the genotype to be high-yielding with respect to a given environment or given conditions to which it is adapted (Cooper *et al.*, 1996).

Some authors, however, have applied the yield stability concept with respect to consistency in time of genotype performance, using the adaptation concept in relation to consistency in space (Lin and Binns, 1988; Evans, 1993). Only genotype $\times$ location (GL) interaction, rather than all kinds of GE interaction, is useful for depicting adaptation patterns, as only this interaction can be exploited by selecting for specific adaptation or by growing specifically adapted genotypes (Piepho *et al.*, 1998).

Several statistical procedures have been deployed in revealing G $\times$ E patterns, the GGE biplot developed by Yan, Hunt, Sheng, and Szlavniks (2000) respectively is the most

efficient. It is an efficient tool for identification of the best performing genotype in a given environment and the most suitable environment for each genotype (Yan *et al.*, 2000).

Crop breeders have therefore, focused on developing genotypes with superior grain yield, quality and other desirable characteristics which can be exhibited over a wide range of different environmental conditions. Therefore, this study was designed to investigate the influence of genotype by environment interaction on the expression of grain yield and related traits on white maize hybrids in Southern Guinea savanna ecology of Nigeria.



Materials and Methods

Seven Extra Early white maize hybrids with tolerance/resistance to multiple stress factors (drought, striga, low N etc) which were developed by maize scientists at the International Institute of Tropical Agriculture (IITA), Ibadan were used for this study. The lists of the genetic materials are presented in Table 1. The experiment was set up on each site in a Randomized Complete Block Design with an alpha lattice arrangement, 5 m long with inter and intra-row spacing of 0.75 and 0.5 m, respectively. Two (2) seeds were planted per hill and each set of trial was replicated three (3) times. The genetic materials were evaluated at six (6) locations in the southern guinea savanna (SGS) ecologies of Nigeria between 2015 and 2016. The locations were Ballah, Lapai, Mokwa, Omu-Aran, Kishi and Ilorin. The details of the testing site are presented in Table 2. Data was recorded for grain yield (GY) (shelled grain weight per plot adjusted to 15% grain moisture and converted to tons per hectare), anthesis date (number of days after planting when 50% of the plants shed pollen), silking date (number of days after planting when 50% of the plants extrude silks), anthesis-silking interval (ASI) (the difference between silking date and anthesis date), Plant height (cm), Ear height (cm), and Plant and ear aspects (rated on a scale of 1 to 5).

Data Analysis

Data collected were subjected to analyses of variance using SAS 9.0 edition statistical

software. Combined analyses of variance (ANOVA) across locations were performed to determine differences in genotypic performances across locations and also to determine whether there were significant differences among the locations. Genotypes (G) and environments (E) were considered as fixed effects while replications and genotypes x environment (GE) were considered random factors. Subsequently, the hybrids with high grain yield means were further subjected to genotype main effect plus genotype by environment interaction (GGE) biplot analysis to separate the GEI into principal component axes. This analysis was carried out using GGE biplot, a window application that fully automates biplot analysis (Yan, 2001). The GGE biplots were constructed using the first two principal components (PC1 and PC2). Information on yield performance and stability of the hybrids were analyzed by the biplot based on the position of their label relative to abscissa (the horizontal axis) and ATC coordination axis (vertical axis) respectively of the vector view of the biplot. The genotypes were ranked along the average-tester axis (ATA abscissa), with an arrow pointing to a greater value based on their mean performance across all environments. The double-arrowed line separates entries with below-average means from those with above-average means. The stability of the genotype is measured by their projection onto the double-arrow line average-tester coordinate (ATC) axis.



Table 1: - List of extra-early and early maturing hybrids used in the study.

S/N	Extra-Early White Hybrids
1.	EEWH-43
2.	EEWH-44
3.	EEWH-47
4.	EEWH-48
5.	EEWH-50
6.	EEWH-52
7.	EEWH-59

Table 2: Description of the test locations used in the study.

Location	State	Latitude	Longitude	Altitude (m)	Mean annual Rainfall (mm)
Ilorin	Kwara	8°30'N	4°32'60E	289	1318
Ballah	Kwara	13°22'0N	5°34'60E	249	1150
Mokwa	Niger	9°16'60N	5°26'0E	87	1250
Kishi	Oyo	9°46'0N	3°51'0E	372	2000
Omu- Aran	Kwara	8°08'18.85"N	5°06'9.4"E	536	1132
Lapai	Niger	9°3'0N	6°9'0E	117	1300



Results and Discussion

Combined Analysis of variance (ANOVA) for grain yield and other agronomic traits in 7 extra-early maturing white maize hybrids evaluated in six environments in the SGS of Nigeria

The results of the combined analysis of variance (ANOVA) across 6 environments for grain yield and related traits in the 7 extra early maturing white maize hybrids revealed significant effects of the environments ($p < 0.01$) and genotypes ($p < 0.01$) for grain yield and other agronomic traits investigated (Table 3). This is an indication of differential response of the genotypes to the environments and underscores the need to identify high yielding and stable genotypes across the environments. This result is consistent with the findings of Badu-Apraku *et al.*, (2003) and Mohammadi *et al.*, (2009) who reported that the largest proportion of total variation in multi- environment trials were attributed to locations. The genotypes also differed significantly for days to anthesis, plant and ear heights while variety GEI was significant only for grain yield and ear height indicating the greater importance of GEI during selection for a high yielding maize cultivar. The observed significant GEI for grain yield also indicates the influence of the different climatic and soil factors at each location on expression of grain yield. Significant differences among the genotypes for a particular trait is an indication that there is sufficient variability among the genotypes for selection or improvement (Badru-Apraku *et al.*, 2013). The test environments used for the study contributed significant proportion of variation in grain yield compared to the genotypes themselves and there was alteration in genotype ranking from one testing site to another.

Grain yield ranged from 3.25 t/ha (EEWH-47) to 5.98 t/ha (EEWH-59) with a mean of 4.28 t/ha. Majority of the hybrids were similar for ASI while hybrid EEWH-47 had the longest interval of four (4) days (Table 4). The difference in height among the

hybrids was 14 cm with hybrid EEWH-59 being the tallest while hybrid EEWH-50 was the shortest. Hybrid EEWH-43 had the highest ear placement while hybrid EEWH-47 had the lowest and the difference was 9 cm. The hybrids were however similar for ears per plant (EPP) across environments.

Polygon view of seven extra-early maturing white maize hybrids across six environments The polygon view of the GGE biplot showed in respect of grain yield of seven top ranked extra-early maturing maize hybrids is presented in Figure 1. The principal component (PC) axis 1 explained 67.9% of the total variation while PC2 explained 22.2% and thus, PC1 and PC2 accounted for 90.1% of the total variation. According to Yan *et al.*, (2005), the vertex cultivar in each sector in the polygon view represents the highest yielding cultivar in the environments that fall within that particular sector. Thus, hybrids EEWH-59 and EEWH-48 were the highest yielding in the environment. EEWH- 43 was the best (vertex cultivar) for Ballah.

Performance and stability of seven extra-early maturing white maize hybrids evaluated in six environments

The mean versus stability view of the GGE biplot displayed the performance as well as the stability of the cultivars at the six environments in the SGS of Nigeria (Fig. 2). The genotypes were ranked along the average-environment axis (AEA abscissa), with an arrow pointing to a greater value based on their mean performance across all environments. The double-arrowed line separates entries with below-average means from those with above-average means. The average yield of the cultivars is approximated by the projections of their markers on the average-tester axis, (Yan and Tinker, 2006). Based on this, EEWH-48 and EEWH-59 with short vector pointing toward a greater value based on the mean performance along the ATC were the most stable and high yielding cultivars while EEWH-50 with a long vector pointing towards greater value based on the mean



performance along the ATC was the least stable and also low yielding cultivar.

Discriminating power versus representativeness view of the testing sites for seven extra-early maturing white maize hybrids evaluated in six environments

Discriminating power versus representativeness view of GGE biplot analysis for the 6 test locations used in the evaluation of the 7 extra early maturing maize hybrids in the SGS of Nigeria in the year 2015 and 2016 is presented in Figure 3. In the biplot, the length of the environment

vector is a measure of its discriminating power and the angle between any vector and average tester axis approximates the correlation coefficient between the vector and the ideal test location, which is an indication of the representativeness of the testing site, (Yan and Tinker, 2006). On this basis, Mokwa happens to be the closest to the ATC and the most representative of all the test environments and therefore the best test environment for selecting generally adapted genotypes while Omu aran and Ballah have Discriminating but non-representative effect and are therefore useful for selecting specifically adapted genotypes.



Table 3: Mean squares from combined ANOVA for grain yield and other agronomic traits in 15 extra-early maturing white maize hybrids evaluated in six environments in the Southern Guinea Savannah of Nigeria (2015 and 2016)

Source	Df	Grain Yield	Days to 50% anthesis	Days to 50% silking	Anthesis-silking interval	Plant Height	Ear height	Ear per plant
Environment (E)	5	17595767.9**	174.88**	201.34**	171.51**	12981.19**	6930.29**	0.16**
Rep (E)	12	3034488.4	12.32**	6.97	2.88	148.16	20.92	0.01
Genotype (G)	6	22250583.6**	15.30**	14.37*	1.15	554.99	186.53*	0.02
G x E	30	2253473.8*	4.45*	4.61	1.85	211.72	88.83	0.02
Pooled Error	72	2232190.8	2.78	3.51	174.10	180.43	69.48	0.02
CV (%)		34.89	3.21	3.44	64.24	9.94	15.30	15.85



Table 4:- Mean Performance for grain yield and other agronomic characters of 7 extra-early maturing white maize hybrids across six environments in the SGS of Nigeria (2015 and 2016).

HYBRIDS	Grain yield (t/ha)	Days to anthesis (days)	Days to silking (days)	ASI (days)	Plant height (cm)	Ear height (cm)	Ears per plant (no)
EEWH-43	4.97	50	53	3	140	55	1
EEWH-59	5.98	53	55	2	141	51	1
EEWH-50	3.46	53	56	3	127	49	1
EEWH-44	3.58	52	53	2	136	53	1
EEWH-47	3.25	52	56	4	131	46	1
EEWH-48	5.33	52	54	2	132	52	1
EEWH-52	3.42	52	54	3	140	53	1
Mean	4.28	52	54	2	135	51	1
LSD	0.99	1.11	1.24	1.03	8.93	5.20	0.10
CV(%)	34.89	3.21	3.44	64.24	9.94	15.30	15.85

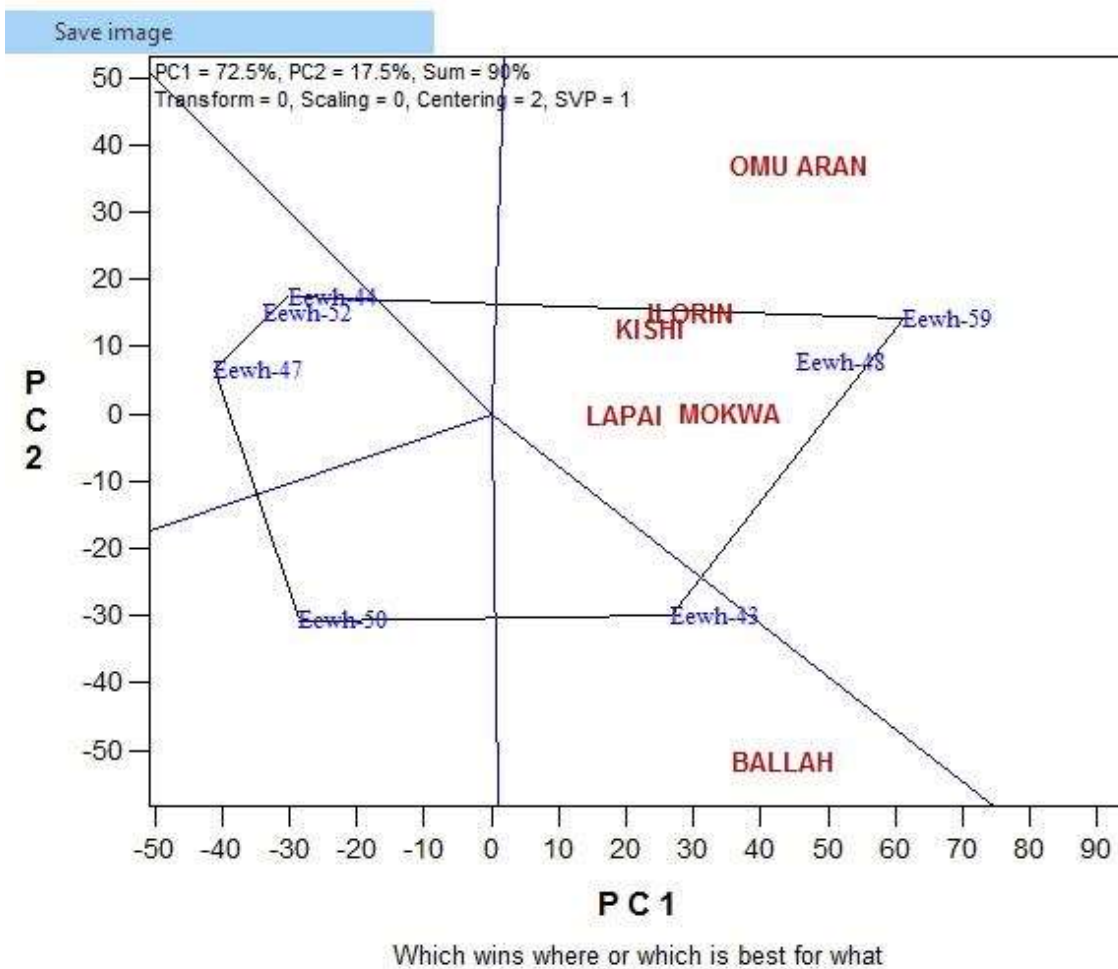


Figure 1:- Polygon view of genotype main effect plus genotype x environment biplot of seven extra early maturing white maize hybrids evaluated at 6 environments in Southern Guinea savanna of Nigeria

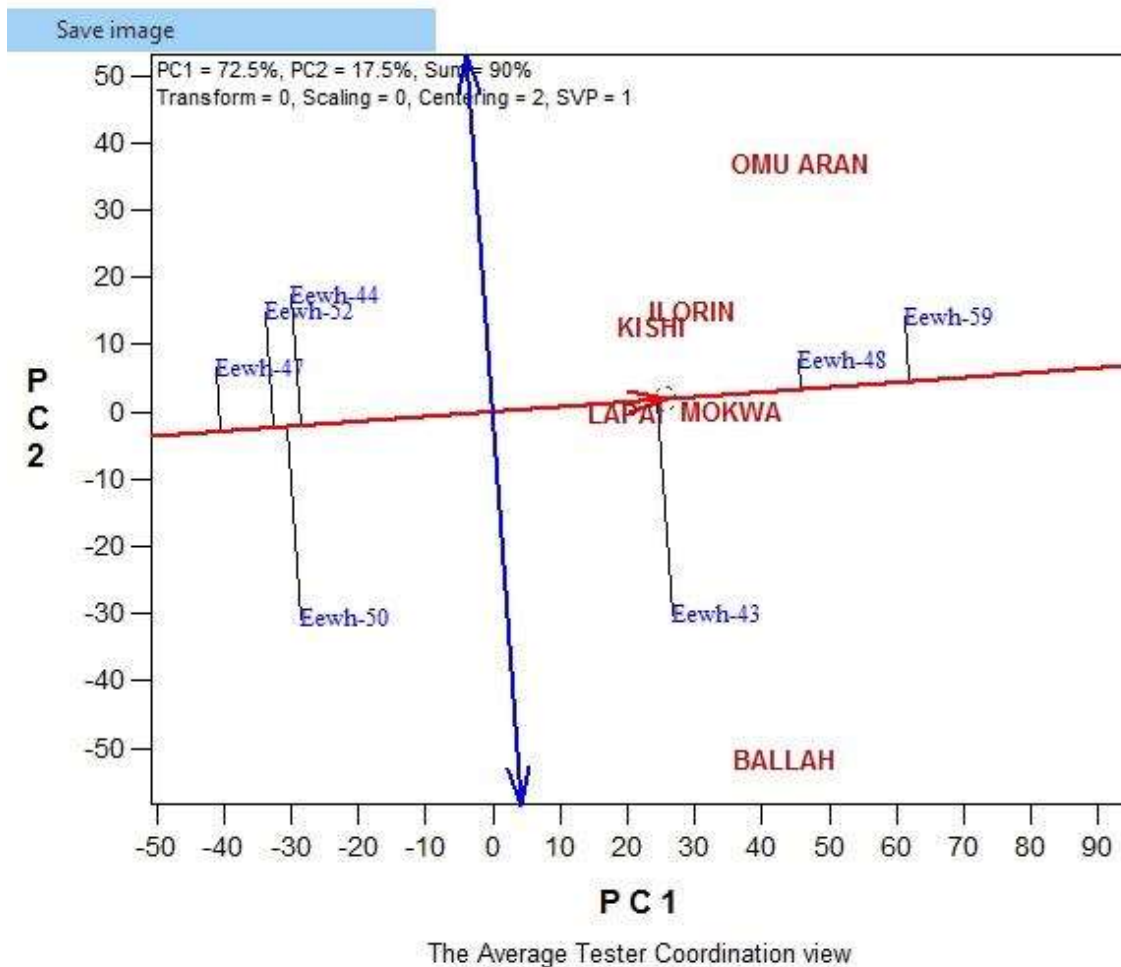


Figure 2: Mean versus stability view of GGE biplot of seven extra-early maturing white maize hybrids evaluated at 6 environments in Southern Guinea Savanna of Nigeria

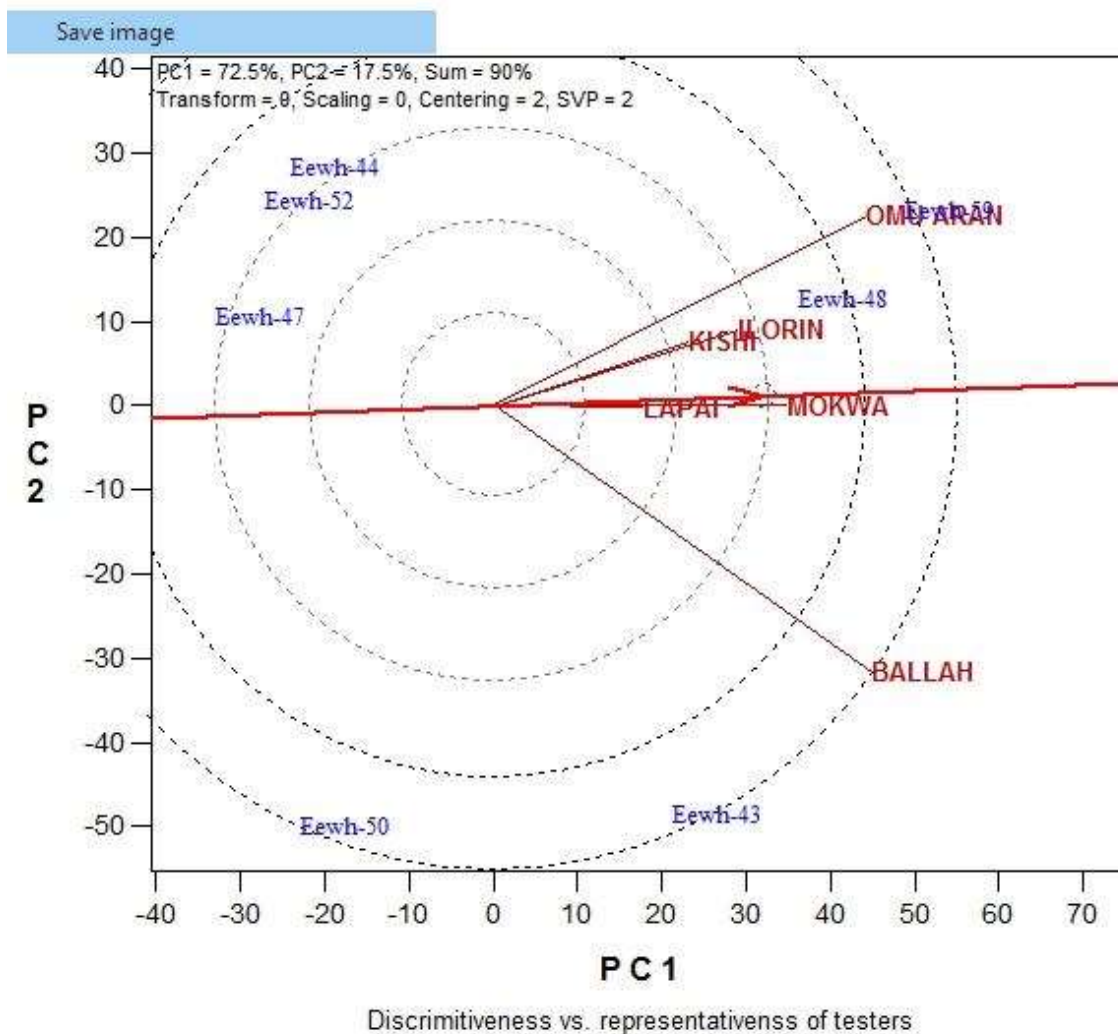


Figure 3: vector view of genotype main effect plus genotype by environment interaction (GGE) biplots showing ideal environments for the seven extra-early maturing white maize hybrids based on their discriminating power and representativeness.



Conclusion and Recommendations

Identification of superior genotypes based on their performance is usually complicated by the phenomenon of genotype by environment interaction (GEI). Large occurrence of GEI causes the relative rankings of genotypes to change from location to location. Thus, it is important to have a proper understanding of the effects of GEI on variety evaluation to aid decisions on cultivar recommendations

Mokwa based on discriminating and representative effect on the GGE biplots

appears to be the ideal test environment for selecting generally adapted genotypes while Omu aran and Ballah have Discriminating but non-representative effect and are therefore useful for selecting specifically adapted genotypes. EEWH-59 and EEWH-48 were the closest to the ideal genotype and may be considered as superior varieties for further testing in farmers' fields for the purpose of release.

References

- Badu-Apraku, B., Abamu F.J., Menkir A., Fakorede M.A.B, Obeng-Atwi K. (2003): Genotype by environment interactions in the regional early maize variety trials in West and Central Africa. *Maydica* 48: 93-104.
- Badu-Apraku, B., Akinwale R.O., Menkir, A. Obeng-Antwi, K., Osuman, A.S., Coulibaly, N., Onyibe, J.E., Yallou, G.C., Abdullai M.S., and Didjara A., (2011). Use of GGE Biplot for Targeting Early Maturing Maize Cultivars to Mega-Environments in West Africa. *African Crop Science Journal*, Vol. 19, No. 2, pp. 79 – 96
- Basford, K.E. and Cooper, M., (1998). Genotype x environment interactions and some considerations of their implications for wheat breeding in Australia. *Australian Journal of Agricultural Research* 49: 154-174.
- Becker, H.C. and Léon, J., 1988. Stability analysis in plant breeding. *Plant Breeding* 101: 1-23.
- CIMMYT. (2000). CIMMYT-Zimbabwe: 2000 Research highlights. Harare, Zimbabwe.
- Cooper, M. DeLacy, I.H. and Basford, K.E. 1996. Relationships among analytical methods used to analyse genotypic adaptation in multi-environment trials. Pages 193-224
- Dowswell, C. R., Paliwal, R. L., Ronald, P. C., (1996). Maize in the Third World. Westview Press, Inc. Pp. 1 – 19.
- Evans, L.T. 1993. *Crop evolution, adaptation, and yield*. New York, Cambridge Univ. Press
- Finlay, K.W., and G. N. Wilkinson. (1963). The analysis of adaptation in a plant breeding programme. *Aust. J. Agri. Res.* 14: 742-754.
- Hayes, H.K.; Immer, F.R.; Smith, D.C. *Methods of Plant Breeding*, 2nd ed.; McGraw-Hill Book Co.: New York, NY, USA, 1955.
- IITA, (2009). Maize Handbook. Retrieved: September 15, 2017 from <http://www.iita.org/cropsnew/maize/#16209236-d1ef>.
- Kang, M.S., 1990. Genotype-by-environment interaction and plant breeding. Louisiana State University, Baton Rouge, LA, USA.
- Lin, C.S. and Binns, M.R., 1988. A superiority measure of cultivar performance for cultivar x location data. *Canadian Journal of Plant Sciences* 68: 193-198



Magari, R., 1989. Stability of some Albanian maize local varieties and hybrids (in Albania). *Bull Agric. Sci.* 4:123-129.

Magari, R. and Kang, M.S., (1993). Genotype selection via a new yield-stability statistics in maize yield trials. *Euphytica* 70: 105-111

Mohammadi, R., Amri, A., Haghparast, R., Sadeghzadeh, D., Armion, M. & Ahmadi, M.M. (2009). Pattern analysis of genotype-by-environment interaction for grain yield in durum wheat. *Journal of Agricultural Science, Cambridge* 147, 537–545.

Piepho, H.P. 1998. Methods for comparing the yield stability of cropping systems—a review. *J. Agron. Crop Sci.* 180:193–213. (<ftp://ftp.fao.org/ag/.../Rusinamhodzi11AgronomySust.Developm.pdf>)

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

Yan, W. 2001. GGE biplot: A windows application for graphical analysis of multi-environment trial data and other types of two- way data. *Agron. J.* 93: 1111- 1118.

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

Yan W, Tinker NA (2006). Biplot analysis of multi-environmental trial data: Principles and applications. *Can. J. Plant Sci.* 86:623-645.