

# Genotype by environment interaction and stability of extra-early maize hybrids (*Zea Mays* L.) for yield evaluated under irrigation.

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**Abstract**— Maize (*Zea mays* L.) is the most important cereal crop produced in Ghana.

However the change in environmental conditions, the expansion of maize to new agro-ecologies coupled with inadequate maize varieties available for the different environments affects yield improvement programmes in Ghana. Hence, the study is to investigate the influence of genotype by environment interaction on the maize hybrids and to identify stable and high yielding hybrids with superior agronomic for farmers use in the country.

The objectives of the study was to investigate the influence of genotype by environment interaction on the maize hybrids and to identify stable and high yielding hybrids with superior agronomic performance for farmers use in Ghana. Thus, fifteen extra-early maize hybrids and three locally released checks were evaluated in a randomized complete block design with three replications in two locations in Ghana. The experiment was carried out at KNUST and Akomadan which represent the forest and forest transition zones of Ghana. Nine of the hybrids out of the fifteen hybrids evaluated produce above the average yield and the effect of genotype, location and genotype by location interaction was significant for grain yield. The GGE biplot used in this study revealed that TZEEI-1 x TZEEI-21, TZEEI-6 x TZEEI-21, TZEEI-15 x TZEEI-1 and TZEEI-29 x TZEEI-21 were high yielding and stable hybrids because they were closer to the ideal. The GGE biplot also identified Akomadan as the most ideal testing environment for these hybrids under irrigation.

**Keywords**— Genotype, Interaction, Genotype by Environment.

## I. INTRODUCTION

Maize (*Zea mays* L.) is cultivated globally and being one of the most important cereal crops produced world-wide after wheat and rice (Golbashy *et al.*, 2010). More maize is produced annually than any other grain, and about 50

species exist and they consist of different colours, textures and grain shapes and sizes. It has become Africa's dominant food crop since its introduction in 1500.

Like many other regions, it is consumed as a vegetable and contains excellent quality edible oil, carbohydrate, starch, protein, minerals and vitamins A (Amaregouda, 2007). The grains actually contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983). In developed countries, maize is mainly utilized as feed for domestic animals and at the same time as raw material for manufacturing products, although in developing countries, it is really utilized as food for human consumption (Badu-Apraku *et al.*, 2012; IITA, 2009). Maize is produced mostly by small holder resource poor farmers under rain- fed conditions (SARI, 1996). In spite of this, the production rate of maize in farmer's fields in the country is low. The average grain yields of maize nationwide are around 1.89 metric tons ha<sup>-1</sup> (MOFA-SRID, 2011). However, yields as much as 5.0-5.5 metric tons per hectare have been achieved by farmers using improved seeds, fertilizer, mechanization and irrigation (MiDA, 2010). Low yields of maize have been as a result to traditional farming practices, the use of low-yielding varieties, poor soil fertility and limited use of fertilizers, low plant population density, and inappropriate weed control. These biotic and a biotic factor have lead to the tremendous limit in productivity of maize across countries in the region (Fajemisin *et al.*, 1985). High yields could be achieved through the use of hybrid maize varieties (Agribusiness Trade Project, 2008).

Stability of desirable genetic characters is important for development of improved varieties and useful for the commercial exploitation over a wide range of agro-climatic conditions. According to (Esechie, H.A, Rodriguez, V. and Al-Asmi, H.) (2004), the consistency in performance for both high and low yields across different environment is referred to yield stability. It is

more practical to develop and release varieties which are adapted to more than a single environment and can be successfully grown over a range of environments. Thus the use of extra-early hybrid maize is required because of the short raining seasons, resulting from climate change. A need to fit crops to the seasons and hence will be very important in improving maize productivity and enhancing food security in Ghana.

Plant breeders have been trying to develop genotypes with better qualities and other worthy characteristics over a wide range of environmental conditions. Genotype by environment interaction in multi-environment trials refers to differential responses of genotypes across a range of environments (Kang and Gorman, 1989). In addition, (Casper Nyaradzai Kamutando *et al.*, 2013) started the important cross-over genotype by environment that raised the need to identify hybrids that performed superior in particular environments. The most important agronomical and economical traits such as grain yield are quantitative in nature and usually exhibit genotype by environment interaction (Fan *et al.*, 2007). Genotype by environment interactions determined in multi-location trials reduced the correlation between phenotypic and genotypic values and have been found to reduce gain from selection (Comstock and Moll, 1963). Also the knowledge of correlation between yield and its component characters is essential for yield improvement programmes (Ofori *et al.*, 2015; Baudh Bharti *et al.*, 2017). Genotype by environment interaction (GEI) according to (Yau, 1995) defined it as the degree of different reactions of a genotype for an exact trait across environments and (Nzuve *et al.*, 2013) mentioned the importance of genotype by environment interaction for various traits. The development of maize hybrids which are high-yielding and relatively stable when grown in different environments is of fundamental importance to commercial maize production (Gama and Hallauer, 1980). Hence, the study is to investigate the influence of genotype by environment interaction on the maize hybrids and to identify stable and high yielding hybrids with superior agronomic performance for farmers use in the country. The objectives of this research therefore were to evaluate the presence of genotype by environment interactions in the 15 maize hybrids and their agronomic performance and identify stable and high yielding hybrids and the pattern of response of the hybrids at different agro-ecologies.

## II. MATERIALS AND METHODS

Fifteen extra-early maize hybrids, including three locally released checks, were used. The study was carried out in two experimental locations in order to estimate G x E interaction. The first site is the drip irrigation site at the

Department of Animal Science which lies in the Forest ecology and the second site is at Akomadan which lies in the Forest transition ecology zones. A dialled cross was made among the inbred lines involving reciprocals at the drip irrigation site. The experimental fields were ploughed with a disc-ploughed and harrowed before planting to achieve a minimum tillage.

Genotypes were planted in one row plots and the plots were 5 m long, spaced 0.75 m apart, with 0.40 m spacing between plants within a row. The experiment was conducted in randomized complete block design (RCBD) with three replications at each location. Three maize seeds per hill were initially planted in each trial but were later thinned to two per hill at two weeks after planting (WAP). Pre-emergence and post-emergence chemical weed control was done with an application of Gramoxone and Atrazine respectively. Hand weeding was also done when necessary to control weeds during the growing period. NPK 15-15-15 fertilizer was applied at the rate of 30 kg N ha<sup>-1</sup> and 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> as basal fertilizer at two weeks after planting and top-dressed with additional N at 60 kg N ha<sup>-1</sup> at four weeks after planting. At the same time urea was also applied as top dressing after six weeks of planting for optimum plant growth at each location and all management practices were based on recommendations for each location.

## III. DATA COLLECTION AND ANALYSIS

The agronomic parameters recorded were days to anthesis (were recorded as number of days from planting to the time 50% of plants had shown complete tassels emergence in each plot), days to silking (were recorded as number of days from planting to the time 50% of plants had shown complete silk emergence in each plot), plant height (the height of five randomly selected plants were measured with a graduated measuring stick from soil surface to the last node in each plot and averaged), ear height (the height of five plants in centimetres from the soil surface to the node on which the uppermost ear sits were measured from the same plant from which plant heights were recorded and averaged), anthesis-silking interval (were calculated as the differences between days to 50% silking and days to 50% anthesis),

Cob length (five randomly selected cobs from each plot were selected and measured using a vainer calliper from the base of the ear to the tip and the average was determined), Cob width (five randomly selected cobs from each plot were selected and measured using a vainer calliper at the middle of the cob and the averaged was also determined), fresh weight (the weight of cobs per plot was measured in kilograms using a measuring scale and the values were recorded) and grain yield at 15%

moisture content based on 80% shelling percentage was also recorded.

#### IV. DATA ANALYSIS

Data were analysed using the Genstat Statistical package version 12.1. Data from each location were subjected to Analysis of Variance (ANOVA) individually to explore differences among entries for all traits and pooled across locations to determine G x E

Interactions. Means separation was carried out using least significant differences (LSD). Correlations among grain yield and yield contributing characters were examined. GGE biplot analysis (Yan, 2002) was used to assess yield stability among the maize hybrids.

Table.1: Description of the maize hybrids tested across the two locations in 2014/ 2015

Entry number	Entry name (single-cross)
CR1	TZEEI-1 X TZEEI-21
CR2	TZEEI-1 X TZEEI-4
CR3	TZEEI-15 X TZEEI-1
CR4	TZEEI-6 X TZEEI-15
CR5	TZEEI-6 X TZEEI-29
CR6	TZEEI-21 X TZEEI-4

CR7	TZEEI-29 X TZEEI-4
CR8	TZEEI-29 X AZEEI-21
CR9	TZEEI-6 X TZEEI-4
CR10	TZEEI-6 X TZEEI-21
CR11	TZEEI-6 X TZEEI-1
CR12	TZEEI-15 X TZEEI-4
CR13	TZEEI-29 X TZEEI-15
CR14	TZEEI-29 X TZEEI-1
CR15	TZEEI-15 X TZEEI-21
CR16	AKPOSOE
CR17	MAMABA
CR18	ETUBI

#### V. Results and Discussion

The combined mean square analysis for grain yield indicated significance differences among the hybrids across the two trial locations (Table 2). Therefore, the significant mean square analysis for location revealed that genetic potentials of the genotypes were predisposed by the surroundings owing to the consequence of diversity in the surroundings. Similar findings were reported by Butron *et al.* (2002) where they mentioned that genotype by environment effect for grain yield in maize in particular were mostly owed to environment yield limiting factor such as minimum temperature, relative humidity, moisture stress and pest and diseases.

Table.2: Combined mean squares analysis of variance of grain yield (t/ha) across the two locations.

Source	df	Mean squares
Replication	4	1.18
GENOTYPE(G)	17	1.38*
Location(L)	1	229.97**
G x L	17	1.63**
Error	68	0.67

\*\* = Significant at 1% level of probability \* = Significant at 5% level of probability

The percentage sum of squares for genotype, location and genotype by location interaction (Table 3) revealed that the location contributed the highest proportion 69.25 % of the total variance for grain yield while genotype contributed 7.08 % and the interaction between the genotype and environment contributed 8.37 % .The result

is in similar findings of Badu-Apraku *et al.* (1995, 2003) who reported that the largest proportion of total variation in multi-environmental trials is attributed to locations, whereas G and G x L sources of variation are relatively smaller.

Table.3: Percentage sum of squares attributed to genotype (G), location (L) and genotype by location interaction and error as the percentage of the total sum of squares.

Source	df	grain yield
Replication	4	1.42
Genotype (G)	17	7.08
Location (L)	1	69.25
G x L	17	8.37

Error	68	13.85
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### Genotype + Genotype × Location Interaction Biplot Analyses

#### Best Hybrid in each Location

The GGE biplot can be used to identify superior maize genotypes for target locations (Dehghani *et al.*, 2009). The biplot (Fig 1) represent a polygon which indicates some of the hybrids located on the vertexes and the others

within the polygon. The perpendicular lines split the biplot into different parts and the winning entry for each part is located on the individual vertex (Yan and Tinker, 2006). Therefore, entry CR10 (TZEEI-6 x TZEEI-21) obtained the highest yield at Akomadan and CR7 (TZEEI-29 x TZEEI-4) obtained the highest yield at KNUST.

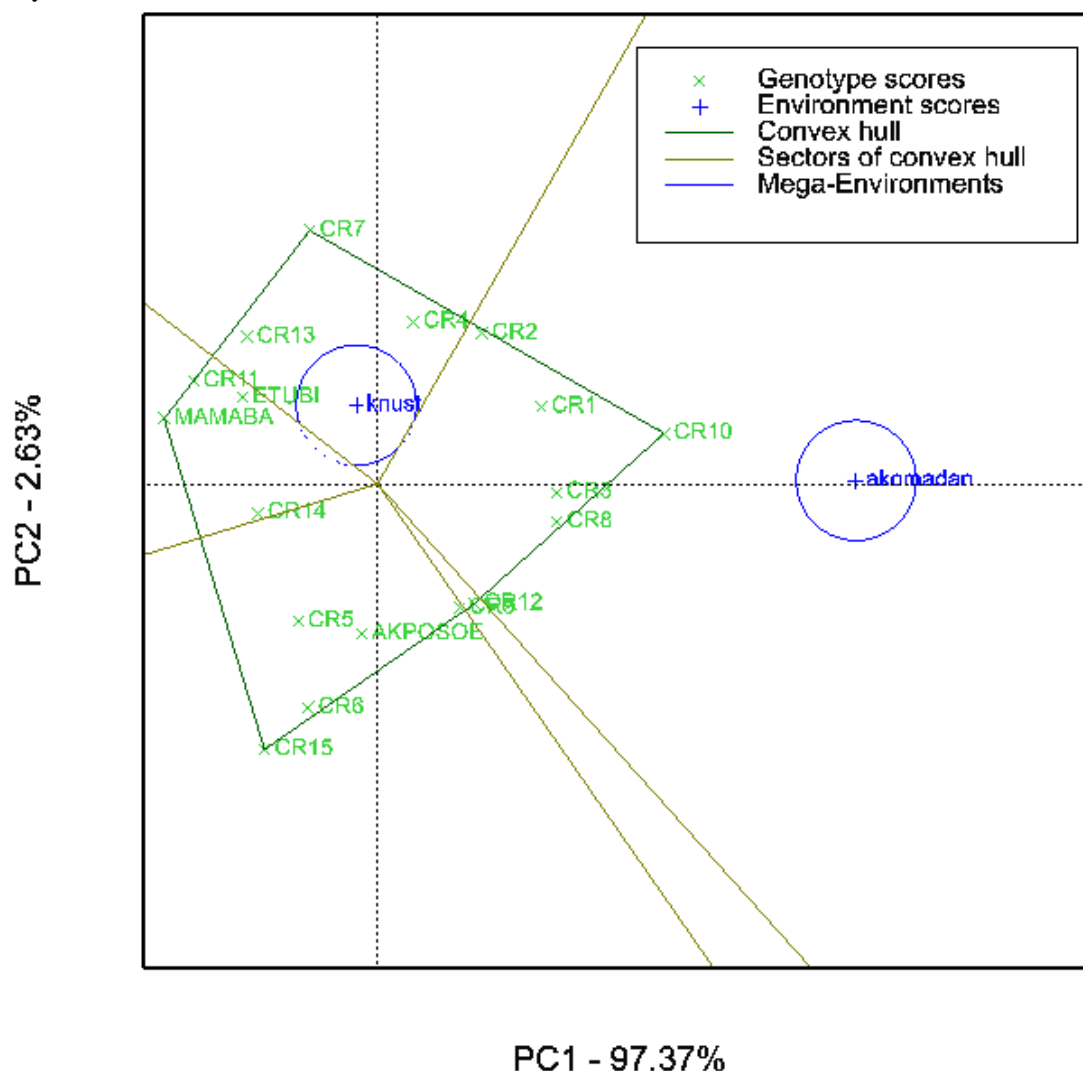


Fig.1: A which-won-where or which was best for what view of the GGE biplot of grain yield for 18 hybrids evaluated across the two locations

#### Average Yield and Stability of Hybrids

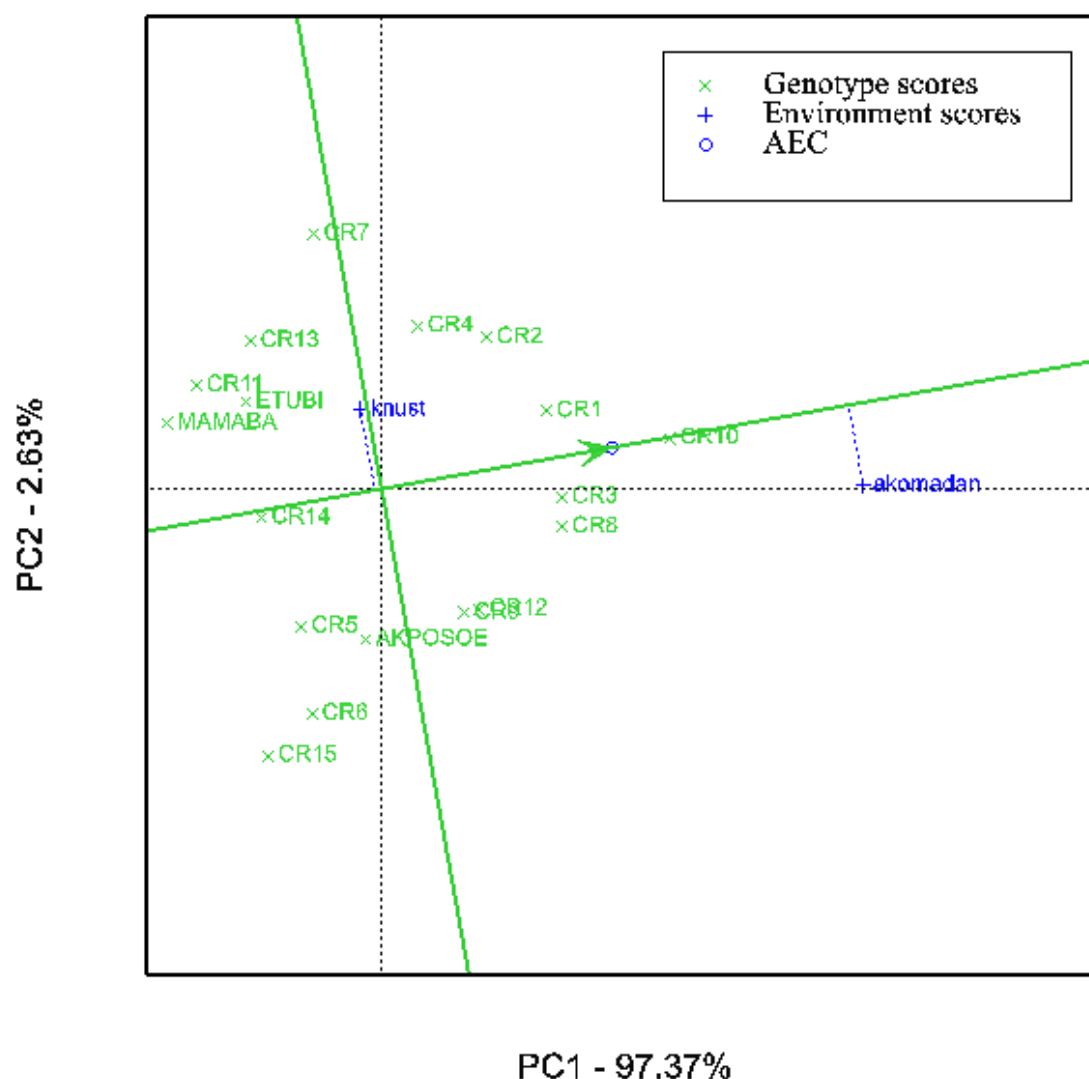


Fig.2: The “mean vs. stability” view of the GGE biplot of grain of grain yield for 18 hybrids evaluated across the two locations

In (Fig 2), the biplot is divided into four parts with an arrowed line (AEC abscissa or x-axis) and a vertical line without an arrow (AEC ordinate or y-axis). The vertical line separates the entries with below average yield from those with above average yield. This simply indicate that entries on the left side of the vertical line obtained lower yield than the average yield while those on the right obtained higher yield than the average yield. The blue circle on the x-axis in the biplot is referred to as the average tester yield. Therefore entry CR10 (TZEEI-6 x TZEEI-21) acquired the highest yield followed by entries CR1 (TZEEI-1 x TZEEI-21), CR3 (TZEEI-15 x TZEEI-1), CR8 (TZEEI-29 x TZEEI-21), CR2 (TZEEI-1 x TZEEI-4), CR4 (TZEEI-6 x TZEEI-15), CR12 (TZEEI-15 x TZEEI-4), CR9 (TZEEI-6 x TZEEI-4), AKPOSOE and CR7(TZEEI-29 x TZEEI-4) in that order. According to Yan *et al.* (2007), the stability of a genotype is determined by their protrusion against the y-axis, hence the nearer the protrusion of the genotype the more stable

it is. Therefore, the biplot revealed that the entries CR1 (TZEEI-1 x TZEEI-21), CR10 (TZEEI-6 x TZEEI-21), CR3 (TZEEI-15 x TZEEI-1), CR8 (TZEEI-29 x TZEEI-21) were the most stable hybrids among the highest yielding hybrids because they were closer to the ideal. Similar result of genotypes for their stability under varying conditions was reported by Tiwari *et al.*, (2014). In contrast, entry CR7 (TZEEI-29 x TZEEI-4) was the least stable among the highest yielding hybrids. However, CR14 (TZEEI-29 x TZEEI-1) which is among the lowest yielding is more stable. Entries CR6 (TZEEI-21 x TZEEI-4) and CR15 (TZEEI-15 x TZEEI-21) were not only low yielding but also amongst the least stable hybrids. Among the checks themselves, Akposoe was highly unstable.

#### Location Ranking Based on both Discriminating Ability and Representativeness

Discriminating ability and representativeness of the trial environment is presented in (Fig 3). An ideal trial

environment may be defined as one that is most discriminating for genotypes and representative of all other environment (Yan, 2001; Yan and Kang, 2003). Although in real life situation an ideal environment might not exist, it can be used as a reference for genotype selection in multi-location yield experiment. It is represented in the biplot by a tiny blue circle with an arrow it (Yan *et al.*, 2007), and the longer the projection, the more discriminative the environment.

On the bases of this requirement, KNUST was highly discriminating but least representative of the test environments whiles Akomadan was most representative and discriminating of the test environments. Hence Akomadan was identified as the most ideal trial environment under irrigation. A similar finding was obtained by Abdulai *et al.* (2007).

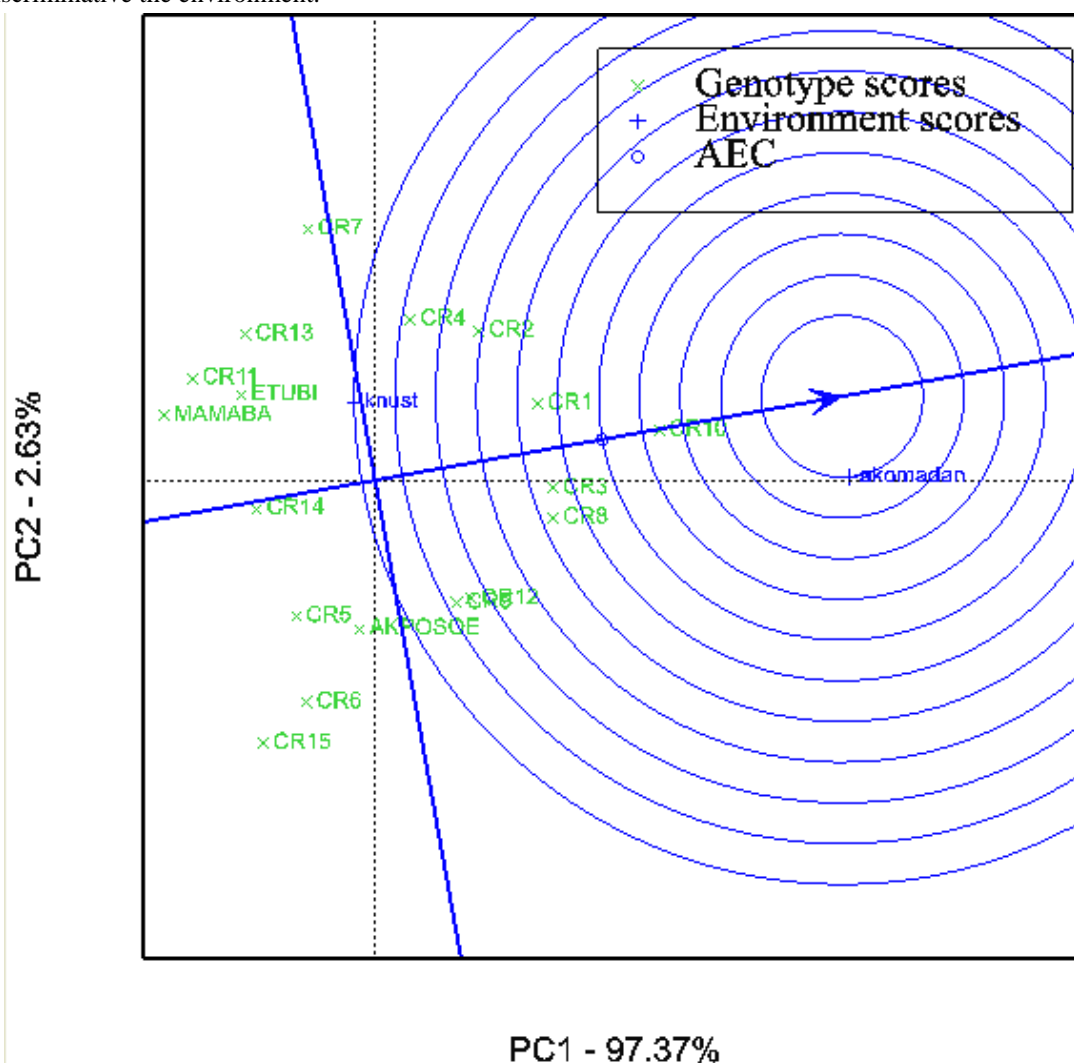


Fig.3: The ranking of locations based on discriminating ability and representativeness GGE biplot of grain yield for the 18 hybrids evaluated across the two locations

## VI. CONCLUSION

Out of the 18 genotypes evaluated across the two locations, the result from the combined analysis revealed that the location contributed the highest proportion 69.25 % of the total variance for grain yield while genotype contributed 7.08 % and the interaction between the genotype and environment and error contributed 8.37 % and 13.85 %, respectively. This indicates that the environment plays a vital role in selecting hybrids for higher grain yield and adaptation. The use of GGE biplot analyses provided clear bases for determining stability

and performance of the eighteen extra-early maize hybrids. Akomadan was the best environment test location for selecting genotypes with wide adaptability. TZEEI-6 x TZEEI-21, TZEEI-1 x TZEEI-21, TZEEI-15 x TZEEI-1 and TZEEI-29 x TZEEI-21 obtained higher yield potential. Hence these hybrids were considered high yielding and stable.

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