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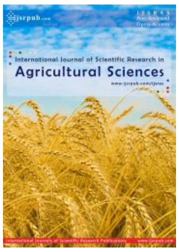

Full Length Research Paper

Assessment of the Relative Yielding Abilities and Stability of Maize (*Zea mays* L) Genotypes under Different Levels of Nitrogen Fertilization across Two Agro-Ecological Zones in Ghana

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Abstract. Farmers' adoption of hybrid varieties would reduce the large discrepancy between current low yields and achievable yields reported by researchers in yield evaluation trials. This is because hybrids wield superior genetic potential over improved open pollinated varieties (OPVs) and local varieties due their heterozygosity which explains their exhibition of high heterosis in yield and general performance. The current low yield necessitated the need to undertake this study to assess the relative yielding potentials of 3 hybrid varieties, 5 OPVs, 1 local variety and 4 inbred lines under three levels of Nitrogen fertilization in forest and transitional ecological zones in the Ashanti region of Ghana. Analysis of variance (ANOVA) revealed significant interactions for genotype by location (G x L), genotype by nitrogen (G x N) and genotype by nitrogen and by location (G x N x L) for grain yield. Averaged across test environments (i.e. location by nitrogen levels), 'Mamaba', a Quality Protein Maize (QPM) hybrid recorded the highest mean grain yield of 4.73 t ha^{-1} whilst the highest yielding OPV, Golden Jubilee, recorded 2.91 t ha^{-1};'Entry 5', the highest yielding inbred line however recorded grain yield of 0.72 t ha^{-1}. GGE biplot analysis for mean yield also showed that hybrids had better yielding abilities than OPVs under both low and high nitrogen fertilization and at different environments. In order to bridge the gap between the current low yields and achievable yields in Ghana, farmers would need hybrid seeds together with adequate levels of fertilizers.

Keywords: Hybrids, Genotype, Environment, Nitrogen fertilizer, Heterosis

1. INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop in West Africa, accounting for slightly over 20% of the domestic production in the sub-region (IITA, 2000). It is one of the most important cereals in Ghana, which is cultivated in all the agro-ecological zones (Fening et al., 2011). Maize yield averaged 4.9 t ha^{-1} globally in 2009 (Edgerton, 2009). However, yields in major maize growing areas in the developing world still lag behind the world average, producing only about 3.1 t ha^{-1} (Pixley et al., 2009). Yields in the United States for example have increased remarkably from an average of 1.6 t ha-1 in the early 1930's to the current approximated yield of 9.5 t ha^{-1}, whereas yields presently obtainable in Ghana hover around 1.7 t ha^{-1} (Edgerton, 2009; MoFA, 2011). This large discrepancy in yields has been ascribed partly to the use of unimproved or open pollinated varieties (OPVs) instead of hybrids, low input rates and poor soil management (Edgerton, 2009). MoFA (2011) reported that achievable yields of about 6 t ha^{-1} have been obtained in maize yield evaluation trials. This therefore indicates that the average maize yield of 1.7 t ha^{-1} currently obtained in Ghana, is about 70% less than what is usually achieved in maize yield trials by researchers.

Attempts have therefore been made to bridge the gap between the current low yields and the achievable yields by promoting the use of hybrid maize varieties. Breeding programmes in Ghana over the last two decades, among other activities, have been geared towards the development of hybrid varieties due to the superior genetic potentials they wield over their open-pollinated counterparts. This is in agreement with the current drive in maize production worldwide which is to encourage a shift from the use of OPVs to hybrid cultivars to take advantage of hybrids that recorded high heterosis in yield and general performance (Karunaratne, 2001). The cultivation of hybrid maize varieties has contributed to remarkable yield increases in many maize growing countries in the world (Karunaratne, 2001).

Farmers, however, have provided a range of reasons why they may not invest in hybrid seeds, some of which are high hybrid seed prices, non-availability of hybrid seed at local shops, high requirement of fertilizer for cultivation, small or no differences in yield when compared to local varieties, poor storability and poor processing quality (Pixley and Banziger, 2001). These arguments have raised the question whether hybrids have indeed an advantage over open pollinated or local varieties under resource-poor farmer conditions where insecure seed availability, low input use and crop failures due to erratic rainfall are very common ((Pixley and Banziger, 2001).

In addition to the genotype, a crop's phenotype is equally influenced by the environment, as well as genotype (G) by environment (E) interaction (or G x E interaction), which accounts for a significant portion of yields attainable in improved varieties (Sallah et al., 2004). High G x E interaction influence on yield due to location, seasons, soil fertility levels and sowing dates have been reported in Ghana (Ewool, 2004). Yield stability of maize genotype is influenced by the capacity of the genotype to react to environmental conditions, which is determined by the composition of the genotype (Borojevic, 1990). Hence extensive studies of maize varieties under stress and optimal growing environments would be useful for identifying varieties that combine high yielding abilities with stability.

Soil fertility decline is also a major biophysical factor challenging crop production in Ghana (Logah et al., 2010). Current increasing population however has put pressure on agricultural lands, preventing resource poor farmers from engaging in shifting cultivation and bush fallowing which initially was the best option for sustaining soil fertility and crop production. This has resulted in declining soil fertility and consequent reduction in yield (Alabi et al., 2003). In developed countries, nitrogen deficiency is alleviated by the addition of inorganic fertilizer. This however is impossible in developing countries because, either fertilizers are unavailable or are very expensive for small scale subsistent farmers (Mkhabela and Pali-Shikhulu, 2001).

Maize breeding programmes in Ghana have seen tremendous transformation from the initial dedication to the development of Quality Protein Maize (QPM) OPVs to the current era of hybrid variety promotion. According to IITA report in 2000, 31 varieties had been released between 1965 and 1998 alone. Ewool (2004) attributed 33% to 41% increases in yields in Ghana to breeding of improved hybrids over OPVs by 1997 under sufficient nitrogen supply. 49% to 63% genetic gain in yield was also attributed to the replacement of local varieties with hybrid varieties available within the same period. Eight new varieties have since been released after this research. The study therefore aimed at evaluating performances of some new varieties of maize under three levels of nitrogen fertilization in two agro-ecological zones in Ghana.

2. MATERIALS AND METHODS

2.1. Experimental sites

The study was carried out in two experimental locations in order to estimate genotype by environment interaction. These were at Kwadaso (6^o 41' N, 1^o 36' W- forest ecology, Coarse sandy-loam Paleustult) and Ejura (7^o 23' N, 1^o21' W- transition ecology, fine- coarse sandy loam Oxisol), both in the Ashanti region of Ghana.

2.2. Land preparation

The fields were disc- ploughed, harrowed and ridged before planting to achieve a minimum tillage. Glyphosate at 1.5 kg ha^{-1} was also applied two weeks before planting to control pre- emergence weeds.

2.3. Soil analysis.

Soil analysis was carried out on soil samples taken before nitrogen application to ascertain the nutrient level of the soils in the two locations for better result interpretation. Results of initial soil properties (Page et al., 1982) of the experimental fields are presented in Table 1. In both fields, phosphorus levels were found to be low (Landon 1991). However, soil at Kwadaso was relatively better than that of Ejura in terms of fertility. Nitrogen levels (Table 1) were considered low in both locations since amounts less than 0.5% were recorded, hence it was expected that results obtained in the study would project the true response of genotypes to externally applied nitrogen.

2.4. Experimental material

Thirteen varieties of maize consisting of 1 local variety, 5 improved open pollinated varieties, 4 inbred lines and 3 hybrid varieties comprising of commercialized varieties were used in the present study. These varieties were obtained from the Crop Research Institute, Kumasi in the Ashanti region of

Ghana. The characteristics of the varieties used are summarized in Table 2 (Sallah et al., 2004; Ewool, 2004).

2.5. Field layout and treatments

The experimental design was 3 x 13 split plot experiment arranged in RCBD with three nitrogen levels as main- plot factor and 13 varieties as sub-plot factor. The treatment combinations were replicated four times in each location. Three nitrogen levels N_1; 0 kg N ha^{-1}, N_2; 45 kg Nha^{-1} and N_3; 90 kg N ha^{-1} were applied to all 13 maize varieties (Table 1) in each location, resulting in 39 treatment combinations. These levels of nitrogen treatment factor were applied in 2 splits with the first half applied at 2 weeks after planting (WAP) and the second split at 4 WAP. Each plot consisted of two rows, 5 m long, spaced at 0.75 m apart with 0.225 m between plants within a row in both locations. Planting was done at three seeds per hill and later thinned to one plant per hill. Application of 60 kg P_2O_5 $ha^{-1}$and 30 kg K_2O ha^{-1} was done as basal fertilizer in addition to the different nitrogen levels. Weeding by hoe was done three times at three weekly intervals after planting to control post-emergence weeds in both locations and to maintain weed- free fields.

Table 1: Initial soil properties in the experimental fields

Soil Properties	Kwadaso		Ejura	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
pH (1:1)	6.32	5.53	5.52	5.27
Organic C (%)	0.94	0.51	0.41	0.41
Total N (%)	0.09	0.04	0.04	0.04
Ex Ca (mg/kg)	854	694	640	374
Ex Mg (mg/kg)	128.4	96	150	112.8
Ex K (mg/kg)	163.8	132.6	39	35.1
Ex Na (mg/kg)	184.3	107.5	46.08	46.08
Av P (mg/kg)	261.50	64.50	5.95	5.02

Ex: Exchangeable, Av: Available

Table 2: Varieties used in the study and their characteristics

Variety	Year of release	Maturity zone	Varietal type	Reason for release
Etubi	2007	Intermediate	WQPHM	DT
Mamaba	1997	Intermediate	WQPHM	DT
Golden jubilee	2007	Intermediate	YOPV/QPM	QPM
Obatanpa	1992	Intermediate	WOPV/QPM	Yield, QPM
Abontem	2010	Extra-early	YOPV/QPM	STR, Earliness
Akposoe	2007	Extra-early	WOPV/QPM	DT, Earliness
Aburohemaa	2009	Early	WOPV/QPM	DT, STR
Local	1955	Late	OPNM	Yield
GH 110	1997	Intermediate	SCH	DT
Entry 5	1997	Intermediate	Inbred line	DT
Entry 6	1997	Intermediate	Inbred line	DT
Entry 70	1997	Intermediate	Inbred line	DT
Entry 85	2007	Intermediate	Inbred line	DT

WQPHM: White Quality Protein Hybrid Maize, YOPV: Yellow Open Pollinated Variety, QPM: Quality Protein Maize, WOPV: White Open Pollinated Variety, OPNM: Open Pollinated Normal Maize, SCH: Single Cross Hybrid, DT: Drought Tolerant, STR: *Striga hermontica* Resistance.

2.6. Data collection

Data were recorded in both locations on days to 50% silking, as the number of days from planting to when 50% of the plants had emerged silks, and days to anthesis when 50% had shed pollen. The anthesis-silking interval (ASI) was calculated as the difference between days to 50% silking and 50% anthesis. Plant height was measured as the distance from the base of the plant to the height of the first tassel branch and ear height as the distance to the node bearing the upper ear respectively. Root lodging (percentage of plants leaning more than 30° from the vertical), and stalk lodging (percentage broken at or below the highest ear node), and ear aspect (based on a scale of 1 to 5, where 1; clean, uniform, large, and well-filled ears and 5; ears with undesirable features), were also recorded. Ear number per plant was obtained by dividing the total number of ears per plot by the number of plants harvested. Open tip was counted as cobs with less than two-third of their tips covered with grains. Harvested ears from each plot were shelled to determine the moisture content in percentage. Number of rotten ears was counted as cobs with more than a third of their kernels rotten. Streak, and blight on a scale of 1 to 5, 1; absence of disease and 5; severe infection. Cob length was measured after dehusking the ear. Cob diameter, grain length, grain diameter grain width and grain thickness were measured by using a Veneer caliper. Weights of 1000 grains were also recorded for each treatment. Grain yield was computed from field weight (kg/m^2), adjusted to 15% moisture content and 80% shelling percentage (Salami et al., 2003).

2.7. Data analysis

Analysis of variance (ANOVA) was performed on collected data separately for each environment and later combined across locations using GenStat Statistical package version 9. Count data were transformed before analysis was done using square root transformation. Mean separation was done using Least significant difference (Lsd) at 5%. Yield data was subjected to genotype main effect and genotype by environment interaction (GGE) biplot analysis to assess yield stability among the maize varieties.

3. RESULTS

The combined analysis of variance (ANOVA) for all 13 genotypes evaluated at Kwadaso and Ejura under the three nitrogen levels revealed highly significant ($P < 0.05$) genotype (G) mean square values for grain yield and all other agronomic traits measured except for grain thickness (Tables 3). Similarly, location (L) showed highly significant mean square values for grain yield and all other agronomic traits considered but not 1000 seed weight. The combined ANOVA also produced highly significant nitrogen (N) mean square values for grain yield at $P < 0.05$ (Tables 3). The G x L x N interactions showed highly significant mean square values for grain yield.

Combined ANOVA showed that genotypes were significantly different in their grain yielding abilities. Averaged across test environments (i.e. location by nitrogen levels), 'Mamaba', a Quality Protein Maize (QPM) hybrid recorded the highest mean grain yield of 4.73 t ha^{-1} which was significantly different from the mean grain yield of remaining varieties except 'Etubi' (Table 5). 'Entry 6' which is an inbred line recorded the lowest grain yield of 0.51 t ha^{-1}. Mean grain yield was significantly higher at Kwadaso (3.16 t ha^{-1}) than Ejura (2.61 t ha^{-1}). With respect to nitrogen levels, generally, all genotypes considered showed appreciable increases in yield in response to increases in nitrogen level from 0 – 90 kg N ha^{-1}. No negative response was recorded for grain yield in any genotype, indicating that yield increase was directly proportional to nitrogen levels and was observed in the order of 0 kg N ha^{-1} < 45 kg N ha^{-1} < 90 kg N ha^{-1}. Although a very high significant G x N x L interaction was observed for grain yield, there were no changes in the ranks among the genotypes across the test environments in their mean grain yielding abilities except for Kwadaso under 0 kg N ha^{-1} and 45 kg N ha^{-1} where 'Etubi' slightly out-yielded 'Mamaba' (Table 6). The highest mean grain yield was recorded at both locations with ranges in mean grain yield from 0.69 – 5.30 t ha^{-1} at Ejura and 0.84 – 6.38 t ha^{-1} at Kwadaso. The lowest mean grain yield was produced at 0 kg N ha^{-1} Ejura and Kwadaso test environments, where ranges in mean grain yield were from 0.2 – 3.21 t ha^{-1} and 0.31 – 3.88 t ha^{-1} at Ejura and Kwadaso, respectively.

A GGE biplot analysis was carried out in which environments were designated as combinations of the two locations (Ejura and Kwadaso) and three nitrogen levels (0 kg N ha^{-1}, 45 kg N ha^{-1} and 90 kg N ha^{-1}) resulting in six test environments in accordance with Beets (1982) definition of an environment as all microclimatological and physical factors such as water, temperature, soil conditions and all other factors that affect plants growth, development and yield. In the GGE biplot analysis, Principal Components 1 and 2 (PC1 and PC2) together explained 99% of variation in grain yield. Thus 99% of the variation in yield was due to genotype and genotype by environment effects (Figure 1).

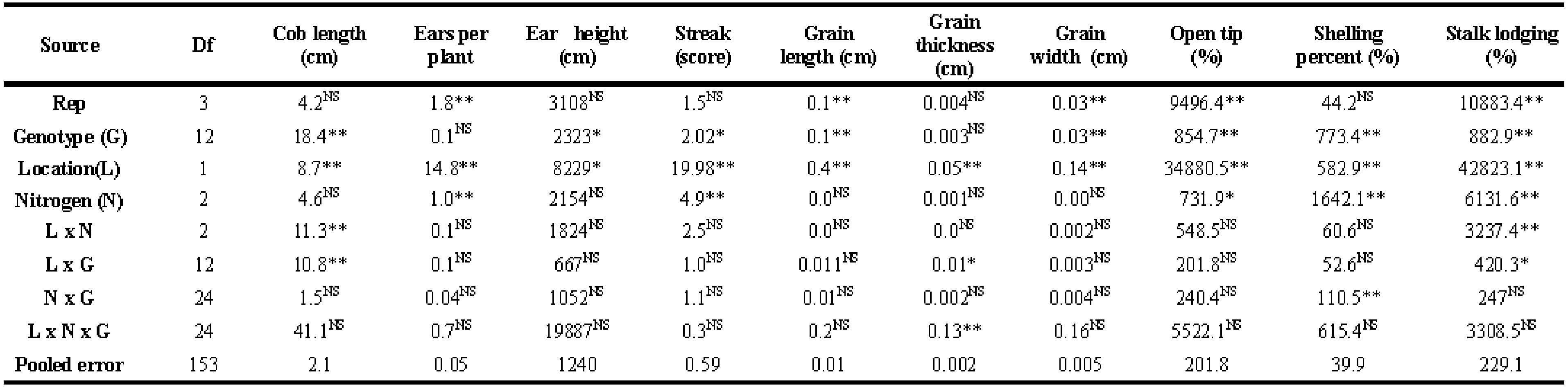
Result from the "which won where" biplot (Figure 1) grouped the six test environments into two mega-environments. The two mega-environments were obtained by grouping Ejura under 90 kg N ha-1 (EN3), Ejura under 45 kg N ha^{-1} (EN2), Kwadaso under 90 kg N ha^{-1} (KN3) Kwadaso under 45 kg N ha^{-1} (KN2) as one mega- environment, with 'Mamaba' as the highest yielding genotype in that environment and Ejura under 0 kg N ha^{-1} (EN1), Kwadaso under 0 kg N ha^{-1} as the other mega environment with 'Etubi' as the highest yielding genotype.

Table 3: Mean sum of squares from combine ANOVA of maize genotypes for grain yield and stability under 3 Nitrogen levels in Kwadaso and Ejura

Source	Df	Grain Yield (t ha^{-1})	1000 seed weight (g)	Mid anthesis (days)	Mid silking (Days)	ASI (Days)	Blight disease (score)	Cob aspects (score)	Cob diameter (cm)	Plant height (cm)	Rotten ears (%)	Root lodge (%)
Rep	3	2.8**	6592*	92.8**	72.2**	8.6**	12.9**	1.3**	0.7**	724**	2105.5**	465.1**
Genotype (G)	12	44.1**	12207**	122.8**	152.6**	3.4**	0.8**	0.8**	1.8**	2706.7**	577.7**	52.1*
Location (L)	1	11.8**	2764^{NS}	1235.4**	785.3**	50.8**	72.0**	6.4**	2.9**	5261.8**	10665.1**	1051.7**
Nitrogen (N)	2	42.4**	2643^{NS}	248.0**	519.5**	49.9**	0.08^{NS}	1.2**	0.04^{NS}	11039.9**	38^{NS}	61.8^{NS}
L x N	2	0.9**	2569^{NS}	23.2**	49.8**	6.4**	0.04^{NS}	5.4**	0.2^{NS}	1267.9**	20.1^{NS}	9.9^{NS}
L x G	12	0.5**	415^{NS}	27.9*	29.7**	1.1^{NS}	0.4^{NS}	0.4^{NS}	0.2**	912.6**	336.8**	26.0^{NS}
N x G	24	0.9**	1660^{NS}	5.7NS	4.1^{NS}	1.5*	0.2^{NS}	0.2^{NS}	0.08^{NS}	88.3^{NS}	110.7^{NS}	19.9^{NS}
L x N x G	24	0.1**	45487^{NS}	186.8**	228.0**	24.8^{NS}	2.6^{NS}	5.9^{NS}	2.4^{NS}	3971^{NS}	1303.5^{NS}	306.2^{NS}
Pooled error	153	0.04	1786	4.0	4.7	0.9	0.24	0.25	0.08	170.6	109.0	26.1

** = significance at 1%; * = significance at 5%; NS = non-significance.

Table 4: Mean sum of squares from combine ANOVA of maize genotypes for grain yield and stability under 3 Nitrogen levels in Kwadaso and Ejura



Source	Df	Cob length (cm)	Ears per plant	Ear height (cm)	Streak (score)	Grain length (cm)	Grain thickness (cm)	Grain width (cm)	Open tip (%)	Shelling percent (%)	Stalk lodging (%)
Rep	3	4.2^{NS}	1.8**	3108^{NS}	1.5^{NS}	0.1**	0.004^{NS}	0.03**	9496.4**	44.2^{NS}	10883.4**
Genotype (G)	12	18.4**	0.1^{NS}	2323*	2.02*	0.1**	0.003^{NS}	0.03**	854.7**	773.4**	882.9**
Location(L)	1	8.7**	14.8**	8229*	19.98**	0.4**	0.05**	0.14**	34880.5**	582.9**	42823.1**
Nitrogen (N)	2	4.6^{NS}	1.0**	2154^{NS}	4.9**	0.0^{NS}	0.001^{NS}	0.00^{NS}	731.9*	1642.1**	6131.6**
L x N	2	11.3**	0.1^{NS}	1824^{NS}	2.5^{NS}	0.0^{NS}	0.0^{NS}	0.002^{NS}	548.5^{NS}	60.6^{NS}	3237.4**
L x G	12	10.8**	0.1^{NS}	667^{NS}	1.0^{NS}	0.011^{NS}	0.01*	0.003^{NS}	201.8^{NS}	52.6^{NS}	420.3*
N x G	24	1.5^{NS}	0.04^{NS}	1052^{NS}	1.1^{NS}	0.01^{NS}	0.002^{NS}	0.004^{NS}	240.4^{NS}	110.5**	247^{NS}
L x N x G	24	41.1^{NS}	0.7^{NS}	19887^{NS}	0.3^{NS}	0.2^{NS}	0.13**	0.16^{NS}	5522.1^{NS}	615.4^{NS}	3308.5^{NS}
Pooled error	153	2.1	0.05	1240	0.59	0.01	0.002	0.005	201.8	39.9	229.1

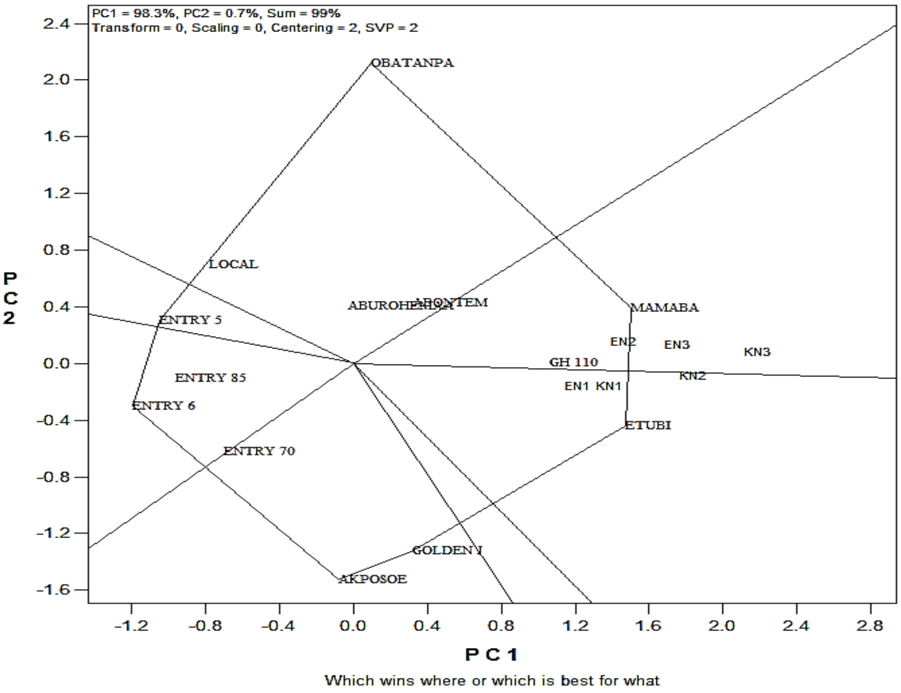


Fig. 1: A 'which won where' GGE biplot of grain yield for 13 genotypes under six environments as EN1 (Ejura under 0 kg N ha^{-1}), EN2 (Ejura under 45 kg N ha^{-1}), EN3 (Ejura under 90 kg N ha^{-1}), KN1 (Kwadaso under 0 kg N ha^{-1}), KN2 (Kwadaso under 45 kg N ha^{-1}) and KN3 (Kwadaso under 90 kg N ha^{-1}). The data was not transformed ("Transform = 0"), not standardized ("scale = 0"), and were environment-centered ("centering = 2"). The biplot was based on genotype- focused singular value partitioning ("SVP = 2") and is therefore appropriate for visualizing the relationship among environments. Principal component (PC) 1 and PC2 for model 3 explained 99% of yield variation.

In the ranking of genotypes based on the mean yield and stability GGE biplot (Figure 2), the double arrowed vertical (blue) line Average Tester Coordinate (ATC ordinate or y axis) measures stability whiles the average yield of a cultivar is approximated by its position on the ATC abscissa or x- axis (the single arrowed horizontal red line). The red circle on the ATC abscissa is the average tester yield, thus 'Etubi', 'Mamaba' and 'GH 110' yielded above the average tester yield (Figure 2). The stability of a cultivar is measured by their projection onto the ATC ordinate, thus the greater the projection of the cultivar the less stable it is (Yan et al., 2007). In the current study, the mean and stability GGE biplot revealed that, 'Mamaba' and 'Etubi' were the highest yielding and most stable cultivars since differences in their individual stability and yield were not significant from each other. Open pollinated varieties (OPVs) had the second highest mean grain yield and were averagely stable but 'Obatanpa' was the least stable among all the cultivars considered. The inbred lines and local varieties were the lowest yielding genotype but were the most stable, following Yan et al. (2007) interpretation. Figure 3 shows the discriminating power and representativeness of the six test environments considered and its appropriateness for studying the relationship between the test environments. It thus helps in selecting the ideal test environment for testing the 13 genotypes considered. An ideal test environment explained by Yan et al. (2007) should be both discriminating of the genotypes as well as representative of the mega- environment. According to Yan (2002), test environments with long vectors as observed for KN3 (Kwadaso under 90 kg N ha^{-1}) in the present study, are more discriminating of genotypes while those with short vectors (e.g. EN1; Ejura under 0 kg N ha^{-1}) are less discriminating and provide little information on the genotype yield differences. In terms of representativeness, KN3 is more representative of the mega-environments as it has the smallest angle of deviation with the single-arrowed axis (Yan et al., 2007). Since test environment KN3 has the longest vector and smallest angle, it provides unique information and is therefore ideal for selecting superior genotypes.

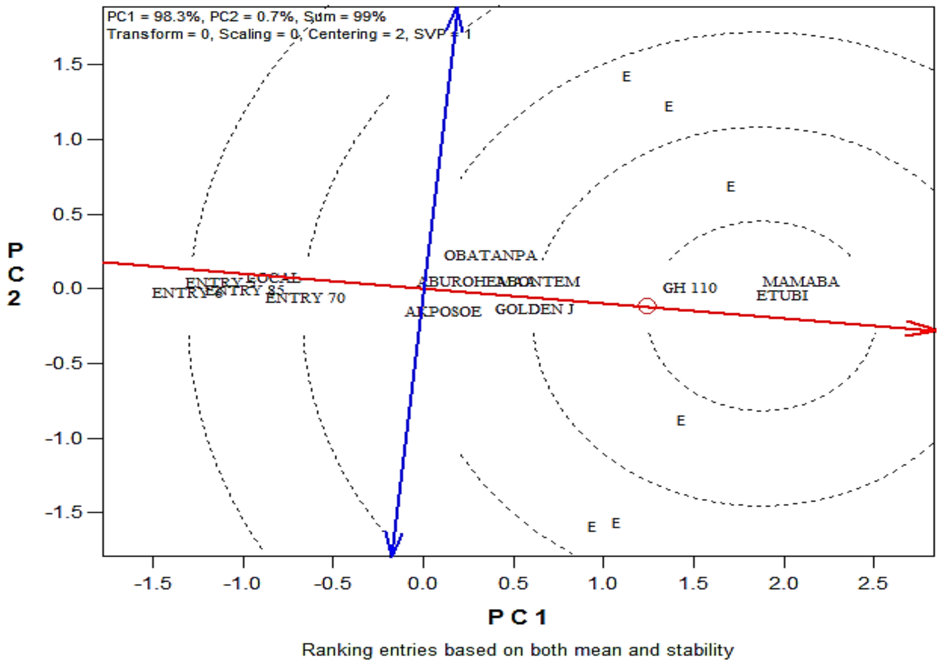


Fig. 2: Ranking of genotypes based on mean and stability GGE biplot of grain yield for 13 genotypes under six environments (EN1 (Ejura under 0 kg N ha^{-1}), EN2 (Ejura under 45 kg N ha^{-1}), EN3 (Ejura under 90 kg N ha^{-1}), KN1 (Kwadaso under 0 kg N ha^{-1}), KN2 (Kwadaso under 45 kg N ha^{-1}) and KN3 (Kwadaso under 90 kg N ha^{-1}). The data was not transformed ("Transform = 0"), not standardized ("scale = 0"), and were environment-centered ("centering = 2"). The biplot was based on genotype-focused singular value partitioning ("SVP = 2") and is therefore appropriate for visualizing the relationship among environments. Principal component (PC)1 and PC2 for model 3 explained 99% of yield variation.

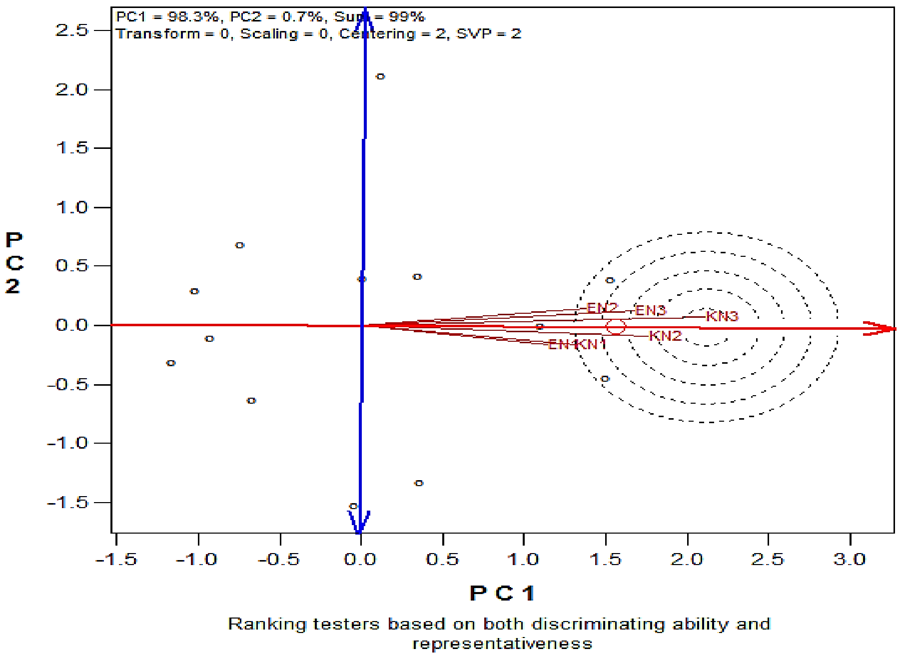


Fig. 3: Ranking of test environment based on both discriminating ability and representativeness GGE biplot of grain yield for 13 genotypes under six environments (EN1 (Ejura under 0 kg N ha^{-1}), EN2 (Ejura under 45 kg N ha^{-1}), EN3 (Ejura under 90 kg N ha^{-1}), KN1 (Kwadaso under 0 kg N ha^{-1}), KN2 (Kwadaso under 45 kg N ha^{-1}) andKN3 (Kwadaso under 90 kg N ha^{-1}). The data was not transformed ("Transform = 0"), not standardized ("scale = 0"), and were environment-centered ("centering = 2"). The biplot was based on genotype- focused singular value partitioning ("SVP = 2") and is therefore appropriate for visualizing the relationship among environments. Principal component (PC)1 and PC2 for model 3 explained 99% of yield variation.

In the present study, mean grain yield for QPM hybrids, OPVs, local varieties and inbred lines were 4.67 t ha^{-1}, 3.67 t ha^{-1}, 2.90 t ha^{-1} and 0.90 t ha^{-1}, respectively when averaged across nitrogen levels and locations (Table 6). From Figure 4, Hybrids recorded 16.6% and 55.4% yield advantage over OPV and local varieties respectively at 0 kg N ha^{-1}. OPVs on the other hand recorded 33.3% yield advantage over local varieties. At 45 kg N ha^{-1}, hybrids recorded 29.7% and 88% yield advantage over OPVs and local varieties respectively. OPVs on the other hand recorded 45.2% yield advantage over local varieties. At 90 kg N ha^{-1}, hybrids recorded 30.9% and 73.45% yield advantage over OPVs and local varieties respectively whiles OPVs consequently recorded 32.45% yield advantage over local varieties. Generally, it was apparent that, Hybrids' yield advantages over OPVs increased sharply with increase in nitrogen level from 0 kg N ha^{-1} to 45 kg N ha^{-1} but at 90 kg N ha^{-1} difference in yield advantage was not significant from that of 45 kg N ha^{-1}.

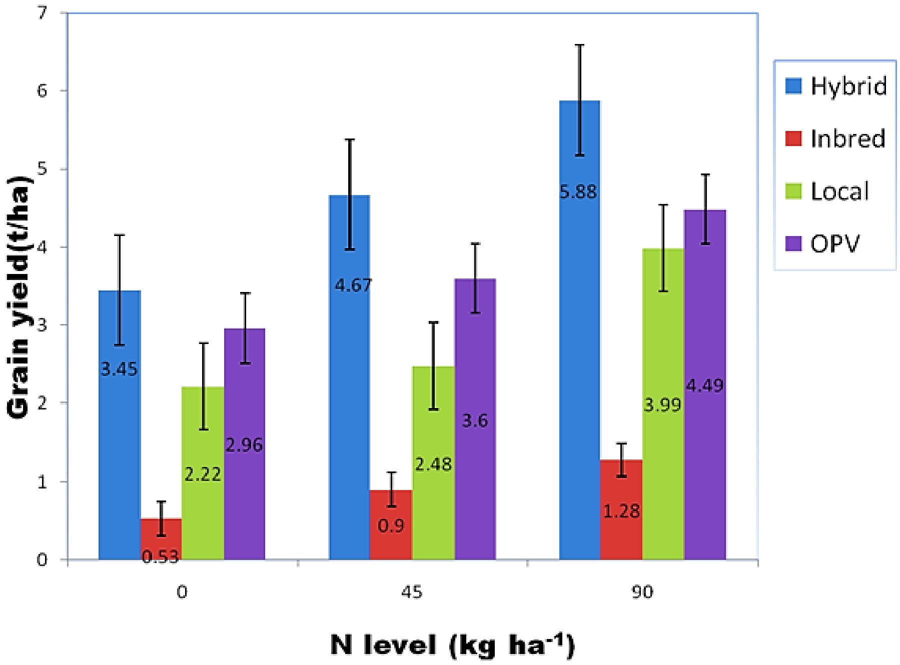


Fig. 4: Mean grain yield of OPVs, inbred lines, local varieties and hybrids evaluated under 3 Nitrogen levels at Kwadaso and Ejura.

Heterosis estimates of hybrids calculated on high parent value basis using mean grain yield of genotypes recorded in Table 4 are presented in Table 5. 'Mamaba' recorded the highest heterosis value of 269.53% ahead of 'Etubi' (264.84%) and GH110 (219.53%).

Table 5: Heterosis of three hybrid varieties planted in the experimental sites under 3 Nitrogen levels

Hybrid	Type of cross	Inbred parents	Inbred parental yields (t ha^{-1})	Heterosis (%)
GH 110	single	Entry 6	0.51	219.53
		Entry 70	1.28	
Mamaba	Three way	Entry 6	0.51	269.53
		Entry 70	1.28	
		Entry 5	0.72	
Etubi	Three way	Entry 6	0.51	264.84
		Entry 70	1.28	
		Entry 85	0.88	

The combine ANOVA showed significances in genotypes for shelling percentages. Shelling percentages of genotypes are presented in Table 6. Local varieties recorded the highest shelling percentage of 79.38% whilst ‘entry 5’ had the smallest shelling percentage of 57.52%. Nitrogen was significant ($P < 0.05$) for shelling percentage with decreasing percentages with increasing nitrogen level in all genotypes except for the local variety which did not record a regular response to nitrogen.

Table 6: Mean shelling percentages of 13 maize genotypes evaluated in Ejura and Kwadaso in the minor and major seasons of 2011 respectively

Genotype	**Variety Type**	**Locations**						**Means**
		Ejura			**Kwadaso**			
		0 kg N ha^{-1}	**45 kg N ha^{-1}**	**90 kg N ha^{-1}**	**0 kg N ha^{-1}**	**45 kg N ha^{-1}**	**90 kg N ha^{-1}**	
Abontem	**OPV**	73.95	69.14	58.06	76.93	71.57	60.82	68.86
Aburohemaa	**OPV**	73.00	66.62	54.69	75.99	69.15	56.34	66.36
Akposoe	**OPV**	73.61	64.4	56.58	76.73	67.18	56.34	66.12
Obatanpa	**OPV**	73.02	67.52	54.46	76.79	69.04	57.12	66.77
Golden J	**OPV**	63.84	66.58	64.59	59.82	69.36	57.12	63.07
Entry 5	**Inbred**	60.44	52.35	49.68	63.77	52.91	60.93	57.52
Entry 6	**Inbred**	61.08	53.26	48.21	64.68	55.99	57.07	57.56
Entry 70	**Inbred**	61.52	53.8	51.67	63.77	57.9	54.98	57.81
Entry 85	**Inbred**	60.57	57.8	49.56	63.77	64.21	52.39	58.74
Etubi	**Hybrid**	68.57	63.79	49.69	71.1	72.79	75.37	68.95
GH 110	**Hybrid**	70.73	67.67	60.43	72.69	75.29	72.79	71.15
Mamaba	**Hybrid**	70.56	67.04	63.08	71.74	71.82	74.57	70.77
Local	**Local**	79.53	78.75	78.86	80.03	79.1	79.5	79.38
Means		68.49	63.75	56.89	70.6	67.41	62.72	65.62
Lsd (5%)		8.82^{NS}	8.82^{NS}	8.82^{NS}	8.82^{NS}	8.82^{NS}	8.82^{NS}	4.16**
Lsd (5%) #		2.45^{NS}						
CV (%)		9.63						

For comparison of environments means;**significance at 1%.

Mean shelling percentages of 69.90%, 66.19% and 60.78% were observed for 0, 45 and 90 kg N ha^{-1} respectively. Location was significant with Ejura recording 63.04% and Kwadaso recording 66.91%. Nitrogen by variety interaction was significant; local varieties had the highest shelling percentages at all nitrogen levels. Under 0 kg N ha^{-1}, local varieties had 12.22% and 9.97% advantage over hybrids and OPVs respectively. Under 45 kg N ha^{-1}, local varieties recorded11.42% and 15.33% advantage over hybrids and OPVs, respectively. Under 90 kg N ha^{-1}, local varieties recorded 15.45% and 37.67% advantage over hybrids and OPVs respectively. Genotype by location and genotype by location by nitrogen interactions were not significant (Figure 5).

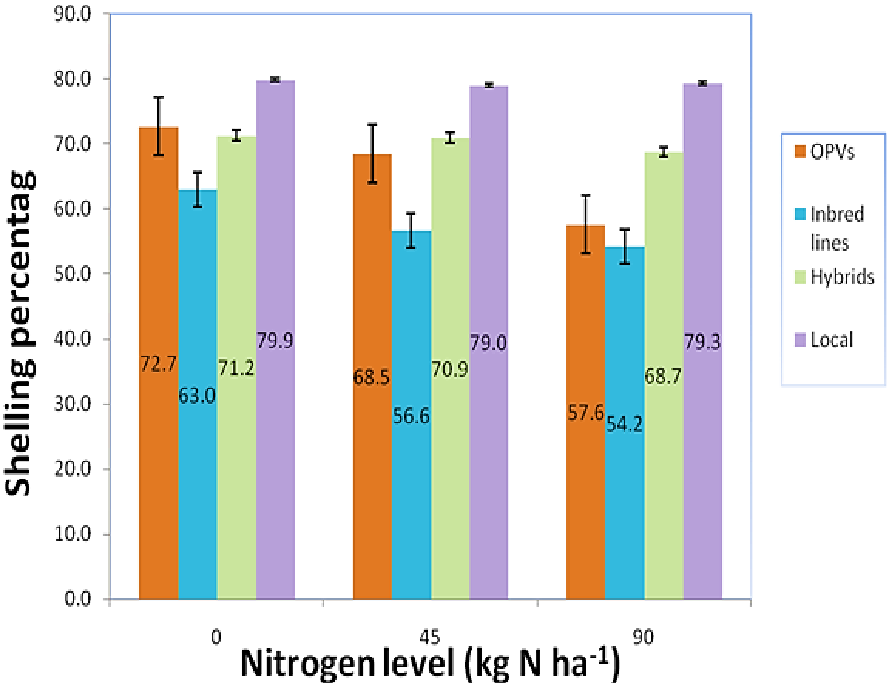


Fig. 5: Mean shelling percentages of OPVs, inbred lines, local varieties and hybrids evaluated under 3 Nitrogen levels at Kwadaso and Ejura

4. DISCUSSIONS

Genotypes were significantly different for grain yield because they were developed from different parental lines, belong to different maturity groups, are season specific and were developed individually to meet specific breeding objectives. Similar results and reasons were cited for genotypic differences in grain yield by Ewool (2004) and Sallah et al. (2004). Generally hybrids had higher yields than OPVs and local check varieties because traits related to yielding abilities in hybrids such as shorter ASI, longer cob length, and better resistance to root lodging were observed to be better in comparison with all other varietal groups. The observations made by Karunaratne (2001) that hybrid maize varieties generally have improved greatly in numerous agronomic traits resulting in their improved yielding abilities due to allelic differences at loci of the parents, leading to heterozygosity in hybrids and resultant expression of heterosis in the hybrids confirms the obtained results.

Significant genotype × environment interaction (GEI) has often been observed in multi-environmental maize yield trials in West and Central Africa (Badu-Apraku et al., 2003; 2007; 2008; 2009; 2010). GEI emanates from changes in the magnitude of response of cultivars to diverse growing conditions, when evaluated across years and locations (Mishra et al., 2006). GEI usually presents a problem for plant breeders because it causes uncertainty when translating the relative performance of cultivars in one environment to performance in a different environment. Consequently, prior to the release of cultivars, it is highly imperative to conduct multi-environmental yield trials so as to enable plant breeders identify and select high yielding cultivars with specific or broad adaptation to different agro-ecological zones. Furthermore, information obtained from such trials could aid national breeding programmes by recognizing suitable breeding materials with specific stress tolerance, desirable agronomic traits, and end-use quality attributes for utilization (Badu-Apraku et al., 2010). In the present study, highly significant genotype × nitrogen, genotype × location, and genotype × nitrogen × location interactions were found for grain yield.

In GEI analysis, one is concerned with identifying the best performing cultivar in a given environment and the most suitable environment for each cultivar, the average yield and stability of the genotypes and the discriminating ability and representativeness of the test environments. The GGE biplot methodology proposed by Yan et al. (2000) is a powerful statistical tool for performing the above-mentioned analyses with ease. In the current study, the “which won where” GGE biplot analysis revealed that ‘Etubi’ and ‘Mamaba’ were the highest yielding genotypes under no nitrogen and high nitrogen application respectively. This means that hybrids are more efficient in using nitrogen than OPVs and local varieties. Although root depth were not checked in this study, the good standability and low lodging in the hybrids could be indicative of deep root system that also made them efficient in nitrogen uptake. Similar reasons were assigned by Laffite and Edmeades (1994).

The reliability of a cultivar's performance across locations is an important consideration in plant breeding. Stability of a cultivar depends on its ability to perform similarly regardless of the productivity levels of environment; thus the cultivar is adapted to a broad range of environments. A cultivar's stability is also influenced by the genotype of the individual plant and the genetic relationship among plants of the cultivar (Fehr, 1987). 'Mamaba' and 'Etubi' were ranked as the genotypes that best combine high yielding abilities with stability across environments (nitrogen and location combinations). Thus under no and high nitrogen application (at both Ejura and Kwadaso), 'Etubi' and 'Mamaba' would produce better yields respectively. The result is supported by findings of Badu- Apraku et al. (2010) which emphasize the need for integrating stability of yield performance with mean yield to select high yielding genotypes. OPVs were high yielding than local varieties but were less stable whilst local varieties were highly stable but low yielding. Stability of local varieties confirm report by Odendo et al. (2001) that farmers prefer local varieties because they can be grown under stress conditions such as low rainfall and diseases as they serve as risk management strategy against environmental disaster. Yields of local varieties are however very low and are therefore not recommended.

Kwadaso under 90 kg N/ ha was the environment observed to be most representative of all test environment and had the highest discriminating ability for selecting superior genotypes. This means that in the selection of ideal genotypes this environment was the best.

Significant grain yield differences observed for the two locations (Ejura and Kwadaso) used in the present study could be attributed to differences in soil property and fertility levels in the forest and transitional agro-ecological zones. Also seasonal effects could account for grain yield differences at the two locations as the present study was conducted in different seasons of the same year for the two locations. Yields at Kwadaso were generally better than those recorded at Ejura for all genotypes because environment provided for maize growth at Kwadaso was nearer to an ideal maize growing environment. Soil at Kwadaso was more fertile than soil at Ejura for all nutrients tested before planting. The soil pH at Kwadaso was also within the optimum requirement for maize growth (5.8 - 6.5) whiles soil at Ejura was more acidic with respect to the optimum recommendation. With respect to cropping history of the two experimental sites, field at Kwadaso had been subjected to continuous cropping under optimum fertilizer supply for several seasons whiles the Ejura experimental site had seen little nutrient replenishment. Sallah et al. (2004) also recorded significant location effect. Significant nitrogen effect observed for grain yield, shelling percentage, cob diameter, and several other agronomic traits, is in agreement with those obtained by Alabi et al. (2003) who detected significant nitrogen effects for grain yield and other agronomic traits.

Significant interaction between genotypes, nitrogen and location for grain yield suggests the possibility of selecting ideal genotypes for specific nitrogen levels at Ejura and Kwadaso. These were due to the differences that existed in the locations involved and difference in response of genotypes to nitrogen supplied. Similar interactions were observed by Sallah et al. (2004).

5. CONCLUSIONS AND RECOMMENDATIONS

Three hybrid varieties, five OPVs, one local variety and four inbred lines were evaluated under three nitrogen levels in Kwadaso and Ejura to compare their relative yielding abilities and stability under low and high nitrogen.

Results showed that:

(a) Hybrid maize varieties had improved yielding abilities over OPVs and local varieties under both low and high nitrogen.

(b) 'Etubi' was the highest yielding genotype under low nitrogen whilst 'Mamaba' was the highest yielding under high nitrogen.

(c) Hybrid varieties were also able to effectively combine stability with their high yielding abilities under no and high nitrogen applications.

From these results, farmers should be encouraged to buy and use hybrid seeds to take advantage of their high yields under low nitrogen. For maximum benefit, the fertilizer subsidy policy by the government should be vigorously pursued and well managed to deliver hybrid seed and fertilizers to farmers at the right time. Secondly, large quantities of hybrid seeds should be produced by seed companies to bring down the unit price of hybrid seed, to make it affordable to farmers.

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