RESPONSE OF MAIZE (*Zea mays* L.) VARIETIES TO MORINGA-BANANA PEEL-MAIZE STALK FERTILIZER AND GRAIN YIELD MODELLING †

[RESPUESTA DE VARIEDADES DE MAÍZ (*Zea mays* L.) AL FERTILIZANTE DE MORINGA-CÁSCARA DE PLÁTANO-TALLO DE MAÍZ Y MODELADO DEL RENDIMIENTO DE GRANOS]

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SUMMARY

Background. Low soil nutrient limit maize production in Nigeria, and inorganic fertilizer used in augmenting yield are expensive and hazardous. **Objective.** In search for a sustainable alternative, the effect of methods of application (foliar and incorporated) of different levels of moringa-banana peel-maize stalk fertilizer (MBPF) on the growth and yield of different maize varieties was investigated. **Methodology.** Pot and field experiments were conducted. Each experiment consisted of 2 x 4 x 6 factorial combinations. In the pot experiment, the treatments were laid out in CRD while RCBD was used in the field experiment. All treatments were replicated three times. Data collected on agronomic, aesthetic and yield traits were subjected to ANOVA using SAS 9.4 version. PCA was done, thereafter, structural equation model (SEM) was constructed, and GGE biplot used to cluster treatment interaction using GEA-R 4.1 version. **Result.** The results of both pot and field experiments had similar trend except that pot experiment had reduced height, poor phenotypic appeal and reduced grain yield. The result showed that mode of application, fertilizer treatments and maize varieties had significant ($p<0.05$) mean square for grain yield. 120N+50P+40K and 100N+40P+30K rate of MBPF applied to single cross hybrids (SCH) with grain yield of 1.85 t/ha clustered with standard national recommended rate of NPK fertilizer. Grain yield was in the order of SCH LY1312-11 > SCH check > Double-cross hybrid > Three-way hybrid > Top-cross hybrid > OPV-STR. **Implication**. MBPF was most effective when incorporated into the soil a week before planting. **Conclusion**. Therefore, MBPF at 120N+50P+40K and 100N+40P+30K are sustainable and eco-friendly alternative to inorganic fertilizer.
keywords: Fertilizer; grain-yield; hybrids; maize; moringa-banana peel-maize stalk; sustainable alternative.

RESUMEN

Antecedentes. Los bajos niveles de nutrientes del suelo limitan la producción de maíz en Nigeria, y los fertilizantes inorgánicos utilizados para aumentar el rendimiento son costosos y peligrosos. **Objetivo.** En la búsqueda de una alternativa sustentable, se investigó el efecto de los métodos de aplicación (foliar e incorporado) de diferentes niveles de fertilizante de cáscara de moringa-banano (MBPF) sobre el crecimiento y rendimiento de diferentes variedades de maíz. **Metodología.** Se llevaron a cabo experimentos en macetas y en el campo. Cada experimento consistió en combinaciones factoriales de 2 x 4 x 6. En el experimento de maceta, los tratamientos se colocaron en un diseño completamente al azar (CRD) mientras que en el experimento de campo se utilizó el diseño de bloques completos al azar (RCBD). Todos los tratamientos se repitieron tres veces. Los datos recopilados sobre características agronómicas, apariencia y de rendimiento se sometieron a ANOVA utilizando la versión SAS 9.4. Se realizó un análisis de componentes principales (PCA), a partir de entonces, se construyó el modelo de ecuación estructural (SEM) y se usó el biplot GGE para agrupar la interacción del tratamiento usando la versión GEA-R 4.1. **Resultados.** Los resultados de los experimentos en maceta y en el campo tuvieron una tendencia similar, excepto que el experimento en maceta tuvo una altura reducida, un atractivo fenotípico deficiente y un rendimiento de grano reducido. El resultado mostró que el modo de aplicación, los tratamientos de fertilizantes y las clases de maíz tenían un cuadrado medio cuadrática significativo ($p <0.05$) para el rendimiento de grano. Las dosis de 120N + 50P + 40K y 100N + 40P + 30K dosis de MBPF aplicadas a híbridos cruzados simples (SCH) con rendimiento de grano de 1,85 t / se agruparon con la dosis estándar nacional recomendada de fertilizante NPK. El rendimiento de grano fue en el orden siguiente SCH LY1312-11> single cross hybrid SCH> híbrido de doble cruzamiento> híbrido de tres vías>

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híbrido de cruce superior> OPV-STR. **Implicación.** El MBPF fue más efectivo cuando se incorporó al suelo una semana antes de plantar. **Conclusión.** Por lo tanto, MBPF a 120N + 50P + 40K y 100N + 40P + 30K son una alternativa sostenible y ecológica a los fertilizantes inorgánicos.
Palabras clave: fertilizante; producción de grano; híbridos maíz; cáscara de moringa y plátano; alternativa sostenible.

INTRODUCTION

Maize (*Zea mays* L.) which used to rank third globally among grain crops after wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.), now ranks first in terms of its production (FAOSTAT, 2018). With respect to its significance, it is second-most cultivated after rice in the world (Ort and Long, 2014). Global maize production in 2018 was 1,147 million tons, cultivated on 193 million hectares, with an average grain yield of 5.92 t/ha (FAOSTAT, 2018). During the same period, maize production was 10 million t on 4.9 million hectares in Nigeria (FAOSTAT, 2018) with a poor yield. Therefore, Nigeria accounts only about 1% of the global production (FAOSTAT, 2018) and yet it was ranked as the primary producer in sub-Saharan African {(SSA) (USAID, 2010)}. Maize contribute more than 45% of total crop production value in SSA with a population of over 950 million people, cumulating to 13% of global population (OECD-FAO, 2016). Maize means life to over 300 million people in SSA (Muscat, 2013) and critical to over 112 million Nigerian smallholders (NBS 2012). More so, its cultivation is expected to double (CIMMYT and IITA, 2010) as a result of increasing demands and utilization and need to match local production with its demands for food, feed and industrial inputs (Relief Web 2017). Maize, as a C_4 plant, has higher yield potential than rice and wheat in the tropics (Gong *et al*., 2015). Declining low soil fertility is the major constraint to maize production in the tropic. In Nigeria, Savannah zones that have the best potential for maize production (as a result of low incident of diseases and highest solar radiation necessary for optimum photosynthesis, assimilate production and consequently yield) are most limited in soil organic matter, buffering capacity, water holding capacity and soil nutrient (Fakorede *et al*., 2001). Causes of soil nutrients depletion are continuous cropping, removal of crop residues for animal feed and shelter, bush burning and leaching as a result of torrential rain and lack of soil fertility restoring inputs and unbalanced soil nutrients (Adams *et al*., 2015). Traditional measures of restoring soil fertility; bush fallowing and land rotation are no longer fashionable as a result of population pressure. Moving forward, farmers embrace the use of inorganic fertilizers to augment soil nutrients and boost yield. Unfortunately, inorganic fertilizers are mostly unavailable, and when available, are expensive, hence, out of the reach of about 70% of Nigeria's workforce (FAOSTAT, 2017) who engage in agriculture as smaller holder farmers. Continuous use of inorganic fertilizer results in its reduced nutrient release efficiency thereby leaving behind in the soil a large proportion of unused nutrients which are likely to damage the soil and the environment. Inorganic fertilizers result in environmental pollution and contamination, global warming and the depletion of non-renewable fossil fuels used in the manufacturing of inorganic fertilizer (Goulding, 2004). Nonetheless, nutrient unavailability is the major constraint to optimum maize performance and hence results in low yield and income to farmers. The persistent exorbitant cost of inorganic fertilizers, land and soil degradation and environmental pollution have necessitated frantic efforts and advocacy for alternatives that are inexpensive and safe natural sources of nutrient replenishment technology for improved soil fertility and crops output at a very reduced cost. Hence, this research was initiated in order to explore the potential of moringa- banana peel and maize stalk organic fertilizer technology in reducing the devastating consequences of inorganic fertilizer to the ecosystem, improving crop output, and increasing the income of the farmers whose highest single input is fertilizer. Moringa- banana peel- maize stalk technology is a low cost bio-fertilizer which combines moringa leaves (MO), banana peel (BP), and maize stalk (MS) in different ratios and different forms (banding or foliar). Moringa leaves are rich in N (2.56%), banana peel (42% K) (Stone, 2015) and maize stalk have P and K of 370 and 1020 (mg/kg) respectively (Galila *et al*., 2012). Moringa- banana peel-maize stalk technology, a blend of moringa leaves, banana peel and maize stalk, a rich organic fertilizer contains most essential plant nutrients N, P and K and micronutrients. Therefore, investigating the response of different maize classes to a cost effective and environmentally friendly technology as a potential substitute to expensive, environmentally hazardous and soil degrading chemical fertilizer in Nigeria is highly desirable. The objectives of this research are to determine the: (i) rate of application of different mix of MO + BP + MS that produces the highest grain yield, (ii) best mode of application of MO + BP + MS mix that produces the highest grain yield, (iii) response of different maize varieties to MO + BP +MS mix, iv) identity the best maize variety and MO + BP +MS mix and v) identify secondary traits that can aid yield improvement under MBPF treatment.

MATERIALS AND METHODS

This research consisted of two experiments namely a pot experiment in the screen house study and an open field experiment at the Teaching and Research Farms, both at Kwara State University, Malete located at Latitude 8° 30' N, 8° 36' E and Longitude 4° 31' N, 4°33' E (Figure 1). The sites are about 345m above the sea level in Southern Guinea Savannah of Nigeria.

The experiment consisted of three factors namely: mode of fertilizer application (Foliar and incorporated), fertilizer treatments and maize classes. The maize classes evaluated included: Improved open pollinated variety (OPV-STR), single cross hybrid (SCH) (Oba Super 1 check), SCH LY1312-11, yellow double cross hybrid, three-way hybrid (LY1312-4) and Top cross hybrid (BRTZL x 1368). All maize seeds were obtained from the Maize Breeding Unit of IITA, Ibadan except the check, bought from a seed store. N, P and K were sourced from Moringa leaves (MO), maize stalk (MS) and banana peel (BP) respectively. Each of the nutrient sources was air-dried and grounded into smaller particles using a blender. The fertilizer treatments consisted of 70N+30P+20K, 100N+40P+30K, 120N+50P+40K and a control, 90kg NPK 15-15-15, a recommended rate for maize. Each of the fertilizers was incorporated into the soil and also applied as foliar fertilizer. The solid fertilizers were incorporated into the soil a week before planting while the foliar fertilizers were applied 2 and 6 weeks after planting to reduce being washed off by rain. To form the foliar fertilizer, each of the fertilizers was dissolved in a litre of water in a jar and covered for three days, thereafter, sieved into sprayer tank containing 1 litre of water and sprayed on the foliar part of the plants.

Representative samples of soils of the experimental sites were collected with the aid of soil auger at a depth of 15 cm for laboratory analysis in order to determine their pH, particle size, total N, total soil C, effective cation exchange capacity (ECEC), available P and exchangeable bases (Ca, Mg, Na and K) as described by IITA (1982) and Anderson and Ingram (1998). The exchangeable sodium (Na^+) and potassium (K^+) were determined through flame photometer as well as calcium (Ca^+) and magnesium (Mg^+) were read with Atomic Absorption Spectrophotometer (AAS). Also, the N, P and K content of Moringa leaves, maize stalk and banana peel were determined.

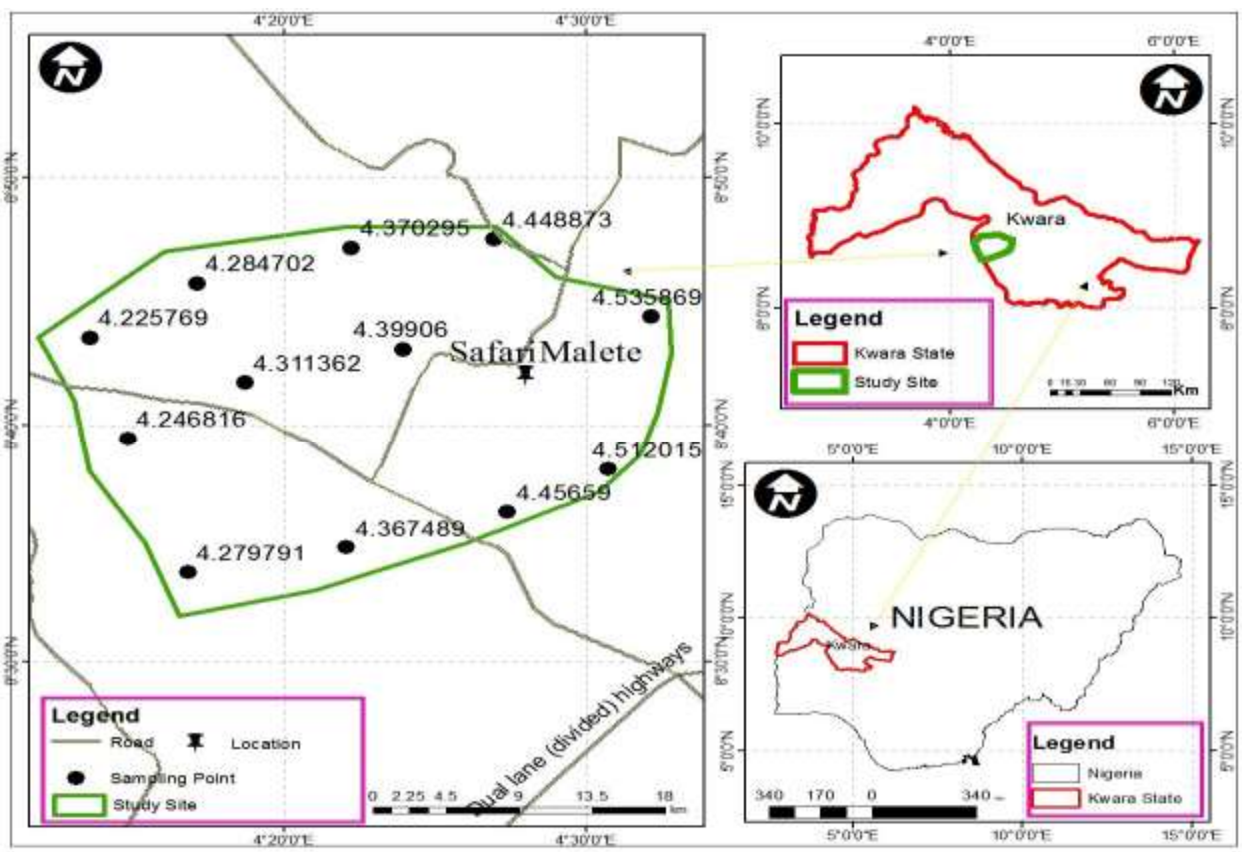


Figure 1. Map of Malete (latitude 080 71'N; longitude 04044'E at 360m above sea level), Moro Local Government Area of Kwara state, Nigeria (Source: Aderolu *et al.*, 2018)

The pot experiment was laid out in completely randomized design (CRD) in a factorial manner. The plots were separated into two blocks; banding application and foliar application. Each of the blocks has all the six maize classes and the four fertilizer treatments replicated three times. Medium sized experimental pots were filled with 10 kg soil to about 75% full. Each treatment consisted of six pots. Two seeds were sown per pot and later thinned to one.

The field evaluation was laid out in randomized complete block design (RCBD). Both pot and field experiments were in the same factorial combinations and replicated three times. For the field experiment, land clearing was carried out mechanically using a tractor to plough and then harrowed with minimal displacement of the top soil. Two seeds were sown at 25 x 75 cm intra and inter row spacing respectively and thinned to one to reduce plant-plant competition. It was a single row plot of 3 m. In order to prevent competition for nutrients (such as water and light) between the crops and the weed both pre and post emergent herbicides were used to control weed in addition to supplementary hand weeding.

Data Collection

Agronomic and yield data was collected on: i) Plant height (cm) was measured from the soil level to tip of the plant at 2, 4 and 6 weeks after planting (WAP) and to the base of tassel at 8 WAP. ii) Number of leaves were counted at 2, 4, 6 and 8 WAP. iii) Days to 50% silking was the number of days from sowing to when 50% of the maize plants have started silk emergence. iv) Days to 50% anthesis was taken as the number of days from sowing to when 50% of the tassels have started shedding pollens. v) Anthesis silking interval (ASI) represents the difference between days to 50% anthesis and silking. vi) Husk cover was the rated score of husk leaves at two weeks before harvesting when the ears are fully developed and the husk leaves are dried. The rating is on a scale of 1- 9. With 1 being tightly arranged and covered to the tip and 9= ear exposed at the tip. vii.) Root lodging (%) was the proportion of plants that are leaning more than 45° from the ground two weeks before harvest. viii.) Stalk lodging (%) was the percentage of plant stalks that broke below the ear two weeks before harvest. ix) Ears per plant was the average number of ears borne by each plant stand. x) Plant aspect was the average plant phenotypic appeal taken when ears are fully developed and still green. It was rated on a scale of 1- 9 with 1= excellent appearance and 9= poor appeal. xi) Plants at harvest represented the number of plants in a plot at harvest. xii) Ear aspect was the ear phenotypic appeal after harvest. It is rated on a scale of 1- 9 with 1 being clean, uniform and well filled ear and 9= rotten, variable and partially filled ear. xiii) Field cob weight (kg) was the weight of all dehusked ears (cob) in a plot at harvest. xiv) Grain yield was estimated and expressed in th^{-1}.

Data Analysis

All data collected were subjected to analysis of variance and means showing significant difference were separated using least significant difference (LSD) with the aid of software SAS ® 9.4 version (SAS Institute Inc. 1996). Orthogonal contrasts were conducted to modes of fertilizer application. Principal component analysis (PCA) was done and traits having significant contributions to grain yield were determined based on PC 1 and PC2. Thereafter, the traits were used for structural equation model (SEM) to show the covariance and variance between traits and grain yield. GGE biplot was used to show which won where for the maize varieties and ranking of the environments GEA-R 4.1 version.

RESULTS

Soil and Nutrient Source Analysis

Table 1 showed that the experimental sites have pH range of 6.62-7.38 with sand content between 80.6-82.4%. Silt ranged between 6.4-7.2 while clay ranged between 11.2-12.2%. The soil in the field has about twice Ca content than the pot experiment (1.65 cmol/kg) and higher effective cation exchange capacity (ECEC) was obtained on the field (5.64 cmol/kg) than the pot (3.59 cmol/kg). Available P was about 30 mg/kg. The pot experiment had lower total N (0.08%) and total organic carbon (0.66) than the total N (0.11%) and total organic carbon (0.97) of the field. Manganese in the pot was twice that of the field (17.8 mg/kg).

Table 2 showed the N, P and K composition of the nutrient sources: banana peel, maize stalk and moringa leaves. Banana peel had 1.74% total N while moringa leaves had 1.64%. Moringa leaves and banana peel had twice total P as maize stalk. Banana peel had the highest (7.61%) amount of K.

Comparison of Agronomic Traits and Grain Yield on the Field under Banding and Foliar Nutrients

Table 3 showed that maize classes had significant ($p<0.05$) mean squares for grain yield, ears per plant, days to silking and days to pollen shed while nutrients differed significantly ($p<0.05$) for grain yield. A comparison of methods of fertilizer application (banding vs foliar form) was significantly different for grain yield, ears per plant, ear aspect and plant aspect. The average grain yield on the field was 1.13 tha^{-1}.

Table 1. Soil physical and chemical properties at the two experimental sites and NPK content of the nutrient sources.

Soil physical and chemical properties	Pot (Screen house)	Field
Physical properties		
PH	7.38	6.62
Sand	82.4	80.6
Silt	6.4	7.2
Clay	11.2	12.2
Textural class	Sandy loam	Sandy loam
Chemical properties		
Exchangeable Bases (cmol/kg)		
Ca	1.65	3.56
Mg	1.02	1.18
K	0.3	0.22
Na	0.57	0.6
Al+H	0.05	0.08
ECEC	3.59	5.64
Base Saturation (%)	98.61	98.58
Total (N %)	0.08	0.11
Total Organic (C%)	0.66	0.97
Available P (mg/kg)	33.13	28.98
Micro-nutrients (mg/kg)		
Mn	32.35	17.8
Fe	8.5	5.6
Cu	0.55	0.55
Zn	0.78	0.69

Combined Effects of Mode Fertilizer Applications on Agronomic Traits and Grain Yield in the Field and Pot Experiments

The result revealed that application of fertilizer in banding form incorporated into the soil produced the highest number of leaves (Figure 2a) and were taller (Figure 2b) under 120N+50P+40K and 90kg NPK. 70N+30P+20K had the least height.

Figure 3a showed that Solid form of fertilizer incorporated in the soil (banding) in the pot had the highest ASI (average of 5 days) across fertilizer treatments, the foliar form of fertilizer had the least (about a day) on the field and in the pot experiment. ASI values were twice in the pot experiment compared to field conditions. 90 kg NPK had the least ASI across experimental conditions. Figure 3b showed that more twice the proportion of plant lodged in the pot experiment than the field with 90 kg NPK having the least number of plants that lodged.

Figure 4 showed that maize plants in the pot experiment had more exposed cobs with an average of a rating of 5/9 compared to the field conditions across the treatments. 90 kg NPK had the least number of exposed cobs (1.8/9) followed by 120N+50P+40K with a rating of 3/9.

Figure 5a showed that cobs produced by maize plants treated with banding fertilizers on the field were the most appealing based on phenotypic score (4.5/9) with 120N+50P+40K (4/9) and 90kg NPK (3.8/9) producing cobs with the best look. Maize cobs produced in the pot experiment had the worst appearance with an average score of 6.2/9. Also, maize planted treated with banding fertilizer on the field produced the heaviest cobs with an average of 0.52$kgplot^{-1}$. 90$kgha^{-1}$ NPK had the highest field weight (0.5 kg) followed by 120N+50P+40K which produced 0.4 kg. Fertilizers applied in foliar form had the least field weight. It was 0.2 kg on the field and 0.1 kg in the pot (Figure 5b).

Combined effects of fertilizer treatments on growth and yield of different maize varieties on the field and pot experiments

Single cross hybrid (SCH) used as check and SCH LY1312-11 were the leafiest (average of 18) with 90 kg NPK producing the highest number of leaves (Figure 7a). Fertilizer treatments resulted in cross over effects on the different maize classes in terms of plant height (Figure 7b). plant aspect (Figure 7c) and ASI, with double cross hybrid exhibiting the highest number of days between anthesis and silking (Figure 7d).

Table 2: Nitrogen (N), Phosphorus (P) and Potassium (K) content of the nutrient sources.

Nutrient source	Total N (%)	Total P (%)	K (%)
Banana peel	1.736	0.09	7.61
Maize stalk	1.256	0.05	0.99
Moringa leaves	1.645	0.10	1.93

Table 3: Mean squares from combined ANOVA for grain yield component obtained from the field experiment for six maize varieties and four nutrient levels evaluated under foliar and banding mode of application.

Source	Df	Days to silking	Days to pollen shed	Root lodging	Stem lodging	Husk cover	Plant aspect	Ears per plant	Ear aspect	Grain yield (tha^{-1})
Replication	2	269.47*	259.51*	31.08*	0.63*	22.90*	5.92*	0.19	1.65	0.06
Nutrient	3	109.64	130.47	0.50	0.02	9.88	1.83	0.04	1.05	3.27**
Maize classes	5	174.29*	195.04*	4.96	0.28	3.48	1.51	0.2*	0.22	1.30**
Banding vs foliar	1	124.69	98.34	13.83	0.11	4.34	14.69**	1.66**	36.00**	5.37**
Error	94	57.22	61.5	8.22	0.21	5.21	1.50	0.09	1.23	0.02
Treatment Mean		55.82	54.58	2.08	0.19	3.56	4.36	0.68	4.88	1.13

*, ** =Significant at 0.05 and 0.01 probability levels respectively; df= degree of freedom,

Figure 8 showed that the most yielding maize was SCH LY1312-11 (1.6 t/ha) while the least grain yield was produced by OPV-STR (0.7 t/ha) under banding and foliar mode of fertilizer application. Grain yield under a combined effect of banding and foliar mode of fertilizer application is in the order of SCH LY1312-11 > Single cross hybrid (SCH) check > Double cross hybrid > Three-way hybrid > Top cross hybrid (BRTZL x 1368) > OPV-STR.

Figure 9a showed that application of 100N+40P+30K (Aband), 120N+50P+40K (B) and 70N+30P+20K (Aband) in banding mode ranked after NPK fertilizer applied in band, and foliar. Which won where/what showed that SCH LY1312-11 (3), double cross hybrid (4), OPV-STR (1), top cross hybrid BRTZL x 1368 (6) are the vertex varieties, forming the best or worst varieties. SCH LY1312-11 (3) is the best variety, followed by a single cross hybrid (SCH) check then double cross hybrid (4).

Figure 10 showed the structural equation model between grain yield (YLD) and other agronomic traits. The model equation is Grain yield =0.37*field weight-0.13*ears per plant-0.28*plant aspect+0.11*husk cover -0.0012root lodging+0.025*ASI-0.0014*plant height@8 + 0.088*number of leaves at 8 weeks after planting (WAP) (NOL@8).

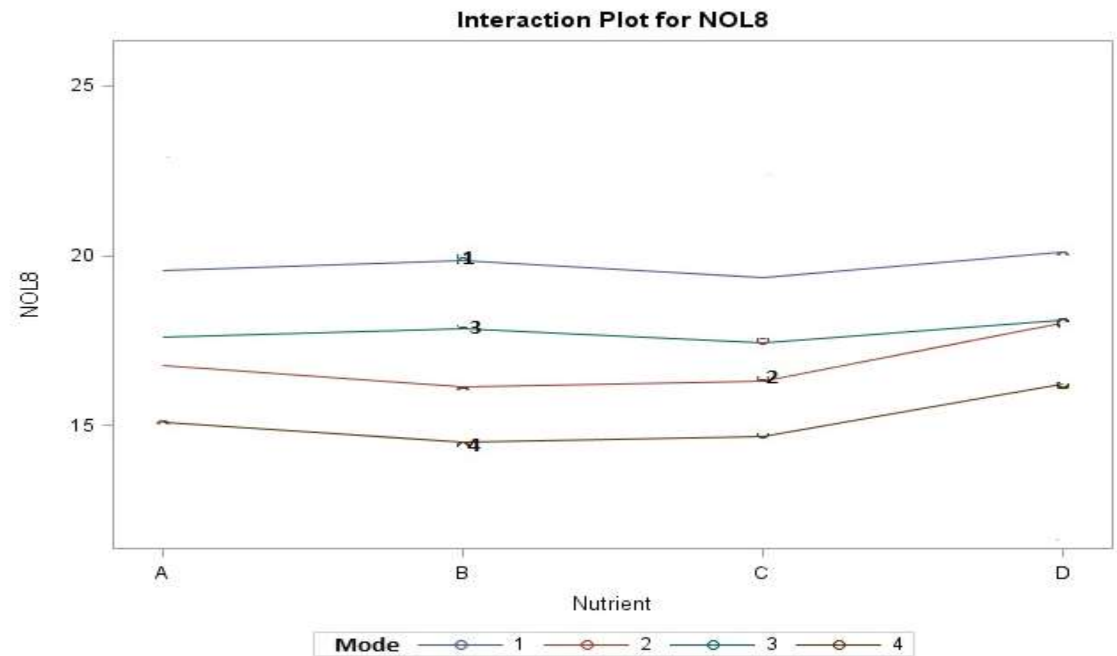
Field weight (0.37) and husk cover (0.11) had the highest positive contribution to grain yield while plant aspect (0.28) had the main negative effect on grain yield. Number of leaves at 8 WAP and ASI (0.58) had strong covariance (0.92) with root lodging.

DISCUSSION

The search for sustainable alternative nutrient sources for plants, to combat the adverse consequences of inorganic fertilizer is continuous. Several alternatives such as animal manure, composting etc., had been proposed, but with varying disadvantages such as bulkiness, technicalities etc. Different maize classes are known to respond differently to soil nutrients. A secured organic fertilizer source as an alternative and planting appropriate maize, a food security crop, are essential in ending poverty (SDG - 1), hunger (SDG 2), and improving health (SDG 3) (Campbell *et al*., 2018). From the present study, experimental soils of the sites (pot and field) were sandy loam and it which is

Table 4: Best and worst interactive effect ranks for field experiment.

Rank	Mode	Nutrient	Variety	PLTAS	Mode	Nutrient	Variety	Yield
1	Banding	NPK	3-way hybrid	2.67	Banding	NPK	SCHLY1312-11	2.23
2	Banding	70+30+20	OPV-STR	3.00	Foliar	NPK	SCHLY1312-11	2.04
3	Banding	NPK	SCHLY1312-11	3.00	Foliar	NPK	SCH_check	2.00
4	Banding	100+40+30	TC hybrid	3.33	Banding	NPK	SCH_check	1.87
5	Foliar	100+40+30	DCH	3.33	Banding	100+40+30	SCHLY1312-11	1.81
6	Banding	NPK	DCH	3.33	Banding	120+50+40	SCHLY1312-11	1.79
7	Banding	100+40+30	DCH	3.67	Foliar	NPK	DCH	1.72
46	Foliar	NPK	SCHLY1312-11	5.67	Foliar	120+50+40	OPV-STR	0.61
47	Banding	100+40+30	SCH_check	6.00	Foliar	120+50+40	3-way hybrid	0.60
48	Foliar	120+50+40	SCH_check	6.00	Foliar	120+50+40	TC hybrid	0.48
Rank	Mode	Nutrient	Variety	NOL8	Mode	Nutrient	Variety	PLTHT8
1	Banding	NPK	SCH_check	25.00	Banding	120+50+40	SCH_check	198.33
2	Banding	100+40+30	SCHLY1312-11	24.33	Banding	NPK	SCH_check	197.00
3	Banding	120+50+40	SCH_check	24.33	Banding	100+40+30	SCH_check	196.00
4	Banding	70+30+20	SCH_check	24.33	Banding	120+50+40	SCHLY1312-11	196.00
5	Banding	100+40+30	SCH_check	24.00	Banding	100+40+30	SCHLY1312-11	195.00
6	Banding	70+30+20	SCHLY1312-11	24.00	Banding	NPK	SCHLY1312-11	191.67
7	Banding	NPK	SCHLY1312-11	24.00	Banding	70+30+20	3-way hybrid	177.67
46	Foliar	120+50+40	3-way hybrid	15.00	Foliar	70+30+20	DCH	141.33
47	Foliar	70+30+20	TC hybrid	15.00	Foliar	NPK	SCH_check	138.33
48	Foliar	120+50+40	SCH_check	14.33	Foliar	70+30+20	OPV-STR	123.33



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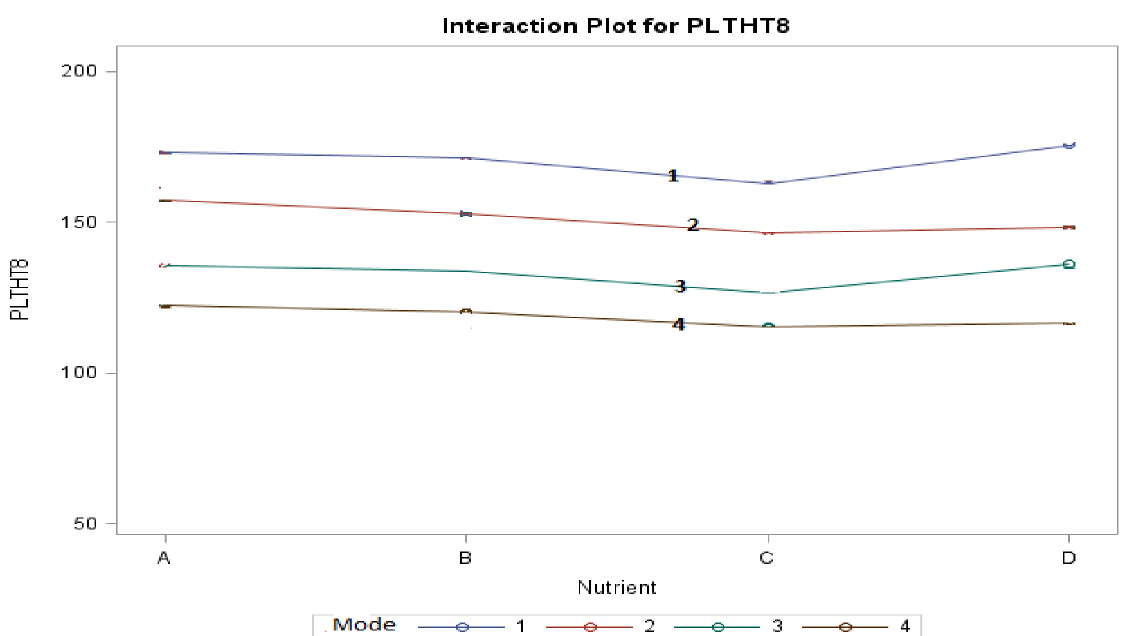
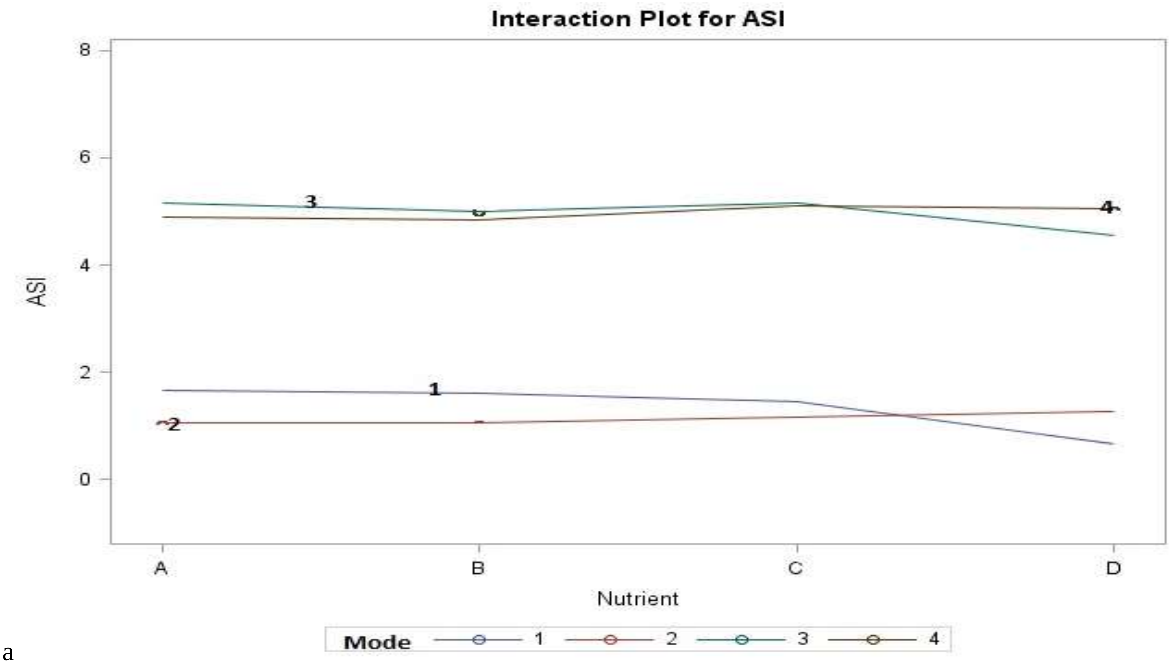


b

Figure 2 a-b: Interactive Effects of Nutrient levels and Mode of application on: (a) number of leaves (NOL) and plant height (PLTH) at eight weeks after planting

Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK

Mode: 1= Banding on the field 2= foliar on the field 3= banding in the pot 4= foliar in the pot.



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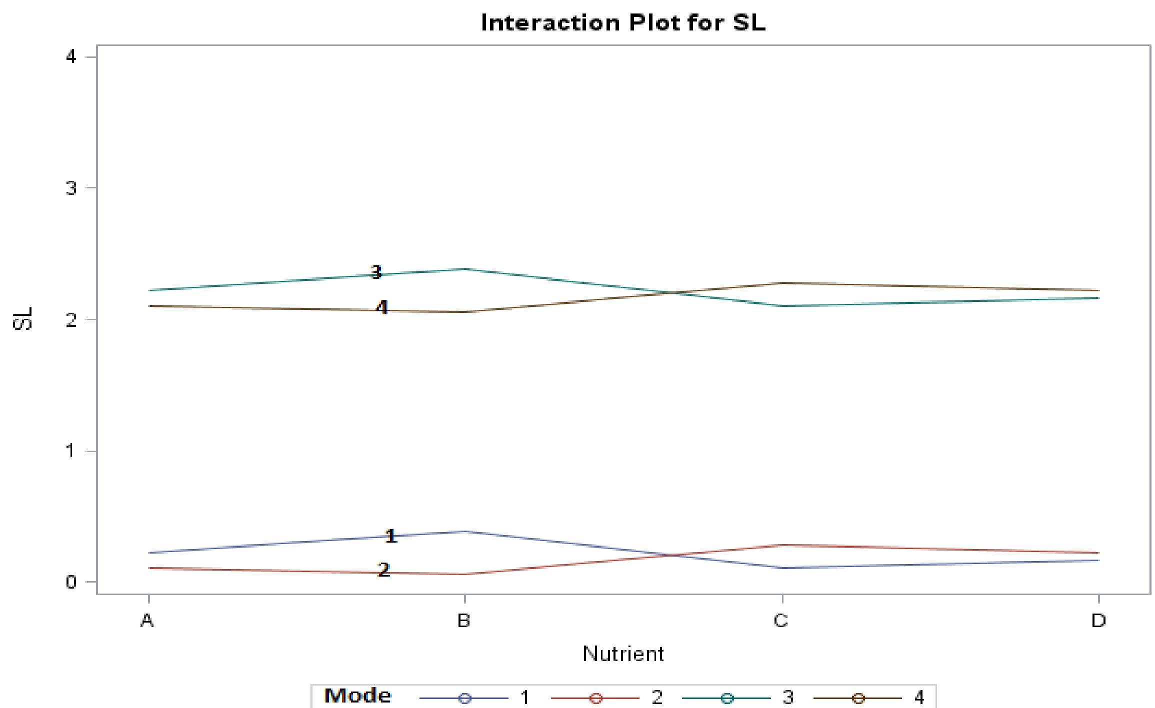


b

Figure 3 a-b: Interactive Effects of Nutrient levels and Mode of application on: (a) anthesis silking interval (ASI) and (b) stem lodging (SL).
Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK
Mode: 1= solid form (banding) on the field 2= foliar form on the field 3= solid form (banding) in the pot 4= Foliar form in the pot.

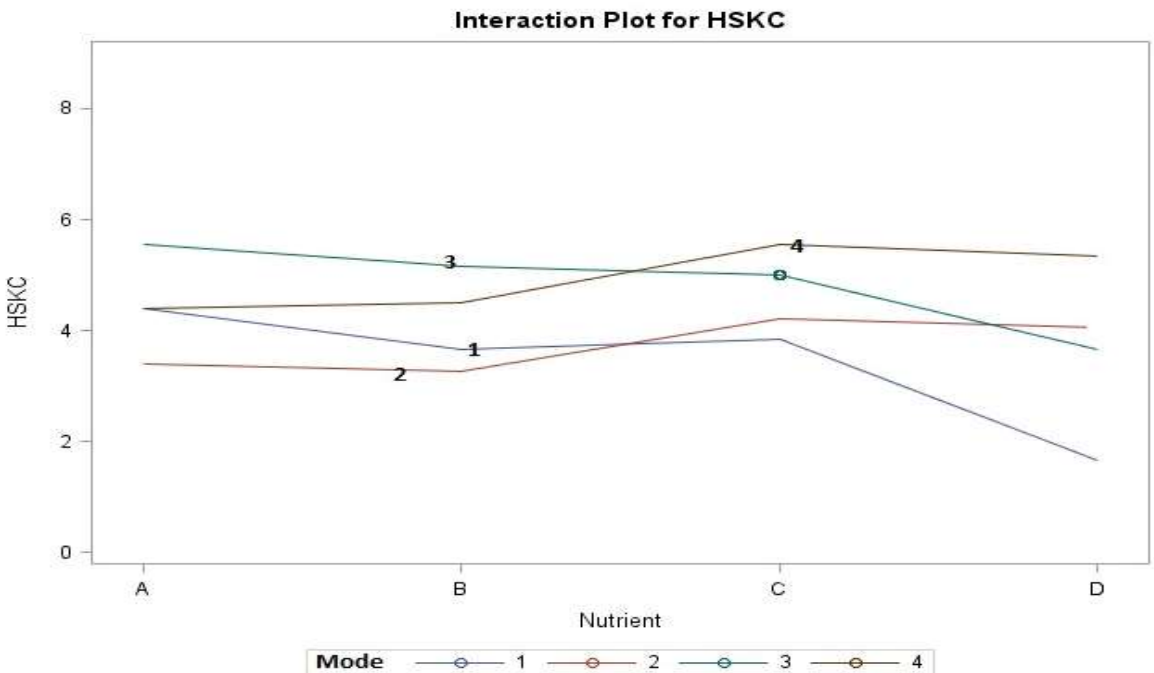
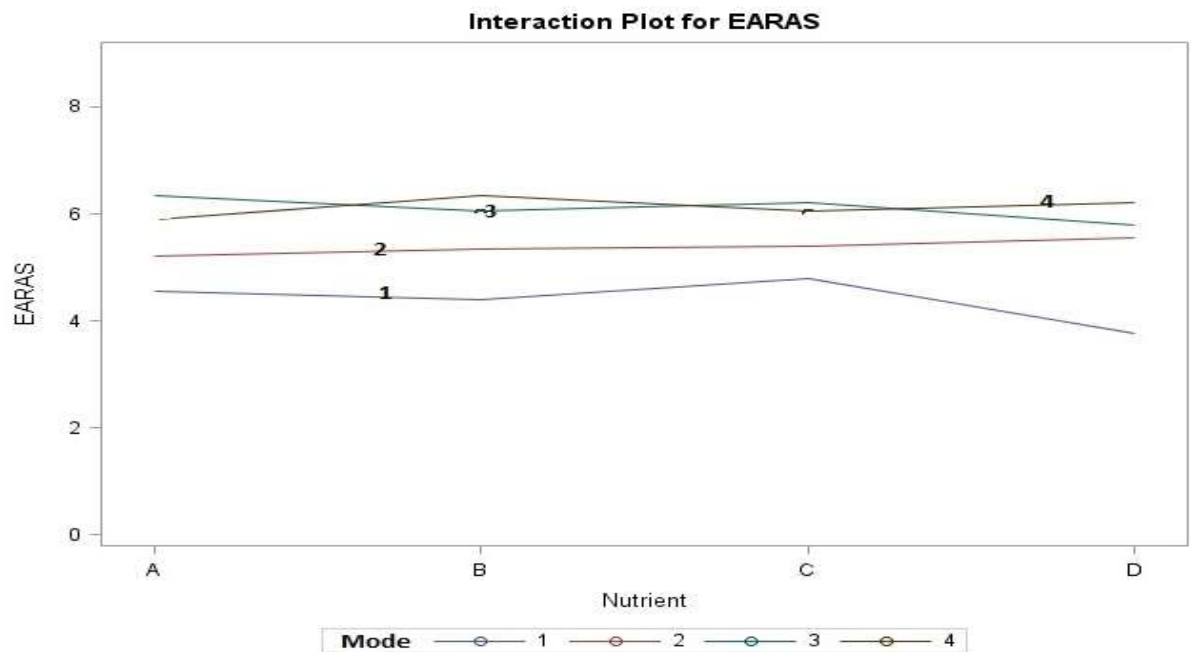


Figure 4: Interactive Effects of Nutrient levels and Mode of application on husk cover (HSKC).
Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK
Mode: 1= solid form (banding) on the field 2= foliar form on the field 3= solid form (banding) in the pot 4= Foliar form in the pot.

suitable for maize cultivation (Alabi *et al*., 2017) and with adequate soil pH (Adesemuyi *et al*., 2014). While exchangeable bases were in the class of medium soil fertility, available P was high and total N was however low under both conditions (Ayodele and Omotoso, 2008). Manganese and Fe in both the field and pot conditions were above critical levels, while Zn was in the high soil fertility range (Ayodele and Omotoso, 2008). The soils of both the field and pot had adequate mineral content except for nitrogen, one of the most essential and most volatile and limiting nutrient element in the tropics (Liu *et al.*, 2013, Maberly *et al*., 2020). Analysis of nutrient composition of moringa leaves as complement by banana peel and maize stalk possess nutrient beyond the critical requirement of maize plant (Ayodele and Omotoso, 2008). Moringa leaves had been used in plant nutrient in many crops such as *Solanium melongena* (Ozobia 2014), *Vigna unguiculata* (Maishanu *et al*., 2017), and *Zea mays* (Yusuf *et al*., 2018) with varying levels of yield accomplishment in different agro zones of the world.

Nutrient application resulted in production of varying grain yield by the different maize classes, implying that grain yield can be improved through the application of nutrients. Mikos-Szymańska *et al*. (2018) reported similar findings in wheat. Increased level of nutrient had resulted in luxurious growth in plant height as reported by Karasu (2012) and Woldesenbet *et al*. (2016). Gustavo *et al*. (2016) also reported that reduced nutrient level reduces grain yield. As important as the nutrient supply is to crop growth, the mode of application as foliar or in banding is also of importance as it influenced grain yield, (Fageria *et al*., 2009) ears per plant and the phenotypic appeal of the ears, and maize plant. In contrary, Dahiru *et al.* (2016) reported that foliar fertilizer did not influence yield in maize. Incorporation of fertilizer a week before sowing had superior performance with regards to vegetative traits compared to foliar spray on maize plant. This may be because organic fertilizers release nutrients slowly (Machado *et al*., 2011) and the nutrient might have been washed off by rain even before nutrient is released and absorbed by plants (Liu *et al.*, 2013). Vegetative growth increased with increased nutrient application (Karasu, 2012).



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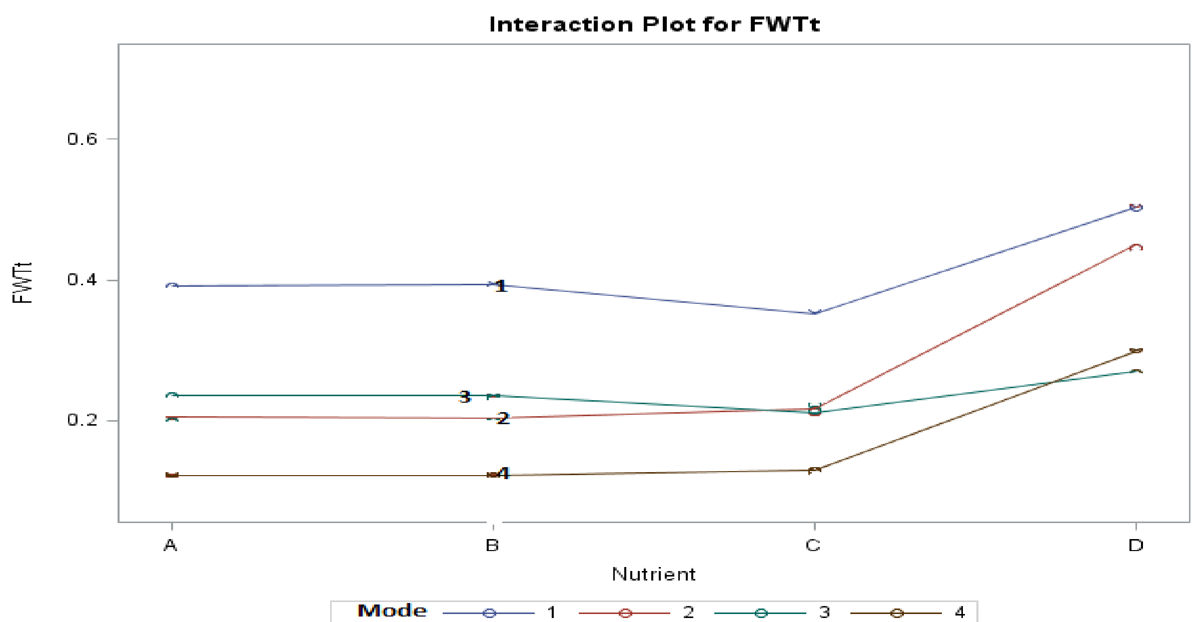


b

Figure 5 a-b: Interactive Effects of Nutrient levels and Mode of application on: (a) ear aspect (EARAS) and (b) Field weight (FWTt)
Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK
1= solid form (banding) on the field 2= foliar form on the field 3= solid form (banding) in the pot 4= Foliar form in the pot.
4= Foliar form in the pot.

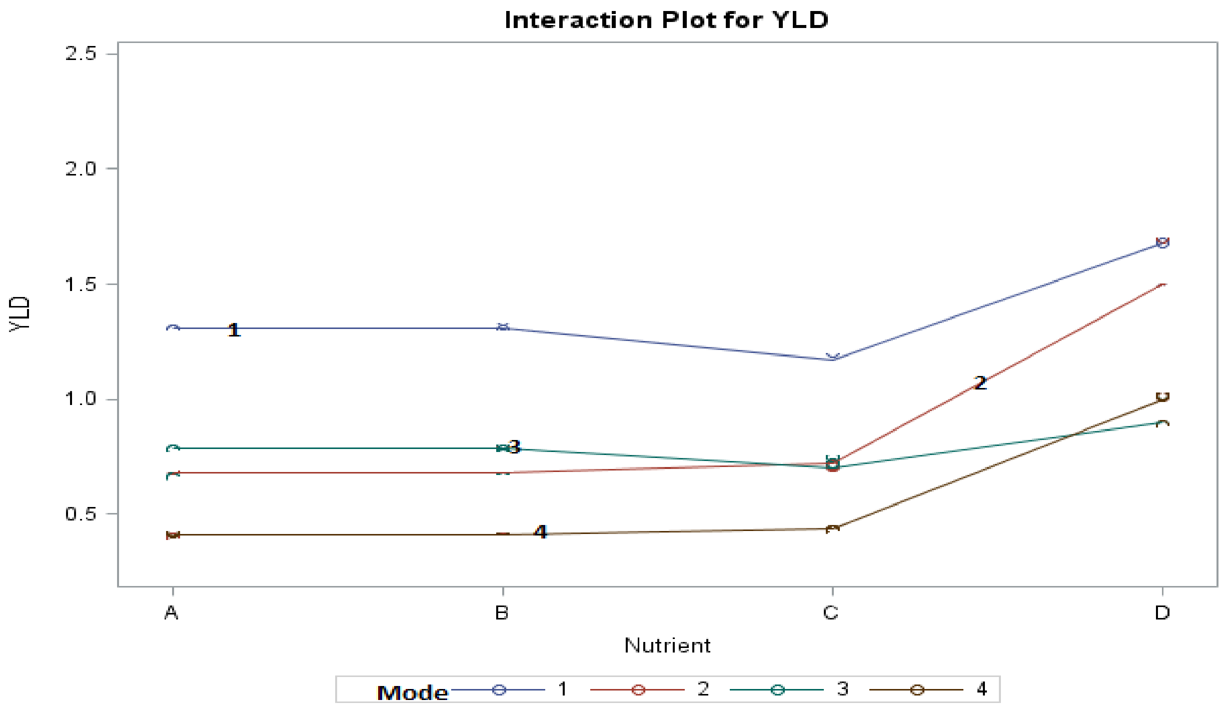
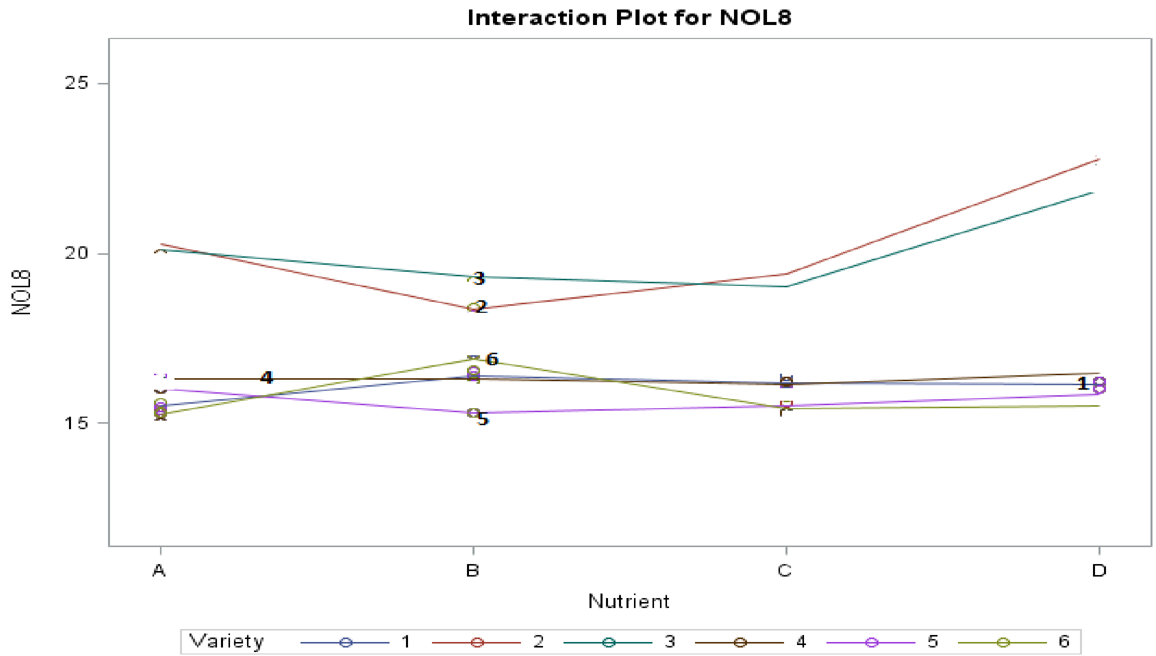


Figure 6: Interactive Effects of Nutrient levels and Mode of application on grain yield (YLD)
Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK
Mode: 1= solid form (banding) on the field 2= foliar form on the field 3= solid form (banding) in the pot 4= Foliar form in the pot

Elongated ASI is a trait associated with abiotic stress such as nitrogen (Monneveux *et al*., 2006) and drought stress (Bänziger *et al*., 2006), which usually results in barrenness and consequently reduced yield. In this study, maize plants in the pot experiment had elongated ASI and hence reduced grain yield. Pot experiments in the screen house are liable to etiolation (Symons *et al*., 2008). The high proportion of lodging in the pot experiment is suggestive of weak stems. Increased lodging makes maize cob susceptible to rodent attack, decaying etc which also could reduce grain yield (Ajala *et al*., 2018). Furthermore, maize plants in the pot had poor phenotypic appeal and with exposed cobs which could subject them to pest and diseases attacks. Xu *et al*. (2017) reported reduce yield in the pot compared to the open field. Bänziger *et al*. (2006) also reported poor phenotypic appeal under stress conditions. 120N+50P+40K and 100N+40P+30K application had well-covered cobs with the highest ears per plant, which is a potential grain yield component. Maize plant grown on the field with fertilizer incorporated in the soil looked healthier and were more appealing based on appearance, with 120N+50P+40K banding application being most appealing. Stress symptoms shown in the pot experiment in the screen house could be responsible for poor ear and plant appeal (Bänziger *et a*l., 2006). Maize plants grown on the field were most yielding under banding fertilizer application (Xu *et al*., 2017) being superior to foliar application (Dahiru *et al*., 2016). 120N+50P+40K though was the most yielding among moringa-banana peel-maize stalk technology, was comparable to 100N+40P+30K.

Grain yield in maize was not only due to the application of nutrient (environment) but also the genotypic composition of the maize varieties (Soyelu *et al*., 2001). The significant influence due to the genotypes (maize classes) and the environment (fertilizer treatments) further corroborate the important roles both play in yield enhancement (Badu-Apraku *et al*., 2011). Varietal differences in the response of that maize varieties to fertilizer treatments with regards to grain yield, ears per plant, days to silking, and days to pollen shed were attributable to differences in the genetic composition of the different maize classes. This is similar to the report on: maize in response to varying soil compaction (Soyelu *et al*., 2001), two rice varieties (Ujiie *et al*., 2016) and among soy bean accessions (Lawal *et al*., 2020). Varietal difference implied that the different maize varieties belonging to different classes differ in their nutrient use efficiency and hence, provide room for selection and improvement among the maize classes (Badu-Apraku *et al*., 2011).



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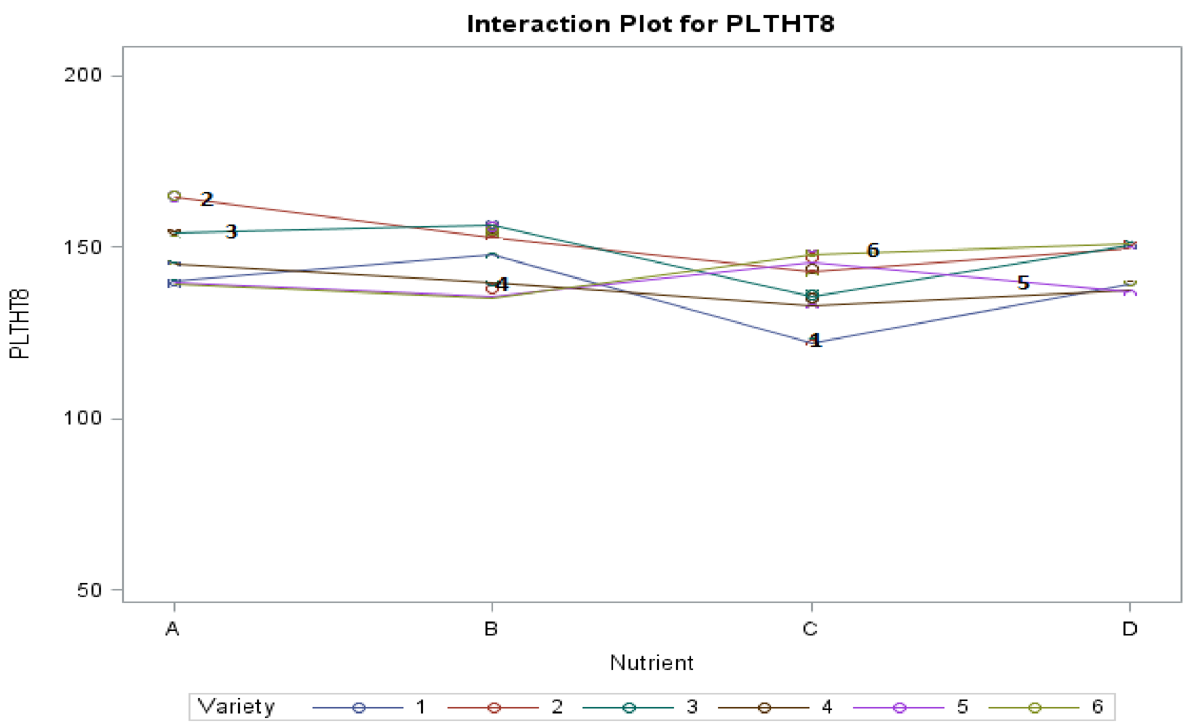
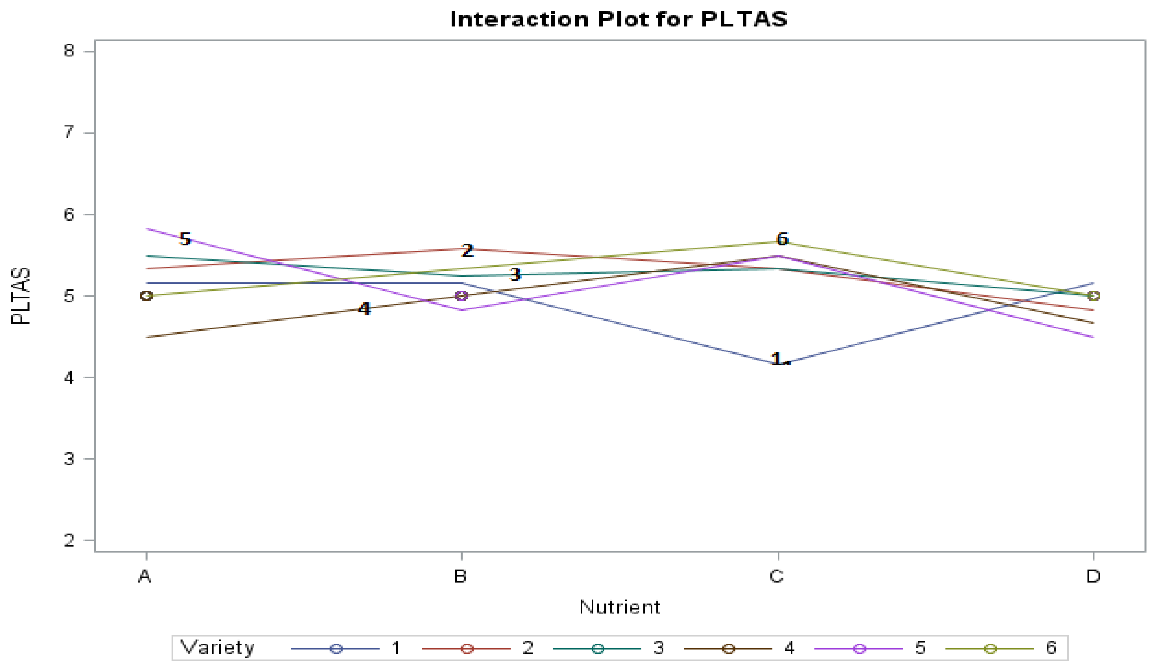


b

Figure 7 (a-b): Interactive effect of Nutrient levels and Maize class on: (a) number of leaves (NOL) (b) Plant height at 8 weeks after planting

Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK

Variety 1=OPV-STR, 2= Single cross hybrid (SCH) check, 3= SCH LY1312-11 4= Double cross hybrid, 5=Three-way hybrid 6=Top cross hybrid BRTZL x 1368.



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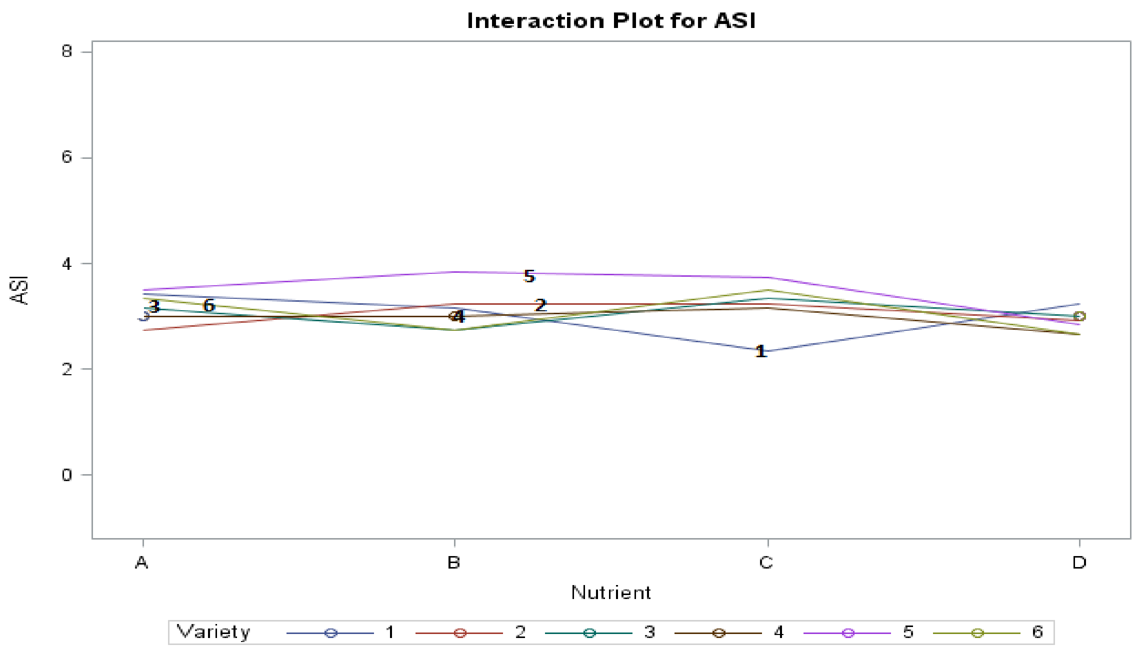


d

Figure 7 (c-d): Interactive effect of Nutrient levels and Maize class on: (c) Plant aspect (PLTAS) and (d) ASI. Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK Variety 1=OPV-STR, 2= Single cross hybrid (SCH) check, 3= SCH LY1312-11 4= Double cross hybrid, 5=Three-way hybrid 6=Top cross hybrid BRTZL x 1368.

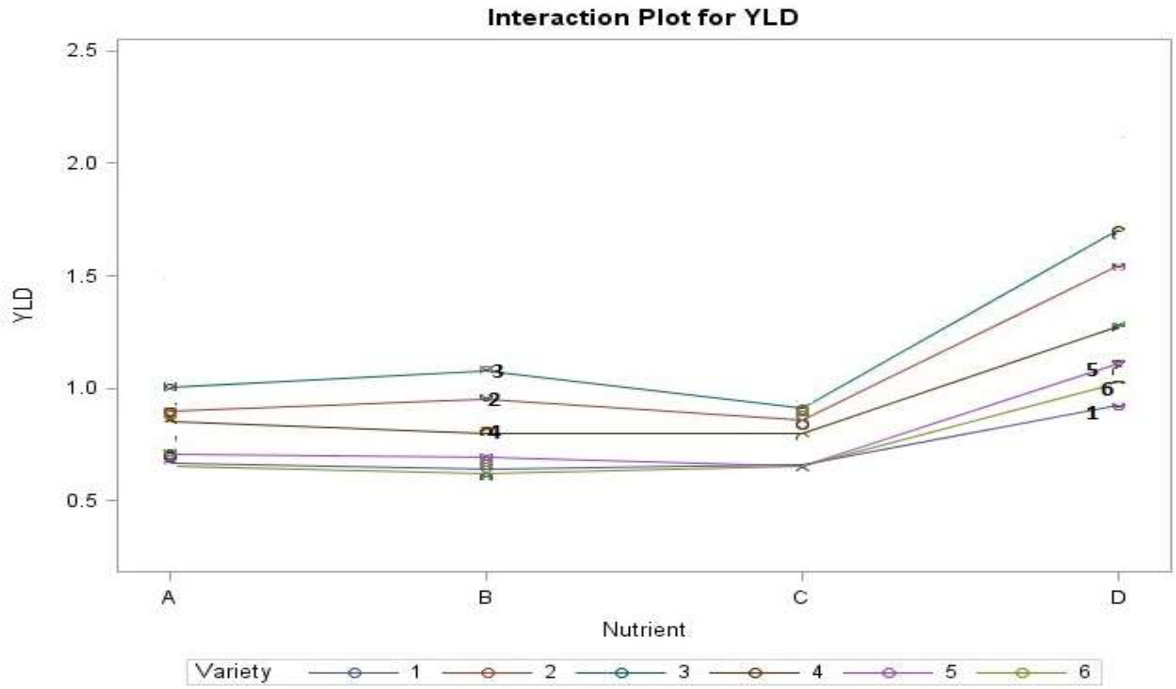
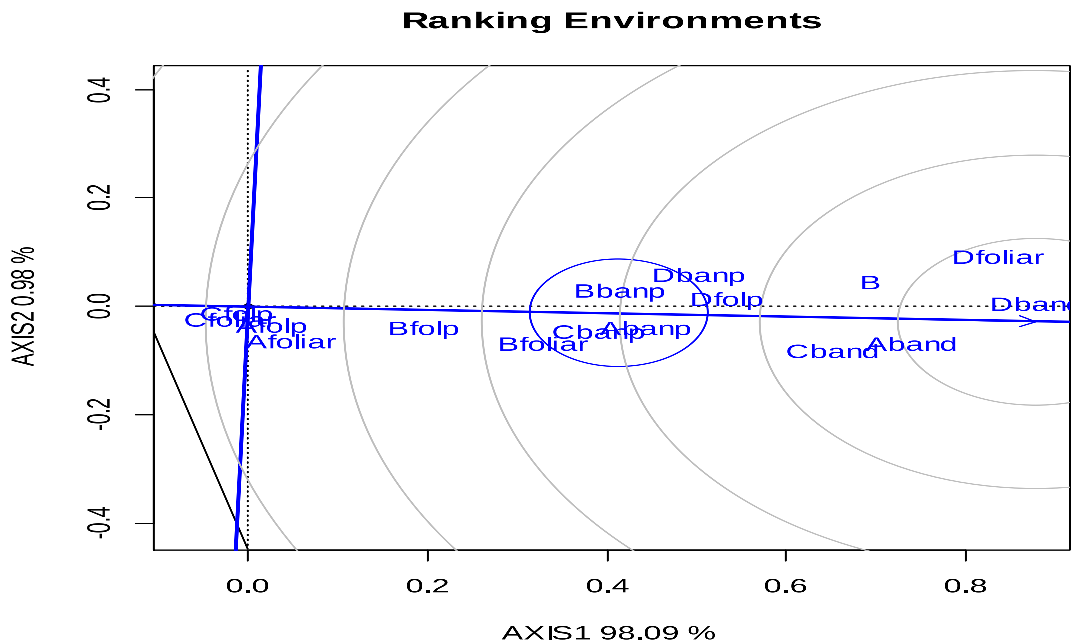


Figure 8: Interactive effect of Nutrient levels and Maize class on grain yield.
Nutrient levels: A= 100N+40P+30K; B= 120N+50P+40K; C= 70N+30P+20K D=90kg/ha NPK
Variety 1=OPV-STR, 2= Single cross hybrid (SCH) check, 3= SCH LY1312-11 4= Double cross hybrid, 5=Three-way hybrid 6=Top cross hybrid BRTZL x 1368.

The OPV out-rightly produced less number of leaves, reduced plant height, days to anthesis and silking, and grain yield compared to the single cross hybrid (SCH) used as a check and SCH LY1312-11. Several researchers have shown the positive relationship between grain yield; and leafiness, as leaves are photosynthetic apparatus (Anuradha *et al*., 2017), plant height (Ajala *et al*., 2018) and maturity (days to silking and anthesis) as early maturing varieties generally have reduced stature and low yielding as they have less time to translocate assimilate to the grain (Girma *et al*., 2015). The results of Pixley and Banziger (2002), Kamara *et al*. (2004) and Adebo and Olaoye (2010) who reported that hybrid maize out-yielded OPVs agree with the present findings. Similarly, single cross hybrid was superior to three-way hybrid and double cross hybrids in respect of these traits. This agreed with the findings of Lynch *et al*. (1973) and Ashakina *et al*. (2016) who reported superior performance of single cross hybrids over three-way in tomato. Single cross hybrids were the most appealing with regards to husk cover, plant aspect and also ears per plant. Elongated days between anthesis and silking exhibited by double cross hybrid is a sign of stress that could induce barrenness and reduced grain yield. SCH LY1312-11 produced an average yield of 1.6 tha^{-1} under both banding and foliar mode of fertilizer application and about 1.85 tha^{-1} under field conditions. The average grain yield under both banding and foliar fertilizer was in the order of SCH LY1312-11 > Single cross hybrid (SCH) check > Double cross hybrid > Three-way hybrid > Top cross hybrid (BRTZL x 1368) > OPV-STR.

The most important traits essential in grain yield improvement are cob weight and husk cover. There is a high tendency to forgo grain yield for plant phenotypic appeal, hence caution should be exercised in improving the aesthetics of the plant. GGE biplot was effective in ranking environment (nutrient levels, mode of application, and pot vs field) (Yan and Tinker 2006) with banding being more effective when compared to foliar application. 120N+50P+40K and 100N+40P+30K fertilizer incorporated into the soil for SCH LY1312-11 clustered with the national recommended rate of 90 $kgha^{-1}$ NPK.



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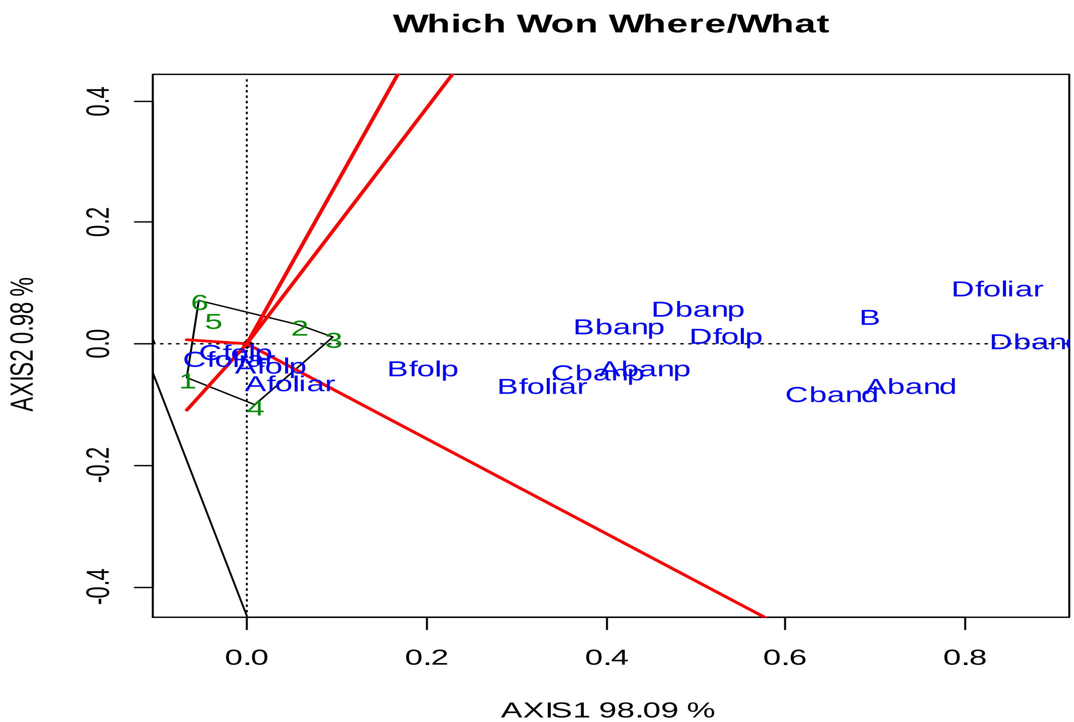

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Figure 9 (a-b): GGE biplot showing: (a) the ranking of the environments (nutrient levels and modes) and (b) which won where/what.

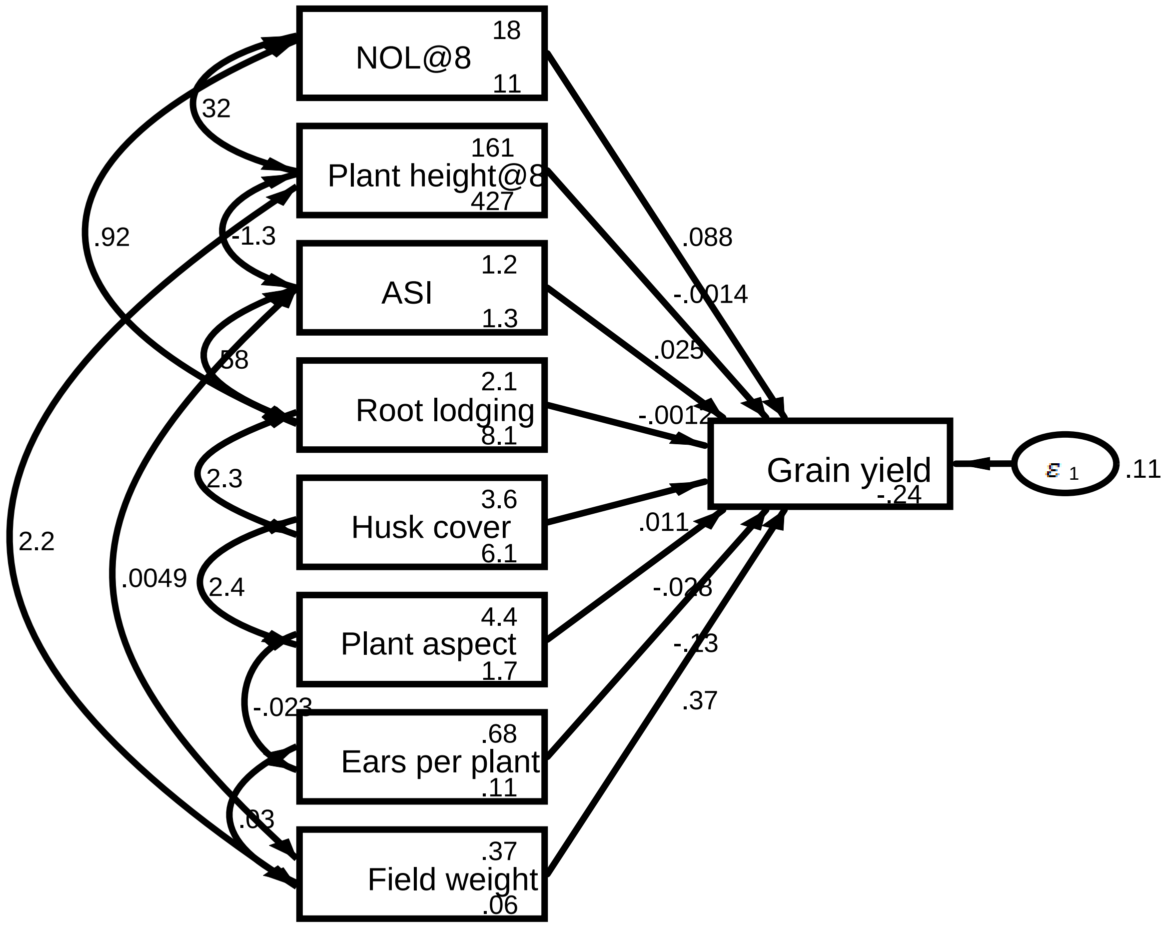

Figure 10: Model for relationship between grain yield and other agronomic traits.

CONCLUSION

Moringa-banana peel-maize stalk fertilizer incorporated in the soil in solid form, a week before planting at the rate of 120N+50P+40K and 100N+40P+30K on the open field provided sustainable, eco-friendly, and cost-effective alternative to inorganic NPK fertilizer at national recommended rate. Organic moringa-banana peel-maize stalk fertilizer were most effective when applied in banding than in foliar form. Moringa-banana peel-maize stalk fertilizer 120N+50P+40K and 100N+40P+30K produced grain yield in order of SCH LY1312-11 > Single cross hybrid (SCH) check > Double cross hybrid > Three-way hybrid > Top cross hybrid (BRTZL x 1368) > OPV-STR with 120N+50P+40K and 100N+40P+30K producing grain yield above national average of 1.3 tha^{-1}. Therefore, single cross hybrids (SCH LY1312-11 and SCH check) were most yielding when the soil nutrient is supplemented with single dose of 120N+50P+40K or 100N+40P+30K moringa-banana peel-maize stalk fertilizer before planting.

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Compliance with ethical standards. The authors declared that they complied with ethical standard.

Data availability: Data are available with author <Dr. Lawal Oluwafemi O. femylawal@gmail.com> upon reasonable request.

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