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GENOTYPIC RESPONSE OF MAIZE TO MICRO AND MACRO NUTRIENTS AS INFLUENCED BY ARBUSCULAR MYCORRHIZA FUNGI (*GLOMUS FACULTATIVE*) IN A RAINFOREST LOCATION

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ABSTRACT

Arbuscular Mycorrhiza Fungi (AMF) has been reported to help plant access nutrients from the soil. The objectives of this study were to evaluate the response of maize genotypes to micro and macro-nutrients as influenced by Arbuscular Mycorrhiza Fungi (AMF) and identify the best maize genotype under the best fertilizer treatment. Ten maize genotypes were evaluated under five different fertilizer treatments at the early and late cropping seasons of 2018 and 2019 respectively using split plot design in three replications. Data were collected on emergence counts, vegetative traits, yield and yield components and were subjected to analysis of variance and means were separated with Least Significant Difference at 0.05 level of probability. Application of NPK fertilizer alone significantly increased the yield of the evaluated maize genotypes by 83% from 0.31 t/ha (No Fertilizer) to 1.21 t/ha (NPK alone) while addition of agrolyser and AMF four weeks after planting did not increase the yield of the maize genotypes evaluated from the 2018 early season trial (0.78 t/ha). However, addition of AMF at planting in the fertilizer treatment (NPK + Agrolyser + Mycorrhiza) during the late season of 2019 increased the ear height of the ten maize genotypes resulting into 20% increase from 0.46 m to 0.54 m and thus, the best fertilizer treatment. The best variety with the highest ear height (0.64m) under NPK + Agrolyser + Mycorrhiza was variety EVDT-W-99STR-QPM. In conclusion, AMF was found to be effective in enhancing and increasing the nutrient uptake of the ten maize genotypes if applied at planting.

Keywords: Arbuscular Mycorrhiza Fungi; Maize; Micro and Macro Nutrients; Tropical Soil.

INTRODUCTION

Maize (*Zea mays* L.) ranks first in world cereal production with rice and wheat following respectively (FAOSTAT, 2017). It is a staple food crop in Nigeria, which is not only consumed directly as food but also used as a raw material for commercial production of starch in agro allied industry. Maize is mainly produced for local consumption in Nigeria with only small quantities if any for export, 55% of the country's production is used as food, 31% as feed, and 2% is processed (Cadoni and Angelucci, 2013). Maize demand has been estimated to double in developing world by 2050 and it is predicted as a crop of greatest production globally and in developing world by 2025 (Rosegrant *et al*., 2008).

Presently, emphasis has been placed on breeding higher yielding varieties to increase local production and productivity. However, soil nutrient depletion is a major factor causing the generally low crop yield recorded in farming systems of sub-Saharan Africa (SSA) (Zingore *et al.*, 2015). The sustainable productivity of soil mainly depends upon its ability to supply essential nutrients, both micro and macro-nutrients, to the growing plants. These nutrients are usually present in various concentrations in the soil. Research that aims to improve soil fertility management and productivity of small-scale farmers has to reckon with soil variation by identifying the most limiting nutrient elements and come up with flexible recommendations (Gani *et al.,* 2018). Balanced fertilization of the soil is therefore necessary and involves the application of both macro and micro nutrients in the right proportions for optimum crop yield (Iren *et al.,* 2012).

Agrolyser® is a biochemical plant nutrient extremely useful for increasing the yield of crops, consisting mostly of inert and naturally occurring nutrients, and classified as a plant growth regulator. Agrolyser® contains ten (10) cations (copper, manganese, magnesium, iron, sodium, calcium, sulphur, boron, zinc, molybdenum), three of which are secondary nutrients (Ca, Mg, S) (Iren *et al.,* 2012). It provides essential trace elements during the growth of various plants, including cassava and maize (Davies *et al*., 2006).

Arbuscular Mycorrhiza Fungi (AMF) are soil fungi that develop symbiotic associations with most plant species (Rodriguez and Sanders, 2015). These fungi colonize the plant root and the soil around the root and can provide water to the host plant. In addition, AMF can uptake nutrients from the soil solution, transport them, and transfer to plants (Salami *et al*., 2005; Zhu *et al.,* 2012). Arbuscular Mycorrhiza Fungi are the most common fungi in soils and represent 9-55% of the soil microbe biomass and 5-36% of the total soil biomass (Goltapeh *et al.,* 2008). The fungi play a vital role in agricultural ecosystems (Salami and Osonubi, 2002), since they can improve plant nutrient uptake, water status, plant growth, improves disease resistance (Oyetunji and Salami 2011; Salami *et al*., 2018) enhance survival rate and development of seedlings (Omoyeni, 2018), crop uniformity and reproductive capacity (Salami *et al*., 2005; Katalin and Nguyen, 2019)

Tropical soils have been reported to be formed in areas with high annual temperature and rainfall (Lindbo *et al.* 2012). Even though the savanna and the tropical rainforest regions have a climate that results in deep, highly weathered soils, they have different organisms. The extent of the soil weathering causes these soils to be nutrient poor and low in organic matter (Lindbo *et al.,* 2012).

The effect of the combined application of Agrolyser (micronutrients) with NPK (macronutrient) has been reported to reduce the crop yield of maize on a typical tropical rainforest soil (Adeyinka 2008). However, Arbuscular mycorrhiza (AM) has been found to aid maintenance and improvement of soil structure, the uptake of relatively immobile elements; both macronutrients (N, P, K) and micronutrients (Zn, Mg, Mn) (Watts-Williams and Cavagnaro 2014); alleviation of the toxicity of some elements; interactions with other beneficial soil organisms (nitrogen-fixing rhizobia), and improved protection against pathogens (Begum *et al.,* 2019). Therefore, the objectives of this study were to evaluate maize genotypes response to micro and macro-nutrients as influenced by

Arbuscular Mycorrhiza Fungi and identify the best maize genotype under the best fertilizer treatment in a typical tropical rainforest soil in Nigeria.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Osun State (7°28' N, 4°33' E, rainfall 1150 mm, altitude 224 m above sea level) during the early and late cropping seasons of 2018 and 2019, respectively. The land was ploughed and harrowed before planting. Soil test was carried out for the presence of exchangeable cations and other nutrients before planting. Ten maize genotypes (Table 1) were evaluated under five fertilizer treatments (Control; no fertilizer added, Agrolyser, NPK fertilizer, NPK fertilizer + Agrolyser and NPK fertilizer + Agrolyser + Mychorriza). The experiment was laid out on the field using split- plot design with three replications. The main plots were the five fertilizer treatments while the subplots were the ten maize genotypes. Each main plot consisted of ten sub-plots of the maize genotypes with single row of 5 m long, spaced 0.75 m apart, within row spacing of 0.5 m. Fifty gram per plot of Mycorrhiza fungus; *Glomus falcultative* with 2.5×10^4 spores/gram was applied four weeks after planting and at planting in 2018 and 2019 respectively. Three seeds were sown per hole which were later thinned to two at two weeks after planting. Atrazine was sprayed as a pre-emergence herbicide at 5 litres/ha, a day after planting. All the treatments were applied four weeks after planting except treatment 5 (NPK+Agrolyser+Mycorrhiza) where Mycorrhiza (*Glomus falcultative*) was applied at planting during the 2019 late season trial.

The application rates for the fertilizer treatments include:

i. Control – No fertilizer
ii. Agrolyser – 0.2Kg/ha which implies 90g of agrolyser per experimental plot (Adeyinka 2008)
iii. NPK 15:15:15 – 60Kg/ha of Nitrogen, 30Kg/ha of Phosphorus and Potassium which implies that 14g of NPK 15:15:15 was applied per stand
iv. Mycorrhiza – 50g (2.5×10^4 spores/g) of *G. facultative* was applied per plot at planting (Salami et al., 2005; Omoyeni, 2018)
v. Agrolyser + NPK + Mycorrhiza

TABLE 1: NAME, MATURITY CLASS AND OTHER CHARACTERISTICS OF THE TEN MAIZE GENOTYPES EVALUATED IN 2018 AND 2019 EARLY AND LATE SEASONS RESPECTIVELY UNDER THE DIFFERENT FERTILIZER TREATMENTS

S/N	Names	Maturity and other characteristics
1	2008 SYN EE DT STR –W	White, extra-early, drought tolerant, *striga* resistant
2	TZEE Y POP STR QPM C_o	Yellow, extra-early, *striga* resistant, quality protein maize
3	TZEE - Y POP STR C_4	Yellow extra-early *striga* resistant
4	99 TZEE-Y POP STR QPM C_o	Yellow, extra-early, *striga* resistant and quality protein maize
5	2000 SYN EE – W STR QPM C_o	White, extra-early, *striga* resistant and quality protein maize
6	EVDT – W- 99 STR QPM	White, early, *striga* resistant and quality protein maize
7	2011 TZE – W DT STR Synthetic	White, early, drought tolerant and *striga* resistant synthetic
8	2008 EVDT STR –Y	Yellow, early, drought tolerant and *striga* resistant
9	TZE – Y DT STR C_4	Yellow, early, drought tolerant and *striga* resistant
10	TZE – W POP DT STR QPM	White, early, drought tolerant, *striga* resistant and quality protein

Data Collection and Statistical Analysis

Data were collected on emergence counts (these are total number of seedlings in a plot that emerged five, seven and nine days after planting), days to flowering were taken as dates when 50% of the plants in a plot attained tasseling, anthesis and silking and were recorded and expressed as days after planting. Plant and ear heights were taken as the distance from the soil surface to the nodes bearing the flag leaf and the top ear respectively. These were obtained from 5 random plants in a plot and their mean expressed as plant height (PHT) and ear height (EHT) respectively.

For the 2018 early cropping season trial, harvested ears were counted and weighed per plot using the weighing balance. Ear aspect which was determined by the general appearance of all the ears, ear size, grain filling, disease and insect damage, uniformity of size, colour and grain texture, was recorded on the scale of 1-9 (where 1 is the best and 9 is the worst). Five ears per plot were selected at random to determine the ear diameter, ear length and kernel row number. The moisture content of the ears per plot was calculated using the moisture meter. Grain yield (t/ha) was adjusted to 15% moisture content and converted to tons/ha as follows

$$\frac{\text{Ear weight per plot}}{\text{Area of plot (m2)}} \times \frac{(100 - \text{Moisture content})}{85} \times \frac{(\text{Shelling }\%)}{100} \times \frac{100{,}000}{1000}$$

where;

1000 kg = 1 ton and 10,000 m = 1 ha

However, during the late season of 2019 planting, data on yield and yield components were not taken due to improper grazing of cattles on the experimental plot that destroyed the experimental field just before harvesting.

Data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS version 9.2 (SAS Institute, 2003) and the means were separated using Least Significant Difference (LSD) at 0.05 level of probability.

RESULTS

Mean squares due to fertilizer treatments effect were highly significant (P = 0.01) for the flowering and vegetative (plant and ear heights) traits studied during the early cropping season trial (Table 2). There were also highly significant (P = 0.01) genotypic effects for emergence, flowering and plant heights except for the ear height which showed significant genotypic effect at 0.05 level of probability (Table 2). Significant fertilizer treatment by genotype interaction effect was observed for emergence index (EI) (P = 0.01) and emergence rate index (ERI) (P = 0.05) (Table 2). This indicated that the maize genotypes evaluated in this study respond differently to different fertilizer treatments in their speed of emergence and rate of emergence. The coefficients of variation (CVs) were generally low for the traits evaluated except for anthesis-silking interval (ASI) (Table 2). The coefficients of determination (R^2) obtained from the model were generally high (60-87%) (Table 2). This indicated that the model was reliable.

Furthermore, during the early cropping season of this study, mean squares due to fertilizer treatment effects were highly significant for yield and yield components except for moisture content and shelling percentage (Table 3). Highly significant (P = 0.01) genotypic effects were obtained for ear number, ear weight, ear diameter, ear length, kernel row number and grain yield (Table 3). In addition, there were significant genotypic (P=0.05) effects for moisture content, ear aspect and shelling percentage (Table 3). Fertilizer treatment by genotypes interaction effects were observed in ear number (P = 0.01) and grain yield (P = 0.05) (Table 3). There were significant replication effects for ear number, ear weight, moisture content, ear aspect, ear diameter, grain yield (P = 0.01) and ear length (P = 0.05) (Table 3). The coefficient of variation (CVs) associated with most of the traits taken except for kernel row number and moisture content, which were 7.47 and 8.18 % respectively from the ANOVA model were moderately high (12.94 – 48.32 %) (Table 3). The coefficient of determination (R^2) of the model ranged from 60 to 84%. This indicated that the model was quite reliable for the statistical analysis.

However, during the 2019 late cropping season trial, highly significant (P = 0.01) fertilizer treatment effect was obtained for emergence index, days to 50% tasseling, anthesis and silking, anthesis-silking interval, plant and ear heights (Table 4). Significant fertilizer treatment (P = 0.05) effect was obtained in emergence percent of the maize genotypes evaluated. Highly significant (P=0.01) genotypic effect was obtained in days to 50% silking and ear height (Table 5). There was also significant genotypic effect (P=0.05) for emergence index (EI). Significant (P = 0.05) fertilizer by genotypes interaction effect was obtained only in ear height of the genotypes evaluated in this study (Table 4).

TABLE 2: MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR EMERGENCE, FLOWERING TRAITS AND VEGETATIVE TRAITS OF MAIZE GENOTYPES EVALUATED AT THE OBAFEMI AWOLOWO UNIVERSITY TEACHING AND RESEARCH FARM (OAU T&RF), ILE-IFE DURING THE EARLY CROPPING SEASON OF 2018 UNDER DIFFERENT FERTILIZER TREATMENTS

Source of Variations	DF	E%	EI	ERI	Days to 50% Tasseling	Days to 50% Silking	Days to 50% Anthesis	ASI	Plant Height (m)	Ear Height (m)
Rep	2	78.30	0.33**	2.88**	1.09	3.31	2.31	4.69	0.23**	0.08**
FERT TRT (T)	4	52.19	0.16	1.13	6.94**	186.12**	6.02**	142.12**	0.53**	0.11**
Error (a)	8	67.66	0.08	0.70	2.02	19.00**	3.24	13.88**	0.10**	0.04**
Genotype (G)	9	2137.20**	0.72**	24.57**	15.11**	15.06**	19.07**	5.41	0.05**	0.02*
T x G	36	51.68	0.14**	1.05*	1.21	3.28	1.82	1.94	0.01	0.01
Error (b)	90	42.25	0.07	0.67	1.61	3.73	1.81	1.96	0.02	0.01*
Total	149	177.2	0.13	2.25	2.44	10.10	2.99	6.60	0.04	0.01
CV		8.59	4.81	11.77	2.34	3.34	2.35	192.59	10.76	15.81
R-Square		0.86	0.76	0.87	0.60	0.78	0.64	0.82	0.82	0.82

*,**Significant at 0.05 and 0.01 levels of probability respectively.

DF: Degree of freedom; E%: Emergence Percentage; EI: Emergence Index; ASI: Anthesis Silking Interval; FERT TRT: Fertilizer Treatment; CV: Coefficient of variation

The CVs associated with emergence index, days to 50% tasseling, anthesis and silking, plant and ear heights from the ANOVA were low and rather high for emergence percent, emergence rate index and anthesis silking interval (Table 4). The coefficient of determination (R^2) generated from the ANOVA associated with the traits ranged from 55 to 71%. This was indication of the reliability of the statistical model.

There were significant increase in plant and ear heights of genotypes on plots treated with agrolyser when compared with plots with no fertilizer treatment in the early cropping season. (Fig. 1). However, there were significant increase in the ear and plant heights of genotypes evaluated on plots treated with NPK and NPK+Agrolyser for the early cropping season of this study (Fig. 1). This is contrary to what was obtained during the late cropping season of this study which indicated that there were no significant increase in the ear and plant heights of the genotypes evaluated on plots treated with these fertilizer treatments (Zero, Agrolyser, NPK, NPK + Agrolyser) except for ear and plant heights of the genotypes evaluated on plots treated with NPK + Agrolyser + Mycorrhiza, which showed significant increase as a result of the addition of mycorrhiza that allowed the roots of the plants to assess the nutrients (micro and macro) for its growth. Generally, the grain yields of the maize genotypes evaluated under No fertilizer and Agrolyser treatments were very low in comparison with the other fertilizer treatments during the early cropping season of 2018 (Table 5). The grain yield performance of the ten maize genotypes planted in plots treated with the combination of NPK and Agrolyser was suppressed by the addition of Agrolyser since few of the genotypes showed better performance while others were not significantly different under NPK alone in comparison to plots treated with NPK and Agrolyser (Table 5). These results corroborated the findings of Adeyinka 2008, who reported no improvement on the yield of maize when Agrolyser was added in combination with NPK fertilizer rather, the yield reduced. This showed that Agrolyser had a masking effect on the absorption of macronutrients from NPK.

Generally, addition of mycorrhiza did not improve the yield of the maize genotypes evaluated in the early season of this study (Table 5). Genotypes; EVDT – W- 99 STR QPM and 2011 TZE – W DT STR Synthetic, had the highest grain yield of 1.19 tons/ha and 1.20 tons/ha respectively on plots treated with NPK+Agrolyser+Mycorrhiza while genotypes; 2008 SYN EE DT STR-W and 2008 EVDT STR –Y had the least grain yield of 0.44 tons/ha and 0.48 tons/ha respectively under the NPK+Agrolyser+Mycorrhiza fertilizer treatment during the early cropping season of this study (Table 5).

TABLE 3: MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR YIELD AND YIELD COMPONENTS OF MAIZE GENOTYPES EVALUATED AT THE OAU T&RF, ILE-IFE DURING THE EARLY CROPPING SEASON OF 2018 UNDER DIFFERENT FERTILIZER TREATMENTS

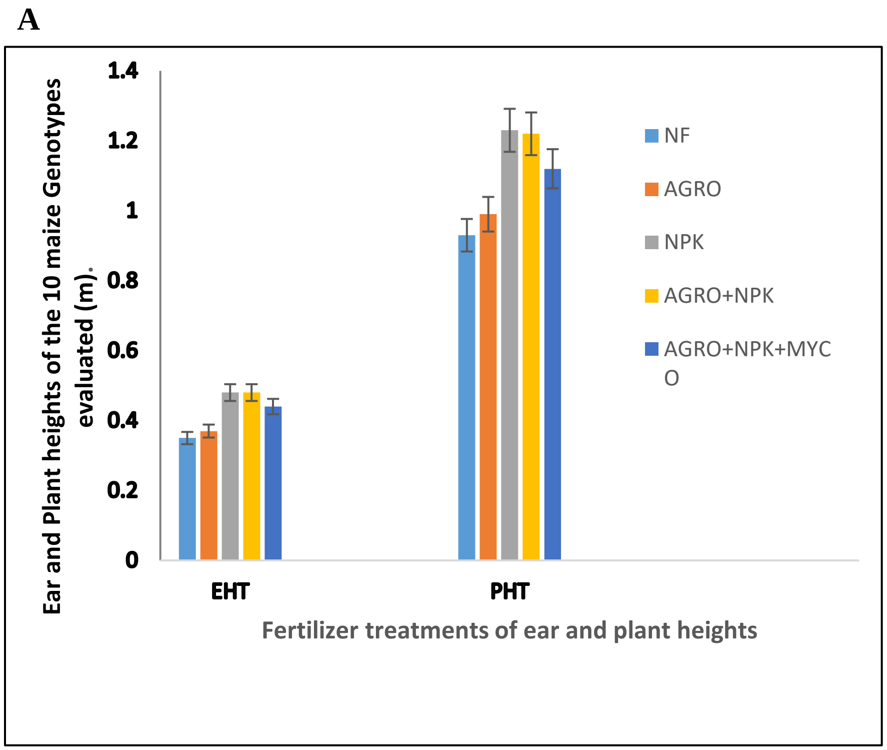
Source	DF	Ear Number	Ear Weight	Moisture Content	Ear Aspect	Ear Diameter	Ear Length	Kernel Row Number	Shelling Percentage	YLD (t/ha)
Rep	2	134.55**	0.18**	40.67**	50.79**	1.62**	7.98*	0.70	295.20	0.58**
FERT TRT (T)	4	119.09**	1.24**	5.22	82.74**	5.08**	60.45**	7.61**	310.10	4.17**
Error (a)	8	18.81**	0.08**	4.89	27.36**	0.76**	5.74**	2.23**	1151.53	0.25*
Genotype(G)	9	46.21**	0.20**	6.13*	4.82*	0.76**	8.78**	3.56**	1460.35*	0.73**
T x G	36	10.74**	0.05	3.83	1.97	0.14	2.18	0.56	812.55	0.21*
Error (b)	90	8.93	0.05	3.12	1.49	0.16	1.66	0.99	691.80	0.16
Total	149	15.25	0.09	3.96	6.50	0.38	4.31	1.14	730.24	0.31
CV		22.66	48.32	8.18	33.86	12.94	15.86	7.47	30.88	45.82
R-Square		0.83	0.81	0.67	0.84	0.79	0.78	0.69	0.60	0.82

*, ** Significant at 0.05 and 0.01 levels of probability respectively. YLD: Yield; CV: Coefficient of variation

TABLE 4: MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR EMERGENCE, FLOWERING TRAITS AND VEGETATIVE TRAITS OF MAIZE GENOTYPES EVALUATED AT THE OBAFEMI AWOLOWO UNIVERSITY TEACHING AND RESEARCH FARM (OAU T&RF), ILE-IFE DURING THE LATE CROPPING SEASON OF 2019 UNDER DIFFERENT FERTILIZER TREATMENTS

Source of Variations	DF	E%	EI	ERI	50% Tasseling	50% Anthesis	50% Silking	ASI	Plant Height (cm)	Ear Height (cm)
Rep	2	378.61**	0.54	248.06**	2.34	3.41	25.04**	18.29**	295.70*	158.76*
FRT TRT (T)	4	1100.18*	1.65**	52.87	47.14**	31.28**	19.38**	14.02**	1391.14**	375.46**
Error (a)	8	264.60	0.16	29.36	16.90	12.98**	23.71	8.00**	263.73**	149.44**
Genotype (G)	9	448.40	0.62*	49.44	5.94	4.56	1.75**	2.67	171.43	121.61**
T x G	36	373.52	0.25	36.58	3.36	2.77	4.06	2.44	92.59	74.51*
Error (b)	90	358.36	0.25	31.08	3.98	3.81	3.95	1.80	102.04	49.01
Total	149	424.20	0.31	36.92	5.78	4.83	5.60	2.89	149.84	75.19
CV		32.95	8.76	50.36	3.65	3.26	3.39	47.36	7.59	13.65
R-Square		0.55	0.58	0.56	0.70	0.68	0.67	0.69	0.69	0.71

*, ** Significant at 0.05 and 0.01 levels of probability respectively. See Tables 1 & 4 for full meaning of abbreviations



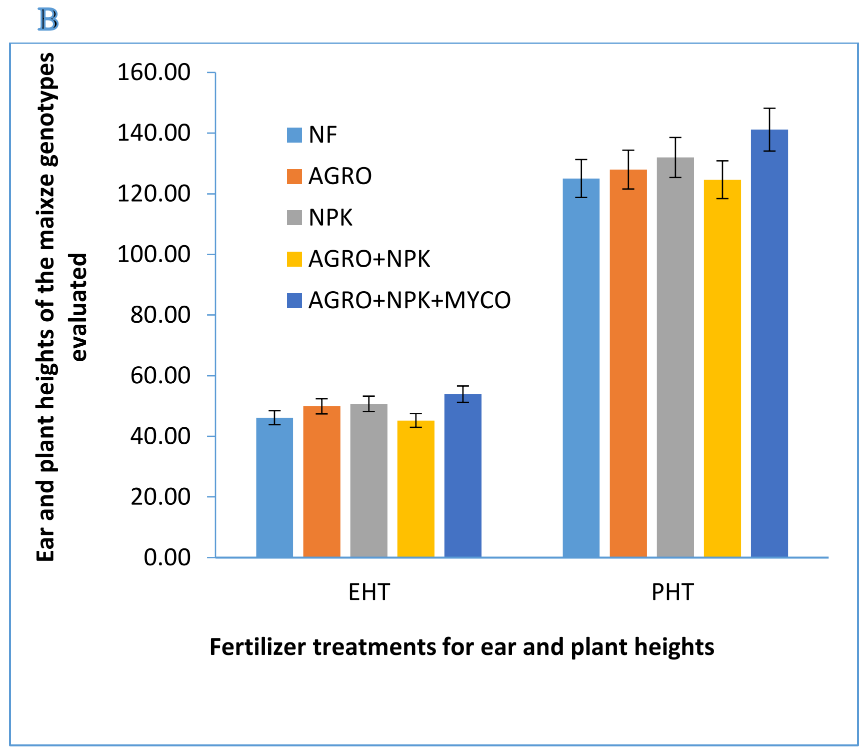


FIG. 1: EFFECT OF FERTILIZER TREATMENTS ON THE 10 MAIZE GENOTYPES EVALUATED AS INFLUENCED BY AMF IN EARLY (A) AND LATE (B) CROPPING SEASONS.

KEY: NF - NO FERTILIZER, AGRO – AGROLIZER, NPK – NITROGEN, PHOSPHORUS, POTASSIUM, MYCO - MYCORRHIZA

TABLE 5: GRAIN YIELD (T/HA) OF THE TEN MAIZE GENOTYPES EVALUATED UNDER FIVE FERTILIZER TREATMENTS DURING THE EARLY CROPPING SEASON OF 2018 AT THE TEACHING AND RESEARCH FARM OF OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA

GENOTYPE	FERTLIZER TREATMENTS					
	NO FERT	**AGRO**	**NPK**	**NPK + AGRO**	**NPK+AGO +MYCOR R**	**$LSD_{0.05}$**
2008 SYN EE DT STR –W	0.26	0.54	1.09	0.31	0.44	**0.66**
TZEE Y POP STR QPM C_o	0.38	0.33	0.80	1.29	0.73	**0.61**
TZEE - Y POP STR C_4	0.26	0.26	1.10	1.07	0.64	**0.78**
99 TZEE-Y POP STR QPM C_o	0.24	0.44	0.71	0.75	0.63	**0.62**
2000 SYN EE – W STR QPM C_o	0.20	0.43	1.16	1.53	0.55	**0.74**
EVDT – W- 99 STR QPM	0.63	0.56	1.53	1.80	1.19	**1.11**
2011 TZE – W DT STR Synthetic	0.27	0.42	1.14	1.14	1.20	**0.68**
2008 EVDT STR –Y	0.24	0.23	0.74	0.82	0.48	**0.37**
TZE – Y DT STR C_4	0.36	0.80	1.62	1.36	0.83	**1.02**
TZE – W POP DT STR QPM	0.24	0.37	2.14	1.61	1.10	**0.61**
$LSD_{0.05}$	**0.32**	**0.51**	**0.78**	**1.08**	**0.37**	

Furthermore, in the late cropping season trial, the ear height of the maize genotypes under No fertilizer and Agrolyzer were also shorter when compared with other fertilizer treatments (Table 6). However, due to addition of mycorrhiza at planting, mycorrhiza was able to assist the roots of the plants to access available micro and macro nutrients in the soil, hence higher ear height performance with treatment that had mycorrhiza in addition to NPK and Agrolyser (Table 6). The genotypes with the highest ear heights under this treatment of NPK+Agrolyser+Mycorrhiza are genotypes; EVDT-W-99-STR-QPM and TZEE-Y-POP-STRC4 with ear height of 0.64 m and 0.62 m respectively while genotypes; TZEYDT STR C4 and TZE-W-POP-DT STR-QPM had the shortest ear height of 0.44 m and 0.45 m respectively (Table 6)

TABLE 6: EAR HEIGHT OF THE TEN MAIZE GENOTYPES EVALUATED UNDER FIVE FERTILIZER TREATMENTS DURING THE LATE CROPPING SEASON OF 2019 AT THE TEACHING AND RESEARCH FARM OF OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

GENOTYPE	FERTLIZER TREATMENTS					
	NO FERT	**AGRO**	**NPK**	**NPK + AGRO**	**NPK+AGO+MYCORR**	**$LSD_{0.05}$**
2008 SYN EE DT STR –W	0.43	0.48	0.41	0.42	0.52	**0.13**
TZEE Y POP STR QPM C_o	0.41	0.47	0.45	0.44	0.59	**0.08**
TZEE - Y POP STR C_4	0.47	0.53	0.48	0.54	0.62	**0.22**
99 TZEE-Y POP STR QPM C_o	0.52	0.54	0.44	0.45	0.53	**0.11**
2000 SYN EE – W STR QPM C_o	0.50	0.51	0.56	0.40	0.55	**0.12**
EVDT – W- 99 STR QPM	0.49	0.56	0.57	0.46	0.64	**0.13**
2011 TZE – W DT STR Synthetic	0.41	0.51	0.52	0.46	0.54	**0.14**
2008 EVDT STR –Y	0.48	0.45	0.55	0.42	0.52	**0.20**
TZE – Y DT STR C_4	0.51	0.48	0.47	0.42	0.44	**0.12**
TZE – W POP DT STR QPM	0.40	0.46	0.62	0.49	0.45	**0.10**
$LSD_{0.05}$	**0.13**	**0.15**	**0.13**	**0.11**	**0.10**	

DISCUSSION

The differences in the response of maize to the different fertilizer treatments implied that the genotypes under the five fertilizer treatments had different response to flowering, vegetative traits and the yield and yield components of the maize genotypes evaluated. This is expected since these fertilizer treatments are of different combination of the micro and macro nutrients in addition to AMF as reported in many fertilizer research findings. For instance, Adeyinka (2008) in a study of response of maize genotypes to micronutrients in a typical tropical soil reported significant fertilizer treatments effect at 0.01 level of probability for yield and yield components. Iren *et al*. (2012) also reported that balanced fertilization is necessary for optimum plant growth and involves the application of both macro- and micro-nutrients in the right amount and proportions for optimum crop yield. Liu *et. al*. 2013 verified that AMF was able to increase and facilitate the absorption and transfer of nutrients. This is similar to the findings of Garba *et. al*. (2018) who reported that the addition of secondary macronutrients and or micronutrients enhanced agronomic use efficiency of N, P and K. Thus, agronomic use efficiency is an indicator of the plant's ability to increase grain yield in response to an applied nutrient and reflects the overall efficiency of the applied nutrient.

Application of NPK and NPK + Agrolyser increased the yield of the maize genotypes and also resulted in increased ear weight and grain yield when compared to the grain yield with no fertilizer application and agrolyser fertilizer treatment which had lesser ear weight and yield during the early season of this study. This result is similar to the findings of Chigbundu and Ibeawuch (2006) who reported non-significant effect of Agrolyser on the yield of cowpea in Zuru, Sahel savanna of Nigeria. Based on this, Agrolyser which consists of 10 micronutrients (copper, manganese, magnesium, iron, sodium, calcium, sulphur, boron, zinc, molybdenum) cannot be used as a substitute for NPK fertilizer but it could be used as a supplementary treatment for the supply of micronutrients Abdullahi *et al*. (2011) also stressed the need for micronutrient inclusion in fertilizer package as supplements of macronutrients for higher yield, especially in soils with micronutrients below critical levels.

However, Adepoju *et al*. (1991) reported significant increases in maize yield due to the application of 200 g of Agrolyser with NPK (120-60-60 kg/ha) at Samaru (22.4%) and Saminaka (50.4%). Agbede and Otonko (2004) also reported increased grain yield of maize when NPK was applied either singly or in combination with Agrolyser at Okuku in Cross River State. The addition of AMF to NPK and Agrolyser did not increase the yield of maize significantly as expected during the early season trial of this study probably because AMF was not added at planting but delayed till four weeks after planting when fertilizer application was carried out. However, during the late season trial, the effect of the application of AMF at planting showed that *G. facultative* was helpful in transferring nutrients that were absorbed from the fertilizer treatments to the plants, thereby overcoming the masking effect caused by Agrolyser on NPK, which led to a reduction in the plant height of the maize genotypes.

Mycorrhiza has a symbiotic association with the plant root. Therefore, the benefits derived by the plants from the fungus largely depends on the efficiency of establishment of the fungus to the plant root (Omoyeni, 2018). This establishment requires time and probably accounted for the non-significant effect recorded during the early season trial. The improvement in the subsequent trial (with respect to the time of application) revealed the potential of the fungus in enhancing nutrient availability and adequate release of these nutrients to the plant for necessary physiological activities (Salami, 2007).

Therefore it can be inferred that the effect of NPK+AGRO+MYCORRHIZA on plant height would directly influence yield which support the hypothsesis that maize yield will increase if AMF (*G. facultative*) is added to the soil with the combined application of agrolyser (micronutrient) and NPK (macronutrients) as *G. facultative* will allow the plant access immobile nutrients in the soil.

CONCLUSION

The maize genotypes responded differently to the fertilizer treatments. The application of *G. facultative* at planting ensured early establishment of symbiotic relationship with the plants and hence, increased nutrient uptake which translated to high plant and ear heights.

Genotype TZE – W POP DT STR QPM performed best under NPK fertilizer treatment and genotype EVDT–W-99 STR QPM performed best under NPK+ Agrolyser treatment during the early cropping season while genotypes 99 TZEE-Y-POP-STR-QPMCO and EVDT-W-99-STR-QPM performed best under NPK+AGRO+MYCORRHIZA during the late cropping season of this study.

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