MAIZE YIELD RESPONSE TO INORGANIC FERTILIZER RATES IN THE TROPICAL RAINFOREST OF SOUTH-EASTERN NIGERIA.

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ABSTRACT

Maize-*Zea mays* production in Southern-Nigeria depends on additional sources of fertilizers including NPK and urea as soils in this region are largely deficient of macro-nutrients. This study investigated the effect of different NPK fertilizer rates and a single rate of urea fertilizer on 2 maize varieties-oba super 6- pro-vitamin A maize and Monsanto yellow maize (DK 920) to determine suitable fertilizer rates for optimum growth and yield in the Obio Akpa cropping community. The experiment was established at the Akwa Ibom State University, Nigeria.The experimental design was an RCBD arranged in a split plot pattern with 3 replications. The main plots were two maize varieties (Oba super 6 and DK 920), the subplots included 3 NPK (15:15:15) fertilizer rates of 250, 300 and 400kg/ha (applied in two equal splits) and a control.Ear weights ranged from 1.5 tons/ha in the control to 3 tons/ha in the 400kg/ha. A linear regression established that fertilizer rates could significantly predict the weight of maize ears $F(1,22) = 8.326$ $P = 0.009$. Fertilizer rates accounted for 27.5% of variability in maize ear weight.Werecommend application of NPK rates above 400kg/ha complemented with urea rates above 75kg/ha for higher yields within this study site.

Keywords: maize, yield, fertilizer,soil infertility

INTRODUCTION

Maize (*Zea mays*) is the third most important cereal crop in the world following rice and wheat (Sher *et al*., 2016). In 2016, the global maize production recorded was about 1 billlion tons; Africa produced about 73 million; of this amount Nigeria was the largest contributor with 11 million tons of maize followed by South Africa with about 7millon tones (FAOSTAT, 2016). Maize yields in most African countries are on average 2tons/hectare/year (Cairn *et al*., 2013; FAO, 2016). This is extremely low compared to average maize yields of 6-11 tons/ha for top maize producing countries like USA,China and Brazil (USDA statistics, 2018; Langemeier, 2016). Therefore, African countries rely extensively on maize importation to meet its consumer demands.

Maize is a staple food in sub-Saharan Africa and it is the most widely consumed cereal (Edmonds *et al*., 2009). Millions of Africans rely on maize as a chief source of carbohydrate because it is cheap and affordable. However, the low yield of maize in sub-Saharan Africa is attributed to a number of stress factors including pest, diseases, water and soil nutrient deficiency (Agyare *et al*., 2014; Liverpool-Tasie*et al*., 2017).Soils in the tropical savannah and rainforest zones of West Africa are exposed to heavy impacts of rain fall causing erosion. Heavy erosion results in nutrient run-off which is the washing away of topsoil nutrients to valleys and neighbouring streams. Furthermore, land deforestation and continuous cultivation has resulted in an exponential decrease in macro nutrients (such as nitrogen) within the top 0-10cm soil layer (Edmonds *et al*., 2009).

To deal with these challenges growers rely on the use of organic manure or inorganic fertilizers (mainly the compound fertilizers-NPK, and the single nitrogen fertilizer-urea). Irrespective of the established benefits of inorganic fertilizers there is still a lingering challenge of high cost of transportation leading to low accessibility at community levels, (Liverpool-Tasie*et al* 2017). Edmonds *et al*., (2009) has warned that the limited fertilizer supply in African crop production is resulting in nutrient mining- nutrients are removed in larger proportion than they are replaced. In farms where fertilizer is available or affordable there is insufficient awareness on the effectiveness of precise timing and amount of fertilizer application (Liverpool-Tasie*et al* 2017; Law-ogbomo and Law-ogbomo, 2009; Ten Berge and Van ittersum, 2019). Future research needs to target the development of more crops with tolerance to nutrient deficient soils and the application of appropriate amounts of fertilizer application for maize yield.

Previous research in the Nigerian South-Eastern rainforest zone by Ekwere *et al* (2013) confirmed a significant increase in maize grain yield when NPK fertilizer was applied compared to a zero application. They found that maize yield at NPK fertilizer rates of 600Kg/ha gave a higher numerical value of1.758 tons/ha; this however was not significantly higher than the yield of 1.718tons/ha at NPK rates of 200 and 400kg/ha. Maize NPK fertilizer studies in the south-western region (humid forest environment) of Nigeria reveals different results. Law-ogbomo and Law-ogbomo (2009) studied the effect of varying NPK rates on maize yield in a soil reported to have low macro nutrient levels(nitrogen, phosphorus, potassium) before planting. They observed maize yield was higher at 7.95tons/ha when 400kg/ha of NPK (15:15:15) was applied compared to 7.01 tons/ha at 200Kg/ha, 5.85tons/ha at 600kg/ha and 3.53tons/ha at 0 kg/ha. Similarly, Adeyemi (2013) in the south-western region reported a higher yield of 5.4 tons/ha and 5.75tons/ha at 500 and 750kg/ha of NPK fertilizer compared to yield at lower fertilizer rates.In this study, the soil nitrogen, phosphorus and potassium level before planting was reported low.

The contrasting results from the above literature show the need for more site specific research to determine the appropriate rates of NPK fertilizer for optimum maize grain yield. Furthermore, as fertilizers are inaccessible to rural farmers in south-eastern Nigeria, it would be beneficial to introduce a strategy in fertilizer use that minimises its application rates. This study will evaluate maize varieties to assess their potential to withstand low NPK and urea rates in this region. It will also study the complementary effect of urea as the most prevalent nitrogen fertilizer in south-eastern Nigeria and different NPK fertilizer rates on maize yield components.The objective of this study is:

To compare the response of maize growth and yield components in 2 maize varieties to varying rates of NPK fertilizercombined with a single low rate of urea.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Teaching and Research Farm of the Crop Science Department of Akwa Ibom State University, Akwa Ibom State, Nigeria. Akwa Ibom State is positioned between latitude 4.32^{o}N and 5.33^{o}N and longitude 7.25^{o}E and 8.25^{o}E. The climate of this area is classified as tropical monsoon with average annual precipitation of 2509mm and temperature of 26.4^{o}C. The experiment was conducted between the month of May and July 2018. The experimental site has been on continuous cropping for the past 10 years. The previous crop sown was cassava.

Land clearing and preparation

The land was first cleared with a tractor-drawn plough and the remaining stumps and weeds were removed manually. The soil was then pulverized using a shovel. The size of each plot was 3x5 m^2 with a planting distance of 0.25 x 0.75m. The field size was 25x 25m^2.

Soil sampling

A composite soil sample at a depth of 0-15cm was collected before planting using a soil auger to determine the physical and chemical properties of the soil. Samples collected were taken to the laboratory where they were air dried and sieved with a 2mm sieve and analysed for soil physical and chemical properties presented in Table 1.

Experimental design

The experimental design was an RCBD arranged in a split plot pattern with 3 replications. The main plots were two hybrid maize varieties (Oba super 6 - provitamin A maize and the Monsanto yellow maize- DK 920), the subplots included 3 NPK (15:15:15) fertilizer application rates of 250 Kg/ha, 300kg/ha, 400kg/ha (applied in two equal splits) and a control.

Planting and cultural practices

Seeds were sown with the planting distance of 0.25 x 0.75m at the rate of 3 seeds/hole. The 3 seeds were thinned down to 1 stand after germination. The field was weeded by hand 2 weeks after planting (WAP). The first split of NPK fertilizer was applied 2 weeks after planting (immediately after first weeding)and the second split was applied 6 WAP when more than half of the plant population had produced tassels. Urea was applied at one single dose of 75kg/ha at 7 WAP (below the standard recommendation of 150 kg/ha for the 2 varieties selected). All fertilizers were applied using the ring method of application. Plants were sprayed twice with the insecticide (Halakat at 250 ml/ha) for control against the pest maize stem borer.

Data collected included plant height at 11 WAP (growth parameter) and yieldparameters including: ears/m^2, 100 grain weight, shoots/m^2, weight of ears with husk and the field weight (weight of dehusked ears).

Data analysis

Data collected was analysed using ANOVA in the statistical software SPSS version 20. In addition,a spearman's rank order was used to assess the relationship between plant height and the weight of dehusked ears; a linear regression analysis was used to determine a relationship between fertilizer rates and yield components measured.

RESULTS

Plant height

There was a statistically significant difference in the average plant height at the variety level for the 0 NPK fertilizer treatmentand the 250Kg/haNPK fertilizer treatment$F (1,16) =4.304$ $P=0.021$. With the 0 fertilizer treatment; plant height was 42.6cm (95% CI 131.78-167.82cm) greater for oba super 6- provitamin A than the DK920 variety. While with the 250Kg/ha treatment; plant height was 25.56 cm (95% CI 89.18-125.23) greater for the oba super 6 than the DK920 variety. Preliminary analysis showed the relationship between plant height and weight of the dehusked ears to be monotonic (maize ear weight increased with increase in height) assessed by visual inspection of a scatter plot but there was no statistically significant correlation between the weight of dehusked earsand plant height r_s (22) $=0.112$ $P=0.602$.

Table 1. Soil physical and chemical properties before planting

Soil properties	Mean values
Sand (%)	92.5
Silt (%)	1.7
Clay (%)	5.8
pH	4.8
Organic matter (%)	4.5
Total nitrogen (%)	0.12
Available phosphorus (mg/kg)	18.33
Exchangeable potassium (Cmol/kg)	0.12
Exchangeable magnesium (Cmol/kg)	2.7
Exchangeable calcium (Cmol/kg)	10.4

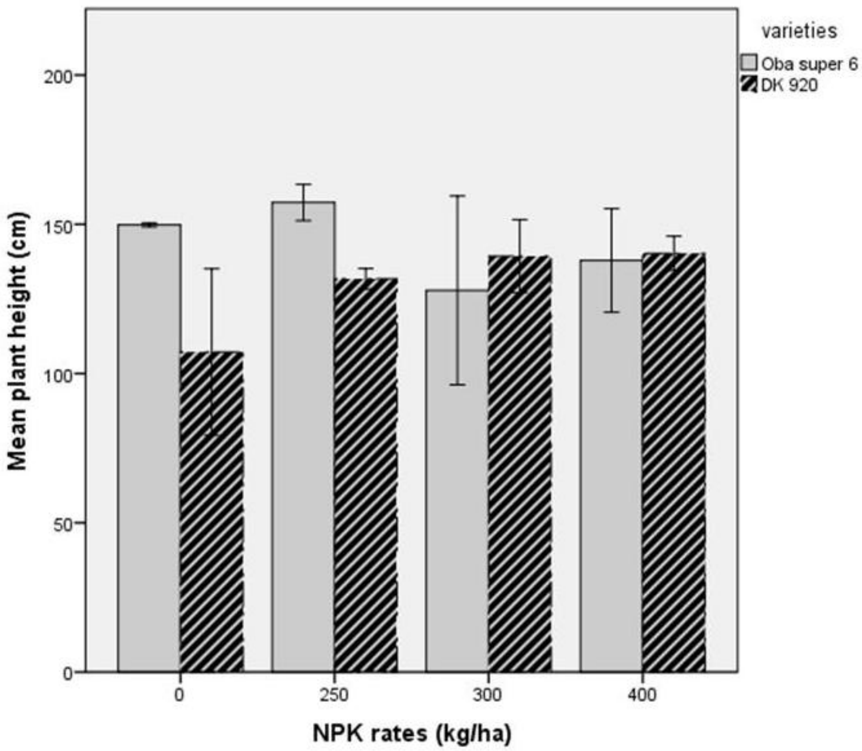

Figure 1: Effect of NPK fertilizer rates on mean plant height at 11 weeks after planting. Error bars indicate ± standard error of means.

Maize yield parameters

At maturity the average number of plants within a plot ranged from 73 in the 0 fertilizer treatment to 76 in the 400kg/ha treatment. In addition, the average ear number/plot ranged from70 ears in the 0 fertilizer treatments to 75 in the 400kg/ha treatment; indicating that most plants produced ears. There was nosignificant effect of NPK fertilizer treatments on ear numbers or plant population and no linear relationship between ear number and fertilizer rates. Between the two varieties:there were no significant differences in ear number,ear weights and 100 grain weights but there were differences in plant populationF (1,16) =4.648 P=0.047. The maize hybrid DK 920 had a higher plant population than Oba super 6 (table 3).

There was no statistically significant effect of fertilizer treatments on100 grain weights even though amounts varied from 11.8g in plants receiving 250 kg/ha to 13.4 g in plants receiving 0 fertilizer treatments (table 2). There was also no linear relationship between fertilizer rates and 100 grain weights.

Ear weight when dehusked ranged from 1.5 tons/ha in plants receiving 0fertilizer to 3.2 tons/ha in plants receiving 300kg/ha but there were no statistically significant differences in ear weight between all treatments. However, a linear regression established that fertilizer rates could significantly predict the weight of dehusked maize ears $F(1,22) = 8.326$ $P = 0.009$ and fertilizer rates accounted for 27.5% of the explained variability in maize ear weight. The regression equation for predicted ear weights is as follows:

Ear weight tons/ha (dehusked)= 1.561+0.004 (NPK fertilizer rates)

Ear weight with the husk varied between 2.13 and 4.67 tons/ha among fertilizer treatments. There was a significant main effect of fertilizer rates on ear weight $F(3,16) = 3.996$ $P = 0.027$. Weight in plots receiving 400kg/ha and 300kg/ha was greater than that of the 0 fertilizer treatment by 2.5 tons/ha; but between all 3 fertilizer rates no significant differences were observed. A linear regression showed that fertilizer rates accounted for 39.1% of the explained variability in the weight of maize ears with husked. In addition, fertilizer rates could statistically predict ear weights $F(1,22) = 14.14$ $P = 0.001$. The regression equation was:

Predicted ear weight tons/ha (with husk) =2.173+0.007 (NPK fertilizer rates) (figure 2).

Table 2: Maize yield components at different rates of NPK 15:15:15 fertilizer application (S.E: standard error of mean)

Fertilizer rate kg/ha	Ear weight +husk (tons/ha)	Ear weight-dehusked (tons/ha)	Ear number/ha	Plant population/ha	100 grain weight (g)
0	2.133	1.53	80,000	48,667	13.41
250	3.676	2.38	85,523	51,000	11.84
300	4.648	3.22	82,666	48,222	13.25
400	4.667	3.02	86,476	50,667	12.42
S.E	0.596	0.47	6880.25	1520	0.67

Table 3: Maize yield components of Oba super 6 and DK920 averaged across fertilizer treatments (S.E: standard error of mean)

Variety	Ear weight +husk (tons/ha)	Ear weight-dehusked (tons/ha)	Ear no/ha	Plant population/ha	100 grain weight (g)
Oba super 6	3.814	2.39	77,047.6	48,000	12.9
DK 920	3.748	2.68	90,285.7	51,278	12.5
S.E	0.422	0.332	4,865.1	1075.11	0.473

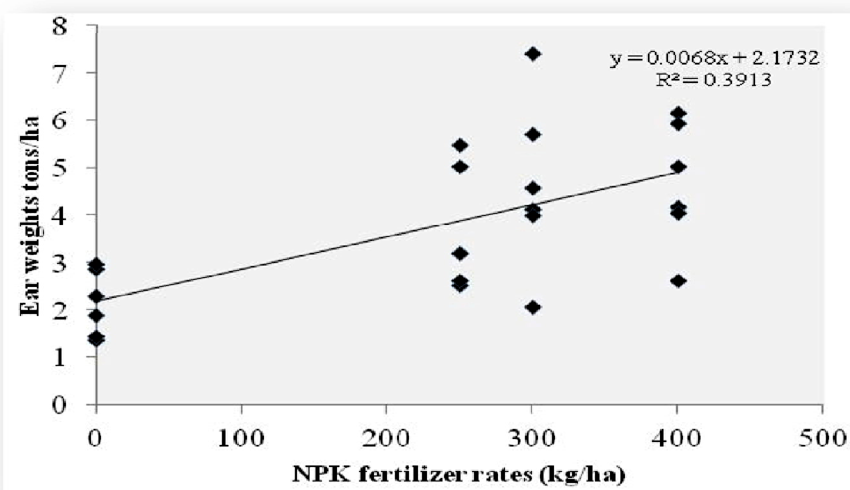

Figure 2: Simple scatter of maize ear weight (tons/ha) by NPK fertilizer rates

DISCUSSION

Soil analysis

The soil in the experimental site has a sandy texture. Soil was moderately acidic (pH 4.8) which is typical of soils in the rain forest region of Nigeria. Mean total nitrogen (N) was 0.12% which is low compared to typical N levels for this ecological zone ranging between 0.16-0.2%(Olatunji 2015). Critical level of N for maize is 0.15% (Ayodele and Omotoso 2008). However, soil organic matter was 4.48% an amount considered preferable for sandy soils, indicating a potential for high N release during the growing season. Available phosphorus level was 18.33mg/kg which is classified as moderate for soils in this ecological zone (Olatunji 2015).

Plant height and yield parameters

This study showed no visible effect of fertilizer treatments on plant height but a clear difference was noted between varieties asOba super 6 plants were taller indicating a potential for efficient uptake and utilization of nutrients for biomass production in this variety. This efficient nutrient use can ultimately amount to increased yield (Ten Berge and Van Ittersum, 2019).

Plant height also increased (although correlation was notsignificant) with increase in maize ear weight aligning with previous research (Yin *et al* 2011; Louis and Salvador 1997). In western Nigeria a study by Law-ogbomo and Law-ogbomo (2009) showed plant height increased with fresh maize ear weight. Additionally, in South-eastern NigeriaNwogboduhu's (2016)research on 3 maize varieties showed a correlation with plant height and yield; varieties with the highest yield (4.35 tons/ha) were also noted as the tallest (216 cm).

Fertilizer treatments affected the weight of ears with the husk and not the ear weights when the husks were removed; suggesting a significant contribution of fertilizerrates to husk weight and not the ears. As there was no difference in ear weights between all three NPK rates (250, 300 and 400kg/ha), it is proposed that the single rate of urea (75kg/ha) combined with each of the above rates of NPK will have the same effect on maize ear weights.

Furthermore,maize ear weights in this study was generally low compared to past literature(Law-ogbomo and Law-ogbomo 2009; Adeyemi (2013); Ogunbodede *et al* 2001). Fresh weight of maize ears as high as 5.32-20.35 tons/ha and grain weights (when separated from the cobs) of 3.52-5.85 tons/ha have been reported in previous research (Law-ogbomo and Law-ogbomo, 2009; Adeyemi, 2013). The low yields in this study may be due to the timing of split applications of fertilizer- fertilizer was applied in 2 equal splits. The first split was administered 2 weeks after planting and the second split 6 weeks after planting according to standard fertilizer recommendations for these varieties. Soil analysis report showed low macro-nutrient levels and low pH levels. Suggesting the need for an earlier and larger amount of fertilizer before sowing to boost crop growth and development, and soil liming to increase the soil pH as maize prefers pH between 5.5-6.5 (Ayodele and Omotoso 2008).

Linear regression predicted an increase in maize ear weights with concurrent increase in fertilizer rates showing that increasing fertilizer rates above the recommended 400kg/ha for these maizevarieties can produce significant yield increments.Adeyemi (2013) and Law-ogbomo and Law-ogbomo (2009) also observed a similar relationship when also working on NPK fertilizer rates. Adeyemi (2013)reported yield increase from 2.9t/ha at 0kg/ha of NPK 15:15:15 applicationto 5.24t/ha at 750Kg/ha.

CONCLUSION

This investigation revealed maize ear weights to be generally low compared to similar works even the highest fertilizer rates amounted to yields as low as 3.02 tons/ha. As results showed evidence of increase in maize ear weights with increasing fertilizer rates, we propose application of higher NPK rates above 400kg/ha complemented with increased urea rates (above 75kg/ha) for this study area. None of the 2 varieties in this study outperformed the other in yield components under low or zero fertilizer application. This indicates that both varieties may require higher fertilizer rates for optimum yield.

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APPENDICES

Two-way ANOVA Table for Plant Height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	45.178[a]	7	6.454	3.430	.020	.600
Intercept	586.537	1	586.537	311.727	.000	.951
variety	14.228	1	14.228	7.562	.014	.321
fertilizer_rate	8.087	3	2.696	1.433	.270	.212
variety * fertilizer_rate	22.863	3	7.621	4.050	.026	.432
Error	30.105	16	1.882			
Total	661.820	24				
Corrected Total	75.283	23				

a. R Squared = .600 (Adjusted R Squared = .425)

Two-way ANOVA Table for Ear weight-dehusked (tons/ha)

Corrected Model	10.986[a]	7	1.569	1.188	.363	.342
Intercept	154.606	1	154.606	116.993	.000	.880
variety	.523	1	.523	.396	.538	.024
fertilizer_rate	10.376	3	3.459	2.617	.087	.329
variety * fertilizer_rate	.088	3	.029	.022	.995	.004
Error	21.144	16	1.321			
Total	186.736	24				
Corrected Total	32.130	23				

a. R Squared = .342 (Adjusted R Squared = .054)

Two-way ANOVA Table for Ear no/ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1353959183.673[a]	7	193422740.525	.681	.686	.230
Intercept	168002666666.667	1	168002666666.667	591.502	.000	.974
variety	1051482993.197	1	1051482993.197	3.702	.072	.188
fertilizer_rate	154721088.435	3	51573696.145	.182	.907	.033
variety * fertilizer_rate	147755102.041	3	49251700.680	.173	.913	.031
Error	4544435374.150	16	284027210.884			
Total	173901061224.490	24				
Corrected Total	5898394557.823	23				

a. R Squared = .230 (Adjusted R Squared = -.108)

Two-way ANOVA Table for Plant Population/plot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	234.625[a]	7	33.518	1.074	.423	.320
Intercept	133057.042	1	133057.042	4263.510	.000	.996
variety	145.042	1	145.042	4.648	.047	.225
fertilizer_rate	79.125	3	26.375	.845	.489	.137
variety * fertilizer_rate	10.458	3	3.486	.112	.952	.021
Error	499.333	16	31.208			
Total	133791.000	24				
Corrected Total	733.958	23				

a. R Squared = .320 (Adjusted R Squared = .022)

Two-way ANOVA Table for 100 grain weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	21.480[a]	7	3.069	1.143	.386	.333
Intercept	3889.524	1	3889.524	1449.037	.000	.989
variety	1.105	1	1.105	.412	.530	.025
fertilizer_rate	9.712	3	3.237	1.206	.339	.184
variety * fertilizer_rate	10.663	3	3.554	1.324	.301	.199
Error	42.947	16	2.684			
Total	3953.952	24				
Corrected Total	64.427	23				

a. R Squared = .333 (Adjusted R Squared = .042)