



Effect of Inorganic Fertilizer on Soil Properties, Growth and Yield of Maize in Makurdi, Southern Guinea Savanna Zone of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AA supervised the study, managed the design and wrote the protocol. Author MU designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author SOO served as external examiner and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted with the objective to determine the effect of inorganic fertilizer on soil properties, growth and yield of maize at the Teaching and Research Farm, Federal University of Agriculture, Makurdi, Southern Guinea Savanna Zone of Nigeria, during 2017 and 2018 cropping seasons. The experimental treatments consisted of 0, 75, 150 and 300 kg ha⁻¹ of NPK fertilizer laid out in a randomized complete block design (RCBD) and replicated thrice. Soil samples were collected from a plough layer of 0-15 cm before and after the experiment for each cropping season according to the treatments and were analyzed for particle size distribution (PSD), soil pH, organic carbon (OC), total nitrogen (TN), available phosphorus, exchangeable cations and cation exchange capacity (CEC). Maize plant (growth and yield) data collected were subjected to analysis of variance after which significant means were separated using least significant difference (LSD) at P < 0.05. From the results, the effects of fertilizer treatments on soil properties investigated were significant. Application of fertilizer increased soil organic matter (SOM), TN and CEC in both

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cropping seasons. However, the SOM was low in all plots with no application of fertilizer. Exchangeable bases, base saturation and CEC reduced in 2017 in no fertilizer treatments but remarkably increased in 2018 due to application of 75, 150 and 300 kg ha⁻¹. The 300 kg ha⁻¹ NPK fertilizer applications produced higher growth and yields of maize plant than remaining treatments. Similarly, soil properties (soil pH, SOM, TN and CEC) were also improved with application higher levels of mineral fertilizers for agricultural production.

Keywords: Inorganic fertilizer; soil properties; maize production; Southern Guinea Savanna; Nigeria.

1. INTRODUCTION

Maize is a staple food crop in Nigeria, because of its ability to adapt to various ecological zones of Nigeria. Maize occupies a unique position of the hunger breaker being among the first crop to be put at the disposal of the farmers after the dry season in Nigeria [1]. Use of maize for direct human consumption as roasted cob, breakfast cereal, pudding, soup, fermented paste, couscous, etc., has remained stable at about 100 million tons per annum since 1988. About three quarters of maize is transformed into meat, milk, eggs and other animal's products [2]. Thus, maize more than any other crop offers the promise of meeting Africa's food needs in this millennium.

Climate and soil are the main environmental factors that determine crops yields [3]. Although maize is found to grow throughout Nigeria under a wide range of agro-climatic conditions, three broad agro ecological zones can be distinguished for maize production. These are the forest, the moist (or Guinea) savanna and the forest/savanna transition zone [2]. The Guinea savanna is the most important maize growing zone in Nigeria.

In Nigeria, productivity of soils is hampered by deficiency of plant nutrients like N, P and K [4]. Apart from the widespread limitations of N and P across the widely distributed weathered soils in Sub-Saharan Africa (SSA), low organic matter content and soil acidity have contributed to low crop yields [4]. High population growth rate in SSA and Nigeria in particular has put pressure on land; therefore, most smallholder farmers are practicing continuous cropping to meet their food requirements. This leads to significant decline in soil pH, exchangeable Ca and Mg levels [5].

Fertilization of soil generally leads to increase in the yield of crops [6,7], increase in the accumulation, mineralization and humification of soil organic matter (SOM) and it determines the level of growth of crops. The amount of fertilizer

applied to the soil affects the amount of nitrogen and SOM content available to the crops [7]. The effects of fertilizer applications on soil physical and chemical properties are important to agricultural production and sustainability [8,9]. The physical and chemical properties of a soil are one of the fundamental factors affecting maize crop growth and yield. This is because these properties have high degree of correlation with maize crop production and have high influence on soil fertility [10,11].

Many Nigerian soils show nutrient deficiency problems for maize production after only a short period of cultivation and it is because of their nature as well as prevailing environmental conditions. Farmers have sought to furnish additional nutrient by applying chemical fertilizer so that the yields of crops will no longer be limited by the amount of plant nutrients that the natural system can supply [12].

However, inorganic fertilizers are applied to soil to increase or maintain crop yields in order to meet the increasing demand of food in Nigeria. Application of inorganic fertilizers leads to increase in SOM, accumulation and microbial activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues [13,14]. Addition of SOM increases soil organic carbon (SOC) content, which is an important indicator of soil quality and crop productivity [14].

The effect of Inorganic fertilizer applications on soil physical properties is directly or indirectly related to aggregate stability, water holding capacity, porosity, infiltration rate, hydraulic conductivity and bulk density as a result of increase in SOM and SOC content. Applications of inorganic fertilizer also affect the chemical composition of soil solution which can be responsible for dispersion/flocculation of clay particles and thus, affects the soil aggregation stability. Inorganic fertilizers are essential component of any system aimed at maintaining

good crop yield in the absence of organic manure [15,16]. However, the rate of application and dosage has a greater influence on soil properties, crop yield and its environment [17]. Excessive application of fertilizer according to these authors does not really enhance sustainability, crop nutrient uptake nor significantly increase yields but tends to encourage economic waste and damage to the environment.

Inadequate application can retard growth and lower yield in short term and in the long run jeopardizes sustainability through soil mining and erosion. This precarious tilt between excessive and inadequate is the major challenge of fertilizer recommendation efforts and can only be effectively bridged when nutrients are applied at the right ratios. The objective of the study was to determine the effect of inorganic fertilizer rates on soil physical and chemical properties as well as the growth and yield of maize in Makurdi, Southern Guinea Savanna Zone of Nigeria.

2. MATERIALS AND METHODS

The experiment was conducted during 2017 and 2018 cropping seasons at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi-Nigeria to determine the effect of inorganic fertilizer on soil properties, growth and yield of maize. The study location falls within the Southern Guinea Savanna Zone of Nigeria with mean rainfall of 1, 250 mm per annum and temperature of 25-30°C. The site had not been cultivated for about two years. It is located between latitude 7°40'N to 7°53'N and longitude 8°22'E to 8°35'E at an elevation of 97 m above mean sea level. The soil is classified as Typic Ustropepts (USDA) [18]. The maize variety (TZESR-W) was used as planting material for the experiment in both seasons. This variety is widely grown by farmers in the study area.

The experimental treatments consisted of 0, 75, 150 and 300 kg ha⁻¹ of NPK fertilizer laid out in a randomized complete block design (RCBD) and replicated thrice. The land was cleared manually and ridges were prepared using hoe and cutlass. The cleared grasses were gathered and burnt. The land was then marked out in three replicates. Each plot measured 4 m x 4 m with spacing of 1 m between replicates and 0.5 m between plots in the same replicate. Planting and other agronomic practices such as weed control, pest and disease control and fertilizer application were carried out as required. Planting was done

on 8th and 9th August in 2017 and 2018 respectively at a depth of 2.3 cm with spacing 25 x 75 cm giving an approximate plant population of 35,000 plants hectare⁻¹.

2.1 Soil Data Collection and Analysis

A composite soil sample was obtained from a plough layer (0-15 cm) at the beginning and at the end of each experiment according to the treatments and analyzed at the Advanced Analytical Laboratory of Soil Science Department of the Federal University of Agriculture, Makurdi. The pH was determined in water (1:1) [19]. The particle size distribution was determined by the hydrometer method [20]. The chromic acid titration method was used to determine the O.C. and O.M [19]. Total N in the soil was determined by the regular Macrokjeldahl method [19]. The amount of cations held exchangeable by a unit mass of soil was determined using NH₄OAC at pH- 7.0 displacement method. The exchangeable K, Ca, Mg and Na were determined using the EDTA titration method while the available P was determined by Bray-1 method. Flame photometer was used to determine K and Na whereas AAS was used to determine Mg and Ca.

2.2 Crop Data Collection and Analysis

Plant height was measured at 8 and 12 weeks after planting. This was done by measuring with a measuring tape from the base of the plant to the tip of the highest shoot/leaf of the plant. The lengths of 10 cobs from each net plot were measured from bottom of the maize cob to the cob apex using a meter rule and the average value recorded.

The diameters of 10 cobs from each net plot were measured using measuring tape round the cob and the average value recorded. A total of 100 seeds from each plot were counted and weighed on an electronic top-loading Mettler balance to obtain the weight of 100 seeds. Five plants in the net plot were sampled, the number of cobs on each plant counted and average value determined and recorded. From the seed yield per plot, seed yield per hectare for each plot was computed by converting it into kilogram per hectare by extrapolation. Data collected for the growth and yield parameters of maize were subjected to the Analysis of Variance (ANOVA) after which significant means were separated using Least Significant Difference (LSD) at P < 0.05.

3. RESULTS AND DISCUSSION

The results of analysis of soil of the experimental site during 2017 and 2018 cropping seasons before application of treatments are presented on Table 1. The soil is sandy loam, slightly acidic, pH (water) being 6.41 and 6.33 respectively, whilst pH (KCl) were 5.60 and 5.50 respectively. The total N is low for both years (0.07 and 0.09%) and SOM (1.57 and 1.65%). The results of soil analysis indicated that adequate soil amendment is required for good crop production [21].

3.1 Influence of Fertilizer Application on Soil Properties

The data obtained from the analysis of soil as influenced by fertilizer application in 2017 and 2018 cropping seasons are presented on Tables 2 and 3 respectively. The soil pH at harvest decreased in all treatment plots except in plots with 300 kg ha⁻¹ NPK fertilizer application. This can be attributed to high application of NPK fertilizer and also in line with the observation of [22] who reported that high application of NPK fertilizer could increase soil pH. The low soil pH as a result of low application of NPK fertilizer could be attributed to complete decomposition of SOM [23].

The use of NPK fertilizer increased SOM (Tables 2 and 3) in 2017 and 2018 cropping seasons.

However SOM was low in all plots with no application of fertilizer. This can be as a result of lack of fertilizer which would have increased the decomposition of SOM in these plots. According to Plaster [24], SOM can be maintained through the application of organic and inorganic fertilizers.

Lowest values of N and P were recorded for no NPK application. Exchangeable bases, base saturation and ECEC reduced in 2017 in no fertilizer treatments but remarkably increased in 2018 due to application of 75, 150 and 300 kg ha⁻¹. This is in agreement with Ojeniyi [25] who observed that fertilizer increased nutrients (N, P, Mg, K, Ca, CEC and base saturation) in soil. Tables 2 and 3 also indicated that maize + 300 kg ha⁻¹ NPK had the highest N, OM and relatively high available P. Table 3 shows that maize + 300 kg ha⁻¹ NPK maximized available soil P and N. The results are consistent with earlier reports that N and P are limiting nutrients to maize productivity [26,27].

3.2 Influence of Fertilizer on Growth and Yield of Maize

The influence of fertilizer treatments on growth and yield parameters of maize during 2017 and 2018 cropping seasons are shown on Figs. 1-4 and Table. From the results, the effects of fertilizer treatments on maize growth and yield

Table 1. Pre-planting soil properties of the experimental site

Property	2017	2018
Chemical Property		
pH H ₂ O (1:1)	6.41	6.33
pH KCl (1:1)	5.60	5.50
Organic Carbon (%)	0.91	0.94
Organic Matter (%)	1.57	1.63
Total Nitrogen (%)	0.07	0.09
Available p (ppm)	3.02	3.60
Exchangeable Cation (Cmol Kg⁻¹)		
Ca	3.27	3.07
Mg	1.40	1.36
K	0.26	0.24
Na	0.63	0.62
CEC	6.28	6.23
Base Saturation (%)	86.5	87.4
Particle size Distribution		
Sand (%)	78.5	77.0
Silt (%)	10.2	10.9
Clay (%)	11.3	12.1
Textural Class	Sandy loam	Sandy loam

Table 2. Soil properties after harvest in 2017

Treatments /Plot	Particle size distribution				pH		Org	Org	N	Bray-1	Exch. Cations (CmolKg ⁻¹)				CEC (Cmolkg ⁻¹)	Base Saturation (%)
	Sand (%)	Silt (%)	Clay (%)	Textural Class	H ₂ O 1:1	KCl 1:1	C (%)	M (%)		P (ppm)	Ca	Mg	K	Na		
T1+F1	72.3	12.5	15.2	Sandy Loam	6.55	5.60	0.87	1.51	0.078	4.30	3.30	1.53	0.28	0.68	6.50	89.20
T2+F2	76.2	11.2	12.6	Sandy Loam	6.63	5.80	0.89	1.54	0.070	3.40	3.01	1.30	0.21	0.52	6.10	88.60
T3+F3	77.6	11.2	11.2	Sandy Loam	6.45	5.65	0.74	1.28	0.091	3.11	2.96	1.26	0.21	0.50	5.80	87.40
T4+F4	77.5	11.3	11.2	Sandy Loam	6.60	5.85	0.90	1.56	0.087	4.60	2.77	1.30	0.23	0.48	5.20	90.20

T1 = F1 = 0 kg⁻¹ Fertilizer, T2= F2 = 75 kg⁻¹ Fertilizer, T3= F3= 150 kg⁻¹ Fertilizer, T4= F4= 300 kg⁻¹ Fertilizer, T1- 4 = Treatment 1-4

Table 3. Soil properties after harvest in 2018

Treatments /Plot	Particle size distribution				pH		Org	Org	N	Bray-1	Exch. Cations (CmolKg ⁻¹)				CEC (Cmolkg ⁻¹)	Base Saturation (%)
	Sand (%)	Silt (%)	Clay (%)	Textural Class	H ₂ O 1:1	KCl 1:1	C (%)	M (%)		P (ppm)	Ca	Mg	K	Na		
T1+F2	73.3	11.8	14.9	Sandy Loam	6.38	5.68	0.90	1.56	0.076	4.50	3.25	1.50	0.23	0.63	6.30	88.00
T2+F3	74.6	11.5	13.9	Sandy Loam	6.51	5.80	0.95	1.64	0.070	3.00	3.00	1.28	0.20	0.50	6.06	87.60
T3+F2	76.9	11.9	11.2	Sandy Loam	6.45	5.67	0.78	1.35	0.093	3.20	2.93	1.23	0.21	0.48	5.60	87.10
T4+F1	76.5	12.0	11.5	Sandy Loam	6.50	5.80	0.96	1.66	0.070	3.00	2.77	1.30	0.22	0.45	5.30	90.00

T1 = F1 = 0 kg⁻¹ Fertilizer, T2= F2 = 75 kg⁻¹ Fertilizer, T3= F3= 150 kg⁻¹ Fertilizer, T4= F4= 300 kg⁻¹ Fertilizer, T1- 4 = Treatment

parameters investigated were significant. However, application of NPK fertilizer at 300 kg ha⁻¹ had significantly ($P < 0.05$) effected the maize plant production in both seasons. The application of 300 kg ha⁻¹ fertilizer of NPK had significantly ($P < 0.05$) higher cob length in both seasons. The highest cob lengths (13.50 and 14.65) were obtained from the application of 300 kg/ha of NPK fertilizer and the shortest cob lengths (8.61 and 9.61 cm) were obtained from the application of 0 kg/ha fertilizer in both seasons. The number of leaf per plant and plant height increased with incremental rate of NPK fertilizer application in both seasons (Figs. 1-4). The increased in growth and grain yield was due to the positive effects of NPK fertilizer

applications on the growth and yield parameters. This observation is consistent with that of Mbah et al. [28] and Mandimba et al. [29] who reported that increase in grain yield of maize is as a result of positive response of the crop to 300 kg ha⁻¹ of NPK fertilizer in the south eastern Nigeria. Similar positive responses of maize to application of NPK fertilizer have been observed by Osunde et al. [30] and Ali et al. [31]. The no NPK fertilizer treatment gave the least growth and yield parameters assessed for both cropping seasons. Considering the results for the two cropping seasons, the highest growth and yield parameters of maize were obtained from application of 300 kg ha⁻¹ NPK fertilizer, followed by 150, 75 kg ha⁻¹.

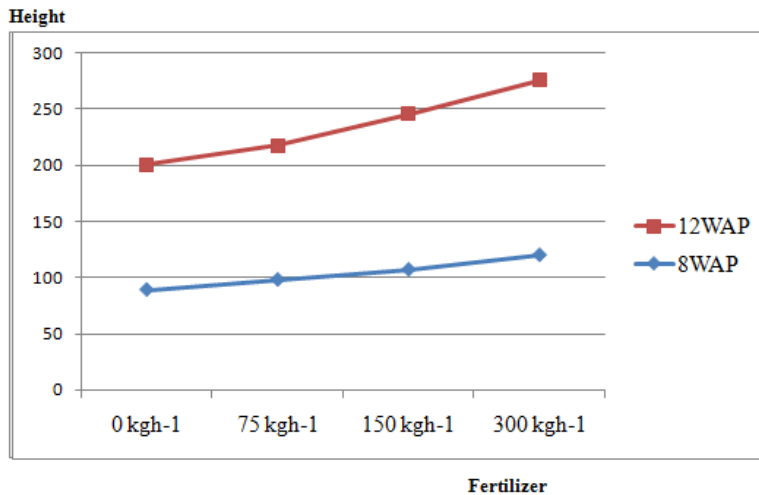


Fig. 1. Influence of fertilizer rates on maize plant height for 2017 cropping season

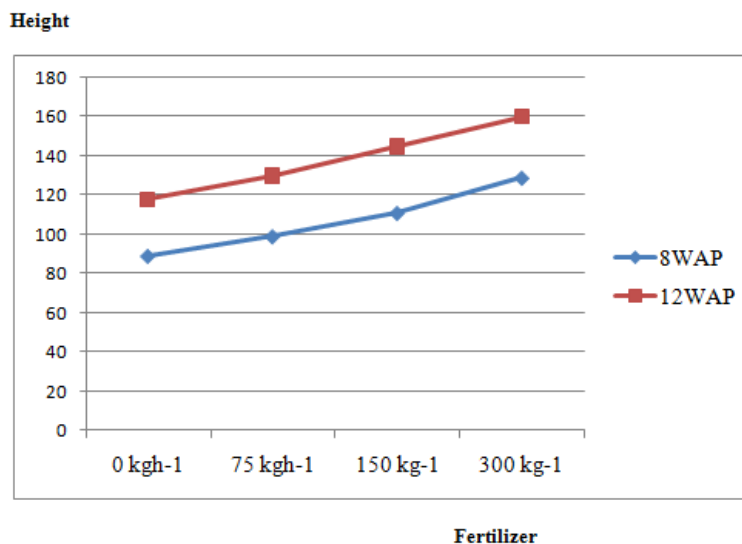


Fig. 2. Influence of fertilizer rates on maize plant height for 2018 cropping season

Table 4. Influence of fertilizer rates on yield parameters of maize

Fertilizer Rates	COB DIA		COB LNT (cm)		COB/PLT		100 S WT(g)		Grain Yield (kg ha ⁻¹)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
0	9.24	10.98	8.51	9.63	0.69	1.51	16.47	20.30	800.00	875.00
75	10.06	11.77	11.45	12.45	0.89	1.40	19.42	21.70	901.00	1125.00
150	12.14	12.27	13.36	14.36	1.01	1.49	19.45	24.12	979.00	1250.00
300	13.12	13.90	13.50	14.65	1.60	1.66	20.22	25.00	996.00	1280.00
LSD (0.05)	2.89	1.42	1.98	1.50	0.14	0.12	1.25	2.28	74.7	121.0

NS = Not Significant, COB DIA= Cob diameter, COB LNT= Cob length, COB/PLT = Cob per plant, 100 S WT = 100 seed weight

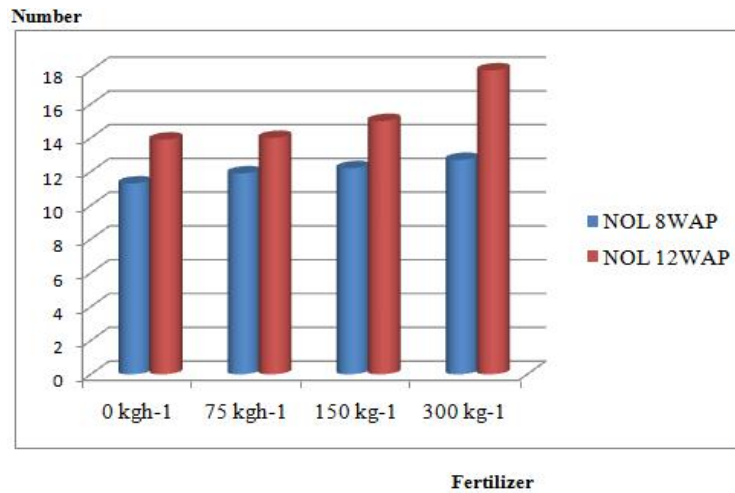


Fig. 3. Influence of fertilizer rates on maize number of leaf per plant for 2017 cropping season

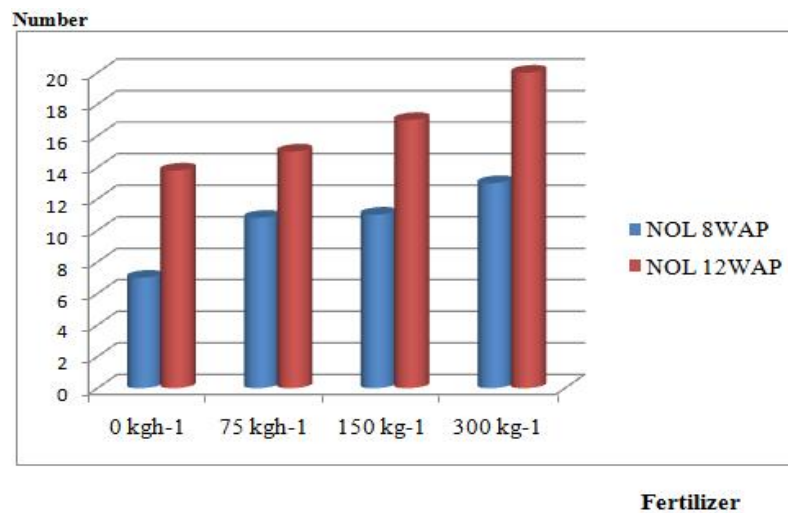


Fig. 4. Influence of fertilizer rates on maize number of leaf per plant for 2018 cropping season

4. CONCLUSION

The results obtained from this study showed that effects of fertilizer treatments on soil properties

investigated were significant. Application of fertilizer increased SOM, TN and CEC in both cropping seasons. However, the SOM was low in all plots with no application of fertilizer. This may

be attributed to lack of fertilizer which would have increased the decomposition of SOM in these plots. Exchangeable bases, base saturation and CEC reduced in 2017 in no fertilizer treatments but remarkably increased in 2018 due to application of 75, 150 and 300 kg ha^{-1} . The 300 kg ha^{-1} NPK fertilizer applications produced higher growth and yields of maize plant than remaining treatments. Soil properties (soil pH, SOM, TN and CEC) can be improved with application higher levels of mineral fertilizers for agricultural production in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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