



Effects of NPK Fertiliser (15-15-15) on the Growth Performance of Three Arable Crops Grown on Degraded Kaolin Mined Soil in Abia State, Southeast Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author CEI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author JNA managed the analyses of the study. Author MON managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ASRJ/2019/v2i3330052

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Complete Peer review History: <http://www.sdiarticle4.com/review-history/52291>

Original Research Article

Received 29 September 2019

Accepted 04 December 2019

Published 13 December 2019

ABSTRACT

Experiments were carried out in the Nursery of the Department of Forestry and Environmental Management, the Michael Okpara University of Agriculture, Umudike in Abia State during 2016 and 2017 cropping seasons to determine the effect of NPK fertilizer on the growth performance of three selected crops, *Zea mays*, *Abelmoschus esculentus* and *Vigna unguiculata* grown on a derelict kaolin mined soil. The experiment comprised of treatment pots which has three rates of fertilizer on the kaolin soil each (kaolin soil +NPK (40 kg), kaolin soil + NPK (30 kg) and kaolin soil + NPK (20

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kg) kaolin soil with zero treatment (Control 2) and a control 1(un-mined) soil, it was replicated three in Complete Randomized Design (CRD). Parameters assessed include Plant height (cm) and the number of leaves weekly for six (6) weeks. Data were analysed using ANOVA at $p < 0.05$. The result obtained showed that growth performance of the test crops was positively affected by NPK treatment based on the quantity applied with the highest recorded height (16.50) and the number of the leaf (11.27) in Kaolin mined soil combined with 40 kg of fertilizer when compared with the control. Plant height obtained with various fertilizer treatments were in the order: 16.50>15.99>14.65 and 11.27>10.20>9.01 for the number of leaves. The result of the macro element levels in the plants showed that the nutrient uptake and accumulation were enhanced by both NPK fertilizer and the quantity added with the highest level of nutrient on the plants obtained in Kaolin soil combined with 40kg of NPK fertilizer. The study showed that kaolin mined degraded soil can be put into good use with the appropriate concentration of fertilizer treatment, thus putting more degraded land under agricultural production and ensuring food security is developing country like Nigeria. The study further suggests a sensitization program for farmers on the appropriate concentration of inorganic fertilizer to be applied to their farmers to avoid pollution.

Keywords: Fertilizer; kaolin; soil; *Zea mays*; *Abelmoschus esculentus*; *Vigna unguiculata*.

1. INTRODUCTION

One of the major challenges faced by resource-poor farmers in Nigeria today is low output occasioned by the poor quality of the soil. Any activity that exposes soil to wind and rain can lead to soil quality loss. Soil contamination by indiscriminate industrial effluent discharge, the decline in soil organic matter under intensive farming systems and mining are among the main activities that impact soil resources. Soil organic content is an essential component of soil ecosystem because it provides substrates decomposing microbes that supply minerals nutrients to plants.

Nowadays the most common organic soil amendments are compost and animal manure, peat moss, wood chips, and sewage sludge [1], use of plants (phytoremediation), microorganisms (bioremediation) and use of chemical fertilizer. Compost decayed to a relatively stable state is made from plant materials mixed with manure and some soil [2]. Fertilizers are simply planted nutrients, be it synthetic or organic applied to agricultural fields to supplement required elements found naturally in the soil for plant growth and productivity [3]. In addition to water, sunshine and carbon dioxide, plants need small amounts of inorganic nutrients for growth and development. The major elements required by most plants are Nitrogen, Potassium, Phosphorus, Calcium, Magnesium and Sulphur. Calcium and Magnesium are often limited in areas of high rainfall and must be supplied in the form of lime. Lack of Nitrogen, Potassium and Phosphorus even more often limit

plant growth. Adding these elements in fertilizer usually stimulates growth and greatly increases crop growth. Fertilisers promote the natural fertility of the soil or replace the chemical elements taken from the soil by harvesting, grazing leaching or erosion.

Maize is a cereal crop that is grown widely throughout the world in a range of agroecological environments. It is a major source of calories all over the world. Worldwide production of maize is 785 million tonnes/annum, with the largest producer, the United States, producing 42%, Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tonnes/annum. Maize is used in the production of secondary raw materials used in various industries ranging from food and beverage, pharmaceutical to the oil industry. Products derived from maize include flour, beer, malt drink, breakfast cereals, syrup, dextrose and animal feeds.

Cowpea is a food and animal feed crop grown in the semi-arid tropics covering Africa, Asia, Europe, United States and Central and South America. The grain contains 25% protein, and several vitamins and minerals. The plant tolerates drought, performs well in a wide variety of soils, and being a legume replenishes low fertility soils when the roots are left to decay. It is grown mainly by small-scale farmers in developing regions where it is often cultivated with other crops as it tolerates shade. It also grows and covers the ground quickly, preventing erosion. Cowpea's high protein content, its adaptability to different types of soil and intercropping systems, its resistance to drought,

and its ability to improve soil fertility and prevent erosion makes it an important economic crop in many developing regions. The sale of the stems and leaves as animal feed during the dry season also provides a vital income for farmers. More than 5.4 million tons of dried cowpeas are produced worldwide, with Africa producing nearly 5.2 million. Nigeria, the largest producer and consumer, accounts for 61% of production in Africa and 58% worldwide.

Okra, {*Abelmoschus esculentus* (L.) Moench} is an angiosperm belonging to the Order Malvales and Family Malvaceae. Okra is grown throughout the tropical and warm temperate regions of the world for its fibrous edible green pods, which are eaten as vegetables while the pod is green, tender and immature. The ripe seeds of okra are sometimes roasted, ground and brewed as a substitute for coffee. The green pods are best used as a thickener of soups [4]. In Nigeria, okra is a special delicacy with garri (eba) or "akpu" [5]. In Nigeria, it ranks third in terms of consumption and production area following tomato and pepper.

There is considerable potential for increasing world food supply by increasing fertilizer use in low-production countries if ways can be found to apply fertilizer more effectively and reduce pollution. If fertilizers are applied sensibly so that plants use all the nutrients and none are leached there is little opportunity for pollution. Hence, this experiment was conducted to investigate how degraded soil can be put into good use with the application of fertilizers at optimal levels and to demonstrate its effect on growth and

development of Okro, Maize and Cowpea as test crops.

2. MATERIALS AND METHODS

2.1 Study Area

The study site is located at a kaolin mining site at Ohia community in Umuahia South L.G.A in Abia State. Ohia is located near the Abia Tower junction on the Umuahia side, along the Enugu-Port Harcourt Expressway. It has an area of 140 km² and a population of 138,570 [6]. The area lies at latitudes 50°26' and 50°34'N and longitudes 70°22' and 70°33'E. It has high relative humidity values over 70% and is characterized by a high temperature of about 29 -31°C. The area is part of the equatorial belt with an average annual rainfall of about 2,400 mm per annum [7].

2.2 Soil Sample Collection and Analysis

Experimental soil was collected with the aid of soil auger at a depth of 0-30 cm soil from Ohia Kaoline mined site shown in Fig. 1. Soil analysis followed the procedure described by [8].

2.3 Collection of Crop Seeds

The maize seeds (*Zea mays* L.), Okra seeds (*Abelmoschus esculentus* L.) and Cowpea seeds (*Vigna unguiculata* L.) used as test crop was procured from Ndioru Market, Umudike, Umuahia, Nigeria. Viability of the seeds was carried out using the floatation method technique [9].

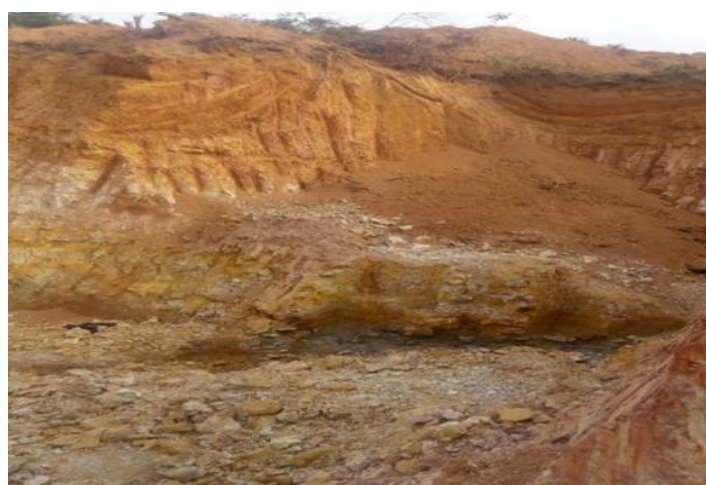


Fig. 1. One of the actively mined pits at Ohia mining site

2.4 Experimental Design

Eighteen (18) experimental pots of equal weight (5 kg) were filled with soil from an un-mined site sourced from 20 kilometres away from the kaolin mined site. 10 viable seeds from each of the test crops were planted in the pots, six (6) pots contained the maize seeds, another six (6) pots contained the okra seeds and the last six (6) pots contained cowpea seeds in order to maintain the availability of plant seedlings for transplanting. The set-up was allowed for two (2) weeks for stabilization and was watered every day at the Nursery of the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike.

Eighteen (18) pots were filled each with 5 kg of the overburden soil collected at a depth of 0-15 cm from the Ohiya kaolin mine site treated with NPK fertilizer (this served as the treatment pots).

Six (6) sets of pots were also filled with 5kg of soil from the un-mined site which served as control one (1), another six (6) sets of pots filled with 5 kg of kaolin mined soil served as control two (2) making it a total of thirty (30) pots. Each of the specie seedlings was transferred from the Nursery Department to the experimental pots. It was replicated into two (2) for each of the species with three levels of treatments (20 kg, 30 kg and 40 kg) of NPK fertilizer. The experiment was laid out in a Randomized Complete Block Design with two replicates and three levels of treatments.

The experiment was maintained for 6 weeks at the Nursery Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike. The plants were watered every other day, and the experimental pots perforated at the base to avoid waterlogging.

2.5 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) at 0.05 level of significance and treatment mean was separated using Duncan Multiple Range Test (DNMRT) SAS version 20.

3. RESULTS AND INTERPRETATION

Table 1 shows the result of the macro element concentration in the kaolin soil before the application of NPK fertilizer. Calcium content was 1.63 mg/kg, the Magnesium, Potassium,

Phosphorus, and Nitrogen contents were 0.40 mg/kg, 0.123 mg/kg, 12.20 mg/kg and 0.11 mg/kg respectively compared to the value of 1.13 cmol/kg, 2.00 cmol/kg, 1.00 cmol/kg, 0.4 cmol/kg, 26.12 cmol/kg and 0.70 cmol/kg reported for optimum growth and development in plants [10]. The low soil nutrient contents justified the need for additional fertilizer treatment. The experimental soil was found to be sandy loamy textured and optimal to retain adequate water for normal crop growth.

Table 1. Preliminary analysis of macro element concentration of degraded kaolin soil from Ohiya mining site

Macroelements	Concentration (mg/kg)
Nitrogen	0.11
Potassium	0.123
Phosphorus	12.2
Calcium	1.63
Magnesium	0.156

Table 2 shows the effect of NPK treatments on plant height and number of leaves. There was no significant difference between 20 kg and 30 kg of NPK fertilizer treated soil on the plant height of the test crops. 40 kg of NPK fertilizer treated soil showed the highest significant effect. ($P \leq 0.001$) on plant height followed by 30 kg and 20 kg of NPK fertilizer treated Kaolin soil compared to the Control 1 and Control 2 with the least plant height of 11.67 cm and 9.83 cm respectively. This shows that all the combination of NPK + Kaolin soil gave a highly significant difference when compared with the Controls.

Plant height increased with increase in time (weeks) with the highest significant height of 17.88 cm at week six. Amongst the crops, the highest significant height was found in Maize with 17.33 cm and the least was found in Cowpea with 10.61 cm. Plant height showed difference interaction amongst the treatments, crops and time.

There was no significant difference between the effects of the treatments on the number of leaves. 40 kg of NPK fertilizer + Kaolin soil showed the highest significant effect ($P \leq 0.01$) on the leaves with a mean value of 11.27 followed by 30 kg of NPK fertilizer + Kaolin soil (10.20) and 20 kg of NPK fertilizer + Kaolin soil (9.01) compared to the Control 1 and Control 2, with the least mean value of 7.11 and 5.73 respectively. This shows that all the combination of NPK + Kaolin soil gave a highly significant difference when compared with the Controls.

The number of leaves increased significantly with the increase in time (weeks) with a significant increase at the mean value of 11.75 at week six. Amongst the crops, the highest number of leaves was found in Maize followed by Cowpea and Okra. The number of leaves showed different interaction amongst the treatments, crops and time.

Table 2. Effect of NPK fertilizer treatments on the plant height

Plant height (cm)	
Treatment (Trt)	
Control 1	11.67 ^d
Control 2	9.83 ^e
Kaolin soil+NPK(20kg)	14.65 ^c
Kaolin soil+NPK(30kg)	15.99 ^b
Kaolin soil+NPK(40kg)	16.50 ^a
Time (Wk)	
1	9.92 ^e
2	11.42 ^d
3	13.30 ^c
4	14.19 ^{bc}
5	15.67 ^b
6	17.88 ^a
Crops	
Maize	17.33 ^a
Okra	13.25 ^b
Cowpea	10.61 ^c
F-Test	
Trt	***
Time	***
Crop	***
Trt x Crop	***
Trt x Time	***
Trt x Crop x Time	**

*Means with different letter(s) are statistically different by DMRT; Ns means not significant **, and *** means significant at 5% and 1% level respectively*

Table 4 shows the macronutrient properties of the treatment pots. Calcium content shows negative significant difference among the treatments when compared to the control 1 (un-mined soil) but it showed a positive significant difference when compared to control 2 (Kaolin soil), with control 1 and K+ 40 kg of NPK fertilizer showing the highest Calcium level of 144.35 mg/kg and 144.00 mg/kg respectively. Calcium level in crops shows that Maize had the highest significant level of 140.43 mg/kg and Okra showed the least with 70.01 mg/kg.

The magnesium content in the treatments showed no significant increase when compared to control 1 but the treatments show positive

significance when compared to control 2, with the highest magnesium content of 155.07 mg/kg and 152.76 mg/kg in 40 kg of NPK + Kaolin soil and control 1 respectively. Magnesium level in the crops showed the highest in Maize with 205.55 mg/kg while the least was found in Okra with 33.16 mg/kg.

Potassium content showed significant differences amongst the treatments with the highest (134.31 mg/kg) of Potassium found in 40 kg of NPK + Kaolin soil followed by Control 1 and the least is found in Control 2 (Kaolin soil.) Potassium level in the crops showed the highest in Cowpea with 129.49 mg/kg followed by Maize with 117.61 and the least in Okra with 48.17 mg/kg.

Table 3. Effect of NPK fertilizer treatments on the number of leaves

Number of leaves	
Treatment (Trt)	
Control 1	7.11 ^d
Control 2	5.73 ^e
Kaolin+NPK(20kg)	9.01 ^c
Kaolin+NPK(30kg)	10.20 ^b
Kaolin+NPK(40kg)	11.27 ^a
Time (Wk)	
1	5.06 ^d
2	6.66 ^c
3	8.33 ^{bc}
4	9.10 ^b
5	11.08 ^a
6	11.75 ^a
Crops	
Maize	16.46 ^a
Okrap	4.50 ^b
Cowpea	5.03 ^b
F-Test	
Trt	***
Time	***
Crop	***
Trt x Crop	***
Trt x Time	**
Trt x Crop x Time	**

*Means with a different letter(s) are statistically different by DMRT; Ns means not significant ** and *** means significant at 5% and 1% level respectively*

Phosphorus content showed significant differences amongst the treatments with the highest (103.96 mg/kg) in 40 kg of NPK +Kaolin soil followed by 94.92 mg/kg in Control 1 and the least Potassium level was found in Control 2 with 60.44 mg/kg. Phosphorus in the crops showed the highest significance in Maize with 104.77 and the least was found in Okra with 40.06 mg/kg.

Table 4. Plant macro element concentrations after NPK fertilizer treatments

Treatment	Ca	Mg	K	P	N
Control 1	144.00 ^a	152.76 ^{ab}	116.44 ^b	94.92 ^b	3.15 ^b
K + NPK (30g)	96.72 ^b	129.94 ^c	87.23 ^c	67.08 ^c	2.88 ^c
K +NPK(20g)	92.52 ^{bc}	127.12 ^{cd}	84.41 ^{cd}	64.48 ^{cd}	2.68 ^c
K +NPK(40g)	144.35 ^a	155.07 ^a	134.31 ^a	103.97 ^a	4.18 ^a
Control 2	78.57 ^c	115.81 ^d	73.07 ^d	60.44 ^d	2.03 ^d
Crops					
Cowpea	123.25 ^b	169.72 ^b	129.49 ^a	89.71 ^b	6.92 ^a
Maize	140.43 ^a	205.55 ^a	119.61 ^b	104.77 ^a	0.67 ^c
Okra	70.01 ^c	33.16 ^c	48.17 ^c	40.06 ^c	1.36 ^b

Means with a different letter(s) are statistically different by DMRT

Nitrogen content showed a significant difference in the treatments with the highest (4.18 mg/kg) in 40 kg of NPK + Kaolin soil followed by Control 1 (3.15 mg/kg) with the least found in Control 2 with 2.03 mg/kg. Nitrogen level in crops showed the highest significant amount of Nitrogen in Cowpea with 6.92 mg/kg and the least amount in Maize with 0.67 mg/kg.

4. DISCUSSION

4.1 Percentage Composition of Macro Elements on Kaolin Soil

From the result of the soil analysis obtained, the Kaolin soil had lower Na (0.156 mg/kg), Ca (1.63 mg/kg), Mg (0.40 mg/kg), k (1.23 mg/kg), P (12.20 mg/kg) and Nitrogen (0.11 mg/kg) compared to the value of 1.13 cmol/kg, 2.00 cmol/kg, 1.00 cmol/kg, 0.4 cmol/kg, 26.12 cmol/kg and 0.70 cmol/kg respectively reported for normal soil macro elements [10]. From the present study, it was deduced that kaolin soil has lower macroelements which could be attributed as a result of kaolin activities in the study area. Hence, the present study agrees with the findings of [8] which stated that kaolin soils have macro elements deficiency. The study area has resulted in an unavoidable excavation of topsoil. Thus soil and vegetation are depleted and soil erosion is enhanced. During mining kaolinised granites are extracted. The mining process results in the transportation of kaolinized granite deposits and other heavy compounds from the mine by water run-off leaving particles and traces of the minerals on the soil surfaces.

These have an impact on vegetation as well as on the soil physical and chemical properties which may affect plant growth.

4.2 Effect of NPK Fertilizer Application on the Growth Parameters of the Selected Crop Species

Result of the Tables 2 and 3 indicate that all treatments, which received NPK fertilizer combined with kaolin soil achieved good plant height and leaf establishment throughout the growth seasons over their precursor (control 2) but treatment combination of 40 kg of NPK and kaolin only showed a higher growth performance than the control 1 (Um-mined soil). This is in agreement with the observations of [11] who reported that the combination of fertilizer application resulted in luxuriant growth of leaves and stem. Good leaf and stem establishment is a precursor to high yields as indicated by the study reported by Bray & Bailey [12] who indicated the high number of leaves on fertilizer treated plants contributed to high yields.

Studies have shown that application of balanced fertilizer accelerates plant growth resulting in taller and greener plants [13,14]. According to Fashina, et al. [15], the availability of sufficient growth nutrients from inorganic fertilizers leads to improved cell activities, enhanced cell multiplication, enlargement, luxuriant growth, and eventually high yields.

This was observed in 40 kg of NPK fertilizer +Kaolin soil, 40 kg of NPK fertilizer +Kaolin soil and 20 kg of NPK fertilizer +Kaolin soil treatments, with the highest growth on 40 kg of NPK fertilizer +Kaolin soil. Control 2 (un-mined soil) achieved low growth performance across the weeks. This agrees with the observation by Adediran and Banjoko [16] who indicated that the absence of N and P nutrients resulted in stunted growth and depressed yields. Nitrogen is typically the most limiting nutrient in maize

production [17]. This observation was confirmed by the poor performance of crops in Control 2.

4.3 Effect of NPK Fertilizer on Macro Nutrient Composition of the Plant Species

It was observed from Table 4 that application of NPK fertilizer to the kaolin soil increased considerably the soil Calcium, total N, available P, exchangeable K and Magnesium content of the plants compared to using only kaolin (control 2) and unmined (control 1) soil. The increase in the levels of the plant macro-nutrients was expected, since, inorganic fertilizer can increase soil nutrient content [18]. The nutrients in the (N-P-K) fertilizer (inorganic fertilizer) were already in the mineralized form and it provides a ready source of nutrients to the soils [19-20].

All the macronutrients from the plants in kaolin soils treated with different level of NPK fertilizer were significantly different from the control 2 (kaolin soil only) values but showed no significantly different from control 1 (un-mined soil) except kaolin soil treated with NPK at 40 kg which gave the highest amount of the macronutrients. These results indicated that the combination of inorganic fertilizer with kaolin soil has a greater potential of raising plant macronutrient contents. This study is in agreement with the findings of Umer, et al. [21] on the effect of Nitrogen and Phosphorus on growth performance of Maize in selected soils of Delta State, Nigeria which revealed that Maize growth was significantly enhanced by the application of Nitrogen fertilizer at the rates of 40 to 60 kg/ha compared to other rates of application.

5. CONCLUSION

The result of this study revealed that NPK fertilizer application on kaolin soil had enhanced the effect on the plant height and the number of leaves of Maize, Okra and Cowpea and the effect was relative to the quantity of NPK fertilizer added. 40 kg of NPK fertilizer on Kaolin soil had the highest growth performance on the crops. The effects increased as time increased with the 6th week showing the highest plant height and leaf growth.

The result of the mineral content of the soils showed that the macronutrient content of the plants was enhanced by the NPK fertilizer treatments which on kaolin soil when compared to the kaolin soil only.

However, from the findings, it can be concluded that the addition of 40 g of NPK fertilizers on the kaolin soil can support the growth of plants than only kaolin soil but had equal effect with un-mined soil. The findings of this study do not divorce the fact that improper application of inorganic fertilizer could lead to soil acidity and nutrient imbalance. Farmers should be sensitized on the proper use and application of inorganic fertilizer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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