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Response of Okra to Incorporating Humic Acid-Derived Active Molecules into NPK Fertilizer and Lime on Coastal Plain Sand in Calabar, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the response of okra to NPK fertilizer with humic acid and lime at the University of Calabar, Teaching and Research Farm between October 2015 and January 2016 cropping season. The experiment was laid out in a randomized complete block design (RCBD) with four replications. The experiment consisted of NPK with humic acid and liming materials as treatments. The test crop was okra. The result of initial analysis of the chemical properties of the soil before the experiment showed that the soil was acidic and was low in exchangeable bases, organic matter (1.13%), total nitrogen (0.14%) and ECEC but high in available phosphorus (26.63 mg/kg) and base saturation. After application of treatment, the result showed that 6.2 g of lime and 4.6 g of NPK with humic acid increase the soil pH from 5.6 units in the control to 5.8 in NPK with Humic Acid, 6.0 in NPK with Humic Acid and lime and 6.4 in lime. Organic carbon content, total nitrogen and available phosphorus also increase in like manner. The results for the growth parameters showed that okra height, number of leaves, and pod yield were significantly ($p \leq 0.05$) different from the control. Based on the result of this study further research is recommended in other locations to fully ascertain the effects of this treatment using a different combination.

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Keywords: Okra; coastal plain sand; humid acid; lime; fertilizer.

1. INTRODUCTION

Okra (*Abelmoschus esculentus (L) Moench*), also known as ladies' fingers in many English-speaking countries is a flowering plant that belongs to the family mallow, and it is popularly grown for its immature fruits and young leaves throughout the tropical and sub-tropical parts of the world. In Nigeria and other African countries, okra is often grown in gardens as mixed crop alongside other arable crops [1]. Okra occupies about 1.5 million hectares of the arable land in Nigeria alone [2] while the world production of okra as fresh fruit is estimated at 1.7 million t/year [3].

Although okra has great potential both as domestic and commercial crop in Nigeria, but its yield on peasant farmer's fields is often very low, yielding about 2.10 t ha^{-1} in Nigeria, which is far less compared to other countries like India (10.12 t ha^{-1}) and world average (7.65 t ha^{-1}) [4]. However, inadequate knowledge of the management of the soils improved varieties and some of the necessary cultural practices such as optimum plant density, and nutrient requirements might have contributed to the low okra yield obtained by these farmers [5].

Soils of the rainforest zone of Nigeria are acidic in nature, classified as Ultisols and Oxisols which are inherently low in pH, organic matter, nitrogen, potassium and other nutrients [6,7]. These soils are prevalent in areas experiencing high annual rainfall (above 1500 mm) and usually have problems associated with aluminium toxicity, low nutrient status, nutrient imbalance and multiple nutrient deficiencies [8] and therefore require fertilization and liming for good crop growth and yield. Nitrogen is the main limiting nutrient for most crops on these soils because of heavy leaching as a result of high rainfall coupled with the sandy nature of the soils [9].

Liming is a soil amendment management strategy of applying substances to manage or raise the pH of the soil to a favorable level. The overall effects of lime on soils include increased pH, Ca, Mg and P availability, neutralization of toxic concentrations of Al and Mn, increase in pH dependent CEC and improved nutrient uptake by plants [10,11]. According to Oluwatoyinbo et al. [12], lime reduced the amount of P fertilizer required for optimum growth and fruit yield of okra and obtained the highest yield at 0.5 t/ha lime rate. There is a need for agricultural practices which are cheap and affordable for the local farmers, although accurate rates of these local liming materials are yet to be established for optimum yield [13]. Okra is often sensitive to the slightly acidic soil in the tropics and hence was used as a test crop in this experiment.

It is worthy of note that nutrient management is the main factor that is accountable for sustainable soil fertility. Over the years the use of inorganic fertilizer on crops increased yield, as well as economic return on investment, have been documented [7,8,12]. Humic acid is the active constituent of organic humus, which can play a very important role in soil conditioning and plant growth [14]. However, recent researches have explored the study area under investigations in the context of mineral and organic fertilizers effect on crop growth and nutrient uptake [15,16,17,18], but no study was found specific to incorporating humic acid-derived active molecules into NPK fertilizer to ascertain its effect in crops in Calabar environment, which is an important food producing area in Cross River State. However, this study seeks to examine the response of okra to incorporating humic acid-derived active molecules into NPK fertilizer and lime on the coastal plain sand in Calabar, Nigeria.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted between October 2015 and January 2016 in poly pots laid out in the open field at Crop Science Teaching and Research farm of the University of Calabar. The University of Calabar lies between latitude 05°32^1 North and longitude 07°15^1 and 9°28^1 East [18]. The climate of the study area was characterized by high relative humidity and rainfall. Rainfall is usually heavy occurring between the months of March to October with a short dry spell in August. The mean total annual rainfall exceeds 3000 mm per annum and the relative humidity of 85% with the mean annual minimum and maximum temperature of 22.93°C and 26.51°C [19]. The rainfall spreads between April and October and characterized by two peak periods and a short break in the month of August known as 'August break'.

2.2 Soil Sampling and Sample Preparation

The experimental site has been previously cultivated for yam, cassava, waterleaf, fluted pumpkin, okra, maize etc. The experimental site was cleared, winnowed and the surface debris was removed before randomly collecting the soil samples. The soil samples were collected at the depth of 0-30 cm as a composite of four (4) auger points from the experimental site. The samples were thoroughly mixed together and 1.5 kg of the soil sample weighed into each pot of length 17 cm and diameter 16.5 cm.

2.3 Experimental Design, Treatment, Planting and Planting Materials

The experimental was laid out in a randomized complete block design (RCBD) with four replications. The experiment consisted of NPK+ humic acid and liming materials as treatment. The test crop okra and liming materials were gotten from Calabar local market, while NPK with humic acid was obtained from a commercial fertilizer plant in Jinan City, China. The composition of lime used is calcium carbonate ($CaCO_3$) and composition of NPK with humic acid; N_2 (10%), P_2O_5 (5%), K_2O (25%), micro-nutrients, that is, Baron, Zinc, Manganese, Iron, Molybdenum were all 0.1% and humic acid (3%).

2.4 Data Collection

Data was collected on growth parameters include plant height, number of leaves, leaf length and leaf width. The number of leaves was determined by counting each plant once in two weeks. The tools that were used for growth parameter data was a meter rule. Biomass data include stem girth and yield was considered at the end of the experiment.

2.5 Laboratory Analysis

In the laboratory, the soil sample collected was air dried, sieved using a 2 mm sieve, stored and analyzed for physical and chemical properties using standard procedures. Particle size distribution was determined by the hydrometer method using sodium hexametaphosphate (calgon) as the dispersant [20]. The percentages of sand, silt and clay were determined. The pH (in water) was determined in soil water ratio of 1:2.5 using a glass electrode pH meter standardized with buffer solutions 4.0 and 6.85 [20]. Organic carbon was determined by the Walkley and Black wet oxidation method described by Udo et al. [20]. Total nitrogen was determined by Macro-Kjeldahl Distillation Method [21] using Sodium Sulphate ($NaSO_4$) and Copper Sulphate ($CuSO_4$) as a catalyst. Available phosphorus was extracted using the Bray-1 method [22] and determined calorimetrically with a spectrophotometer. Exchangeable bases (Ca, Mg, K and Na) were extracted in 1 N NH_4OAc at pH 7. Potassium and sodium were determined with a flame photometer while calcium and magnesium were determined by the EDTA titration method [23]. Exchangeable acidity was by titration method using 1 N Kcl extract [24]. Cation Exchange Capacity (CEC) was by summation of exchangeable bases while Effective Cation Exchange Capacity (ECEC) was a summation of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity. Percent base saturation was obtained by dividing the total exchangeable bases (Ca, Mg, K and Na) by the effective cation exchange capacity.

2.6 Data Analyses

The data was statistically analyzed using Analysis of Variance (ANOVA). Means were compared using F-LSD test at 0.05 level of probability [25].

3. RESULTS AND DISCUSSION

3.1 Physical Properties

3.1.1 Particle size analysis

The soil was high in sand (73.0%, 74.0% and 76.0%) for NPKHA, control and NPKHA + Lime and Lime, silt (14%, 15%, 16%, and 18%) for Lime, NPKHA + Lime, control and NPKHA and the clay (9%, 10%, and 11%) for NPKHA, control and Lime, and NPKHA + Lime. The soil still maintains sandy loam as its textural classes and such soil lack the absorption capacity for basic plant nutrients and water [26].

3.2 Chemical Properties

3.2.1 Soil pH

The pH increases with treatment, for instance, control (5.6), NPKHA (5.8), NPKHA + Lime (6.0), and lime (6.4). The increased soil pH was due to the addition of lime. Liming material has the ability to raise soil pH from slightly acidic to near neutral [12].

3.2.2 Organic carbon

The organic carbon content increase with treatments, for instance, control (1.12%), NPKHA

+ Lime (1.54%), Lime (1.56%) and NPKHA (1.70%) which is below the critical level of 2% for soils of the humid tropical region [27,28]. This low value obtained for the result might be due to the acidic nature of the humic acid fertilizer and non-availability of organic materials in the treatments. However, the value can be increased by including organic sources as part of the treatments.

3.2.3 Total nitrogen

The value of total nitrogen reduces from control (0.07%), NPKHA + Lime and Lime (0.05%) and NPKHA (0.03%) which was lower than the critical level of 1.5% given by Aduayi et al. [27]. Meanwhile, nitrogen is one of the main nutrients needed by these crops. The decrease in nitrogen might be attributed to leaching as a result of high rainfall that characterized the area [9] alongside with the sandy nature of the studied soil. It has become one of the most limiting nutrients in the soil.

3.2.4 Available phosphorus

The value of available phosphorus increases with the treatments Lime (18.00 mg/kg), control (26.61 mg/kg), NPKHA (34.75 mg/kg) and NPKHA + Lime (40.13 mg/kg) as compared to the critical level of 8 mg/kg given by Aduayi et al. [27]. There was also a significant increase in available phosphorus, except on the sole application of lime which yielded the least available phosphorus. The increased P level could be attributed to increased soil pH. It has been reported that overall effects of lime on soils include increased pH level and availability of nutrient including P availability [10].

3.2.5 Exchangeable calcium, magnessium, potassium and sodium

The value of calcium present in the soil increases with treatment Lime (4.5 cmol/kg), NPKHA + Lime (3.9 cmol/kg), NPKHA (3.6 cmol/kg) and control (2.4 cmol/kg). The value of magnesium present increase with treatment Lime (2.7 cmol/kg), NPKHA + Lime (2.01 cmol/kg), NPKHA (1.6 cmol/kg) and control (0.6 cmol/kg). There was a significant increase in the exchangeable Ca^{++} in the treatment with Lime as well as the combination of Lime and NPK with humic acid yielding the highest exchangeable Ca^{++}. The value of potassium in the soil slightly increases with treatment Lime (1.08 cmol/kg), NPKHA + Lime (0.11 cmol/kg), control (0.09 cmol/kg), NPKHA (0.08 cmol/kg). There was no significant increase in magnesium and sodium. The values of sodium present in the soil increases with treatment NPKHA and NPKHA + Lime (1.2 cmol/kg), Lime (0.91 cmol/kg) and Control (0.07 cmol/kg). The increase in level of most exchangeable bases maybe attributed to increased soil pH [10].

3.2.6 Exchangeable acidity

The values of Al^{+++} reduce in treatment with lime was 0.01 (cmol/kg) and NPKHA + Lime 0.09 (cmol/kg). The exchangeable acidity was low, this influencing the biochemical behavior of the soils. The values of H^{+} increased with treatment Lime 0.40 (cmol/kg), NPKHA + Lime (0.90 cmol/kg) and NPKHA (1.0 cmol/kg) and control (2.3 cmol/kg).

3.2.7 Effective cation exchange capacity

The value of ECEC was low in control as established for productive soil [28]. The values of lime and NPKHA + Lime were also. This can be attributed to the low content of exchangeable cation.

3.2.8 Base saturation

The base saturation (Ca, Mg, K and Na) increases with treatment indicating that the supply of nutrients in the soil can support growth to an extent [11]. This show that the exchange complex of the soil particles is occupied by reserved acidity. There was a significant increase in the base Saturation (BS) with soils treated with sole applications of Lime giving the highest BS of 95.73%. The implication of this lime can reduce acidity and increase the exchangeable cations thereby making the soil fertile.

3.3 Growth Parameter

3.3.1 Plant height and number of leaves

In Table 3, the response of okra to NPK with humic acid plus lime (NPKHA + Lime) in height at four sampling periods (3WAP, 5WAP, 7WAP and 9WAP) during the growing seasons showed that there was no significant increase in height ($p>0.05$) at 3WAP and 9WAP. However, at 5WAP and 7WAP, there was a significant increase in plant height. A close examination of the data reveals that control and lime pots grew taller than NPKHA + Lime and NPKHA pots. This is as a result of the inability of the plant roots to access the available nutrients in the soils at a different rate of addition of treatments. This result is not in accordance with the findings of El-Meskser et al. [29] who reported that application of humic acid was associated with a significant increase in plant height of crops. The difference in this result could be attributed to sandy nature of the soil which tends to leach any applied nutrient. The response of okra to NPKHA and lime on a number of leaves were not significant ($p>0.05$) in 3WAP, 5WAP and 7WAP. At 9WAP, the test crop was significant ($p>0.05$). This is in agreement with the findings of Oluwatoyinbo et al [12], who observed significant increases in plant height, a number of leaves and fruits of okra with the application of all rates of lime up to the 1000 kg/ha rate used. This is not surprising as Oluwatoyinbo et al. [12], had earlier reported that lime can increase optimum growth and fruit yield of okra and obtained the highest yield at 0.5t/ha lime rate.

3.3.2 Leaf length and leaf width

In Table 4, the response of okra to NPK with humic acid plus lime (NPKHA+Lime) in leaf length and leaf width at four sampling periods (3WAP, 5WAP, 7WAP and 9WAP) during the growing seasons showed that there was no significant difference ($p\leq0.05$) in both parameters.

3.3.3 Leaf area index

In Table 5, the response of okra to NPK with humic acid plus lime (NPKHA +Lime) in the leaf area index at four sampling period (3WAP, 5WAP, 7WAP and 9WAP) during the growing seasons showed that there was no significant difference at ($p\leq0.05$) in the leaf area index. This is a pointer to the fact that changes in numbers of leaves are bound to alter the overall performance of the plant as the leaf serves as the photosynthetic organ of the plant [30]. Also, the unfertilized plants had lower leaf area due to less number of leaves resulting from premature leaf fall and early vine senescence [31]. The higher leaf area index associated with the fertilized plants was probably due to a higher number of leaves.

Table 1. Soil properties before experiment

Physico-chemical properties	Quantity
Sand (%)	74.0
Silt (%)	16.0
Clay (%)	10.0
pH (H_2O)	5.6
Org. Carbon (%)	1.13
Total nitrogen (%)	0.14
Av. P (mg/kg)	26.63
Exchangeable cations (cmol/kg)	
Ca^{2+}	2.4
Mg^{2+}	0
K^{+}	0.09
Na^{+}	0.07
Exchangeable acidity (cmol/kg)	
Al^{3+}	1.32
H^{+}	2.36
ECEC	6.64
B.S (%)	44.58

Table 2. Physico-chemical after application of treatment

Properties	Control	NPKHA	NPKHA+Lime	Lime
Sand (%)	74	73	74	76
Silt (%)	16	18	15	14
Clay (%)	10	9	11	10
pH	5.6	5.8	6.0	6.4
Organic Carbon (%)	1.12	1.70	1.52	1.56
Total Nitrogen (%)	0.07	0.03	0.05	0.05
Av. P	26.61	34.75	40.13	18.00
Exchangeable cation (cmol/kg)				
Ca^{++}	2.4	3.6	3.9	4.5
Mg^{++}	0.6	1.6	2.01	2.7
K^{+}	0.09	0.08	0.11	1.08
Na^{+}	0.07	1.2	1.2	0.91
Exchangeable acidity (cmol/kg)				
Al^{+++}	1.32	4.4	0.09	0.01
H^{+}	2.34	1.0	0.90	0.40
ECEC	6.82	11.88	9.64	9.60
B.S (%)	46.33	54.55	74.90	95.73

Table 3. Response of NPKHA and lime on plant height and number of leaves

Treatment	Plant height				Number of leaves			
	3WAP	**5WAP**	**7WAP**	**9WAP**	**3WAP**	**5WAP**	**7WAP**	**9WAP**
Control	7.17	11.87	14.2	16.23	4.67	4.83	5.5	7.67
NPKHA	4.35	6.05	6.88	10.52	3.16	4.33	5.33	5.5
NPKHA + Lime	4.28	4.9	9.02	14.93	3.16	4.00	5.17	5.83
Lime	5.28	9.12	11.97	15.27	3.83	4.5	4.67	5.67
F-LSD (0.05)	NS	**	**	NS	NS	NS	NS	**

WAP = Week after planting; NPKHA (NPK with Humic Acid) and NPKHA+Lime (NPK with Humic Acid and Lime)
*Note: NS means not significant * means Significant at 5 %*

Table 4. Response of NPKHA and lime on leaf length and leaf width

Treatment	Leaf length				Leaf width			
	3WAP	**5WAP**	**7WAP**	**9WAP**	**3WAP**	**5WAP**	**7WAP**	**9WAP**
Control	3.26	4.67	5.1	5.82	3.6	5.43	6.38	7.52
NPKHA	2.18	3.52	2.93	4.82	2.2	3.58	4.22	6.08
NPKHA + Lime	2.6	4.53	6.22	6.95	2.71	5.03	7.52	8.85
Lime	3.08	3.93	4.63	5.22	3.22	4.9	4.52	6.52
F-LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

WAP = Week after planting; NPKHA (NPK with Humic Acid) and NPKHA+Lime (NPK with Humic Acid and Lime)
*Note: NS means not significant * means Significant at 5 %*

Table 5. Response of NPKHA and lime on leaf area index

Treatment	3WAP	5WAP	7WAP	9WAP
Control	0.04	0.03	0.04	0.05
NPKHA	0.06	0.04	0.02	0.06
NPKHA + Lime	0.02	0.03	0.06	0.18
Lime	0.03	0.02	0.04	0.13
F-LSD (0.05)	NS	NS	NS	NS

WAP = Week after planting; NPKHA (NPK with Humic Acid) and NPKHA+Lime (NPK with Humic Acid and Lime)
*Note: NS means not significant * means Significant at 5 %*

Table 6. Response of NPKHA and lime on biomass data

Treatment	Stem girth	Root	Pod yield
Control	1.33	0.52	6.21
NPKHA	1.37	0.19	5.26
NPKHA + Lime	2.62	0.6	6.29
Lime	2.6	0.27	6.86
F-LSD (0.05)	NS	NS	**

WAP = Week after planting; NPKHA (NPK with Humic Acid) and NPKHA+Lime (NPK with Humic Acid and Lime)
*Note: NS means not significant * means Significant at 5 %*

3.3.4 Biomass data and pod yield

The response of okra to NPK with humic acid plus lime (NPKHA + Lime) in Biomass data and pod yield are presented in Table 6. The result shows that there was no significant difference at ($p\leq0.05$) in stem girth and root. However, there was a marginal increase in stem girth and roots with NPKHA + Lime (2.62 and 0.60). These results is not in harmony with the findings of Cimrin and Yilmaz [32] who stated that humic substances have been shown to stimulate shoot and growth and nutrient uptake of vegetable crops. The result obtained for this study may be due to the sandy nature of the experimental soil.

The result shows that there was a significant difference at ($p\leq0.05$) in pod yield. Crop yield is significantly increased by integrated use of lime and fertilizer. These results are good agreement with those obtained by Karakurt et al*.* [33] who found that humic acid enhanced nutrient uptake, plant growth, yield and quality in a number of plant species. Lime had a significant effect on all the yield attributes name fresh pod weight (Table 6).

4. CONCLUSION

The results from this study showed that for optimum performance of okra on coastal plain derived soil, the application of NPK with humic acid (HA) and lime respectively is beneficial as this gave the highest pod yield. It also revealed the potency of NPK with humic acid and lime on okra in our environment. Further trials in other locations are recommended to fully ascertain the performance of this fertilizer in okra and other arable crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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