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Effects of Rates of NPK, Neem-Based Organic Fertilizer and their Combinations on Okra (*Abelmoschus esculentus* L. Moench) Yield and Leaf Nutrient Content in South-eastern Nigeria

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ABSTRACT

Herein, the effect of applying different rates of inorganic fertilizer (NPK 20:10:10) and organic fertilizer (neem seed) and their combinations on plant nutrient concentration and yield of okra was studied under field conditions at two locations within the University of Calabar Teaching and Research Farm. The experiment was laid out in a randomized complete block design with three replications. Eleven treatments were applied. These were comprised of a control (no amendment), sole NPK 20:10:10 fertilizer and neem-based organic fertilizer applied at two rates (100 and 120 kg N/ha), combinations of 60 kg N/ha NPK+ 60 kg N/ha Neem, 50 kg N/ha NPK+ 50 kg N/ha Neem, 90 kg N/ha NPK + 30 kg N/ha Neem, 25 kg N/ha NPK+ 75 kg N/ha Neem, 30 kg N/ha NPK + 90 kg N/ha Neem and 25 kg N/ha NPK+ 75 kg N/ha Neem. Amongst the two rates (100 and 120 kg N/ha) of sole application of either NPK or Neem-based organic fertilizer, the 120 kg N/ha recorded the highest number of fruits set and okra fresh fruit yield. The combination of 60 NPK + 60 Neem kg N/ha increased the yield (8.43 t/ha) and yield components of okra, while the 90 NPK + 30 Neem kg N/ha and 30 NPK + 90 Neem kg N/ha increased nutrient concentration in the okra plant. Thus, for sole application, the 120 kg N/ha application of either nutrient source is appropriate, but for optimum yield of okra in the tropical rainforest zone of Nigeria, the combination of both, organic and inorganic fertilizer especially at 60 kg N/ha of each nutrient source, is recommended.

Keywords: Fertilizer rates, leaf nutrient content, neem-based organic fertilizer, NPK, okra

1. INTRODUCTION

The goal of most local farmers is to ensure food availability at reduced cost, thereby maximizing profits but they are often posed with the challenge of low nutrient reserve in the soils of south-eastern Nigeria. Soils of south-eastern Nigeria are low in organic matter and available nutrients; hence, its uptake and utilization by crops decline over time when engaged to continuous crop production. In an effort to ameliorate these deficiencies for okra cultivation, the application of either organic or inorganic source of nutrients is widely practiced. Nonetheless, the fertility of the soil has not been able to sustain optimum okra production that can feed the growing population as a result of their demerits. The inorganic fertilizers are scarce, expensive, and their continuous application acidifies soil while organic manures are bulky, slow in nutrient mineralization, as well as low in nutrient.

An appropriate application of inorganic fertilizers along with organic manure is a welcome practice, as it constitutes the concept of integrated nutrient management. The combined application of organic and inorganic fertilizers minimizes the bulkiness of organic fertilizer needed for the maximum agricultural production and prevents a rapid degradation of the soils because of continuous use of inorganic fertilizers. This method also prevents the excessive leaching effect obtained in mineral fertilizer and the slow mineralization process of organic manures (Makinde *et al.*, 2010). The integrated application of organic and inorganic fertilizers to the arable soil has been viewed as an appropriate technique to recycle nutrients and organic matter that can support field crop production and improve soil quality (Makinde *et al.*, 2007, John *et al.*, 2009, Iren *et al.*, 2012, 2014, and 2016a). However, the exact amount required of these nutrient materials (organic with inorganic combination) for an optimum okra production places a hindrance in their usage.

Neem-based organic fertilizer is a natural organic fertilizer produced from neem-seed kernel (Orgo Neem, 2015). It is a non-synthetic soil amendment that aids to enhance soil quality, thereby improving the vegetative and seed parts of crops (Subbalakshmi *et al.*, 2012). It does not only ensure a maximum crop yield but retards certain insect attack on the crop, and since they are biodegradable, they pose no harm to the soil and environment at large and are also cheap compared to other soil conditioners. Combined application of neem-based organic fertilizer with NPK fertilizer in okra production is expected to solve the problems associated with sole use of inorganic fertilizers and organic manures by okra farmers. There has been little or no research information on integrated the use of NPK fertilizer and neem-based organic fertilizer for okra production in southeast Nigeria where okra is mainly cultivated.

This study was therefore conducted to compare the effects of rates of NPK 20:10:10 fertilizer, neem-based organic fertilizer and their combinations on plant nutrient content and yield of okra in south-eastern Nigeria. It was also designed to establish the best combination of these nutrient sources for okra production (Tiwari, 1998; Sengkhamparn, 2009; Joshi, 2009; Kuwada, 1957; Pal, 1952; Roy, 1958).

2. MATERIALS AND METHODS

2. 1. Experimental site

The experiment was conducted in the field at two locations within the University of Calabar Teaching and Research Farm, with the coordinates of latitude N 04°57'035" and latitude

E008°21'28.5" at an elevation of 39.39 m above the sea level. The study area is in the humid tropical environment marked by two distinct seasons, namely the rainy season and the dry season. Calabar is characterized by tropical wet (March to October) and dry (November to February) seasons. Annual rainfall in Calabar ranges from 1900 mm to 2650 mm. Early rain occurs between March to July and late rain occurs between August to October. There is usually a short dry spell in August which is referred to as 'August break'. The minimum and maximum temperatures range from 19 – 24 °C and 28 – 34 °C, respectively while relative humidity minimum and maximum ranges from 39 – 81% and 52–87%, respectively, in the area. The soil is classified as an Ultisols (Soil Survey Staff, 1999) with a low base saturation and is therefore, referred to as highly weathered soils with low basic cations (Esu, 2005).

2. 2. Land Preparation, Experimental Design and Treatments

The study site was manually cleared, tilled and plots measuring 3 m × 2 m (6 m²) marked out. Alleyways between blocks were 2 m, while those between plots were 1 m wide. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. They were eleven treatments comprising of a control (no amendment), sole NPK20:10:10 fertilizer, and neem-based organic fertilizer applied at two rates (100 and 120 kg N/ha), combinations of 60 kg N/ha NPK+ 60 kg N/ha Neem, 50 kg N/ha NPK+ 50 kg N/ha Neem, 90 kg N/ha NPK + 30 kg N/ha Neem, 25 kg N/ha NPK+ 75 kg N/ha Neem, 30 kg N/ha NPK + 90 kg N/ha Neem and 25 kg N/ha NPK+ 75 kg N/ha Neem. The rate of application of the fertilizers (NPK and Neem) was based on the N content of the fertilizer material and applied on dry weight basis. The Neem-based organic fertilizer was incorporated into the soil 4 days before planting to allow mineralization of nutrients. The inorganic fertilizer source, NPK 20:10:10 was applied 2 weeks after planting to specified plots.

2. 3. Soil Sampling and processing

Composite soil sample was taken from the experimental site before experiment, using soil Auger at a depth of 0-20 cm. About 10-12 Auger points were taken from each block and thoroughly mixed to get a composite sample before the commencement of experiment for routine laboratory analysis. The soil samples were air-dried, ground and sieved with 2 mm sieve to remove materials greater than 2 mm in diameter before analysis. For organic carbon and total nitrogen determinations, the samples were further ground and sieved through 0.5 mm diameter mesh.

2. 4. Planting and Maintenance of the Experimental Units

Four okra seeds were sown per hole at a planting distance of 50 cm × 50 cm on a well-prepared seedbed. It was later thinned down to 2 plants per stand few days after emergence giving a plant population of 48 plants/plot and 80,000 plants/ha. The experimental plots were kept weed free throughout the period of the experiment. Weeding was done at two, four and six weeks after planting (WAP).

2. 5. Data Collection for Yield Components and Yield of Okra

Five plants at the centre row of each plot were selected, tagged and used for yield components and yield measurements. Yield components and yield measured include fruit

length, number of fruits per plant and fruit yield. These parameters were assessed at fruit maturity stage and values were thereafter summed up from the first to last harvest and recorded per plot. Fruit lengths from the tagged plants were measured using a meter rule and the average was obtained for each plot. Fresh fruits harvested from the tagged plants were counted and recorded on per plant basis. Fruit yield was the sum of weights of four harvests of fruits per plot which was thereafter converted to kilogram per hectare (kg/ha).

2. 6. Plant Sampling, Processing and Analysis

Leaf samples of okra were obtained at 8 weeks after planting by taking the upper leaves from the five tagged plants per plot, oven dried at 65 °C to constant weight and milled for analysis.

The neem-based organic fertilizer and leaf samples were analysed using standard procedures, as described by Udo *et al.* (2009). The dried milled leaf samples were subjected to acid digestion using nitric per chloric acid mixture. The reagent used for the digestion of the plant samples was prepared under a fume hood by measuring 100 mL of H₂SO₄ into a conical flask, and to it was added 0.35 g selenium catalyst. This mixture was heated to a clear solution in the fume cupboard. This was allowed to cool, and to it was dissolved 7.92 g salicylic acid which then served as the reagent in the digestion.

Acid digestion involves weighing 0.2 g of the plant sample into a 100 mL conical flask with 5 mL of the reagent added and left overnight. Thereafter, it was heated in a digestion chamber for 3 hours. After cooling, 5 mL of perchloric acid was added and heated to a clear solution, filtered and measured up to 50 millilitres in a 50 millilitres volumetric flask. The filtrate was then used in the determinations of primary nutrients (N-nitrogen, P-phosphorus, and K-potassium), secondary nutrients (Ca, Mg), and Na in the leaf sample. Total nitrogen content in the plant was determined by the macro-Kjeldahl method. Phosphorus was obtained using the phosphor-vanado-molybdate colorimetry method, K and Na contents by EEL flame photometer, while Ca and Mg were determined by the EDTA titration method.

2. 7. Statistical Analysis

Data collected were subjected to a statistical analysis using Genstat software and Duncan Multiple Range Test was used to compare the mean at 5% level of probability.

3. RESULTS AND DISCUSSION

3. 1. Nutrient Content of the Soil and Neem fertilizer used for the Study

Tables 1 and **2** show the nutrient contents of the soil and neem-based organic fertilizer used for the study. The soil texture was sandy loam with pH in water value of 6.3 and pH in KCl value of 5.5 indicating slightly acid and strongly acid reaction, respectively, based on the ratings given by Adaikwu and Ali (2013) for humid tropical soils in Nigeria. The soil was low in organic carbon content (4.0 g/kg), exchangeable bases (Ca, Mg, K, and Na) and effective cation exchange capacity (ECEC) but moderate in total nitrogen (2.2 g/kg), available phosphorus (12.9 mg/kg), and high in base saturation (84.29 %).

The chemical analysis of the neem-based organic fertilizer showed that the organic fertilizer had a slightly alkaline pH (7.8) when measured in water and slightly acidic pH (6.4) when measured in KCl. The organic fertilizer had 12.4% organic carbon, 21.58% organic

matter, and 2.68% total nitrogen. The low C:N value indicates the ability of the organic fertilizer to mineralized fast and release nutrients for crop uptake.

Table 1. Physicochemical properties of the soil before experiment

Parameter	Value
Sand (%)	75.52
Silt (%)	12.48
Clay (%)	12.00
Textural class	Sandy loam
pH (H ₂ O)	6.30
pH (KCl)	5.50
Organic carbon(g/kg)	4.00
Total nitrogen(g/kg)	2.20
Avail. P (mg/kg)	12.9
Exchangeable K ⁺ (cmol/kg)	0.18
Exchangeable Ca ²⁺ (cmol/kg)	2.00
Exchangeable Mg ²⁺ (cmol/kg)	0.90
Exchangeable Na ⁺ (cmol/kg)	0.14
CEC (cmol/kg)	3.22
Exch. Acidity (cmol/kg)	0.60
ECEC (cmol/kg)	3.82
Base saturation (%)	84.29

Table 2. Chemical composition of the Neem- based organic fertilizer

Parameter	Value
pH (H ₂ O)	7.8
pH (KCl)	6.4

Organic carbon (%)	12.4	
Organic matter (%)	21.58	
Total N (%)	3.00	
C: N ratio	4.14	
P (mg/kg)	1.82	
K	} cmol(+) kg ⁻¹	2.75
Ca		1.46
Mg		0.91
Zn (ppm)	360	
Cu (ppm)	138	
Fe (ppm)	420	
Mn (ppm)	96	
NH ₄ ⁻ (mg/kg)	65.7	

3. 2. Influence of rates of NPK, neem-based organic fertilizer and their combinations on okra yield components

An amendment of soil with different rates of NPK, neem-based organic amendments and their combined rates significantly ($P \leq 0.05$) increased the length of okra fruit compared with the control (**Table 3**) excepting soil amended with 75 NPK + 25 Neem (kg N/ha). The highest fruit length of 7.15 cm was obtained from plants amended with 60 NPK + 60 Neem though not significantly longer than the other treated fruits except in plot amended with 75 NPK + 25 Neem. However, the shortest fruit length of 4.24 cm obtained from the control plot was not significantly ($P > 0.05$) shorter than the fruit length of 5.29 cm obtained in plots amended with 75 NPK + 25 Neem.

The number of fruit set in one plant was significantly ($P \leq 0.05$) higher in all the amended plots compared with the control (Table 3). More fruits were significantly produced in plots amended with either 120 kg N/ha Neem or 60 NPK + 60 Neem or 50 NPK + 50 kg Neem compared with plots amended with 90 NPK + 30 Neem or 25 NPK + 75 Neem. The highest number of fruits per plant (8.37) was obtained from plants amended with 60 NPK + 60 Neem. There were no significant differences in the number of fruits set per plant among the other fertilizer treatments. Smith *et al.* (2001) and Iren *et al.* (2016 a and b) have stated that the application of soil amendments under a humid tropical rainforest gave a positive increase in the vegetative growth and okra pods yield.

All the treatments applied significantly increased the fruit yield of okra when compared with the control, as shown in Table 3.

The highest average yield of 8.43 t/ha was obtained from the plot amended with the combined application of 60 NPK + 60 Neem (kg N/ha) and was significantly higher than the yield obtained in all the other treated plots. This was closely followed by plants treated with 30 NPK + 90 Neem (7.88 t/ha) which was, however, not higher than the yield obtained from the combination of 50 kg N/ha, each from the two fertilizer types. The least okra fruit yield was obtained in the control plot (there were also significant ($P < 0.05$) differences in the yield of okra among the other fertilizer amendments. As demonstrated by the increased in yield of okra in plots amended with both, organic and inorganic nutrient sources in this study, this shows that the combined treatments favour availability of nutrients in the soil for optimum yield. This goes to confirm the report by Makinde *et al.* (2010) who stated that integrated nutrient management prevents the excessive leaching effect obtained in mineral fertilizer and the slow mineralization process of organic manures, thereby leading to the yield increase. The range of okra fruit yield (1.07 – 8.43 t/ha) obtained in this study was similar to the range of 1.25 – 6.22 t/ha obtained by Iremiren *et al.* (2013) from using kola pod husk and NPK fertilizer at Ibadan in Nigeria, and also similar to that obtained by Nnah *et al.* (2016) who recorded a range of 2.40 – 6.87 t/ha in the south-eastern tropical rainforest region of Nigeria when the soil was amended with organic manures and NPK fertilizer. It was also within the range of 3.83 – 6.58 t/ha obtained by Muhmood *et al.* (2015) when plants were treated with inorganic fertilizers and bio-slurry in Pakistan. They reported the highest okra fruit yield of 6.58 t/ha from treatment receiving 90 kg N/ha of inorganic fertilizers and it was at par with the treatment where fresh slurry was integrated with inorganic fertilizer (6.52 t/ha) in Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan. However, the highest yield of 8.43 t/ha reported in this study was relatively lower than the yield of 16.73 t/ha obtained by Firoz (2009) in Bangladesh from using different levels of nitrogen.

Generally, the combined applications of NPK 20:10:10 fertilizer and neem-based organic fertilizers increased okra yield more than their sole application. This is similar with the results reported by Awanlemhen *et al.* (2016) that combined use of organic amendments and chemical fertilizers, increased pod weight of okra more than when applied solely. Amongst the different rates of single application of either NPK or Neem-based manure, the highest number of fruits set and okra fresh fruit yield was obtained from the application of 120 kg N/ha.

Table 3. Influence of NPK, Neem based organic fertilizer and their combinations on yield components and yield of okra

Treatments (kg N/ha)	Fruit length (cm)	Number of fruits/plant	Yield (t/ha)
Control	4.24 c	2.37e	1.07i
120 NPK 20:10:10	6.01 ab	6.97 abcd	7.43ef
100 NPK 20:10:10	5.96 ab	6.33 bcd	5.71h
120 Neem	7.04 a	8.03 a	7.51de

100 Neem	6.37 ab	7.83 ab	7.13g
60 NPK + 60 Neem	7.19 a	8.37 a	8.43a
50 NPK + 50 Neem	6.99 a	8.23 a	7.77bc
90 NPK + 30 Neem	5.70 ab	5.90 d	7.62cd
25 NPK + 75 Neem	7.00 a	6.27 bcd	7.71c
30 NPK + 90 Neem	7.15 a	6.83 abcd	7.88b
75 NPK + 25 Neem	5.29 bc	6.93 abcd	7.71c

*Mean values with the same letter within a column are not significantly different ($P \geq 0.05$) by Duncan Multiple Range Test

3. 3. Influence of rates of NPK, neem-based organic fertilizer, and their combinations on the leaf nutrient content of okra

The different rates of NPK, neem-based organic fertilizer, and their combinations significantly ($P < 0.05$) enhanced nutrient concentrations in okra plant except for sodium content (**Table 4**). Application of 30 NPK + 90 Neem (kg N/ha) significantly enhanced the concentration of nitrogen (N) in okra plant compared with the control. The maximum amount of N-concentration (1.65 g/kg) was observed in plots amended with 30 NPK + 90 Neem. Similar results have been reported by Muhmood *et al.* (2015) where N-uptake in okra plants was increased due to the application of soil amendment in Pakistan. However, the minimum concentration (0.73 g/kg) was recorded in plot amended with 60 kg N/ha NPK + 60 kg N/ha Neem which may be that the plant used most of the nutrients in pod formation.

Table 4. Plant nutrient concentration as influenced by rates of NPK, neem - based organic fertilizer and their combinations

Treatments	N (g/kg)	P (mg/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)
Control	1.20 cde	0.42 abc	0.73 c	22.39 cd	1.79 a	0.46 a
120 NPK 20:10:10	0.96 ef	0.32 d	0.73 c	13.27 e	1.17 de	0.38 a
100 NPK 20:10:10	1.33 bcd	0.40 bcd	0.67 cd	14.87 de	1.31 cd	0.44 a

120 Neem	1.08 de	0.33 cd	0.61 cde	13.65 e	1.76 ab	0.41 a
100 Neem	1.29 bcd	0.32 d	0.54 def	15.71 de	1.62 abc	0.44 a
60 NPK + 60 Neem	0.79 f	0.35 bcd	0.46 ef	11.93 ef	1.56 abcd	0.36 a
50 NPK + 50 Neem	1.22 cd	0.20 e	0.37 fg	8.11 ef	1.38 bcd	0.47 a
90 NPK + 30 Neem	1.19 cde	0.42 abc	0.58 cde	14.17 e	1.55 abcd	0.41 a
25 NPK + 75 Neem	1.44 abc	0.39 bcd	0.49 ef	12.18 ef	1.34 cd	0.37 a
30 NPK + 90 Neem	1.65 a	0.16 e	1.50 a	45.14 a	0.90 e	0.53 a
75 NPK + 25 Neem	1.27 bcd	0.36 bcd	0.57 cde	13.43 e	1.49 abcd	0.37 a

*Mean values with the same letter within a column are not significantly different ($P \geq 0.05$) by Duncan Multiple Range Test

The highest level of P-concentration (0.42 mg/kg) was obtained in the plot amended with 90 NPK + 30 Neem and the control plot, though not statistically different from the other amended plots, except the sole NPK and Neem applied at 120 and 100 kg N/ha, respectively, 50 NPK + 50 Neem and 30 NPK + 90 Neem.

The highest concentration of K and Ca (1.50 cmol/kg, 45.14 cmol/kg) was from the plots amended with 30 NPK + 90 Neem while the lowest concentration by the okra plant for both, K and Ca was observed in plots amended with 50 NPK + 50 Neem. For Mg-concentration, the highest occurred in the control plot, though not statistically higher than all the plots amended with the sole applied Neem, 60 NPK + 60 Neem, 90 NPK + 30 Neem, 75 NPK + 25 Neem and 20 NPK + 60 Neem but was higher significantly than the other treated plots. The treatments applied did not affect sodium concentration significantly.

4. CONCLUSIONS

Okra responds to application of organic and inorganic fertilizers. The nutrient sources, when used alone or combined at different and lower rates, increased okra yield and plant nutrient concentration. Amongst the two rates (120 and 100 kg N/ha) of the sole application of either NPK or Neem-based organic fertilizer, the 120 kg N/ha recorded the highest number of fruits set and okra fresh fruit yield.

However, the highest yield of okra (8.43 t/ha) was obtained from the combination of NPK and neem-based organic fertilizer at the rate of 60 NPK + 60 neem (kg N/ha) while 90 NPK +

30 neem and 30 NPK + 90 neem increased nutrient concentrations in okra plant. Thus the combination of both, organic and inorganic fertilizer especially at 60 kg N/ha of each nutrient source is recommended for an optimum yield of okra.

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