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Effects of Soil Amendment on Productivity of Okra (*Abelmoschus esculentus* (L) Moench) in an Ultisol of Southeastern Nigeria

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Abstract

Background: Soil fertility management plays a vital role in determining okra yield in Nigeria. The majority of soils in southeastern Nigeria are primarily classified as ultisols. These soils tend to be acidic and deficient in nutrients, resulting in declining crop yield over time. A field experiment was carried out during the 2021 and 2022 cropping seasons at the National Horticultural Research Institute's Mbato Okigwe Sub-station, situated within the rainforest zone of Nigeria.
Aims: The study aimed to assess the impact of different organic fertilizer sources on the sustainable cultivation of okra in southeastern Nigeria.
Methods: The experiment was organized in a randomized complete block design and replicated three times. The treatments included four sources of organic fertilizers (poultry manure, goat manure, cow dung, and wood ash) and a control (no soil amendment). Data on growth and yield were collected from the okra plants and analyzed using analysis of variance.
Result: The results indicated a significant improvement in both soil fertility and okra yield. Notably, the application of poultry manure resulted in the highest organic matter content at harvest: 2.79% and 2.81% in the 2021 and 2022 cropping seasons, respectively. The use of wood ash led to a significant increase in soil pH. The control treatment, which did not receive any organic amendments, recorded the lowest levels of organic matter content, total nitrogen, and exchangeable bases. Poultry manure treatment produced a substantial okra fruit yield of 7.86 and 7.84 t/ha in the 2021 and 2022 cropping seasons, respectively, compared to only 2.31 and 2.28 t/ha observed in the control treatment.
Conclusion: Based on the study findings, the application of poultry manure was recommended to achieve higher okra yields. The study suggests that other organic fertilizer applications can be considered for sustainable soil management in southeastern Nigeria.

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1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is a fruit vegetable of significant economic value, widely cultivated not only in Nigeria but across various regions of the globe. The primary appeal of okra fruits lies in their unique 'draw' or mucilaginous properties, which are often utilized in culinary applications to thicken soups and stews. Additionally, the immature fresh leaves and vibrant flowers of the okra plant are also consumable, particularly during the dry season when other leafy vegetables such as amaranthus, garden egg (*Solanum melongena*) leaves, and fluted pumpkin (*Telfairia occidentalis* Hook) become scarce (Ikeh *et al.,* 2013).

In Nigeria, okra stands out as one of the essential fruit vegetable crops, with its cultivation and production practices being widely adopted, especially in West Africa. This can be attributed to various factors, including its high nutritional value, early maturation of many popular varieties, and its contribution to household income. Despite these benefits, okra is often regarded as a minor crop by many farmers, who typically prioritize the production of staples like yam, cassava, and maize. This disparity in perceived importance can lead to a lack of attention and resources dedicated to enhancing okra cultivation (Ekunwe *et al.,* 2017).

Nutritionally, okra is a powerhouse. Its fruits are rich in dietary fiber, which aids in digestion, and they contain essential vitamins such as vitamin C, which is crucial for immune function and skin health, and vitamin B9 (folate), vital for DNA synthesis and repair. Additionally, the fruits are packed with antioxidants that combat oxidative stress in the body. For people in developing countries who primarily rely on cereal crops that often lack sufficient proteins, okra serves as a valuable dietary supplement, enhancing their nutritional intake with its appealing profile of proteins, vitamins, and minerals (Kota *et al.,* 2022).

Moreover, according to research by Omololu *et al.* (2023), beyond its nutritional benefits, okra is also a source of edible oil and protein. The mucilage, a thick gel-like substance found in the fruit, has been traditionally utilized for its medicinal properties, including soothing gastrointestinal issues and aiding in hydration. Overall, while okra may not always receive the recognition it deserves, its contributions to nutrition and economic stability make it a crop worthy of greater focus and investment.

Insufficient knowledge regarding the sustainable production of okra using fertilizers in the ultisols of southeastern Nigeria poses a significant challenge for soil conservationists and okra farmers. In the humid tropics, effective soil fertility management is essential for sustainable crop production. The productivity of rainforest soils under continuous cultivation can be economically sustained through sound agronomic practices and effective management. Proper soil management enhances soil fertility, boosts crop yields, minimizes soil erosion, and improves the chemical, biological, and physical properties of the soil. It is crucial to maintain soil organic matter and the physical and nutritional characteristics of the soil at favorable levels.

Most soils in the southeastern region of Nigeria have been severely degraded due to prolonged cultivation practices that lack sufficient soil conservation measures. This degradation is exacerbated by the naturally acidic characteristics of these soils and the short fallow periods allowed for recovery. These factors contribute significantly to nitrogen loss, hinder the accumulation of organic matter, and promote soil erosion. Consequently, farmers are faced with diminished crop yields and poor soil health.

In addition to these challenges, soil pH emerges as a critical factor influencing okra (*Abelmoschus esculentus*) production within rainforest ecosystems. A study conducted by Ikeh *et al.* (2013) identified an optimal soil pH of 6.5 for maximizing okra yield. Deviations from this pH level—whether acidic or alkaline—can adversely impact both the growth and productivity of okra plants.

Given these considerations, this study aims to investigate the effects of various organic soil amendments on soil health, plant growth, and yield outcomes of okra cultivated in the high-humidity conditions of southeastern Nigeria. The anticipated positive results from this research could potentially promote sustainable okra production practices in the Okigwe area, thereby improving food security and economic stability for local farmers.

2. Methods

2.1 Experimental Site and Cropping History

The experiment was conducted Umuowa Ibu1 via National Institute of Horticultural Research (NIHORT) Mbato, Okigwe, Imo State, Nigeria. Okigwe is situated at longitude 7°2°E and latitude 5°55°IN of Okigwe with a mean annual range of rainfall of 80 to 375 mm; mean relative humidity of 79% and mean temperature of 22.7 to 34°C. The experimental site was previously used to cultivate some arable crops such as fluted pumpkin, garden egg, and maize, and it was followed for one year before the commencement of the experiment. Rainfall usually starts in March and ends in November with a short period of relative moisture stress in August, traditionally referred to as "August Break". The temperature of the area is generally high in February through April). The experimental site was previously cropped to maize, and okra before it was followed for two years

(a) Soil sampling and analysis: Composite soil samples were collected at a soil depth of 0-30cm using a soil auger before planting. The samples were carefully placed in polyethylene bags, labeled, and transported to the laboratory for analysis. The soil samples were air-dried, crushed, and sieved at the laboratory through a 2.0mm mesh. Subsequently, they were labeled and stored for physicochemical analysis.

(b) Land Preparation: The site was cleared using machetes, and seedbeds measuring 3m x 2m were carefully constructed with spades after marking out the field with tape, rope, and pegs. The seedbeds were separated by 1m pathways between and within rows. Organic soil amendments were added to the soil during land preparation, and this was done based on specific treatment requirements.

2.2 Experimental

The experiment was laid out in a Randomized Complete Block Design (RCBD). The treatments were replicated three times. The treatments were four organic soil amendments (poultry manure, goat manure, cow dung, wood ash) and one control (no soil amendment). The entire experiment occupied a 25m x 15m (375m2) plot size. Each plot size was 3m x 2m. Each plot and block were separated one from the other at one metre apart respectively.

The planting material utilized for this experiment consisted of the Okra variety known as Lady Finger. This specific variety was sourced from the National Horticultural Research Institute (NIHORT) sub-station, located in Mbato Okigwe, Imo State, Nigeria. The selection of this sub-station is significant due to its reputation for cultivating high-quality horticultural varieties. The Lady Finger Okra is well-regarded for its slender pods and tender texture, making it a popular choice among both local farmers and consumers. This experiment aims to assess the growth and yield characteristics of this variety under controlled conditions.

2.3 Agronomic Practices

(i) Planting: In March 2021 and 2022, planting activities were carried out meticulously. A total of three seeds were planted using a drilling method, ensuring a consistent spacing of 60 cm x 60 cm. To optimize plant development, the seedlings were thinned down to two per planting hole three weeks after planting (WAP). Weeding: Weeding was conducted manually on two occasions: the first weeding took place at 3WAP, and the second was scheduled at 7 WAP, utilizing a traditional native weeding hoe. Fertilizer Application: Organic fertilizers were carefully incorporated into the soil during the seedbed preparation. This application occurred on a treatment-specific basis, two weeks prior to planting.

2.4 Data Collection and Analysis

The following growth, yield, and yield components were assessed: Number of leaves per plant: This was obtained by counting the number of fully formed leaves per plant. Number of branches per plant: The number of branches per plant was determined by counting the number of branches per plant. Number of fresh pods per plant: The total number of fresh pods per plant was determined by counting the number of tubers per plant. Fresh pod yield (t/ha): This was determined by the use of a weighing scale, and the weight per plot was converted to tons per hectare.

All the growth and yield data collected were subjected to Analysis of Variance (ANOVA) and treatment means that indicated significance at 5 percent level of probability were separated using Least Significant Difference (LSD).

3. Results

3.1 Soil Physico-chemical Properties of the Experimental Plot Before Planting

The soil analysis showed that the soil was acidic (Table 1), with pH values of 5.30 and 5.20 in the 2021 and 2022 cropping seasons, respectively. The organic matter content was low, while available P (mg/kg) was high. The exchangeable bases, Ca, Mg, Na, and K were low. The particle size analysis indicated a high proportion of sand, 89.40% and 84.70% in 2021 and 2022, respectively, with clay portions of 6.80% and 8.10%, respectively while silt particle was 3.90% and 4.20%, respectively. The particle size analysis revealed that the experimental site was loamy sand (LS).

Table 1. Soil Physico-chemical properties of the experimental site before planting

Soil Parameter	Soil Depth (cm)	
	2021	2022
Soil pH	5.30	5.20
Ec (ds/m)	0.112	0.110
Organic matter (%)	1.81	1.72
Total Nitrogen (%)	0.06	0.06
Available P (mg/kg)	18.65	13.88
Exchangeable Base (cmol/kg)		
Ca	3.00	2.44
Mg	1.33	2.73
Na	0.04	0.06
K	0.08	0.24
Exchangeable acidity	2.24	2.56
ECEC	6.65	8.27
Base Saturation (%)	66.32	69.05
Particle Size (%)		
Sand	89.30	87.70
Silt	3.90	4.20
Clay	6.80	8.10

3.2 Soil Physico-chemical Properties of The Experimental Plots at Harvest

Soil chemical properties at harvest as influenced by organic soil amendments are presented in Table 2. The result showed a decrease in soil pH with increased application of organic soil amendments. The treatment of wood ash had soil pH of 6.50 and 6.70 in the 2021 and 2022 cropping seasons, respectively, while soil pH of 6.10 and 6.20, respectively, was recorded in poultry manure soil amendment. The treatment of cow dung had soil pH of 5.80 and 5.70 in 2021 and 2022, respectively. In the treatment of goat manure, soil pH recorded was 5.70 and 5.60, respectively. Control (no soil amendment) treatment had a soil pH of 5.30 in both cropping seasons.

The result of the percentage of organic matter content at harvest is presented in Table 2. The treatment that received poultry manure had significantly higher percentages of the organic matter content of 2.75 and 2.80 % in the 2021 and 2022, cropping seasons, respectively. The treatment of cow dung was 2.33 and 2.40% at harvest. The treatment of goat manure had organic matter content of 2.11 and 2.13 % in 2021 and 2022 cropping seasons, respectively while percentage organic matter content of 2.01 and 2.03, respectively was recorded in wood ash treatment. Control treatment had the least organic matter content at harvest; 0.78 and 0.81%, respectively.

Total nitrogen as influenced by organic soil amendments showed a significant difference ($p<0.05$) in both cropping seasons (Table 2). Soil amended with poultry manure had total nitrogen of 0.20 and 0.21 % in 2021 and 2022, respectively. The treatment of cow dung had total nitrogen of 0.18 and

0.19 % in both cropping seasons. The least total nitrogen at harvest; 0.05% in both cropping seasons was recorded in the control treatment.

Table 2. Soil Physico-chemical properties at harvest

Treatment	2021					2022				
	Soil Chemical Properties					Soil Chemical Properties				
	pH	Org. Matter (%)	Total N (%)	Avail P (mg/kg)	K (cmol/kg)	pH	Org. Matter (%)	Total N (%)	Avail P (mg/kg)	K (cmol/kg)
Control	5.30	0.78	0.05	18.33	0.08	5.30	0.81	0.05	15.20	0.07
Goat manure	5.70	2.11	0.15	43.08	0.11	5.60	2.13	0.14	40.12	0.11
Wood Ash	6.50	2.01	0.08	50.40	0.15	6.70	2.04	0.08	51.30	0.14
Poultry manure	6.10	2.75	0.20	58.47	0.11	6.20	2.80	0.21	58.18	0.11
Cow dung	5.80	2.33	0.18	49.13	0.12	5.70	2.40	0.19	50.40	0.11
LSD(P<0.05)	**0.75**	**1.10**	**0.03**	**3.89**	**0.04**	**0.81**	**1.13**	**0.04**	**3.73**	**0.03**

The available P as influenced by organic soil amendments is presented in Table 2. The result showed a significant increase in available P in both cropping seasons. The highest available at harvest; 58.47 and 58.18 mg/kg was recorded in poultry manure treatment in both cropping seasons. Wood ash had available P of 50.40 and 51.30 mg/kg in 2021 and 2022, respectively. Cow dung treatment had 49.13 and 50.50 mg/kg available P in the 2021 and 2022 cropping seasons, respectively. The least available P in both cropping seasons; 18.33 and 15.20 mg/kg was recorded in the control treatment.

Potassium content at harvest is shown in Table 2. The result of K varied significantly ($p>0.05$) in both cropping seasons. The highest K value was recorded in the wood ash treatment: 0.15 and 0.14 mg/kg in both cropping seasons. This was followed by 0.11mg/kg, respectively, recorded in cow dung, and 0.11 mg/kg recorded in the treatment of poultry manure, respectively. The least k recorded at harvest, 0.08 and 0.07 mg/kg, respectively, was recorded in the control treatment.

3.3 Effect of Soil amendment on Plant

The number of leaves per plant as influenced by organic soil amendments is presented in Table 3. The result showed significant differences ($p<0.05$) at 3, 6, and 9 weeks after planting (WAP) in both cropping seasons. Treatment of organic soil amendments had a significantly higher number of leaves per plant compared to no soil amendment treatment. Treatment of poultry manure had 19.20 and 20.43 at 9WAP in 2021 and 2022, respectively. In cow dung treatment had 18.55 and 19.20 leaves per plant in both cropping seasons. The least number of leaves per plant in both cropping seasons was recorded in the control treatment. At 9WAP, control had 8.77 and 8.22 leaves per plant in 2021 and 2022, respectively.

Table 3. The number of leaves per plant as influenced by soil amendments.

Treatment	2021			2022		
	Weeks after Planting			Weeks after Planting		
	3	6	9	3	6	9
Control	3.02	6.33	8.77	3.09	6.01	8.22
Goat manure	5.60	11.75	16.78	3.18	14.40	18.47
Wood ash	5.47	13.40	16.81	5.80	15.01	18.04
Poultry manure	5.81	14.30	19.20	6.33	16.22	20.43
Cow dung	5.77	12.59	18.55	4.88	15.75	19.20
LSD(P<0.05)	**1.15**	**2.14**	**2.44**	**1.93**	**2.33**	**2.59**

The number of branches per plant as influenced by organic soil amendments is shown in Table 4. The result varied significantly ($p<0.05$) at 3, 6, and 9 WAP. Treatment that received organic fertilizer had significantly higher number of branches per plant compared to the control treatment. Poultry manure treatment had 14.40 and 13.44 branches per plant at 9 WAP, while treatment of cow dung had 12.33 and 13.11 in 2021 and 2022 cropping seasons respectively. At 9WAP, the control treatment had 4.18 and 4.22 branches per plant.

Table 4. Number of branches per plant as influenced by soil amendments

Treatment	2021			2022		
	Weeks after Planting			Weeks after Planting		
	3	6	9	3	6	9
Control	0.81	2.75	4.18	0.53	2.33	4.22
Goat manure	3.43	10.83	12.09	2.60	10.71	12.74
Wood Ash	3.39	8.71	10.33	3.40	10.20	10.91
Poultry manure	3.48	10.78	14.40	3.91	11.33	13.44
Cow dung	3.31	9.93	12.33	2.85	10.94	13.11
LSD(P<0.05)	**1.20**	**2.09**	**2.26**	**1.31**	**2.16**	**2.37**

The number of pods per plant as influenced by organic soil amendments is shown in Table 5. The application of organic soil amendments significantly influenced the number of pods per plant. The treatments that received organic soil amendments had significant higher number of number of pods per plant compared to no soil amendment. Treatment of poultry manure had the highest number of pods per plant; 10.41 and 10.45 in the 2021 and 2022 cropping seasons, respectively while 3.17 and 3.11 pods per plant were recorded in the treatment of no soil amendment.

Pod yield as influenced by soil amendments is presented in Table 5. The result differed significantly different when the pod yields from treatments of soil amendments were compared to no soil amendment. The highest pod yield; 7.86 and 7.84 t/ha was recorded in the treatment of poultry manure. The treatment of cow dung had 7.31 and 7.33 t/ha pod yield in 2021 and 2022, cropping seasons. Treatment of wood ash had pod yields of 6.71 and 6.70 t/ha, respectively. Control treatment (no soil amendment) produced 2.31 and 2.28 t/ha pod yields in 2021 and 2022, respectively.

Table 5. Yield and Yield Components of Okra as Influenced by Organic Soil Amendments

Treatment	2021		2022	
	Number of Pods/Plant	Fresh pod Yield (t/ha)	Number of Pods/Plant	Fresh pod Yield (t/ha)
Control	3.17	2.31	3.11	2.28
Goat manure	8.22	7.20	8.18	7.16
Wood Ash	6.71	6.58	6.93	6.70
Poultry manure	10.41	7.86	10.45	7.84
Cow dung	9.84	7.31	9.77	7.33
LSD(P<0.05)	**3.11**	**2.16**	**3.14**	**2.19**

4. Discussion

The result of this study showed an increase in the growth and yield of okra in the treatments of soil amendments compared to the control treatment (no soil amendment). The increase in growth and yield parameters could be due to improved soil chemical and physical characteristics of the treatments that received organic soil amendments. This observation agrees with the findings of Udoh (2023) that okra responds to improved soil conditions. Ikeh *et al.* (2023a) equally reported significant improvement in the growth and yield of egusi melon (Colocynthis citrulus) when oil palm bunched ash was amended in an ultisol of southeastern Nigeria. Significant improvement in soil chemical properties with the application of organic soil amendments in kaolinitic ultisols of southeastern Nigeria has been reported by some authors (Idem *et al.*, 2012) in fluted pumpkin, Ndaeyo *et al.* (2013) and Ikeh *et al.* (2023b) in waterleaf (*Talinum triangulare* Jacq) while Ikeh *et al.* (2019) reported significant improvement in garden egg yield under different organic mulching materials which served as a source of organic fertilizers. In cassava production, Akata *et al.* (2016) and Ikeh *et al.* (2023c) growth and yield enhancement of cassava (*Manihot esculenta* Crantz) under different organic fertilizer sources. The significant increase in pod yields recorded in the treatments of soil amendments compared to the control could be attributed to a significant increase in the number of branches per plant. According to Ikeh *et al.* (2013) report, okra with a significantly higher number of branches per plant produced a significantly higher number of fruits per plant and fruit yield. Udoh (2023) stated that more branching per plant accounts for a greater increase in pod yield as fruit develops in the axil of every branch that flowered. Aliyu *et al.* (2015) reported that the positive effect of organic soil amendments on the growth and yield of okra could to balanced C: N ratio, high organic matter build-up, efficient microbial activity, and quick mineralization established by organic soil amendments applied. Positive increases in the number of leaves per plant, number of branches per plant, number of pods per plant, and pod yield from the treatments that received organic soil amendments compared to the control (no soil amendment) could be a result of sufficient moisture and nutrients received from those treatments of organic soil amendments.

5. Conclusions

From the findings in this study, organic soil amendments significantly improved the soil fertility of ultisol and improved the growth and yield of okra. The use of poultry manure, goat manure, cow dung, and wood ash could help farmers manage and conserve the soil organic matter status and nutrient availability and improve the yield of crops. These organic soil amendments are cheap and easily accessible. They are available all year round and are alternatives to scarce and high-cost mineral fertilizers. They are also environmentally friendly, healthy, and ecologically sound. The study, therefore, recommends all the organic soil amendments studied for high okra yield and soil sustainability.

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