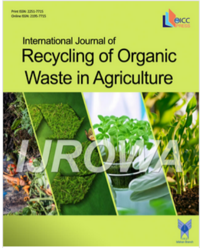

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Effect of plant and animal based compost on the growth and yield of Okra (*Abelmoschus esculentus*) in a Nigeria-derived Savanna

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Original Research

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Abstract:

Purpose: The limitation of the use of some agricultural wastes is their C/N ratio. This study was aimed at integrating cocoa pod husk, moringa leaves, and poultry droppings in composted form for enriched soil amendments for vegetable production.
Method: Three compost types: cocoa pod husk, moringa leaf, and poultry droppings were composted for 60 days in a ratio of 3:1:1, 3:1, and 3:1, respectively. Each compost type was applied at the rate of 2.5, 5.0, 7.5, and 10 t ha^{-1} with a zero control and an optimal control of NPK 20.10.10 at 200 kg ha^{-1}. The treatments were 14 which were laid out in RCBD and replicated thrice. The effect of the compost manures was assessed on the growth, yield, and yield components of Okra in two seasons.
Results: The results indicated that Compost1, Compost 2, and Compost 3 at a rate of 10 t ha^{-1} produced significantly ($P<0.05$) the tallest plants with the least height in the zero control. The leaf area result indicated that Compost1, Compost 2, and Compost 3 at 10 t ha^{-1} and NPK 20.10.10 produced the largest leaves and highest number of fruits per plant. Fruit yield was highest ($P<0.05$) in Compost1 at 10 t ha^{-1} in 2020 and 2021 (8.6 t ha^{-1} and 8.8 t ha^{-1}), respectively and the least in the zero control.
Conclusion: The result from this study showed that the integration of cocoa pod husk, Moringa leaf, and poultry droppings in composted form is a suitable organic amendment for optimal production of okra in Nigeria-derived savanna.

Keywords: Agricultural wastes; Cocoa pod husk; Poultry droppings; Moringa; Biomass; Mineralization

1. Introduction

Okra (*Abelmoschun esculentus*) is a multipurpose vegetable valued for its tender and delicious pods. In addition to the cherished pods, the leaves, buds, and flowers are consumed particularly in West Africa (Sharma, 1993). In Nigeria, the production and consumption of Okra ranked third following tomato and pepper (Ibeawuchi, 2007). In the globe, India is the largest producer of this vegetable with about 6.1 million tones followed by Nigeria with about 2.0 million tonnes. Okra has a wide climatic adaptation – tropical, subtropical, and warm temperate regions on a wide range of soils (NRC, 2006).

Okra responds well to various nutrient sources. The problems, however, associated with inorganic fertilizers such as nutrient imbalance, soil acidification scarcity, and cost as well as disruption of soil structure make their use limited to farmers (Akanni et al., 2011; Adeniyan and Ojeniyi, 2005). Inorganic fertilizers increase vegetable yields but their continuous usage produces negative imprints in the soil-plant system. The crop has been reported to favorably respond to organic sources of nutrients. Moyin-Jesu and Ojeniyi (2000) reported that plant residues applied up to 6 t ha^{-1} increased the leaf and fruit nutrient content of Okra as well as its growth and yield. These residues were ground cocoa pod husk, wood ash, spent grain, and sawdust. Adekunle (2008) reported an increase in the growth and yield of Okra due to the application of poultry droppings, cow dung, and sawdust. Similar findings were reported by Kekong and

Ojikpong (2009) on increased growth, yield, and yield components of garden eggs due to poultry droppings and cow dung. Integrated nutrient management with organic and inorganics has widely been reported. Ojikpong and Kekong (2019) used Rice mill wastes and N-fertilizer that increased the growth and yield of maize; poultry manure and NPK were used by Ndaeyo et al. (2005) which increased the yield and yield components of Okra. Similar results were reported by Ojeniyi et al. (2009) on Amaranthus; and Ayeni et al. (2010) searched on tomatoes which results showed superior crop performance of combined organic and inorganic over their sole applications.

Moringa oleifera plant is known to have a high concentration of bioavailable nutrients, particularly in its leaf biomass. This plant has been exploited for livestock feed, human nutrition, and health as well as water purification. Booth and Wickens (1988) asserted that moringa leaves contain high protein biomass while Price (2000) reported that in addition to the Nitrogen (N) content of the plant, the concentration of Calcium (Ca) and Magnesium (Mg) are also high. Moringa's adaptation to a wide range of soils including marginal soils was reported by Palada et al. (2004). The endowment of this plant makes it a scavenger of nutrients even in less fertile soils.

Moreover, the fast regeneration rate of the plant after pruning can yield four harvests of the leaf biomass per plant per year.

Poultry droppings, as agricultural waste, are a rich source of plant essential nutrients Mbah et al. (2004) and Ano and Agwu (2005) reported that poultry droppings are generally richer in nutrients than other animal manures, especially phosphorus (P).

Cocoa pod husk wastes are generated in tons as spent and usually discarded in concentrated heaps at dump sites in cacao farms. Campos-Vega et al. (2018) reported that seed processing of cocoa generates a huge amount of cocoa pod husk about 67% of the pod, amounting to an estimated 10(ten) tons per every ton of dry seeds processed. Maliki et al. (2020) reported that the main metallic ions in cocoa pods are Potassium (K) and Sodium (Na), followed by Mg > Ca > Cu > Fe.

The ionic composition of cocoa pod husk and its availability as waste dump sites in cocoa farms justifies the use of moringa leaf biomass and poultry droppings for their high N content to facilitate the decomposition process by providing the microbial nutrients needed for the degradation of high C/N organic wastes and subsequent mineralization. Results are scanty on the integration of organic sources of nutrients, which are sustainable for continuous vegetable production, particularly in fragile tropical soils. It is on this premise that this research was designed to investigate the integration of plants and animal wastes in composted forms on growth, yield, and yield components of Okra.

2. Materials and methods

Location of experiment

The study was carried out at the Teaching and Research Farm of the Cross River University of Technology, Obubra Campus during the 2020 and 2021 cropping seasons on latitude 6° 06′ N and 8° 18′ E in the derived savanna belt of Nigeria. Obubra is characterized by a mean annual rainfall density of 2050 - 2200 mm with an annual temperature range of 25 - 28°C. The derived savanna zone has a mean annual rainfall of 2000 mm and minimum and maximum temperatures of 250°C and 370°C, respectively (NIMET, 2021).

Design of the experiment, treatments, and field layout

The design of the experiment was a Randomized Complete Block design (RCBD) and replicated 3 times as shown in Fig. 1. The treatments were 14 which were three compost types: cocoa pod husk + Moringa leaf + poultry droppings (CMP 1), cocoa pod husk + Moringa leaf (CMP 2), and cocoa pod husk + poultry droppings (CMP 3) were composted for a period of 60 days in a ratio of 3:1:1, 3:1, and 3:1, respectively. Each compost type was applied at the rate of 2.5, 5.0, 7.5, and 10 t ha-1 with a zero control and an optimal control of NPK 20.10.10 at a rate of 200 kg ha^{-1}. Each plot size measured 4 m × 3 m (12 m^2) separated by 0.5 m between plots and 1 m between blocks (replicates).

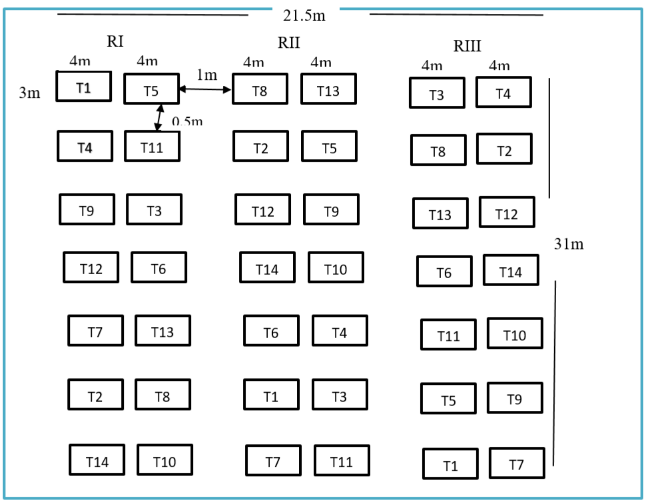

Figure 1. Field layout of experiment.

The gross experimental plot measured 27.5 m $\times$ 24.0 m (664.5 m^2) or 0.066 ha.

Experimental material, compost preparation, and application

The variety of Okra used was Clemson spineless.
The cocoa pod husk was obtained from the Cocoa Research Institute of Nigeria farm breaking points at Ikom, the moringa leaves were collected from the University orchard, and the poultry droppings were obtained from the Department of Animal Science Farm, Cross River University of Technology. The materials were partitioned by weighing at a ratio of 3:1:1, 3:1, and 3:1 of the cocoa pod + moringa + poultry droppings, cocoa pod + moringa, and cocoa pod + poultry droppings, respectively. These compost ingredients were shredded and thoroughly mixed and formed into heaps. The heap was moistened with water, spread on plastic sheets, and covered with plastic tarpaulin. The heap's temperature was monitored daily at the beginning of the composting process and at three days intervals for another three weeks. Thereafter, the temperature was taken weekly until full compost maturity while turning was done in every 14 (fourteen) days for 8 (eight) weeks and the compost was ready in 60 days. The compost was incorporated into the prepared seed bed and allowed for two weeks before sowing the okra seeds.

Data collection

Soil sampling and processing: At the commencement of the experiment, a composite soil sample was collected at random points within the experiment plot which was bulked using a soil auger at 0 – 25 cm. These samples were air-dried and sieved through a 2 mm mesh for laboratory analysis.
Plant sampling and analysis: A net plot of inner ridges for each treatment was used with five tagged plants for growth and the yield components parameters. The plants were sampled for height, number of leaves per plant, stem girth, leaf area, number of fruits per plant, weight of each fruit, and fruit yield per unit area.
The meter rule was used for plant height while a Vernier calliper was used to measure the stem girth. Leaf area meter, model: Blam-1 was used for the leaf area. The test unit is a millimeter and Square Centimeter (cm^2) with a precision of $\pm$ 2% and a resolution of 0.01 cm^2. The product is Infitek, manufactured in China. The compost materials and the compost were collected from within the stock and processed for laboratory analysis.

Statistical analysis

Analysis of variance (ANOVA) for RCBD was performed on the Okra growth and yield parameters using the computer software Genstat. The means were separated by using the Duncan's Multiple Range Test (DMRT) where values followed by different lowercase letters are significantly different at $P < 0.05$.

Soil and compost analysis

Routine analysis was conducted for the compost materials and the compost and the composite soil sample to determine the fertility properties of the soils using standard laboratory procedures as outlined:

Soil physical properties

Particle size distribution (PSD): this was determined by the Bouyoucos (Hydrometer) method procedure by Udo et al. (2009). This involves the suspension of soil samples with sodium hexametaphosphate (calgon). The reading on the hydrometer was taken at 40 seconds. The second reading was taken three hours later. The particle size was then calculated using the following formulae:

$$\text{Sand} = 100 - (\text{H}_1 + 0.2(\text{T}_1 - 68) - 2.0)^2$$

$$\text{Clay} = (\text{H}_2 + 0.2(\text{T}_2(\text{T}_2 - 68 - 2.0)^2$$

$$\text{Silt} = 100 - (\%\text{sand} + \%\text{clay})$$

where:
H_1 = Hydrometer first reading at 40 seconds
T_1 = temperature first reading at 40 seconds
H_2 = Hydrometer second reading after 3 hours
T_2 = Temperature second reading after 3 hours

Soil chemical properties

Soil pH. This was determined in both water and 0.1 N KCL in a ratio of 1:1 soil: water and 1:2.5 soil: Kcl respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter (McClean, 1982).

Organic matter (OM)

This was determined by the Walkley-Black method as outlined by Page et al. (1982) which involves the oxidation with dichromate and tetraoxosulphate vi acid (H_2SO_4). The excess was titrated against Ferrous Sulphate. The organic carbon was then calculated using the relationship:

$$\%\text{org.C} = \text{N}(\text{V}_i - \text{V}_2)0.3\text{f}$$

where:
N = Normality of Ferous Sulphate solution
V_1 = Ml Ferrous Ammonium Sulphate for the black
V_2 = ml Ferrous Ammonium Sulphate for the sample
W = mass of sample = farm
F = correction factor = 1.33
% organic matter in soil = % org.C x 1.729
Nitrogen in soil. Total nitrogen in the soil was determined by the macro kjeldahl method as described by (Udo et al., 2009). The soil samples were digested with Tetraoxosulphate (Vi) acid (H_2S0_4) after the addition of excess caustic soda. This was distilled into a 2% Boric acid (H_3Bo_4) and then titrated with 0.01 HCl. Nitrogen was obtained from the relationship below.

$$\%\text{N} = \frac{\text{T} \times \text{M} \times 14 \times 100}{\text{N}}$$

where:
T = Titre value
M = Molarity of Hcl
W = Weight of soil used
N = Normality of H_2SO_4
Available phosphorus: Available P was determined by Bray

1 method as outlined by Page et al. (1982). This involved mechanical shaking of the sample in an extracting solution and then centrifuging the suspension at 2000 rotations per minute for 10 minutes. Using the Ascorbic acid method, the percentage transmittance on the spectrophotometer at 660 nm wavelength was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm and the extractable P of the soil was then calculated.
Cation Exchange capacity (CEC) and Exchangeable acidity (EA) were determined by the Kjeldahl distillation and titration method as outlined by IITA (1979) using ammonium acetate solution. The soil samples were leached, then the soil was washed with methyl alcohol and allowed to dry. The soil was then distilled in Kjeldahl operation into a 4% Boric acid solution. The distillate was then titrated with a standard solution of 0.1 N HCl.

Exchangeable cations

This was determined by the ammonium acetate extraction method as described by IITA (1979). The soil samples were shaken for 2 hours then centrifuged at 2000 rpm for 5-10 minutes after decanting into a volumetric flask, ammonium acetate (30 ml) was added again and shaken for 30 minutes, centrifuged, and the supernatant was transferred into the same volumetric flask. An Atomic Absorption Spectrophotometer (AAS) was used to read the cations.

3. Result and discussion

Pre-treatment soil characteristics

The soil properties before the compost amendment application (Table 1) showed that the soil was a sandy loam in texture. The OM of these experimental soils were moderate (1.26% and 1.34%), respectively for 2020 and 2021, as these values fell within the threshold limits of 1.17 – 2.42 (Chude et al., 2011). Total N (0.8 and 0.9%), Available P (3.4 mg/kg and 4.1 mg/kg), and exchangeable K (0.22 and 0.21 cmol/kg) in the two years were low in the experimental soils. These values were below the critical levels set for Nigeria soils by Chude et al. (2011) of 0.15%, 10-16 mg/kg, and 0.31cmol/kg for N, P, and K. The Ca (2.6 and 2.52 cmol/kg) and Mg (1.01 and 1.20 cmol/kg) levels were above the critical limits of 0.95 and 0.25 cmol/kg respectively for the Ca and Mg ((Ed), 1989). The Cation Exchange Capacity (CEC) of the soils (6.75 and 6.21 cmol/kg) were above the threshold limits of 3.0 - 5.0 cmol/kg as stated by (Landon, 1991). This CEC level is normal to prevent the fixation of P. The pH of the experimental site (5.30 and 5.46) for cropping seasons in 2020 and 2021 respectively were acidic. The pH ratings for Nigerian soils by Chude et al. (2011) rate 5.0 – 5.5 as strongly acidic.
The percentages of the particle size of soils make the soil a sandy loam texture which was adequate for seed germination and seedling growth and development. The pH of the experimental site of strongly acidic fell below the range recommended for okra crop by Lester and Seck (2004) who stated that the pH range for Okra growth and yield is 5.5 - 6.8. These low nutrients and exchangeable cations characterized the fertility status of tropical soils as described by Fernandez and Sanchez (1990) and Brussard et al. (1993). This low pre-treatment soil nutrient status and properties of the experimental site corroborated the earlier report of Chude (1998) who stated that Cross River State soils of Nigeria have low P, Ca, and Mg.
The percentages of the particle size of soils make the soil a sandy loam texture which was adequate for seed germination and seedling growth and development. The pH of the experimental site of moderately acidic fell within the range recommended for okra crops by Lester and Seck (2004) who stated that the pH range for Okra growth and yield is 5.5 - 6.8. These low pH, N, P nutrients and exchangeable K characterized the fertility status of tropical soils as described by Fernandez and Sanchez (1990) and Brussard et al. (1993). This low pre-treatment soil nutrient status and properties of the experimental site corroborated the earlier report of Chude (1998) on P for Cross River State soils but Ca and Mg levels of this experimental site were above the levels reported by Chude (1998) for Cross River State.

Table 1. Pre-cropping soil physical and chemical properties at the experimental site.

Parameter	2020	2021
Sand (g/kg)	853	797
Silt (g/kg)	79	106
Clay (g/kg)	68	98
Texture class	S/L	S/L
pH (water)	5.30	5.46
pH (KCl)	4.30	4.42
Organic matter (%)	1.26	1.34
Total nitrogen (g/kg)	0.8	0.9
Available P (mg/kg)	3.4	4.1
Exchangeable Ca (cmol/ kg)	2.60	2.52
Exchangeable K (cmol/ kg)	0.22	0.21
Exchangeable Mg (cmol kg^{-1})	1.01	1.20
Exchangeable Na (cmol kg^{-1})	0.17	0.18
Exchangeable acidity	2.75	2.73
CEC (cmol kg^{-1})	6.75	6.21

Table 2. Nutrient Composition of compost materials and composts.

Compost Material	Org C%	N%	P%	K%
Cocoa Pod Husk CPH	1.12	1.30	13.48	20.1
Moringa leaf Biomes MLB	3.82	1.10	8.21	10.8
Poultry Droppings PD	2.34	2.26	3.28	8.2
Compost				
CPH +MLB +PD = CMP1	2.88	1.48	1.66	3.5
CPH +MLB = CMP2	2.61	0.55	1.20	3.3
CPH + PD = CMP3	2.01	0.81	1.23	2.9

KEY: CPH = Cocoa pod husk, MLB = Moringa leaf biomes, PD = Poultry droppings
CMP1 = Cocoa pod husk + Moringa biomass + poultry droppings
CMP2= Cocoa pod husk + Moringa biomass
CMP3 = Cocoa pod husk + poultry droppings

Composition of compost materials and compost

The nutrient composition of the compost and compost materials (Table 2) indicated that Moringa leaf biomass has the highest content of nitrogen (3.82%) above poultry droppings and cocoa pod husk which its total N concentrations were 2.34% and 1.12%, respectively. Poultry droppings had the highest concentration of P (2.26%) than Moringa leaf and cocoa pod husk with 1.15% and 1.10%, respectively. The cocoa pod husk contains the highest K (34.86%), then Moringa leaf (17.21%) and 3.28% K for poultry droppings. Upon composting, the compost of Cocoa pod + Moringa leaf and poultry droppings (CMP1) contained the highest concentration of N, P and K (2.88, 1.48 and 1.66%), respectively. The compost with cocoa pod husk + Moringa leaves (CMP2) had N, P, K content of 2.61%, 0.55% and 1.20%, respectively while compost of Cocoa pod husk + poultry drop-pings (CMP3) contained N, P, K concentrations of 2.01%, 0.81%, and 1.23%, respectively.

The differences in the nutrient composition of the compost materials are a function of the physiological differences between plants and animals. The high N and P nutrients from the poultry droppings agree with the analysis by Ano and Agwu (2005) and Paterson et al. (1998) stated that poultry droppings generally have the highest N, P, K, nutrient content among all animal fecal wastes. The high N and K in Moringa biomass agrees with the assertion of Booth and Wickens (1988) who stated that Moringa leaves produce high protein biomass while the low P content of the leaf biomass was earlier reported by Aslam et al. (2005) and Price (2000) who reported low P in Moringa leaf as it should be for plants. The high organic carbon content of cocoa pod husk with a C/N ratio of 18 will immobilize nutrients. This is so because the threshold level for mineralization as stated by Fairhurst (2012) is < 16 and this justifies the integration of moringa leaves biomass and poultry droppings in the cocoa pod compost.

Effect of plant and animal-based compost on the growth of Okra (Tables 3 and 4)

The soil application of the compost manures (Tables 3 and 4) significantly (P>0.05) affected the growth of Okra plants for the two years under investigation. In 2020, the manure composted with cocoa pod husk, Moringa leaf, and Poultry droppings (CMP1) applied at the rate of 10 t ha^{-1}, 7.5 t ha^{-1}, CMP2 10 t ha^{-1}, and CMP310 t ha^{-1} produced tallest plants (61.0cm, 60.6cm, 60.15cm and 60.01 cm), respectively. This was followed by other compost types CMP2 (7.5 t ha^{-1}), CMP3 (7.5 t ha^{-1}), and Optimal NPK 200 kg ha^{-1} with plant heights of 58.40 cm, 57.80 cm, and 57.40 cm, respectively. The lowest plant height was obtained from the control which received no manure.

The number of leaves produced by Okra plants in response to the manures was statistically significant (P>0.05). CMP1 10 t ha^{-1} and CMP1 7.5 t ha^{-1} produced the highest number of leaves per Okra plant. This was followed by other manure rates and the inorganic NPK 20:10:10 while the least number of leaves was produced in the no manured plants. The result of stem girth was in the order of CMP1 10 t ha^{-1} > CMP1 7.5 t ha^{-1} = CMP1 5 t ha^{-1} = CMP2 10 t ha^{-1} = CMP2 7.5 t ha^{-1} = CMP1 5 t ha^{-1} = CMP2 10 t ha^{-1} = CMP2 7.5 t ha^{-1} = CMP3 10 t ha^{-1} = CMP3 7.5 t ha^{-1} = NPK 200 kg ha^{-1} > CMP1 2.5 t ha^{-1} = CMP2 2.5 t ha^{-1} = CMP3 5.0 t ha^{-1} > the control. The leaf area result indicated that CMP1 10 t ha^{-1}, CMP2 10 t ha^{-1}, CMP3 7.5 t ha^{-1}, CMP3 10 t ha^{-1}, and NPK 200 kg ha^{-1} produced the largest leaves than other amendments and the least leaf size (66.61 cm^2) was obtained from zero manure application.

The growth result for 2021 (Table 4) indicated that the compost manures significantly (P>0.05) affected the growth and growth parameters of okra plants. The result followed the same trend as that of 2020 where CMP1 outperformed all other treatments.

The effect of compost on the growth of Okra indicated the adequate mineralization of the manure which led to the release of nutrients for the growing plants. This significant growth of Okra in plant height, higher number of leaves,

Table 3. Nutrient Composition of compost materials and composts.

Treatment	Compost rate(t ha^{-1})	Plant height (cm)	No. of leaves	Stem girth (cm)	Leaf area (cm^2)
Control	0	34.55d	5.1d	1.89c	66.61c
CPH + MLB +PD	2.5	44.30c	6.7bc	2.04bc	105bc
CPH + MLB +PD	5.0	52.50bc	7.66b	2.11b	166.8b
CPH + MLB +PD	10.0	61.0a	8.8a	2.41a	205.2a
CPH + MLB	2.5	49.60c	5.9c	2.06bc	164.6b
CPH + MLB	5.0	53.2bc	6.8bc	2.09b	170.1b
CPH + MLB	7.5	58.46b	7.1bc	2.11b	180.2b
CPH + MLB	10.0	60.15a	8.2ab	2.28ab	201.7a
CPH + PD	2.5	41.25c	6.9bc	2.02bc	124.2bc
CPH + PD	5.0	54.23bc	7.6b	2.06bc	168.4b
CPH + PD	7.5	57.80b	7.7b	2.11b	198.8a
CPH + PD	10.0	60.01a	8.1ab	2.16b	200.9a
Opt Control(NPR)	200kgha-1	57.40b	7.8b	2.19b	200.4a
	Mean	53.2	7.3	2.12	167.1
	SE±	0.10	0.4	0.2	6.4

Values followed by different lowercase letters are significantly different at P<0.05 using Duncan's Multiple Range Test (DMRT).

Table 4. Nutrient Composition of compost materials and composts.

Treatment	Compost rate(t ha^{-1})	Plant height (cm)	No. of leaves	Stem girth (cm)	Leaf area (cm^2)
Control (No manure)	0	32.6d	5.0d	1.82d	65.81
CMP1	2.5	45.1bc	6.8c	2.03c	106.10
	5.0	54.2bc	7.5b	2.15b	165.7
	7.5	61.3a	8.4ab	2.17b	187.0ab
	10.0	61.9a	8.9a	2.39a	204.4a
CMP2	2.5	46.8bc	5.6	2.04c	121.3
	5.0	52.4b	6.7c	2.09bc	168.2
	7.5	58.2ab	7.2bc	2.13bc	179.1b
	10.0	61.3a	8.3ab	2.27a	202.2a
CMP3	2.5	40.9c	6.8c	2.03c	124.0
	5.0	53.7b	7.4b	2.06c	166.2
	7.5	58.8ab	7.7b	2.12bc	189.2ab
	10.0	60.8	8.3ab	2.17b	198.6a
Opt Control NPR	200kg ha^{-1}	56.8b	7.7b	2.16b	197.7a
	Mean	53.16	7.31	2.12	162.5
	SE±	2.8	0.55	0.18	10.7

*Values followed by different lowercase letters are significantly different at $P<0.05$ using Duncan's Multiple Rage Test (DMRT).

and leaf area of the crop by compost above the control and the NPK inorganic fertilizer could be the low C/N ratio of these wastes that facilitated the biodegradation and mineralization of the materials. This is in agreement with the result obtained by Moyin-Jesu (2015) who noted that the supply of adequate amounts of nutrients in the right proportion could influence the leaf area development in many tropical crops. The result of this study is in tandem with the findings of other investigators on organic wastes including Adegunloye and Olotu (2018) who reported the tallest plants of maize in response to Cocoa pod composted with poultry droppings over control and NPK inorganic fertilizer treatments; Akanni and Ojeniyi (2007) who reported that cocoa podhusk ash increased growth and nutrient uptake of Kola seedlings and Fairhurst (2012) who reported increased growth rate of cocoa seedlings due to application of composted poultry droppings with inorganic Phosphorus. The growth performance of the okra and other growth parameters of Leaf Area and Stem Girth could have resulted from the soil amendment effect of the cocoa pod-based compost. This compost effect was similar to the findings of Mbabazize et al. (2023) who reported that the application of biochar increased soil pH and that this increase could have possibly increased nutrient release and availability for tested crops.

Yield and yield component of Okra influenced by integrated organic compost (Table 5)

Application of compost manures on soils used for Okra significantly ($P>0.05$) affected the number of fruits per plant, the fruit weight, and the fruit yield per unit area for both years of the trial (Tables 5 and 6). The number of fruits produced was in the order of CMP1 10 t ha^{-1} = CMP2 10 t h^{-1} = CMP2 7.5 t ha^{-1} = CMP3 10 t ha^{-1} > CMP1 7.5 t ha^{-1} = CMP3 7.5 t ha^{-1} = NPK 200 kg ha^{-1} > other compost

Table 5. Yield and yield components of okra as influenced by compost 2020.

Treatment	Compost rate(t ha^{-1})	No. of fruits per plant	Mean fruit weight (g)	Fruit yield (t ha^{-1})
Control	0	3.2d	13.4c	4.6c
CPH + MLB +PD	2.5	6.1c	15.8bc	4.6e
CPH + MLB +PD	5.0	7.0b	13.4ab	5.1d
CPH + MLB +PD	7.5	7.8ab	15.8a	7.0b
CPH + MLB +PD	10	9.8a	17.9a	8.6a
CPH + MLB	2.5	6.0c	18.1ab	5.0de
CPH + MLB	5.0	7.1b	18.6a	6.9bc
CPH + MLB	7.5	7.9ab	17.8a	7.2bc
CPH + MLB	10	9.3a	18.1a	8.1ab
CPH + MLB	2.5	6.5c	16.8b	5.1de
CPH + MLB	5.0	7.8ab	17.1ab	6.4c
CPH + MLB	7.5	9.0a	17.4ab	7.1bc
CPH + MLB	10.0	8.9a	18.2a	8.2ab
Opt control NPK	200kgNPKha-1	8.6ab	17.9ab	7.8b
	Mean	7.5	16.1	6.7
	SE±	1.0	0.8	0.4

Values followed by different lowercase letters are significantly different at P¡0.05 using Duncan's Multiple Rage Test (DMRT).

Table 6. Yield and yield components of okra as affected by compost 2021.

Treatment	Compost rate(t ha^{-1})	No. of fruits by plant	Mean fruit weight (g)	Fruit yield (t ha^{-1})
Control	0	3.1d	13.1d	4.2e
CMP1	2.5	6.2c	15.7c	5.2de
CMP1	5.0	7.1bc	17.8ab	5.6d
CMP1	7.5	7.7b	18.2a	7.8ab
CMP1	10.5	9.7a	18.6a	8.7a
CMP2	2.5	5.9	17.3ab	5.1dc
CMP2	5.0	7.2 bc	17.9a	6.8c
CMP2	7.5	7.9ab	18.0a	7.3b
CMP3	10.0	9.5a	18.1a	8.2ab
CMP3	2.5	6.4c	16.7b	5.1dc
CMP3	5.0	7.6b	17.1b	6.3c
CMP3	7.5	8.8ab	17.5ab	7.2b
CMP3	10.0	9.0a	17.8a	8.1ab
Opt. Control NPK	200kgha-1	8.5ab	17.4ab	7.7ab
	Mean	7.5	17.2	6.7
	SE±	1.1	0.8	0.4

Values followed by different lowercase letters are significantly different at P¡0.05 using Duncan's Multiple Rage Test (DMRT).

rates and the least number of fruits were obtained from the control without manure.

The weight of each fruit was higher in all compost-treated plots and NPK 200 t ha^{-1} over the control. However, the highest fruit weight was obtained in all the compost types at 10 t ha^{-1} and 7.5 t ha^{-1} in 2020 while in 2021 the highest fruit weight was obtained from CMP1 10 t ha^{-1}, CMP1 7.5 t ha^{-1}, CMP 2 10 t ha^{-1}, CMP3 10 t ha^{-1}, and CMP3 7.5 t ha^{-1}. These weights were higher than other rates including the inorganic NPK 20:10:10 at 200 kg ha^{-1} with the least weighted fruits from the control.

The yield of Okra plants per unit area was highest in plots treated with CMP1 at 10 t ha^{-1} for both years (2020 and 2021) whose yields were 8.6 t ha^{-1} and 8.8 t ha^{-1}. All other manure rates and the optimal control (NPK 20:10, 200 kg ha^{-1}) out yielded the control with the least yield of 4.6 t ha^{-1} and 3.9 t ha^{-1}.

The highest number of pods of okra per plant and yield of crop per unit area from 10 t ha^{-1} compost of Cocoa pod + Moringa leaf + Poultry droppings in this study over the inorganic NPK and control corroborates the findings of Kayode et al. (2013) who reported highest plant and root dry matter yield from plants treated with 10 t ha^{-1} compost of Cocoa pod + Poultry droppings and Neem leaves. Similarly, Adeleye and Ayeni (2010) reported the combination of cocoa pod husk ash and poultry droppings significantly increases maize stover, dry matter, and grain yield of maize. Furthermore, on the combination of organic wastes, Kekong (2020) reported increased growth and yield of watermelon using combined rice mill wastes and poultry droppings; Moyin-Jesu (2015) reported increased growth and head yield of cabbage from manures supplemented with poultry droppings; Kekong et al. (2016) reported on Moringa and rice husk that increased garden egg yield and Ojikpong et al. (2018) reported the increased growth and yield of Garden egg over control using Moringa, Cow dung, and poultry droppings manures. The higher yield of Okra in this integrated compost for this study agrees with the assertion of Wright et al. (2022) who observed that compost amendment improved soil health, soil water content, crop yields, and impressive long-term increases of N/P/K concentration in the soils. Similarly, Kayode and Adeoye (2021) reported a higher dry matter yield of okra due to the application of cocoa pod-based compost and concluded that cocoa pod-based compost could be a good fertilizer for okra growth.

4. Conclusion

The low cost and availability of these compost materials and the low level of technology involved in the compost production is a promising substitute for the costly inorganic fertilizers that are not even sustainable for continuous crop production for poor resource farmers that dominate the Nigeria agricultural landscape. Composting therefore is a viable means to reduce the need for resource-poor and small-scale farmers that dominate the Nigerian agricultural landscape to supplement with the scarce and costly inorganic NPK fertilizers. The application of plant and animal-based compost of cocoa pod husk (CPH), Moringa leaf (MLB), and poultry droppings (PD) significantly influenced the growth parameters and yield components of Okra plants. 10 t ha^{-1} CPH+MLB+PD (CMP1) being the most effective in terms of optimal nutrient release that manifested in the yield of Okra is recommended over inorganic NPK for sustainable production of Okra in tropical fragile soils of Obubra Cross River State of Nigeria.

Author contribution

All the authors have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript.

Conflict of interest statement

The authors declare that they are no conflict of

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