



Variations in Soil Properties and Okra Yield as Influenced by Different Types and Forms of Organic Amendments

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Authors' contributions

This work was carried out in collaboration among all authors. All the authors contributed to the conception of the idea. Author BOA designed the study, performed the statistical analysis, managed the literature search and wrote the first draft of the manuscript. Authors OAA and KO supervised and reviewed the article. All authors read and approved the final manuscript.

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ABSTRACT

The overexploitation of agricultural lands have necessitated the use of fertilizers to enhance food production. However, due to the cost and environmental impacts of mineral fertilizers, the utilization of readily available organic wastes as soil amendments have become necessary. The effect of the sole or combined application of yam, cassava and plantain peels on soil properties was evaluated in an on-farm study conducted at Akufo farm settlement, Ibadan, southwestern Nigeria. The experiment was laid out in a Randomized Complete Block Design with fifteen treatments which consisted of seven amendments (peels of yam (Y), plantain (P), cassava (C), Y+P, Y+C, C+P, Y+C+P) applied in two forms (ground and unground) at a uniform rate of 4 t ha⁻¹ and a control (without amendment). After 3 months of application, the soils were analyzed to determine the effect of the applied treatments on soil properties, after which they were sown to okra. All the amended soils had relatively higher organic carbon, nitrogen, phosphorus and exchangeable bases than the control, but ground treatments performed relatively better than unground ones. Also, irrespective of

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treatment and form of application, okra yield was considerably improved by the utilized amendments, with ground Y+C recording the highest (14.33 t ha⁻¹). This study showed that the sole or combined use of yam, plantain and cassava peels, either ground as powder or used as mulch, has the potential to improve soil fertility and crop yield and may provide an effective and simple means to utilize organic wastes as soil amendments, especially among poor farmers who cannot afford composting technology.

Keywords: *Cassava peel; form of application; organic amendment; plantain peels; yam peels.*

1. INTRODUCTION

The productivity and sustainability of agricultural soils in sub-Saharan Africa are threatened by the widespread decline in soil fertility across the region [1,2]. This can be attributed to the use of unsustainable farming practices among small scale farmers who make up about 80% of the continent's agrarian industry [3]. Traditionally, soil fertility management was achieved through shifting cultivation and bush fallowing, however as land becomes increasingly scarce due to demographic pressure, farmers have been forced to shorten or completely forgo fallow periods and either bring increasingly marginal lands into continuous cultivation, or migrate into tropical forest areas, exacerbating the problem of land degradation [4–6]. As at 2014, about 65% of arable land, 30% of grazing land and 20% of forests in Africa were severely degraded [7] and these figures are likely to have escalated.

The overexploitation and depletion of arable lands have made it necessary to apply fertilizers in order to increase soil nutrients and boost land productivity [4,8]. However, inorganic fertilizer use is relatively low in Africa compared to other regions of the world because they are generally too expensive for indigenous farmers to adequately utilize them according to recommended standards [1,4,9]. Organic fertilizers, made from readily available biodegradable wastes, are cheaper alternatives to soil fertility improvement [10]. They are valuable sources of organic matter and when applied to soil, slowly release nutrients with little or no risk to the environment. The use of organic fertilizers to improve soil quality has been extensively researched, but the degree of improvement is determined by the composition of the organic material and the method of application [11–13].

Several food and agricultural wastes have been explored for use as organic fertilizers, including fruit and vegetable wastes [14–16], potato peels [17], palm kernel cake wastes [18,19]; rice husk [20,21], among others. However, many organic

wastes are still yet to be researched. In western Nigeria, yam, cassava and plantain are processed in large quantities daily and their generated peels are often heaped around farms, processing sites and market places. These peels reportedly contain considerable amount of organic carbon and other essential nutrients that may be beneficial for the enhancement of soil fertility [8,22,23].

Many organic amendment studies utilized composting technology which is often too expensive and technical for indigenous farmers to adopt [24–26]. Nevertheless, several authors have recorded good success from simpler techniques, such as the use of organic wastes as surface or incorporated mulch [12,27–29], and milling them into powder and used as natural fertilizers [15,30,31]. Furthermore, most amendment studies were carried out under controlled environments which neither bear semblance to, nor capture the heterogeneity of farmers' field, hence, farmers adoption of the results is often limited [32,33]. An on-farm experiment was therefore conducted to evaluate the effectiveness of yam, plantain and cassava peels, applied as powder and surface mulch, to improve soil fertility and crop yield.

2. MATERIALS AND METHODS

2.1 Study Area

A two-year on-farm experiment was conducted at the Akufo farm settlement, located in Ibadan, a rainforest zone in the western region of Nigeria, in 2018 and 2019. The site is geographically located at latitude 7°29'35"N and longitude 3°48'41"E, at an altitude of 230.1 m above sea level. The study site is characterized by mean annual temperature of 28.7°C and rainfall of about 1,205 mm [34]. The rainfall distribution is bimodal, with peaks in June and September.

Prior to this study, the field had been continuously used for the raising orange and mango seedlings for about 6 years.

2.2 Collection and Processing of the Organic Materials

Yam, cassava and plantain peels were obtained from major processing units in Ibadan. The collected peels were washed to remove debris, cut into smaller bits of about 4 cm² and sun-dried for about 1 to 2 week to constant weight. Samples of the dried peels were subjected to chemical analysis to determine their nutrient compositions.

The peels were further processed in two forms-ground, using a local milling machine (Tigmax Petrol Engine, model- Gx160 - 5.5HP) and unground; and then bagged and stored under room temperature until they were used.

2.3 Experimental Layout and Treatments

The land was cleared manually and bulked soil sample was collected at a depth of 0-15 cm to determine the initial physicochemical properties of the field. Raised beds, measuring 1 m by 1 m were then erected with a spacing of 0.5 m between the beds. The experiment was laid out in a Randomized Complete Block Design (RCBD) with a total of fifteen treatments (seven amendments applied in 2 forms- ground and unground, and a control) replicated thrice. The amendments were:

Yam peels (Y),
Cassava peels (C),
Plantain peels (P),
Y + C (1:1) (YC),
Y + P (1:1) (YP),
C + P (1:1) (CP) and
Y + C + P (1:1:1) (YCP), (All ratios are expressed by weight).

The treatments were randomly applied to the beds at a uniform rate of 4 t ha⁻¹ at 3 months before the beginning of the planting season in both 2018 and 2019 (January to March). Whereas the ground materials were thoroughly incorporated into the soil, the unground ones were applied as surface mulch. After 3 months of application, soil samples were collected and analyzed to determine the effect of the applied amendments. Okra seeds (*Albemochus hibiscus*-Clemson spineless variety) were then sown on the raised beds at a spacing of 30 x 30 cm. At about 2 months after planting (50% flowering), plant height, number of leaves, petiole length, leaf area, and stem diameter were measured. Yield data was also collected at about 3 months after planting.

2.4 Laboratory Analysis

Soil particle size distribution was determined by the Bouyoucos hydrometer method, using sodium hexametaphosphate as a dispersant [35], and bulk density was determined using the undisturbed core method (Klute et al., 1986). Soil pH was measured in a 1:1 soil-water suspension using a glass electrode meter. Organic carbon content was determined using the Walkley and Black wet digestion method [37] and total nitrogen was determined by the Kjeldahl distillation method [38]. Available phosphorus was determined using the Bray P-1 method [39]. Exchangeable Ca, Mg, K and Na were extracted with 1N ammonium acetate solution and then analyzed using Atomic Absorption Spectrophotometer (AAS) [40]. Micronutrients (Fe, Mn, Zn and Cu) were extracted using 0.1N HCl and analyzed with AAS [41].

2.5 Statistical Analysis

Soil and plant data were subjected to Analysis of Variance using the statistical software- SAS (version 9.3, 2011). Where significant differences were observed, Fisher's least significant difference was used to separate the means at 5% level of probability.

3. RESULTS

3.1 Initial Properties of the Soil and Organic Materials Used

Prior to the experiment, the soil was slightly acidic (5.8), with low concentrations of organic carbon (1.2%), available P (6 mg kg⁻¹) and total N (0.11%) (Table 1). Exchangeable Ca (1.08 cmol kg⁻¹), Mg (1.10 cmol kg⁻¹), K (0.37 cmol kg⁻¹) and Na (1.43 cmol kg⁻¹) were moderately low. It also contained fair amounts of micronutrients (Mn, Fe, Cu and Zn). The soil was sandy loam in texture with moderate bulk density (1.5 g cm⁻³).

Yam peel was highest in organic carbon (13.44%), total N (3.70%), Ca (0.06%) and Cu (8.30 mg kg⁻¹), whereas plantain peels recorded the highest total phosphorus (0.34%), Mg (0.26%), K (2.85%), Na (0.26%) and Zn (20.90 mg kg⁻¹). Cassava peels, however, had the lowest concentration of all the analyzed elements, except K and Fe. Howbeit, all the materials had low C/N ratios which is crucial for rapid microbial decomposition.

Table 1. Initial soil properties of the plot used for the field experiment

Parameter	Value
pH (H ₂ O)	5.80
Organic carbon (%)	1.20
Available phosphorus (mg kg ⁻¹)	6.00
Total nitrogen (%)	0.11
Exchangeable cations (cmol kg⁻¹)	
Calcium	1.08
Magnesium	1.10
Potassium	0.37
Sodium	1.43
Cation exchange capacity	3.98
Micronutrients (mg kg⁻¹)	
Manganese	118.80
Iron	109.90
Copper	1.64
Zinc	11.96
Particle size distribution (%)	
Clay	20.60
Silt	12.40
Sand	67.00
Textural class	Sandy loam
Bulk density (g cm ⁻³)	1.50

3.2 Effect of the Treatments on Soil Properties at 3 Months after Application

The amendments resulted in significant improvement ($P \leq 0.05$) in soil chemical properties, however, the degree was influenced by treatment type and form of application (Table 3). Whereas the pH of the unamended soil was slightly acidic (6.2), the use of organic amendment, irrespective of form, resulted in an increase in soil pH, with ground P recording the significantly highest value (7.4).

The application of ground (G-) treatments resulted in relatively higher increase in soil organic carbon, phosphorus, nitrogen and exchangeable cations, than the unground (U-) counterparts. Organic carbon was lowest in the control soil (1.19 %), but increased by about 12 to over 100% in the amended soils, with G-YCP recording the highest value (3.16%) which was significantly different from all the other treatments, except G-P. Also, the amended soils had relatively higher concentration of available phosphorus than the control (5.96 mg kg⁻¹) and G-Y resulted in the highest value (92.11 mg kg⁻¹). However, compared to the control, the increase was only statistically different ($P \leq 0.05$) for soils amended with ground treatments. Whereas the lowest nitrogen content was observed for the

unamended soil (0.10%), the least improvement was observed for those amended with U-C, whereas G-YCP resulted in the significantly highest value (0.33%).

The concentration of exchangeable cations varied significantly ($P \leq 0.05$) among the experimental soils. Whereas the unamended soil had the least concentrations of Ca, Mg, K and Na (1.08, 1.10, 1.30 and 1.43 cmol kg⁻¹ respectively), those amended with G-P had the highest Ca and Na (4.03 and 10 cmol kg⁻¹ respectively), but G-Y and G-YCP resulted in the highest Mg (5.59 cmol kg⁻¹) and K (3.71 cmol kg⁻¹) respectively.

3.3 Effect of the Applied Organic Amendments on the Growth and Yield of Okra

The interaction of treatment and form of application significantly affected ($P \leq 0.05$) the observed okra growth parameters, except the number of leaves (Table 4). Amending with both ground and unground organic materials enhanced the growth of okra in comparison with the control, however, the degree of improvement was greater for the former. The control plots had the lowest mean plant height (59.33 cm), number of leaves (6.33), leaf area (261.76 cm²), petiole length (18.50 cm) and stem diameter (10.3 mm). In contrast, plant height and number of leaves were highest for plants amended with G-YC (96.18 cm and 8.83 respectively), whereas leaf area and stem diameter were highest for those amended with G-Y (369.13 cm² and 15.7 mm respectively), and petiole length was longest for plants amended with G-P (26.67 cm).

Plants grown on amended plots had relatively higher okra yield performance than the control (Table 5). Although the mean number of fruit pods observed per plant was highest for those amended with G-Y (6.33), it was not statistically different ($P \leq 0.05$) from majority of the other amended plants. On the other hand, the control plants had the least number of pods (3.67) which was significantly lower than most of the other treatments. The mean fresh weight of the harvested pods ranged from 21.45 g (control) to 26.7 (G-P), however, the variation was not statistically significant ($P \leq 0.05$). Furthermore, the mean total yield per hectare was highest for plants amended with G-YC (14.39 t ha⁻¹); however, it was not significantly different ($P \leq 0.05$) from all the other treatments, except U-C, as well as the control which recorded the lowest yield (7.1 t ha⁻¹).

Table 2. Nutrient composition of cassava, plantain and yam peels used

Peel powder	pH (H ₂ O)	Total P (%)	O C (%)	Total N (%)	C:N Ratio	← Ca Mg K Na →		← Mn Fe Cu Zn →					
						(%)		(mg kg ⁻¹)					
Cassava (C)	7.90	0.20	3.60	1.05	3.44	0.30	0.08	0.76	0.04	41	597	5.40	19.10
Plantain (P)	8.69	0.34	6.70	2.90	2.32	0.40	0.26	2.85	0.26	99	586	5.60	20.90
Yam (Y)	8.89	0.24	13.44	3.70	3.64	0.06	0.10	0.75	0.06	63	311	8.30	19.80

OC: organic carbon, P: phosphorus; N: nitrogen; Ca: calcium; Mg: magnesium; Na: sodium; K: potassium; Mn: manganese; Fe: iron; Cu: copper; Zn: zinc

Table 3. Interaction effect of the treatment and form of application on soil properties at 3 months after treatment application

Interaction (Treatment x form)	pH (H ₂ O)	O.C (%)	Av .P (mg kg ⁻¹)	T.N (%)	← Ca Mg K →		Na	
					(cmol kg ⁻¹)			
G-C	6.30	1.82	12.67	0.18	2.99	1.22	1.36	4.36
G-P	7.40	2.49	35.65	0.23	4.03	4.40	1.25	10.00
G-Y	6.50	1.46	92.11	0.15	1.64	2.57	2.07	5.87
G-YP	7.00	2.03	24.83	0.21	3.12	5.59	3.58	7.80
G-YC	6.30	2.39	25.19	0.25	3.87	1.60	3.55	9.11
G-CP	7.30	1.73	31.49	0.18	3.59	5.13	2.46	8.73
G-YCP	6.80	3.16	83.61	0.33	2.55	3.69	3.71	6.96
U-C	6.40	1.49	6.53	0.13	1.39	1.92	1.31	1.88
U-P	6.60	1.62	6.43	0.15	1.87	1.58	1.91	1.86
U-Y	6.30	1.77	6.05	0.12	1.55	1.11	1.45	1.85
U-YP	6.60	1.33	7.02	0.16	1.18	1.58	1.96	2.24
U-YC	6.40	1.44	6.98	0.17	1.50	1.14	1.71	3.47
U-CP	6.40	1.70	8.73	0.14	2.12	1.82	2.27	1.60
U-YCP	6.60	1.75	9.09	0.18	1.52	1.29	2.35	1.58
Control	6.20	1.19	5.96	0.10	1.08	1.10	1.30	1.43
LSD	0.23	0.69	4.52	0.11	0.42	0.63	0.47	1.13

G- ground; U- unground; P= plantain peel; Y= yam peel; C= cassava peel; YP= yam + plantain peels; YC= yam + cassava peels; CP= cassava + plantain peels; YCP= yam + plantain +cassava peels; control = un-amended soils. LSD = least significant difference; OC = organic carbon; AvP = available P; TN = total nitrogen; Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; Mn= manganese; Fe = iron; Cu = copper; Zn = zinc. LSD= least significant difference ($P \leq 0.05$)

Table 4. The interaction effect of treatment and form of application on okra growth and yield parameters

Interaction (Treatment x form)	Plant height (cm)	No of leaves	Leaf area (cm ²)	Petiole length (cm)	Stem diameter (mm)
G-C	73.50	7.83	330.40	22.57	12.95
G-P	94.38	7.50	353.08	26.67	13.77
G-Y	95.50	8.00	369.13	26.10	15.70
G-YP	84.54	8.17	319.87	23.18	12.50
G-YC	96.18	8.83	362.13	26.00	14.45
G-CP	75.48	8.33	329.66	22.87	12.43
G-YCP	84.62	8.50	336.53	23.02	13.50
U-C	71.10	7.57	319.62	21.83	12.53
U-P	82.53	6.56	308.74	23.32	12.04
U-Y	80.55	6.86	342.50	22.93	12.32
U-YP	79.07	7.64	299.19	21.68	11.69
U-YC	82.62	7.58	311.07	22.33	12.41
U-CP	69.35	7.65	267.87	21.01	10.58
U-YCP	71.46	7.18	284.18	19.45	11.40
Control	59.33	6.33	261.67	18.50	10.03
LSD	20.81	NS	83.32	4.37	4.06

G- ground; U- unground; P= plantain peel; Y= yam peel; C = cassava peel; YP = yam + plantain peels; YC = yam + cassava peels; CP = cassava + plantain peels; YCP = yam + plantain +cassava peels; control = un-amended soils. LSD= least significant difference ($P \leq 0.05$), ns = not significantly different ($P \leq 0.05$)

Table 5. Interaction effect of the applied treatment on okra yield parameters

Interaction (Treatment x form)	Pods/plant	Weight of fruit (g)	Yield (t ha ⁻¹)
G-C	4.78	23.98	10.32
G-P	5.78	26.78	13.93
G-Y	6.33	24.55	13.99
G-YP	6.22	24.46	13.69
G-YC	6.00	26.54	14.33
G-CP	5.67	26.06	13.30
G-YCP	4.67	24.56	10.32
U-C	4.66	23.20	9.73
U-P	5.05	23.42	10.64
U-Y	4.83	23.74	10.32
U-YP	5.82	22.88	11.98
U-YC	5.15	22.80	10.57
U-CP	5.21	23.94	11.23
U-YCP	4.94	22.74	10.11
Control	3.67	21.45	7.08
LSD	1.33	NS	4.54

G- ground; U = unground; P= plantain peel; Y= yam peel; C = cassava peel; YP = yam + plantain peels; YC = yam + cassava peels; CP = cassava + plantain peels; YCP = yam + plantain +cassava peels; control = un-amended soils. LSD= least significant difference ($P \leq 0.05$), NS= not significantly different ($P \leq 0.05$)

4. DISCUSSION

The sole or combined use of yam, plantain and cassava peels as organic amendments resulted in significant improvement in soil chemical properties. Irrespective of the form of application, the amended soils had relatively higher pH than the control, and the increase was statistically significant for majority of the treatments. The

observed increase in soil pH may be attributed to the initial pH of the soil (acidic) and the organic materials (moderate to strongly alkaline) used for the study. Improvement in the pH of acidic soils after the addition of organic wastes has been widely reported, and may be due to the exchange of proton (H^+) between the soil and the added organic material [42–45]. In a field experiment conducted in eastern Nigeria, Iren et

al. [8] observed an increase in the pH of acidic soils after amending with 4 t ha⁻¹ of cassava peels compost. Likewise, Naramabuye and Haynes [46] conducted an experiment using 15 different plant, animal and industrial wastes on acidic soils in KwaZulu-Natal, South Africa and observed considerable improvement in soil pH by all the applied materials. Opala et al. [43] also had similar observation after amending acidic soils of Bukura and Kakamega in western Kenya with both farm yard manure and ground tithonia.

The amended soils had higher concentrations of organic carbon, nitrogen, phosphorus and exchangeable cations than the control. However, significant increase was mostly observed for soils amended with ground treatments, especially P, YP, YC and YCP. Among the sole treatments, the superior performance of plantain peels may be due to its relatively higher initial composition of majority of the analyzed nutrients and its lower C/N ratio which may have accelerated the rate of microbial decomposition and nutrient mineralization [47,48]. Furthermore, the better performance of ground materials over unground ones may be attributed to their increased contact with soil particles due to their finer particle size, which may have enhanced their rapid decomposition and nutrient mineralization [49]. This agrees with the findings of Okonkwo & Mbah [12] who evaluated the impact of five various forms of cassava peels on soil properties and observed relatively higher organic matter and macronutrients in soils amended with dried ground cassava peels than the unground. In the same vein, Doublet et al. [50] and Fanguero et al. [51] also observed higher degree of nutrient mineralization in soils amended with finer particles of cattle sludge than coarser ones. Surprisingly, Singh et al. [52] and Walpola et al. [53] observed reduction in nutrient mineralization with finer particles of gliricidia leaves and canola residues respectively, in the early stages of decomposition than coarser ones, however, the reverse was observed afterwards.

Irrespective of the organic material and form of application, okra growth and yield were considerably higher in the amended plots than the control. But despite the greater impact of ground treatments on soil chemical properties than unground ones, okra yield was not significantly different among the amended soils (except between GYC and UC). The appreciable performance of the unground amendments on the productivity of okra may be because their capacity as surface mulch may have provided a

more favorable environment for crop growth and yield, as the use of organic mulch has been reported to significantly improve soil moisture, reduce runoff, improve infiltration, reduce evaporation, suppress weed, improve crop growth and increase yield [27–29,54]. Likewise, findings by Ewere [54], Mubarak et al. [55] and Okonkwo & Mbah [12] also showed that the size of applied materials, did not significantly affect the yield of pineapple, fodder maize and maize respectively, in organically amended soils. It thereby implies that crop growth and yield can benefit from the addition of organic amendments, whether in fine or coarse form.

5. CONCLUSION

The sole or combined use of yam, plantain and cassava peels improved soil chemical attributes, however, those applied in powder form (ground) performed better than the unground (surface mulch). Nevertheless, grinding the materials did not seem to substantially increase crop yield because for most of the treatments, there were no significant differences in okra yield between ground and unground. Therefore, the time and cost of grinding soil inputs such as yam, plantain and cassava peels appear not to be justified by a commensurate increase in crop yield, hence, the use of these materials as organic mulch is rather encouraged.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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