Variations in soil properties and okra yield as influenced by different types and forms of organic amendments

Abstract

The use of readily available organic wastes for soil fertility improvement is a cheap and sustainable approach to the challenge of soil fertility decline plaguing agricultural soils in Africa. The effect of the sole or combined application of yam, cassava and plantain peels to improve soil properties and okra yield was evaluated in an on-farm study conducted at Akufo farm settlement. The experiment was laid out in a Randomized Complete Block Design with seven treatments applied at 4 t ha^{-1}, in 2 forms (ground and unground) and three replicates. After 3 months of application, soil samples were taken for analysis, after which okra seeds were sown. 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. Also, irrespective of treatment and form of application, okra yield was considerably improved by the applied amendments, with ground yam + cassava peels 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 surface mulch, have 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.

Key words: cassava peel**,** form of application, organic amendment, plantain peels, yam peels.

Introduction

The productivity and sustainability of agricultural soils in sub-Sahara Africa (SSA) are threatened by the widespread decline in soil fertility across the region (Agwe *et al.*, 2007; FAO, 2001). 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 (OECD and FAO, 2016). Traditionally, soil fertility management which 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 (Mwangi, 1996; Ogunjinmi *et al.*, 2017; Shehu *et al.*, 2015). As at 2014, about 65% of arable land, 30% of grazing land and 20% of forests in Africa are already severely degraded (Montpellier Panel, 2014), 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 (Mwangi, 1996; Iren *et al.*, 2015). 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 the recommended standards (Agwe *et al.*, 2007; Mwangi, 1996; World Bank, 2010). Organic fertilizers, made from readily available biodegradable wastes, are cheaper alternatives to soil fertility improvement (Ukoje and Yusuf, 2013). 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 (Albiach *et al.*, 2001; Okonkwo & Mbah, 2011; Opeyemi *et al.*, 2015).

Several food and agricultural wastes have been explored for use as organic fertilizers, including fruit and vegetable wastes (Kalemelawa *et al.*, 2012; Mercy *et al.*, 2014; Panwar, 2015), potato peels (Priyanga *et al.*, 2016); palm kernel cake wastes (Effiong *et al.*, 2012; Kolade *et al.*, 2005); rice husk (Demir and Gülser, 2015; Ogbo and Odo, 2011), 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 (Agama-Acevedo *et al.*, 2016; Iren *et al.*, 2015; Lawal *et al.*, 2014).

Many organic amendment studies utilized composting technology which are often too expensive and technical for indigenous farmers to adopt (Mustafa-Msukwa *et al.*, 2010; Mgbenka *et al.*, 2015; Kaza *et al.*, 2016). However, several authors have recorded good success from simpler approaches to the utilization of organic wastes as soil amendments, such as the use of organic wastes as surface or incorporated mulch (Amenkhienan, 2018; Ogban *et al.*, 2001; Okonkwo & Mbah, 2011; Teame *et al.*, 2017) and milling them into powder form for use as natural fertilizers (Adrija & Navni, 2018; Mercy *et al.*, 2014; Wazir *et al.*, 2018). Nevertheless, 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 (Gana, 2000; Yeshaneh, 2015). An on-farm experiment was therefore conducted to evaluate the ability of yam, plantain and cassava peels, applied as powder and surface mulch, to improve soil fertility and crop yield.

Materials and Methods

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 geographical located at longitude 3^o 48' E and latitude 7° 29' 35"N, at an altitude of 230.1 m above sea level. The study site is characterized by mean temperature of 28.7 ^oC, and rainfall of about 1,205 mm (Egbinola and Amobichukwu, 2013). The rainfall distribution is bimodal, with peaks in June and September.

Prior to this study, the field has been used for the raising orange and mango seedlings for the past 6 years.

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 bits measuring about 3 to 5 cm 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 nutritional compositions. The peels were 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.

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 a new planting season in both 2018 and 2019 (January to March). 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 and branches, leaf area, and stem diameter were measured. Yield data was also collected at about 3 months after planting.

Laboratory analysis

Soil particle size distribution was determined using the hydrometer method, using sodium hexametaphosphate as a dispersant (Bouyoucos, 1962), 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 (Walkley & Black, 1934) and total nitrogen was determined by the Kjeldahl distillation method (Kirk, 1950). Available phosphorus was determined using the Bray P-1 method (Bray & Kurtz, 1945). Exchangeable Ca, Mg, K and Na were extracted with 1N ammonium acetate solution and then analyzed using Atomic Absorption Spectrophotometer (AAS) (Bao, 2000).

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, least significant difference was used to separate the means at 5% level of probability.

Results

Initial properties of the soils and organic materials used for the study

The physicochemical properties of the experimental soils prior to treatment application is presented in Table 1. The soil was slightly acidic (5.8), with low levels of organic carbon (1.2%), available P (6 mg kg^{-1}) and total N (0.11%). Exchangeable Ca (1.08 cmol kg^{-1}), Mg (1.10 cmol kg^{-1}) and K (0.37 cmol kg^{-1}) and Na (1.43 cmol kg^{-1}) were moderately low. It also contained low concentrations of micronutrients (Mn, Fe, Cu and Zn). The soil was sandy loam with moderate bulk density (1.5 g cm^{-3}).

There was variation in the nutritional composition of the yam, plantain and cassava peels used for this study (Table 2). Organic carbon (13.44%), total N (3.70%), Ca (0.06%) and Cu (8.30 mg kg^{-1}) were highest in yam peels. 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 favorable for rapid microbial decomposition.

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Effect of the applied treatment on soil properties at 3 months after application

The amendments used significantly improved ($P \leq 0.05$) soil chemical properties, however, the degree of improvement 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,

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The application of ground treatments resulted in relatively higher increase in soil organic carbon, phosphorus, nitrogen and exchangeable cations, than the unground counterparts. Organic carbon was lowest in the control soil (1.19 %), but the amended soils showed about 12 to over 100% increase in the concentration of organic carbon, with ground YCP recording the highest value (3.16%). Also, the amended soils had relatively higher concentration of available phosphorus than the control (5.96 mg kg^{-1}), and ground Y resulted in the highest value (92.11 mg kg^{-1}). Howbeit, 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 unground C , and ground 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 ground P had the highest Ca and Na (4.03 and 10 cmol kg^{-1} respectively), and ground Y and YCP resulted in the highest Mg (5.59 cmol kg^{-1}) and K (3.71 cmol kg^{-1}) respectively.

Effect of the applied organic amendments on the growth and yield of okra

All the observed okra growth and yield were significantly affected ($P \leq 0.05$) by the interaction of treatment and form of application, except number of leaves and branches and pod weight (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 higher for the former. The control plots had the lowest mean plant height (59.33 cm), number of leaves (6.33), leaf area (261.76 cm^2), petiole length (18.50 cm), number of branches (1.33) and stem diameter (10.3 mm). In contrast, plant height and number of leaves were highest on plots amended with ground YC (96.18 cm and 8.83 respectively), whereas leaf area, number of branches and stem diameter were highest for those amended with G-Y (369.13 cm^2, 2.50 and 15.7 mm respectively), and petiole length was longest for plants amended with G-P (26.67 cm).

Irrespective of form of application, plants grown on amended plots had relatively higher yield performance than the control. Although the highest mean yield was recorded for plots amended with ground YC (14.39 t ha^{-1}); it was not significantly different ($P \leq 0.05$) from all the other plots, except those amended with unground C, as well as the control which recorded the lowest yield (7.1 t ha^{-1}).

Discussion

The field used for this study was slightly acidic, with very low soil organic carbon, nitrogen, available phosphorus and CEC, an indication of low soil fertility (Landon, 1991). Low soil fertility has been extensively reported across the agro-ecological zones of Nigeria (Adeboye *et al.*, 2009; Adiaha, 2017; Iren *et al.*, 2015; Shehu *et al.*, 2015). According to a report by the FAO (2001), about 62.76% of the agricultural lands in Nigeria are of low soil fertility, and this is attributed to the prevailing climatic conditions of high temperature and rainfall which enhance organic matter decomposition and nutrient leaching (IAFN, 2014; Onwuka, 2016), as well as the use of unsustainable farming practices which substantially depletes soil fertility (Agwe *et al.*, 2007; Montpellier Panel, 2014; Shehu *et al.*, 2015).

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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 value than the control. Improvement in soil pH after the addition of organic fertilizers has been widely reported. In a field experiment conducted in eastern Nigeria, Iren *et al.* (2015), observed an increase in the pH of acidic soils after amending with 4 t ha^{-1} of cassava peels compost. Likewise, Naramabuye and Haynes (2006) 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.* (2012) also had similar observation after amending an acidic soil with both farm yard manure and ground tithonia. The observed increase in soil pH may be partly attributed to the pH of the cassava, yam and plantain peels used for the study, which was moderate to strongly alkaline. It may also be due to the exchange of proton (H^+) between the soil and the added organic material (Angelova *et al.*, 2013; Benites. & Bot, 2005; Opala *et al.*, 2012).

The amended soils had higher concentrations of organic carbon, nitrogen, phosphorus and exchangeable cations than the control. Although the improvement in soil nutrients varied among the treatments, ground materials performed relatively better than unground ones. This may be because fine particle size materials are more easily incorporated into the soil than coarse ones, hence, are more easily decomposed by microorganisms and as a result, nutrients are more easily released (Poon and Schmidt, 2010). This agrees with the findings of Okonkwo & Mbah (2011) 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. (2010) and Fangueiro et al. (2008) also observed higher degree of nutrient mineralization in soils amended with finer particles of cattle sludge, than coarser ones.

Irrespective of type and form, okra growth and yield was considerably improved by the sole or combined application of yam, plantain and cassava peels. However, despite the greater impact of ground treatments on soil chemical properties than unground ones, okra yield was not significantly different among all the amended soils, except for one (between G YC and UC). Likewise, findings by Ewere (2017), Mubarak et al. (2009) and Okonkwo & Mbah (2011) also showed that the size of applied materials, did not significantly improve the yield of pineapple, fodder maize and maize respectively, in organically amended soils. The appreciable performance of the unground amendments on the productivity of okra may be attributed to their ability to serve as organic mulch which provides a favorable environment for crop growth and yield. 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 (Amenkhienan, 2018; Ewere *et al.*, 2017; Ogban *et al.*, 2001; Teame *et al.*, 2017). It thereby implies that crop growth and yield can benefit from the addition of organic amendments, whether in ground or unground form.

Conclusion

The sole or combined use of yam, plantain and cassava peels improved soil chemical attributes, howbeit, ground amendments performed relatively better than unground ones. The difference was however compensated for as both forms of treatments considerably improved okra growth and yield parameters beyond the control. This study therefore shows that the use of these readily available wastes as agricultural amendment represent a simple and effective means of disposing organic wastes, improving soil quality and enhancing crop performance.

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

Parameter	Value
pH (H_20)	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

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

Peel powder	pH (H_20)	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_2O)	O.C (%)	Av .P (mg kg^{-1})	T.N (%)	Ca (cmol kg^{-1})	Mg	K	Na
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	1.04	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.

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)	No of Branches	Stem Diameter (mm)	Yield ($t\ ha^{-1}$)
G-C	73.50	7.83	330.40	22.57	2.17	12.95	10.32
G-P	94.38	7.50	353.08	26.67	2.00	13.77	13.93
G-Y	95.50	8.00	369.13	26.10	2.50	15.70	13.99
G-YP	84.54	8.17	319.87	23.18	2.17	12.50	13.69
G-YC	96.18	8.83	362.13	26.00	2.33	14.45	14.33
G-CP	75.48	8.33	329.66	22.87	1.33	12.43	13.30
G-YCP	84.62	8.50	336.53	23.02	2.00	13.50	10.32
U-C	71.10	7.57	319.62	21.83	2.10	12.53	9.73
U-P	82.53	6.56	308.74	23.32	1.75	12.04	10.64
U-Y	80.55	6.86	342.50	22.93	1.66	12.32	10.32
U-YP	79.07	7.64	299.19	21.68	2.03	11.69	11.98
U-YC	82.62	7.58	311.07	22.33	2.00	12.41	10.57
U-CP	69.35	7.65	267.87	21.01	2.14	10.58	11.23
U-YCP	71.46	7.18	284.18	19.45	1.69	11.40	10.11
Control	59.33	6.33	261.67	18.50	1.33	10.03	7.08
LSD	20.81	NS	83.32	4.37	NS	4.06	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 ($P \leq 0.05$).