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 sole or combined application of yam, cassava and plantain peels on soil properties and okra yield 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 consist 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, soil samples were taken to determine the effect of the applied treatments on the soil properties, after which the soils 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 treatment and form of application, okra yield was considerably improved by the applied 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.

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 is 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 and used 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 effectiveness 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 geographically located at latitude 7° 29' 35"N and longitude 3^o 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 ^{o}C 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 had been used for the raising orange and mango seedlings in the past 6 years. 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}).

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. 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.

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.

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). 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 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, A. and 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

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

The amendments 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, 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 the amended soils showed about 12 to over 100% increase in the concentration of organic carbon, with G-YCP recording the highest value (3.16%) which was significantly higher than 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}). 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 U-C, and 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.

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

The interaction of treatment and form of application significantly affected ($P \leq 0.05$) all 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 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) 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, 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).

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}).

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 value than the control, and the increase was statistically significant for majority of the treatments. 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). Improvement in the pH of acidic soils 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 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 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 (Liu *et al.*, 2013; Lynch *et al.*, 2016). Furthermore, the better performance of ground materials over unground ones may be due to their increased contact with soil particles due to their finer particle size which may have enhanced their rapid decomposition and nutrient mineralization (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. Surprisingly, Singh et al. (2004) and Walpola et al. (2009) 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 (Amenkhienan, 2018; Ewere *et al.*, 2017; Ogban *et al.*, 2001; Teame *et al.*, 2017). 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. It thereby implies that crop growth and yield can benefit from the addition of organic amendments, whether in fine or coarse form.

Conclusion

The sole or combined use of yam, plantain and cassava peels improved soil chemical attributes, howbeit, those applied in powder form (ground) performed better than the unground (surface mulch). However, 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 okra yield, hence, the use of these materials as organic mulch is rather encouraged among indigenous farmers.

References

Adrija, S. and Navni, R. (2018). Efficacy of banana (Musa paradisiaca) and sweet lime (Citrus limetta) peels as natural fertilizer in herbs. *International Journal of Agriculture Sciences*, *10*(8), 5822–5825.

Agama-Acevedo, E., Sañudo-Barajas, J. A., Vélez De La Rocha, R., González-Aguilar, G. A. and Bello-Peréz, L. A. (2016). Potential of plantain peels flour (Musa paradisiaca L.) as a source of dietary fiber and antioxidant compound. *CYTA - Journal of Food*, *14*(1), 117–123. https://doi.org/10.1080/19476337.2015.1055306

Agwe, J., Morris, M. and Fernandes, E. (2007). Africa's Growing Soil Fertility Crisis: What Role For Fertilizer? In *Agricultural and Rural Development Note. World Bank, Washington DC.* (Issue 21).

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. (2001). Organic matter components and aggregate stability after the application of different amendment to a horticultural soil. *Bioresource Technology*, *76*, 125–129.

Amenkhienan, B. (2018). Influences of cassava peels on some soil physical properties , maize growth and yield in an Ultisols. *International Journal of Innovative Agriculture & Biology Research*, *6*(3), 31–38.

Angelova, V., Akova, V. I., Artinova, N. S. and Ivanov, K. (2013). The effect of organic amendments on soil chemical characteristics. *Bulgarian Journal of Agricultural Science*, *19*(5), 958–971.

Bao, S. D. (2000). *Soil agro-chemical analysis* (3rd ed). China Agriculture Press.

Benites, A. and Bot, J. (2005). *Key factors in sustained food production. In: The importance of soil organic matter: Key to drought-resistant soil and sustained food production* (FAO Soils). FAO, Rome, Italy.

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal*, *54*(5), 464–465. https://doi.org/10.2134/agronj1962.00021962005400050028x

Bray, R.H. and Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.*, *59*, 39–45.

Demir, Z. and Gülser, C. (2015). Effects of rice husk compost application on soil quality parameters in greenhouse conditions. *Eurasian Journal Soil Science, 4*(3), 185–19.

Doublet, J., Francou, C., Pétraud, J, P., Dignac, M. F., Poitrenaud, M. and Houot, S. (2010). Distribution of C and N mineralization of a sludge compost within particle-size fractions. *Bioresource Technology, 101*(4), 1254–1262. https://doi.org/10.1016/j.biortech.2009.09.037

Effiong, G. S., Ekong, U. J., Ibia, T. O. and John, N. M. (2012). Palm kernel cake and sawdust composts: chemical properties and effects on maize growth in acid sands of Uyo, Nigeria. *Archives of Applied Science Research*, *4*(3), 1255–1260.

Ewere, C. O., Iseghohi, I. O. and Gold, E. J. (2017). Effects of different mulch materials on soil properties, weed control, growth and yield of pineapple in Akure, Nigeria. *Fuoye Journal of Agriculture and Human Ecology*, *1*(2), 62–74.

Fangueiro, D., Chadwick, D. and Bol, R. (2008). Assessment of the potential N mineralization of different particle-size fractions in two dairy cattle slurries. *Journal of Plant Nutrition and Soil Science*, *171*(3), 313–315. https://doi.org/10.1002/jpln.200700226

FAO. (2001). *Status and Challenges of Soil Management in Nigeria*. http://www.fao.org/fileadmin/user_upload/GSP/docs/WS_managinglivingsoils/Status_Soil_Management_Nigeria_Ojuola.pdf

Gana, B. K. (2000). *Effect of agriculture on soil quality in Northeastern Ghana*. University of Saskatchewan.

Heerink, N. (2005). Soil fertility decline and economic policy reform in sub-Saharan Africa. *Land Use Policy*, *22*, 67–74.

Iren, O. B. Akpan , J. F., Ediene, V. F. and Asanga, E. E. (2015). Influence of cassava peels and poultry manure-based compost on soil properties, growth and yield of waterleaf (Talinum triangulare Jacq) in an ultisol of south-eastern Nigeria. *Journal of Soil Science and Environmental Management*, *6*(7), 187–194. https://doi.org/10.5897/JSSEM15. 0486

Kalemelawa, F., Nishihara, E., Endo, T., Ahmad, Z., Yeasmin, R., Tenywa, M. M. and Yamamoto, S. (2012). An evaluation of aerobic and anaerobic composting of banana peels treated with different inoculums for soil nutrient replenishment. *Bioresour. Technol, 126*, 375–382. https://doi.org/10.1016/j.biortech.2012.04.030

Kirk, P. L. (1950). Kjeldahl Method for Total Nitrogen. *Analytical Chemistry, 22*(2), 354–358. https://doi.org/10.1021/ac60038a038

Klute, A., Blake, G. R., and Hartge, K. H. (1986). Bulk density. In *Methods of soil analysis: Part 1—Physical and mineralogical Methods*. Soil Science Society of America. https://doi.org/10.2136/sssabookser5.1.2ed.c13

Kolade, O. O., Coker, A. O., Sridhar, M. K. C. and Adeoye, G. O. (2005). Palm kernel waste management through composting and crop production. *Journal of Environmental Health Research*, *5*(2), 81–85.

Kortei, N. K., Dzogbefia, V. P. and Obodai, M. (2014). Assessing the effect of composting cassava peel based substrates on the yield, nutritional quality, and physical characteristics of Pleurotus ostreatus (Jacq. ex Fr.) Kummer. *Biotechnology Research International*, 1–9. https://doi.org/10.1155/2014/571520

Lawal, B., Ossai, P. C., Shittu, O. K. and Abubakar, A. N. (2014). Evaluation of phytochemicals, proximate, minerals and anti-nutritional compositions of yam peel, maize, chaff and bean Coat. *International Journal of Applied Biological Research*, *6*(2), 21–37.

Mercy, S., Mubsira, B. S. and Jenifer, I. (2014). Application Of Different Fruit Peels Formulations As A Natural Fertilizer For Plant Growth. *International Journal of Scientific & Technology Research*, *3*(1), 300–307.

Montpellier Panel. (2014). No ordinary matter: Conserving, restoring and enhancing africa's soils. *Agriculture for Impact*, *Imperial College, London, December,* 40.

Mubarak, A. R., Ragab, O. E., Ali, A. A. and Hamed, N. E. (2009). Short-term studies on use of organic amendments for amelioration of a sandy soil. *African Journal of Agricultural Research*, *4*(7), 621–627.

Mwangi, W. M. (1996). Low use of fertilizers and low productivity in sub-Saharan Africa. *Nutrient Cycling in Agroecosystems, 47*(2), 135–147. https://doi.org/10.1007/bf01991545

Naramabuye, F. X. and Haynes, R. J. (2006). Effect of organic amendments on soil pH and Al solubility and use of laboratory indices to predict their liming effect. *Soil Science*, *171*(10), 754–763. https://doi.org/10.1097/01.ss.0000228366.17459.19

Ogban, P.I., Ekanem, T.P. and Etim, E. A. (2001). Effect of mulching methods on soil properties and growth and yield of maize in south-eastern Nigeria. *Tropical Agriculture*, *78*, 82–89.

Ogbo, F. C. and Odo, M. O. (2011). Potential of rice husk and cassava peel as carriers for bio-fertilizer production. *Nigerian Journal of Biotechnology*, *23*, 1–4.

Ogunjinmi, O. F., Kolawole, G. O. and Oyeyiola, Y. B. (2017). Soil fertility assessment and determination of potential ameliorants for an Alfisol under long-term continuous cultivation in southwestern Nigeria. *Journal of Soil Science and Environmental Management*, *8*(9), 159–163. https://doi.org/10.5897/JSSEM2017.0649

Okonkwo, C. I. and Mbah, C. N. (2011). Influence of different forms of Cassava peel on physicochemical properties of an Ultisol and yield of Maize (Zea mays L.) in Abakaliki

South Eastern-Nigeria. *Journal of Agriculture and Biological Sciences*, *2*(4), 78–83.

Opala, P. A., Okalebo, J. R. and Othieno, C. O. (2012). Effects of organic and inorganic materials on soil acidity and phosphorus availability in a soil incubation study. *ISRN Agronomy*, *2012*, 1–10. https://doi.org/10.5402/2012/597216.

Opeyemi, T. O., Ayodele, A. and Christopher, J. O. (2015). Effects of organic and inorganic soil amendments on growth performance of plantain (Musa paradisiaca L.). *African Journal of Agricultural Research*, *10*(3), 154–160. https://doi.org/10.5897/ajar2014.8645

Organization for Economic Co-operation and Development (OECD) and Food and Agriculture Organization (FAO). (2016). Agriculture in Sub-Saharan Africa: Prospects and challenges for the next decade. In *Agricultural Outlook: 2016-2025* (pp. 59–95). OECD Publishing.

Panwar, N. (2015). Studies on physicochemical characteristics and fertility of soil by addition of banana peels – waste management. *International Journal for Scientific Research & Development|*, *3*(1), 121–125.

Poon, D. and Schmidt, O. (2010). *Nutrient management reference guide*.

Priyanga, K., Reji, A., Bhagat, K. and Anbuselv, S. (2016). Production of Organic Manure from Potato Peel Waste. *International Journal of ChemTech Research*, *9*(5), 845–847.

Shehu, B. M., Jibrin, J. M. and Samndi, A. M. (2015). Fertility status of selected soils in the Sudan Savanna Biome of Northern Nigeria. *International Journal of Soil Science*, *10*, 74–83. https://doi.org/10.3923/ijss.2015.74.83

Singh, B., Rengel, Z. and Bowden, J. W. (2004). Canola residues decomposition: the effect of particle size on microbial respiration and cycling of sulphur in a sandy soil. *SuperSoil: 3rd Australian New Zealand Soils Conference, University of Sydney, Australia.*, 1–7.

Teame, G., Tsegay, A. and Abrha, B. (2017). Effect of Organic Mulching on Soil Moisture, Yield, and Yield Contributing Components of Sesame (Sesamum indicum L.). *International Journal of Agronomy*, 1–6. https://doi.org/10.1155/2017/4767509

Ukoje, J. A. and Yusuf, R. O. (2013). Organic fertilizer: The underestimated component in agricultural transformation initiatives for sustainable small holder farming in Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *6*(6), 794–801.

Walkley, A. and Black, I. A. (1934). An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, *37*(1), 29–38. https://doi.org/10.1097/00010694-193401000-00003

Walpola, B. C., Aruna, K. K., Senanayake, A. P. and Wanniarachchi, S. D. (2009). Gliricidia leaves decomposition: The effect of particle size on microbial respiration. *Bangladesh J. Agril. Res.*, *34*(3), 343–350.

Wazir, A., Gul, Z. and Hussain, M. (2018). Comparative Study of Various Organic Fertilizers

Effect on Growth and Yield of Two Economically Important Crops, Potato and Pea. *Agricultural Sciences*, *9*(6), 703–717. https://doi.org/10.4236/as.2018.96049

Yeshaneh, G. T. (2015). Assessment of farmers ’ perceptions about soil fertility with different management practices in small holder farms of Abuhoy Gara Catchemnt, Gidan District, North Wollo. *American Journal of Environmental Protection*, *3*(4), 137–144. https://doi.org/10.12691/env-3-4-4

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	pH	O.C	Av .P	T.N	Ca	Mg	K	Na
(Treatment x form)	(H_20)	(%)	(mg kg^{-1})	(%)	(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 ($P \leq 0.05$).