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Integrated Cocoa Pod Compost Affect Soil Physical and Chemical Properties and Yield of Okra in a Derived Savanna of Obubra Nigeria

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Abstract

Degradation and mineralization of organic materials are limited by their Carbon/ Nitrogen ratio. A study was carried out at the Cross River University of Technology, Calabar in 2020 and 2021. The experiment was aimed at integrating cocoa pod husk (CPH), moringa leaves (MLB) and poultry droppings (PD) into a compost (CMP) for Okra production. Three compost types: CPH+MLB+PD as CMP1, CPH+MLB as CMP2 and CPH+PD as CMP3 were composted for 60 Days in a ratio of 3:1:1, 3:1 and 3:1 respectively. Each compost was applied at the rates of 2.5, 5, 7.5 and 10 t ha^{-1} with a zero control and NPK 20.10.10 at 200 kg ha^{-1} as an inorganic check. Treatments were 14 which were laid out in RCBD and replicated 3 times. Results of the post-cropping indicated bulk density reduction from 1.33g/cm^3 of pre-treatment soils by all compost-applied soils to a range of 1.11-1.17g/cm^3 and increased porosity of 55.8% - 58.1% with highest bulk density of 1.3g/cm^3 from control. All rates of compost increased OM and available P above their critical level. Total N was above critical levels by all compost manures at rates of 7.5 and 10 t ha^{-1}. Exch. K, Mg, Ca and ECEC were increased with a reduction in exchangeable acidity over the controls. CPH+MLB+PD at 10 t ha^{-1} produced the highest yield of okra pods (8.6 t ha^{-1}). CPH +MLB + PD compost at 10 t ha^{-1} is best suited for soil properties improvement and optimal yield of okra in the study area.

Keywords: cocoa pod husk, integrated compost, soil properties, yield of okra, and mineralization

Introduction

Soil degradation and nutrient depletion are major drawbacks in sustainable crop production, particularly in tropical agroecologies. For optimal growth and yield of crops in all cases, adequate nutrient supply is imperative. However, the source of plant nutrients input into the soil has in most cases posed a challenge to continuous soil productivity. Chemical fertilizers have a high concentration of readily available nutrients upon application, but their continuous use adversely affects crop yield, physical and chemical properties of soil, microbial ecological balance and water as a result of runoff (Elemike, 2019). These fertilizers have also been found to decrease base saturation and increase acidification and physical degradation (Isherwood, 2008). The observed deleterious effects of chemical fertilizers have necessitated the exploration of organic sources of plant nutrients. This view is shared with that of Ayeni *et al.* (2010) who noted that research attention in tropical countries has shifted to the utilization of agro-industrial and organic wastes that are cheap, readily available and environmentally friendly. The effects of organic materials on tropical soils have been reported to include improvement in crop performance, soil fertility, soil organic matter and microbial activities (Blair *et al.*, 2005; Kundu *et al.*, 2006; Kekong 2020). In other findings, Abouel-Magd *et al.* (2005) reported that nutrients contained in organic manures are released more slowly and stored for a longer time in soils thus supporting better root development for higher crop yields. Furthermore, on imprints of organic manures, Cheng *et al.* (1988) reported improved soil aggregation and aggregate stability, reduced bulk density, increased porosity and water-holding capacity while Omenihu and Opara-Nadi (2015) reported favourable soil physical and hydrological properties as well as pH. The variability in the C/N ratio and other nutrients in organic wastes informed the thrust of this study which aimed at composting these materials and testing their nutrient availability to Okra vis-a-vis their soil conditioning properties. Okra is a well-cherished vegetable that is very responsive to optimum soil nutrient levels and suitable soil physical properties.

Materials and Methods

Location: 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 6^0 06' N and 8^0 18' E in the forest belt of Nigeria. Obubra is characterized by a mean annual rainfall density of 2250 mm - 2500mm with an annual temperature range of 25^{o}C – 28^{o}C.

Eup Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The treatments consisted of three types of composts: CMP1 – cocoa pod husk + moringa leaves + poultry droppings, CMP2 – cocoa pod husk + moringa leaves and CMP3 – cocoa pod husk + poultry droppings. Each compost type was applied at the rate of 2.5 t ha^{-1}, 5.0 t ha^{-1}, 7.5 t ha^{-1} and 10 t ha^{-1} with two controls as optimal(NPK 20.10.10 at 200 kg ha^{-1}) and absolute (0 t ha^{-1} compost) making 14 treatments.

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 while turning was done every 14 days for the first 8 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, composite soil samples were collected at random points within the experimental plot which was bulked using soil anger at the 0 – 20 cm. The samples were air-dried and sieved through a 2mm mesh ready for laboratory analysis.

Soil Analysis: Routine analysis was conducted for the composite sample to determine the particle size distribution using the Bouyouchos Hydrometer method as outlined by [22]. Soil pH using a glass electrode pH meter and soil N by the Macro Kjeldahl apparatus as described by [22]. Soil organic matter was analysed using the Walkley – Black wet Oxidation method as outlined by [23]. The excess was titrated against ferrous sulphate. The org. carbon was then calculated using the relationship. % org. C. = N (V1 – V2) 03 f. The % org. matter in soil = % org. C x 1.729. Soil phosphorus was determined using the Bray 1 method as described by [23].

Statistical Analysis: Analysis of variance (ANOVA) for RCBD was performed on the watermelon plant yield parameters using the computer software Genstat [24]. FLSD was calculated on the means at P>0.05 to separate the means

Results and Discussion

Soil properties before compost application

Nutrient composition of the organic materials and the compost, Table 2

The analysis of the materials indicated that the moringa leaf biomass contained 3.82% nitrogen which was higher than poultry droppings and cocoa pod husk with total N concentrations of 2.34% and 1.12% respectively. The concentration of P was highest in poultry droppings (2.26%) over the moringa leaf and cocoa pod husk with values were 1.15% and 1.10% respectively. The cocoa pod husk contains the highest K (13.4%) > moringa leaf (8.21%) > poultry droppings (3.28%). After composting, the compost from cocoa pod husk + moringa leaf + poultry dropping (CMP1) had a nutrient content of N, P, K of 2.88%, 1.48% and 1.66% respectively; cocoa pod husk + moringa leaf (CMP2) had a concentration of N, P, K of 2.61%, 0.55% and 1.20% respectively while compost of cocoa pod husk + poultry droppings (CMP3) had a nutrient content of 2.01%, 0.81%, 1.23% and 2.9% respectively of N, P, K and organic carbon (OC). 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) who stated that poultry droppings generally have the highest N, P, K, and nutrient content among all animal faecal 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); Price (2000) who reported low P in Moringa leaf as it should be for plant. 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.

Effect of Integrated Cocoa Pod Compost on Soil Physical Properties

The effect of integrated cocoa pod compost on soil physical properties is presented in Table 3. The application of cocoa pod-based compost of moringa leaf and poultry droppings did not affect the textural class of the soils after cropping. The pre-treatments soil texture of sandy loam was not changed for the two years of the compost application for the growth of the okra. Though there were slight variations in the percentages of sand, silt and clay, these differences were not significant to alter the textures for the two years. The soil bulk density and porosity were significantly affected by the compost application (Table 4) for the two-year experiment. In 2020, all the composts CMP1, CMP2 and CMP3 applied at the rates of 2.5t ha^{-1}, 5t ha^{-1}, 7.5t ha^{-1} and 10t ha^{-1} reduced the pre-compost application soil bulk density of 1.33g/cm^3 to a lower bulk density that ranged from 1.11g/cm^2 – 1.17g/cm^3 which was closely followed by

$1.23 g/cm^3$ bulk density soils produced in the inorganic optimal control (NPK 200kg ha^{-1}) and the highest bulk density of $1.3 g/cm^3$ was obtained in the control where neither compost nor NPK fertilizer was applied. The highest soil porosity values which ranged from 55.8% - 58.1% were obtained from the compost manure applied plots. This was closely followed by the porosity value from the inorganic NPK fertilizer applied plot (53.6 %) and the least soil porosity obtained from the control which value was 48.7%. In 2021, the three compost forms at all rates applied (Table 4) produced the lowest bulk density values which ranged from $1.13 g/cm^2$ – $1.17 g/cm^3$. This was followed by bulk density from soils applied with inorganic NPK fertilizer ($1.2 g/cm^3$) and the highest value of bulk density was $1.37 g/cm^3$ from the soils that did not receive any soil manure. The soil porosity followed the same trend as the bulk density. The textural class of the experimental soil did not change with the application of compost. This is so because the texture is determined by the parents' material as influenced by climate over time. Troech and Thompson (1993) reported that the texture of the residual soil is closely related to the grain size of the parent rock. Organic manure can only improve the productivity of a soil textural class. The reduction in the soil bulk density of the experimental soils by all compost types and rates is a primary function of organic manures as a soil conditioner. Organic manure has a direct effect on soil physical properties by improving water transmissivity and root penetration. Ogunwole (2005) reported a significant reduction of soil penetration resistance by FYM; Sultani *et al*. (2007) observed a 5% reduction in soil bulk density by using green manure. Reduction of soil bulk density using different organic materials has also been reported by Zhao *et al*. (2009) using Straw, Tester, (2006) using compost and Sewage and Kekong *et al.,* (2008) who used poultry manure and cow dung. The compost manure application produced good porosity for crops while the inorganic fertilizer and the control treatments produced only fair porosity. This is in line with the ratings of Kichinkii (1965) who suggested that porosity over 50% is for good soils, 45-50% is fairly satisfactory and 40-45% is unsatisfactory.

Effect of Integrated Cocoa Pod Compost on Soil Chemical Properties

The post-cropping soil chemical properties as influenced by integrated cocoa-based compost as presented in Table 4 indicated that pH, OM, Total N and Av. P were improved. All compost types and rates of 2.5t ha^{-1} up to 10t ha^{-1} increased the pH from the pre-treatment soils of 5.6 in 2020 to pH that ranged from 5.83-6.23 corresponding to moderately acid to slightly acid. The control and inorganic fertilizer soil pH were 5.42 and 5.43 respectively. In 2021, the soil reaction showed the same trend as compost-treated soils raised the initial pH of 5.4 to pH values ranging from 5.81 - 6.22 with compost at a rate of 7.5 t ha^{-1} of each compost type producing the highest pH values. Soil organic matter content of the soil was raised by all compost-applied treatments over the inorganic NPK fertilizer and the control that received no manure. The values ranged from 1.61% - 1.98% for 2020 with the application of 10 t ha^{-1} of the compost producing the highest values and the least value produced in the control. In 2021 the organic matter content in soils showed the same trend with the least value obtained in the control and the highest value of 2.10% was obtained in 10 t ha^{-1} of compost (CMP1). Total N content ranged from 0.11% - 0.21% for soils that received the compost from 5.0 t ha^{-1} to 10 t ha^{-1} in 2020 with lower content in the control, the inorganic fertilized soils and compost rates of 2.5tha^{-1}. In 2021 the N content showed the same pattern as that of 2020. The available P value for all the compost-treated soils ranged from 16.40 mg/kg - 26.22 mg/kg showing marginal sufficiency to sufficiency levels. The P for control was low (6.82 mg/kg) in 2020 and 7.24 mg/kg in 2021. The marginal to sufficiency P levels for all compost-treated soils in 2021 ranged from 15.98 mg/kg – 27.22 mg/kg. The exchangeable cations (Table 5) showed that exch. K value ranged from 0.50 cmol/kg-0.83 cmol/kg for all the compost-treated soils in 2020 and 0.51cmo1/kg - 0.79 cmo1/kg in 2021. The exchange Ca and Mg content for all compost-applied soils ranged from 2.98 cmo1/kg - 4.44 cmol/kg and 0.51cmol/kg - 0.80cmol/kg respectively for Ca and Mg in 2020. In 2021, the exch. Ca and Mg contents for compost-treated soils were 2.89 cmol/kg - 4.54 cmol/kg and 0.58cmol/kg - 0.79cmol/kg respectively for Ca and Mg. The exchangeable acidity in all compost applied plots ranged from 0.12cmol/kg - 0.10 cmol/kg with the least of 0.10 cmol/kg obtained from the three compost types at rates of 7.5 t ha^{-1} and 10 t ha^{-1} in both 2020 and 2021. The highest exch. The acidity level was in the control with 0.14 cmol/kg. The ECEC from the compost-applied soils ranged from 3.84 cmol/kg – 5.98 cmol/kg in 2020 and 4.20 – 5.88 cmol/kg in 2021. The initial pH of 5.6 in 2020 and 5.4 in 2021 was moderately acidic and strongly acidic. The compost manure raised these pH values to slightly acidic (Chude *et al*., 2011). This increase in pH by the compost is one of the major influence of organic manure on soil reaction. The pH increased with the rate of the compost up to 10 t ha^{-1}. This increase in pH due to the compost manure may be attributed to the release of exchangeable cations that reduced H^+ and Al^{3+} solubilities in the soils which confirms the findings of Ano and Ubochi (2007). Lower pH in the control and inorganic fertilizer soils may have arisen from leaching of N which is more pronounced in low organic matter soils. Organic matter that ranged from 1.61% - 1.98% in 2020 and 1.65% - 2.10% in 2021 were above the critical limits of 1.5% (Sobulo and Osiname, 1981) whereas the OM content of soils from the control (0 compost) and the inorganic fertilizer plots of 1.28 and 1.48 respectively were below the critical limits. The studies of Anikwe (2010) and Mbah *et al.* (2017) support the result of this increase in OM due to integrated compost application as they noted that retention or incorporation of crop residues may increase carbon input while decreasing the rate of carbon loss from the soil. The total N from the compost at rates of 2.5t ha^{-1} and 5.0 t ha^{-1} and the total N for the control 0 t ha^{-1} manure and the inorganic fertilizer soils were below the critical limits of sufficiency levels of total N in postharvest soils. Available P in all compost-treated soils and the inorganic NPK fertilizer treatment in both years show sufficiency levels except in the control whose value represents a deficiency level considering the critical level for crop production of 10 -16 mg/kg (Sobulo and Osiname, 1981). The increase in the amount of N and P due to the compost application can be attributed to the high rate of mineralization of this amendment due to its high nutrient contents (Table 2). These increases due to organic amendment in post-cropping soils in N and P were also reported by Adegbite and Olayinka (2010), Adeyemi and Ojeniyi (2005), Kekong *et al.,* 2010 and David (2006). The exchangeable cation of K indicated that the soils were generally rich in K considering the 0.16 - 0.25cmol/kg critical level for crop production (Adeoye and Agboola) or 0.31-0.60 cmol/kg as moderately high (Chude *et al*., 2011). The increase in exch. Ca and Mg showed a considerable increase with increasing rate of the compost over the control (0 t ha^{-1} compost). The increase can be attributed to the mineralization of the compost materials. This trend of nutrient release has been reported by Boateng *et al*., 2009. The increase in ECEC for both years can be accounted for by the high Ca levels obtained from the manures. Organic manure has been reported to be the major contributor to the CEC of soils. Brady and Weil, (2014) reported that organic manure accounts for 50-90% of cation adsorbing power of mineral surface soils. The decreases in Exchangeable acidity (EA) could also be seen as the effect of the high level of Ca generated in the soils by the compost. The possible complexation of Al^{3+} and H^+ by soluble organic matter explains why EA was reduced in all compost-treated plots. This result aligns with the postulations of Narambuye and Haynes (2006) who stated that at lower pH where Al^{3+} is highly soluble, the addition of organic manures will reduce Al^+ concentration from the soil solution. The bonding of Al^{3+} by soluble organic matter was reported by Berek *et al*. (1995).

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. 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 rates and the least number of fruits was obtained from the control without manure. The weight of each fruit was higher in all compost-treated plots and NPK 200 kg 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 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} respectively for 2020 and 2021. The yield response of Okra to the integrated cocoa pod husk compost is an indicator of the nutrients mineralized from the rich compost and the improvement in the soil's physical properties of this experiment. These physical properties of reduced compaction and increased porosity as well as the increase in pH could have facilitated the availability of nutrients especially phosphorus and a likely reduction in the rate of nitrogen leaching. Cocoa pod husk and other manures have been reported to increase crop yields: Adegunloye and Olotu (2018) reported tallest plants of maize in response to cocoa pod composted with poultry droppings over inorganic NPK and control; Akanni and Ojeniyi (2007) increased growth and nutrients uptake of kola seedlings; Kris Fidelis and Rajashekhar Rao (2017) who reported increased growth rate of cocoa seedlings due to composted poultry dropping. The highest number of pods of okra per plant and highest pod of okra yield per unit area from 10 t ha^{-1} composted cocoa pod husk + moringa leaf + poultry droppings in this experiment over the inorganic fertilizer and the control corroborate the findings of Kayode *et al*. (2013) who reported highest plant and root dry matter yield of Roselle from a compost of cocoa pod husk + poultry dropping + Neem leaves. Similarly, Adeleye and Ayeni (2010) reported the highest grain and stem yield of maize from cocoa pod husk + poultry droppings while Kekong (2020) reported increased growth and yield of watermelon using combined rice mill wastes and poultry droppings.

Conclusion

The use of integrated compost of cocoa pod husk (CPH), moringa leaf (MLB) and poultry dropping (PD) as a soil conditioner improved soil physical properties of pH, OM, total N, available P and exchangeable cations and significantly increased yield and yield components of okra. The application of the integrated compost (CPH + MLB + PD) at 10t ha^{-1} being the most effective in optimal improvement in soil physical and chemical properties and producing the highest okra pod yield per unit area consecutively for two years is recommended for okra production in

References

Adegbite, E.A and A. Olayinka (2010) Effect of Organic Amendments and Nitrogen on Microbial Activity, Nitrogen and Phosphorus Mineralization in an Alfisol. *Nigeria Journal of Soil Science* 20 (2), 87-91.

Adegunloye, D. V. and Olotu, T. M. (2018) Effect of Compost Made from Decomposing Cocoa pod and Animal Dung on the Yield of Maize Crop. *Journal of Environment, Agriculture and Biotechnology.* 3 (4), 1166 -1174.

Adeleye, E.O and Ayeni L.S. (2010) Effect of Cocoa Pod Ash And Poultry Manure Combinations on Soil and Plant Nutrient Contents and Performance of Maize – Screen House Experiment. *Researcher*, 2(12): 51 – 56.

Adeoye, G. O. and Agboola A. A. (1985). Critical levels for soil pH, available P, K, Zn and Mn in Sedimentary soil of Southerneatern Nigeria. *Fertilizer Research* 6: 65-71.

Akanni, D.I and Ojeniyi S.O. (2007). Effect of Different levels of Poultry Manure on Soil Physical Properties, Nutrient Status, Growth and Yield of Tomato.(Lycopersicom esculentum). *Research Journal of Agronomy* 1:1 – 4.

Anikwe, M.A.N. (2010). Carbon storage in soils of southeastern Nigeria under different management practices. *Carbon Balance and Management* 5(1): 5.

Ano, A. O. and Ubochi, C. I. (2007) Understanding Soil and Plant Nutrition. 260pp.

Ano, A.O and Agwu, J.A. (2005) Effects of animal manures on selected soil properties. *Nigeria Journal of Soil Science* 15: 14 – 19.

Aslam, M., F. Anwar, R. Nadeem, U. Rasmid, T. G. Kazi and M. Nadeem, (2005). Mineral Composition of *Moringa oleifera* leaves and pods from Different Regions of Punjab, Pakistan. *Asian Journal of Plant Science,* 4:417-421.

Berek, A. K., B. Radjagukguk and A. Maas, (1995). The Effect of Different Organic Materials on the Alleviation of AI Toxicity in Soybean on a Red-yellow Podzolic Soil. In: Plant-soil Interaction at low pH: Principles and Management, (Eds R. A. Date, N. J. Grundon, G. E. Rayment, M. E. Probert) Pp. 579-584.

Blair, N. R., Fulkner, D., Till, A. R. and Poulton, P. R. (2005) Long Term Management Impacts on Soil Carbon, Nitrogen and Physical Features. *Soil and Tillage Research* 91: 30 – 38

Boateng, S. A. J. Zickermann and M. Kornahrens (2006). Poultry Manure Effect on Growth and Yield of Maize. *West African Journal of Applied Ecology 9* (Jan. – Jun. 2006) 11 pp – ISSN: 0855 – 4307.

Booth, F. E. M. and G. E. Wickens (1988). Non-Timber Uses of Selected Arid Zone Trees and Shrubs in Africa. FAO Conservation Guide, Rome pp 92-101.

Brady, N. C. and R. R. Weil (2014). The Nature and Properties of Soils. Fourteenth Edition Dorling Kindersley (India) Pvt. Ltd 1046 Pp.

Cheng, F. J., Yang, D. Q. and Wu, Q. S. (1998) Physiological Effects of Humic Acids on Drought Resistance in Wheat. *Chinese Journal of Applied Ecology* 6: 363 – 367

Chris Fidelis B. K. and Rajashekhar Rao (2017) Enriched Cocoa Pod Composts and their Fertilizing Effects on Hybrid Cocoa Seedlings. *International Journal Recycling Organic Waste in Agriculture*, 6:99–106.

Davis, A. S., D. F. Jacobs, and K. E. Wight Man. (2006). Organic Matter Amendment of Fallow Forest Tree Seedlings Nursery Soils Influences Soil Properties and Biomass of Sorghum Cover Crop. Purdue University, West Lafayette, IN. pp. 112 – 118.

Elemike, E.E., Uzoh, I.M., Onwudiwe, D.C. and Babalola, O.O. (2019) The role of nanotechnology in the fortification of plant nutrients and improvement of crop production. Applied Science. 9, 499pp

Fairhurst T. (ed) (2012) Handbook for Integrated Soil Management. Africa Soil Health Consortium. Nairobi. 154pp

FAOSTAT (2016). Food and Agriculture Organization of the United Nations Statistics Division. Available at: http://faostat3.fao.org/download/Q/QC/E.

Isherwood, K. F. (2008) Fertilizer use and the Environment. INTERNATIONAL Fertilizer Industry Association. Revised Edition Paris, France February 2008 – 187pp.

Kachinskii, N. A. (1965) Soil Physics: P.I. Moscow, In Zonn, S. V. (1986). Tropical and Sub-Tropical Soil Science: Moscow – Mir Publishers, 718pp.

Kayode, C.O., Akanda, M.O, Adekunle, A.F., Ogunleti, D.A. and Adeoye, G.O. (2013) Effect of Cocoa Pod Husk Based Compost on the Growth, Nutrients Uptake and Dry Matter Yield of Roselle. *Nigeria Journal of Soil Science,* 23(1) 136-144.

Kekong, M. A. (2020) Combined Rice Mill and Poultry Wastes Affect Some Soil Chemical Properties and Water Melon (*Citriluslanatus)* Yield in a Derived Savanna of Obubra, Southern Nigeria. Department of Agronomy Cross River University of Technology, Calabar, Nigeria. *Journal of Agriculture and Veterinary Science*. 13(10), 45-51.

Kekong, M. A., S. A. Ayuba and A. Ali (2008). Effect of Cow Dung and Poultry Dropping on Soil Physical Properties and Yield of Garden Egg in Makurdi and Obubra, Nigeria Soil and Water Resources Management for Sustainable Environment and Economic Empowerment. Proceedings of the 32nd Annual Conference of the Soil Science Society of Nigeria, Yola. 10-14 2008. Pp 257-263.

Kekong, M. A., S. A. Ayuba and A. Ali (2010). Effect of Cow Dung and Poultry Dropping on Soil Chemical Properties and Yield of Garden Egg *(solanum spp.)* in the Sub-Humid Guinea Savannah and Rainforest Belt of Nigeria. *Nigeria Journal of Soil Science*, 20 (1): 97-104.

Kundu, S. R., Bhattacharyya, V., Parkash, B. N. and Gupta, H. S. (2006) Carbon Sequestration and Relationship between Carbon Addition and Storage under Rainfed Soybean Wheat Rotation in a Sandy Loam Soil of Himalayas: *Soil and Tillage Research*, 92:87-95

Mbah, C.N., Njoku, C., Okolo, C.C., Attoe, E. and Osakwe, U.C. (2017). Amelioration of a Degraded Ultisol with Hardwood Biochar: Effects on Soil Physico-Chemical Properties and Yield of Cucumber (Cucumis sativus L). *African Journal of Agricultural Research* 12: 1781 - 1792.

Naramabuye, F. X. and R. J. Haynes (2006). Short-term Effects of Three Animal Manures on Soil pH and Al Solubility. *Australian Journal of Soil Research*, 15 pp.

Ogunwole, J.O (2005) Changes in an Alfisol under long-term Application of Manure and Inorganic Fertilizer. *Soil Use and Management* 21(2), 260-261.

Omenihu, A. A. and Opara-Nadi, O. A. (2015) Changes in Tropical Ultisol under Different Management Systems in Southeastern Nigeria 1. Soil Physical and Hydrological Properties. *Nigeria Journal of Soil Science,* 25: 70-79

Patterson, P.H., E.S. Lorenz, and W.D. Weaver, Jr. 1998.

Litter Production and Nutrients from Commercial Broiler Chickens. *Journal of Applied Poultry Research*, 7:247-252.

Price, M. L. (2000). The Moringa Tree. ECHO Technical Note. Echonet. Org / tropical ag/moringa 3. htm.

Sobulo, R.A. and O.A.I. Osiname (1982). Fertilizer use in the Tropics- Nigerian Experience, In Soil Tilth and Post Clearing Land Degradation in the Humid Tropics. Proceeding of International Society of Soil Science, commission iv-vi SSSN 21-26 July Ibadan.

Sultani, M. I., M. A. Gill., M. M. Anwar and M. Athar (2007). Evaluation of Soil Physical Properties as Influenced by Various Green Manuring Legumes and Phosphorus Fertilizer under Rainfall Conditions. *International Journal of Environment, Science and Technology,* 4(1), 109 -118.

Tester, C.F. (2006). Organic Amendment Effects on Physical and Chemical Properties of a Sandy Soil. *Journal Soil Science Society* JD4 54 (3), 827-831.

Troeh, F. R. and L. M. Thompson (1993). Soils and Soil Fertility. Fifth Edition. Oxford University Press, New York 462 pp.

Zhao, Y., P. wang, L. Jianlong, Y. Chen, X. Ying and S. Liu (2009). The Effects of Two Organic Manure on Soil Properties and Crop Yield on a Temperate Calcareous Soil under a Wheat–Maize Cropping System. *European Journal of Agronomy,* 31 (1), 36 - 42.

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
Exch. Ca (cmol kg^{-1})	2.60	2.52
Exchange. Mg (cmol kg^{-1})	0.22	0.21
Exchange. Mg (cmol kg^{-1})	1.01	1.20
Exchange Na (cmol kg^{-1})	0.17	0.18
Exchange. Acidity	2.75	2.73
CEC (cmol kg^{-1})	1.8	6.21

Table 3: Effect of Integrated Cocoa Pod Compost on Some Physical Properties of the Soil

TREATMENT		**SAND (g/kg)**	**SILT (g/kg)**	**CLAY (g/kg)**	**TEXTURE CLASS**	**BULK DENSITY g/cm^{3}**	**POROSITY %**
Control	Otha^{-1}	854	84	62	SL	1.36^{b}	48.7^{b}
CMP 1	2.5 tha^{-1}	852	83	65	SL	1.17^{a}	55.8^{a}
CMP 1	5.0 tha^{-1}	850	85	65	SL	1.14^{a}	57.0^{a}
CMP 1	7.5 tha^{-1}	851	86	63	SL	1.13^{a}	57.3^{a}
CMP 1	10 tha^{-1}	845	87	68	SL	1.13^{a}	57.3^{a}
CMP 2	2.5 tha^{-1}	844	88	68	SL	1.15^{a}	56.6^{a}
CMP 2	5.0 tha^{-1}	820	111	69	SL	1.14^{a}	57.0^{a}
CMP 2	7.5 tha^{-1}	818	114	68	SL	1.14^{a}	57.0^{a}
CMP 2	10 tha^{-1}	848	91	61	SL	1.13^{a}	57.3^{a}
CMP 3	2.5 tha^{-1}	843	89	68	SL	1.14^{a}	57.0^{a}
CMP 3	5.0 tha^{-1}	825	92	83	SL	1.14^{a}	57.0^{a}
CMP 3	7.5 tha^{-1}	827	95	78	SL	1.11^{a}	58.1^{a}
CMP 3	10 tha^{-1}	830	92	88	SL	1.11^{a}	58.1^{a}
OPT. CONTROL	NPK 200kgha^{-1}	849 Ns	88 NS	63 NS	SL NS	1.23^{ab}	53.6^{ab}
2021							
Control	Otha^{-1}	852	85	63	SL	1.37^{c}	48.3^{c}
CMP 1	2.5 tha^{-1}	851	85	64	SL	1.16^{a}	56.2^{a}
CMP 1	5.0 tha^{-1}	820	102	78	SL	1.15^{a}	56.6^{a}
CMP 1	7.5 tha^{-1}	818	104	78	SL	1.15^{a}	56.6^{a}
CMP 1	10 tha^{-1}	800	116	84	SL	1.14^{a}	57.0^{a}
CMP 2	2.5 tha^{-1}	808	118	74	SL	1.17^{a}	55.8^{a}
CMP 2	5.0 tha^{-1}	797	122	81	SL	1.15^{a}	56.6^{a}
CMP 2	7.5 tha^{-1}	793	124	83	SL	1.14^{a}	57.0^{a}
CMP 2	10 tha^{-1}	820	103	77	SL	1.14^{a}	57.0^{a}
CMP 3	2.5 tha^{-1}	821	102	77	SL	1.16^{a}	56.2^{a}
CMP 3	5.0 tha^{-1}	802	119	79	SL	1.13^{a}	57.3^{a}
CMP 3	7.5 tha^{-1}	810	120	70	SL	1.14^{a}	57.0^{a}
CMP 3	10 tha^{-1}	784	121	95	SL	1.13^{a}	57.3^{a}
Opt. Control	NPK 200kg ha^{-1}	816 NS	112 NS	96 NS	SL	1.28^{b}	51.7^{b}

Table 4: Influence of Integrated Cocoa Pod Compost on Soil Chemical Properties

TREATMENT (COMPOST/RATE)		PH (H_{20})	OM (%)	TOTAL N %	AV.P (mg/kg)
2020					
Control	(no compost) 0tha^{-1}	5.42	1.28	0.07	6.82
CMP 1	2.5 tha^{-1}	5.83	1.68	0.09	16.66
CMP 1	5.0 tha^{-1}	6.16	1.86	0.11	19.44
CMP 1	7.5 tha^{-1}	6.21	1.79	0.19	21.32
CMP 1	10 tha^{-1}	6.23	1.98	0.27	26.22
CMP 2	2.5 tha^{-1}	5.90	1.59	0.08	17.04
CMP 2	5.0 tha^{-1}	6.11	1.80	0.13	18.98
CMP 2	7.5 tha^{-1}	6.15	1.98	0.18	20.88
CMP 2	10 tha^{-1}	6.15	1.98	0.20	23.68
CMP 3	2.5 tha^{-1}	5.87	1.61	0.10	16.40
CMP 3	5.0 tha^{-1}	5.98	1.76	0.16	19.01
CMP 3	7.5 tha^{-1}	6.23	1.88	0.27	22.02
CMP 3	10 tha^{-1}	6.22	1.89	0.18	24.92
NPK	200kg ha^{-1}	5.43	1.48	0.19	15.02
2021					
Control	(0tha^{-1} no compost)^{1}	5.30	1.31	0.16	7.24
CMP 1	2.5 tha^{-1}	5.82	1.69	0.19	15.98
CMP 1	5.0 tha^{-1}	6.12	1.98	0.14	18.88
CMP 1	7.5 tha^{-1}	6.20	1.97	0.19	24.44
CMP 1	10 tha^{-1}	6.21	1.10	0.21	27.22
CMP 2	2.5 tha^{-1}	5.84	1.65	0.08	16.28
CMP 2	5.0 tha^{-1}	6.12	1.81	0.11	17.98
CMP 2	7.5 tha^{-1}	6.11	1.96	0.18	21.22
CMP 2	10 tha^{-1}	6.13	1.98	0.20	23.44
CMP 3	2.5 tha^{-1}	5.81	1.60	0.08	16.22
CMP 3	5.0 tha^{-1}	6.10	1.80	0.13	18.84
CMP 3	7.5 tha^{-1}	6.22	1.97	0.18	23.41
CMP 3	10 tha^{-1}	6.22	1.97	0.18	22.98
NPK	200kg ha^{-1}	5.56	1.46	0.08	14.88

Table 5: Exchangeable Cation as Effected By Integrated Cocoa Pod Compost

TREATMENT (COMPOST/RATE)		K	Ca	MG	EA	ECEC	BALANCE SATURATION (%)
		------------------------CMOL/KG-----------------					
2020							
Control	(no compost)	0.41	1.82	0.34	0.14	2.55	
CMP 1	2.5 tha^{-1}	0.50	2.98	0.52	0.11	3.84	
CMP 1	5.0 tha^{-1}	0.64	3.88	0.64	0.10	4.88	
CMP 1	7.5 tha^{-1}	0.63	4.53	0.62	0.11	5.42	
CMP 1	10 tha^{-1}	0.72	4.50	0.78	0.10	5.98	
CMP 2	2.5 tha^{-1}	0.59	3.10	0.51	0.12	4.01	
CMP 2	5.0 tha^{-1}	0.64	3.22	0.60	0.10	4.90	
CMP 2	7.5 tha^{-1}	0.81	4.20	0.70	0.10	5.88	
CMP 2	10 tha^{-1}	0.83	4.40	0.73	0.11	5.92	
CMP 3	2.5 tha^{-1}	0.62	2.89	0.60	0.11	4.04	
CMP 3	5.0 tha^{-1}	0.66	3.90	0.68	0.11	4.88	
CMP 3	7.5 tha^{-1}	0.78	4.38	0.80	0.10	5.60	
CMP 3	10 tha^{-1}	0.76	4.44	0.76	0.10	5.70	

NPK	200kg ha^{-1}	0.48	2.40	0.40	0.13	3.70	
2021							
Control	(no compost)	0.39	1.79	0.32	0.13	2.70	
CMP 1	2.5 tha^{-1}	0.51	2.89	0.58	-.11	4.20	
CMP 1	5.0 tha^{-1}	0.62	3.64	0.62	0.10	4.82	
CMP 1	7.5 tha^{-1}	0.64	4.48	0.64	0.10	5.20	
CMP 1	10 tha^{-1}	0.70	4.54	0.75	0.10	5.80	
CMP 2	2.5 tha^{-1}	0.57	3.10	0.61	0.11	3.89	
CMP 2	5.0 tha^{-1}	0.66	3.92	0.68	0.11	4.84	
CMP 2	7.5 tha^{-1}	0.74	4.20	0.73	0.10	5.02	
CMP 2	10 tha^{-1}	0.79	4.24	0.71	0.10	5.88	
CMP 3	2.5 tha^{-1}	0.60	2.90	0.60	0.12	4.10	
CMP 3	5.0 tha^{-1}	0.70	3.78	0.72	0.11	4.80	
CMP 3	7.5 tha^{-1}	0.73	4.22	0.79	0.10	4.88	
CMP 3	10 tha^{-1}	0.72	4.21	0.78	0.10	5.60	
NPK	200kg ha^{-1}	0.46	2.60	0.44	0.13	3.66	