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Evaluating the effects of Biochar and decomposed Poultry Manure on Soil chemical properties, Growth and Yield of Amaranthus (*Amaranthus cuentus*) in Ebonyi State

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Abstract

A Greenhouse trial was conducted in Research farm of Akanu Ibiam Federal Polytechnic to investigate the effects of composted poultry manure and biochar on soil chemical properties, growth and yield of *Amaranthus*. Treatments consisted of three rates (0, 1 and 2 tonha^{-1}) composted poultry manure (PM) and three rates (0, 1 and 2tonha^{-1}) biochar (BC). The experiment was laid out in a Complete Randomized Design in a factorial pattern with three replications. Results showed that both the mineralized poultry manure and biochar at all rates, relative to control significantly improved the soil nutrient properties studied. Similarly, significant increase ($P< 0.05$) on growth and yield parameters of amaranthus were observed. Treatment combination of 2tonha-^{1} PM and 2tonha^{-1} BC gave the most appreciable increase in both soil nutrient parameters and plant yield and it is therefore recommended for optimum and sustained Amaranthus production in the study area.

Keywords: Poultry manure, Biochar, fertility, Growth and Yield.

Introduction

Nigeria has been ranked 103 out of 121 countries in the 2022 Global Hunger Index**,** a position that signifies the nation "has a level of hunger that is serious".(Premium Times, 30th December, 2022). This condition can be attributed to several factors including climate change, insecurity and soil degradation. Soil fertility deterioration occasioned by nutrient loss through leaching, acidity, erosion, sorption and aggressive mineral fertilizer use has led to loss of soil quantity and quality (Osodeke, 1996; Azu *et al*., 2018; Awodum, 2007) in southeastern Nigeria. This has not only limited crop production, but has also affected the socio-political variables in this region. To address the problem of food insecurity in

southeastern Nigeria, concerted effort should be taken to improve and sustain the fertility of the already degraded soils. Several studies have been carried out to improve the soil fertility conditions of the region. Such studies have reported increased soil fertility with the application of both organic and inorganic materials into soils (Onwuka *et al*., 2007; Eneje and Azu, 2009; *Azu et al*., 2018).Different organic manure sources have been used to promote soil fertility and one of such plant material which is currently at a global trend is the biochar.

Biochar is a solid material obtained from a pyrolysis process that performs a thermo chemical transformation of biomass at high temperatures and in total or partial absence of oxygen, dramatically reducing greenhouse gas emissions (Smiele *et al*., 2022). Due to its rich carbon concentration (Lehmann and Joseph,2009), biochar has been shown to increase soil carbon and water content as well as macro aggregates, electrical conductivity, pH, total nitrates/nitrites, ammonia, nitrogen (Jones *et al.,* 2012), that leads to increase in crop/plant yield. When applied to the soil, biochar helps in effective sequestering of the applied carbon, increased plant productivity, mitigating anthropogenic CO_2 emissions, and reduced nutrient leaching (Biederman and Harpole 2013).

Vegetables provide excellent means of supplementing the mineral and vitamin deficiencies in the diets of most vulnerable families in Nigeria (Azu *et al.,* 2017). Amaranthus produces the highest amount of proteins and dry matter per unit area and time among vegetables (Messiaen, 1992). Therefore it has the potential of aiding in combating malnutrition in Nigeria (Chdha, 2006). Despite the huge nutritional and economic benefits of amaranthus, large scale production in southeastern Nigeria has remained practically a mirage due to due to soil quality loss and improper soil use methods. Several attempts by Researchers in this region to address the problem of declining soil fertility through the use of several organic inputs such as poultry manure, algal compost, wood ash, etc (Eneje and Azu, 2009; Onwuka et al., 2007). However, information on the potentials of biochar and poultry manure in soil fertility enhancement and amaranthus production is still dearth. This informed the choice of this study.

Materials and Methods

The study was carried out in the Green House of Akanu Ibiam Federal Polytechnic, Unwana (latitudes 5^{o} 48N and longitude 7^{o} 55E). The climate and vegetation types are generally humid tropical rainforest with mean annual rainfall of about 3,500mm and mean daily temperature range of 27^{o}C to 38^{o}C (Njoku *et al*., 2006).

The soil sample for the experiment was collected from the Research Farm of Horticulture and Landscape Technology Department using soil auger at 0–20cm.depth. 5Kg of the soil was weighed into polyethylene bags perforated at the bottom. The poultry manure which was obtained from the livestock unit, Akanu Ibiam Federal Polytechnic was composted in an enclosed container for an incubation period of two months. Also the Biochar was produced from wood particles of *Tectona grandis, Irvingia gabonensis* and *Gmelina arborea* with limited air supply. The biochar was produced in 1-gal cylindrical metal containers filled with feedstock samples and placed in a controllable muffle furnace (model 3-1750; Neytech Vulcan, Bloomfield, CT). Each container was loaded with 400 g of raw feedstock before tightly securing the lid allowing only the evolved volatiles to escape through 3-mm vents on the lid. In this study, the evolved volatiles were not collected nor quantified. Before placing the containers in the furnace, they were purged with nitrogen (N) gas through one of the 3-mm vents for 10 min to ensure minimal oxidation of the feedstock. The furnace temperature and the residence time were set at 400 °C and 2 h, respectively. The feedstocks were placed into the heated furnace once the desired temperature level was achieved. After retrieval from the heated furnace, containers were immediately covered with aluminum foil to prevent biochar oxidation and were allowed to cool (Evans et al., 2017). The produced biochar was taking to the laboratory for nutrient analysis according to standard methods.

Appropriate weights of biochar (BC) and Poultry manure (PM) were added to each polyethylene bag (plant pot). The treatments comprised of three rates (0, 1 and 2 t/ha) BC and three rates (0, 1 and 2 t/ha) PM arranged factorially in Complete Randomised Design in three replications. *Amaranthus* seeds were sown in drills one month after soil amendment and later thinned down to one seedling per pot two weeks after germination.

The following growth and yield parameters were taken six weeks after planting: Plant height, Numbers of leaves and stem girth.Post-harvest soil samples were collected from each pot and the following chemical analysis were carried out: soil pH was determined in soil to water and soil to $CaCl_2$ at a ratio 1:2 soil water and soil $CaCl_2$ respectively using glass electrode pH meter (Udo *et al*., 2009).Organic carbon was determined by the wet oxidation method according to Pansu and Gautheyrous (2006) and converted to organic matter by multiplying by 1.724. The total nitrogen determination was done by the macro Kjeldahl digestion method (Simmone *et al.,* 1994). Available P was determined using the Bray II method of Bray and Kurtz (1945) as described by Udo *et al*. (2009). Exchangeable acidity was determined by the nikel extraction procedure as described by Udo *et al*. (2009). Exchangeable basic cations(K^+,

Ca^{2+}, Mg^{2+}, Na^{+}) were determined by the ammonium acetate method (Carter and Gregoich, 2008). Ca and Mg in the extract were determined using the atomic absorption spectrophotometer, while K and Na were determined using the flame photometer. Effective cation exchange capacity **(**ECEC) was obtained by summation of all the exchangeable cations and exchangeable acidity as described by Udo, *et al*. (2009).The base saturation was obtained mathematically with

$$BS\ (\%) = \frac{\text{Total exchangeable bases}}{\text{ECEC}} \times \frac{100}{1}$$

Statistical Analysis

Data from agronomic parameters and soil chemical properties were subjected to analysis of variance (ANOVA) and the means separated using $FLSD_{0.05}$.

Results and Discussion

The textural class was clayey-loam and the pH indicated acidity both in water and in $CaCl_2$ (Table 1). These results corroborated with the findings of earlier researchers on soils of Unwana, (Azu *et al*., 2017; Azu *et al*., 2018; Eneje and Azu, 2009). While the organic carbon, organic matter and total nitrogen were moderately high, the available phosphorus was low (7.53 mg/Kg) according to nutrients rating by Udo *et al.,* (2009) for tropical soils. The high clay content with their corresponding high concentrations of Fe^{2+} and Al^{+3}oxides favour P sorption and thus low available P (Osodeke and Ubah, 2005; Azu *et al*., 2017). Total exchangeable bases were moderately high, with (Ca^{2+}) occurring more than others (3.21 cmol/Kg). This may be related to high occurrence of limestone in most soils of Ebonyi State. Obasi *et al*.,2015).

Table 1: Some properties of the Soil, Poultry manure and Biochar and used for the Study

Properties	Soil	Poultry manure	Biochar
Sand	39.98	-	-
Silt	16.35	-	-
Clay	43.67	-	-
Texture	Clayey-loam	-	-
pH (H_2O)	5.23	8.9	10.1
pH ($CaCl_2$)	4.13	7.6	9.3
Organic Carbon (%)	2.55	18.0	8.3
Organic Matter (%)	4.42	31.0	14.4

Total Nitrogen (%)	0.21	0.8	0.8
Available P (mg/kg)	7.58	7.2	12.6
Ca^{2+} (cmol/Kg)	3.21	8.2	18.1
K^{+} (cmol/Kg)	0.16	1.5	2.0
Mg^{2+} (cmol/Kg)	1.94	1.3	4.6
Na^{+} (cmol/Kg)	0.02	0.3	0.9
TEA (cmol/Kg)	3.00		
ECEC (cmol/Kg)	8.36		
BS (%)	63.64		

TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation

The exchangeable acidity was high (3.04 cmol/Kg), owing to the high concentration of sesquoxides in the soil. The effective cation exchange capacity (ECEC) and base saturation were moderately high (8.36 cmol/Kg and 63.64% respectively).

Chemical analysis of the poultry manure showed a pH of 8.9 and 7.6 in water and salt respectively. This indicated its potentials in reducing soil acidity and a suitable replacement for commercial lime. Organic carbon, organic matter total nitrogen, available P and the basic cations were high. The high nutrient content poultry manure if appropriately harnessed can provide nutrients to both soil and growing plants in the nutrient deficient and poor structured soils of South-eastern Nigeria. Other researchers have previously reported high nutrient concentration in poultry (Eneje and Azu, 2009, Azu *et al*., 2018, Utietiang *et al*., 2013).

Result from the chemical analysis of the biochar showed that the biochar was alkaline with pH of 10.1 and 9.6 respectively. Apart from organic carbon and organic matter, the biochar was generally superior to poultry manure in all mineral elements. These results corroborated with the report of Evans et al., (2017), who studied the mineral elemental concentrations of biochar from different feedstock.

Effect of Biochar and Decomposed Poultry Manure on Selected Soil Fertility Properties

The mean effect of biochar and poultry manure is presented in Table 2. Results showed significant improvement on pH due the addition of the biochar and poultry manure and the improvement were directly proportional to the rate of amendment. The experimental pot that had 2 $tonha^{-1}$ BC and 2$tonha^{-1}$ PM comparatively had the greatest pH value of 6.85.Similar results on the increase in soil pH due to incorporation of plant sources of manure were reported by Akanbi and Ojeniyi (2007) for *Chromolaena* leaves, and Ogeh (2010) for almond

leaves. The mechanism responsible for this increase in soil pH was probably due to ion exchange reactions which occur when terminal OH - of Al^{3+} and Fe^{2+} hydroxyl oxides are replaced by organic anions which are products of decomposition of organic manures (Lehmann,2009)Table 2: **Mean effect of Biochar and poultry manure on selected soil fertility properties.**

Treatments	Soil Properties									
BC + PM	pH		OC	OM	TN	AP	TEA	TEB	ECEC	BS
	H_2O	$Cacl_2$	%	%	%	mg/kg	→	Cmol/kg	←	%
0 + 0	4.92	4.37	0.78	1.35	0.11	13.44	1.96	5.02	6.98	71.82
0 + 1	5.41	4.98	1.03	1.77	0.15	20.00	1.61	5.91	7.52	78.63
0 + 2	5.88	5.06	2.38	4.10	0.25	23.65	1.02	6.53	7.55	86.48
1 + 0	5.17	4.46	0.94	1.62	0.19	17.47	1.65	6.13	7.78	78.82
1 + 1	5.91	5.14	3.41	5.88	0.43	26.37	0.87	8.04	8.91	90.29
1 + 2	6.10	5.24	4.23	7.30	0.51	32.72	0.56	9.74	10.30	94.57
2 + 0	5.94	5.06	2.35	4.05	0.46	31.30	0.60	7.84	8.45	92.85
2 + 1	6.41	5.88	4.52	7.80	0.60	35.92	0.36	11.12	11.48	96.88
2 + 2	6.85	6.24	5.39	9.29	0.67	42.02	0.28	12.78	13.06	97.88
Mean	5.84	5.16	2.78	4.80	0.38	26.99	0.99	8.12	9.11	87.58
LSD(0.05)BC	0.190	0.165	0.344	0.523	0.036	0.919	0.079	0.377	0.396	0.915
LSD(0.05)PM	O.190	0.165	0.344	0.523	0.036	0.919	0.079	0.377	0.396	0.915
(BC X PM)	0.330	0.286	0.596	0.911	0.063	1.592	0.137	0.653	0.686	1.585

Where BC is Biochar, PM is poultry manure, OC is organic carbon, OM is organic matter, TN is total nitrogen, AP is available phosphorus, TEB is total exchangeable bases, TEA is total exchangeable acidity, ECEC is effective cation exchange capacity and BS is base saturation.

The interactive effect of the BC and PM significantly increased the organic matter content of the soils. According to Evans et al., (2017), the high carbon content in biochar may potential increasing effect on soil carbon and organic matter. Organic manures have been reported to increase the organic matter content of soils (Azu *et al*., 2018). The total nitrogen was significantly increased by the application of these materials. The available P was also significantly increased with the application of these manures and the increase was proportional to amendment rate. Organic matter is known to compete with P at adsorption

sites in the soil colloid, thus reduces P fixation (Osodeke and Ubah, 2005). The TEA declined with rate of manure application and this effect was statistically significant ($P<0.05$). The base saturation was also influenced significantly ($P<0.05$) by the lone and combined application of the BC and PM. These findings agreed with reports of other studies on the improvement of soil fertility by organic manure application (Azu *et al.,* 2018*;* Onwuka *et al.,* 2007*).*

Effect of Biochar and Poultry Manure on the growth and yield properties of Amaranthus.

The effect of biochar and poultry manure on growth and yield of Amaranthus is presented in figure 1. Results showed that relative to control, significant improvement on number of leaves, plant height and stem girth were observed.

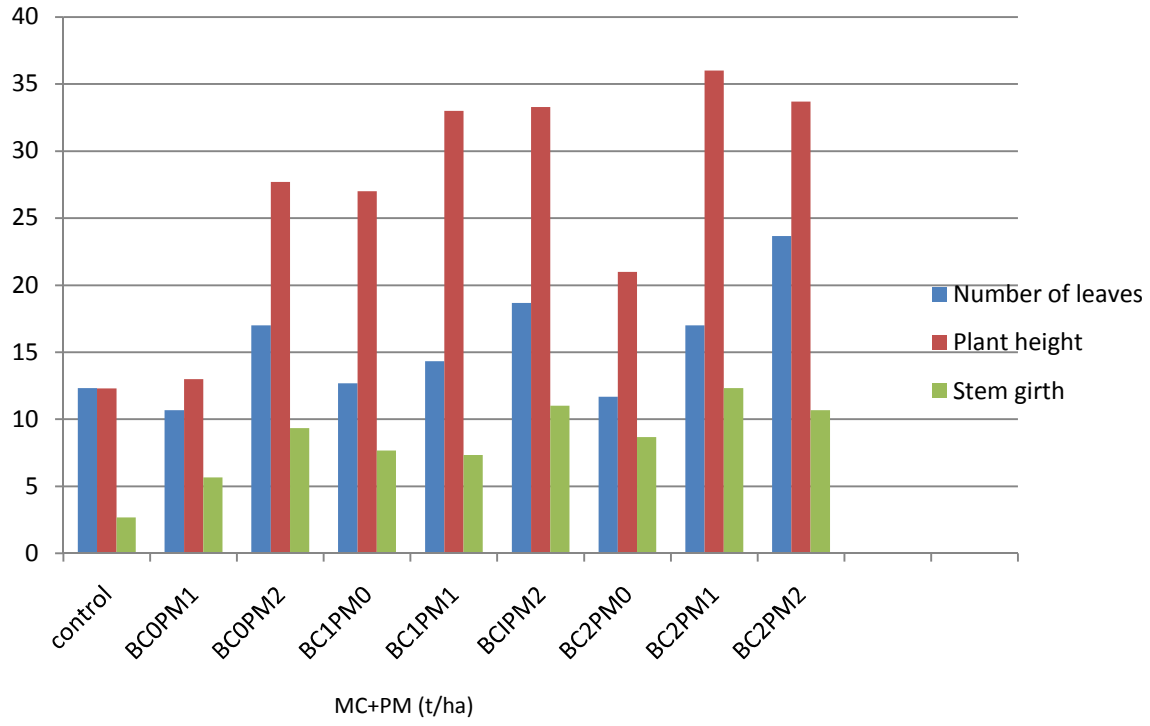

Figure1: Effect of BC and PM on number of leaves, plant height and stem girth of Amaranthus.

Where BC=Biochar and PM= Poultry manure.

The yield response of the Amaranthus due to these organic manure sources agreed with the assertions by Isitekhale and Osemota (2010) that organic manures are important short-term suppliers of nutrients as well as for long-term maintenance of soil organic matter. This yield response showed that the higher the nutrient indices in the soil, the higher the yield of

amaranthus. The increase in pH due to BC and PM application corroborated the amaranthus response to these manures since pH been has regarded as the most important indicator of soil fertility in tropical soils (Ojeniyi *et al.,* 1999; Sanchez and Logan 1992)).

The yield increase of amaranthus due to biochar agrees with the findings of Biederman and Harpole (2013). who reported high yield of vegetables due to biochar use..

Conclusion

The soil fertility and productivity enrichment potentials of biochar and poultry manure, their positive effects on soil nutrient indices were found to be efficient in increasing and maintaining soil fertility for sustainable amaranthus production. Application of these manure sources significantly increased the soil nutrient elements and yield of amaranthus over the control. The higher the rate of application, the more increase on soil nutrient properties and yield of amaranthus. Inclusion of biochar and poultry manure in cropping system will have positive and sustainability effects on soil fertility properties and production of amaranthus.

References

Akanbi, O.S. and Ojeniyi, S.O. (2007). Effect of Siam weed mulch on soil properties and performance of yam in Southwest Nigeria. *Nigerian Journal of Soil Science* 17: 120-125

Awodun, M. A. (2007). Influence of sawdust ash on soil chemical properties and cowpea performance in Southeastern Nigeria. Intl. J. Soil Sci. 2(1): 78-86.

Azu, Donatus E.O., Osodeke, V.E., Nwanja, O.U.(2017) Effect of algae on phosphorus sorption characteristics of an ultisol of Southeastern Nigeria. Direct Research Journal of Agriculture and Food Science 5(2):88-95.

Azu, D.E.O., Osodeke, V.E., Ukpong, I.M. and Osisi, A.F. (2018). Chemistry and mineralogy of soils derived from different parent materials in Southeastern Nigeria. Int. J. of Plant and Soil Science, 25(25):1-16.

Biederman LA and Harpole WS (2013). Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis . GCB Bioenergy. 5: 202–214, doi: 10.1111/gcbb.12037

Carter MR, Gregorich EG.(2008) Soil sampling and methods of analysis 2nd (ed). Can Soc. Soil Sci.;1224.

Chadha, K.L.(2006). Handbook of Horticulture, Directorate of information and publication of Indian Council of Agricultural Research, New Delhi pp187-192

Eneje, R. C. and Azu E. O. (2009). Algae compost effect on soil nutrient status and aggregate stability. *Journal of Soil Society of Nigeria,* 19(2):118-126.

Evans, M.R., Jackson, B.E., Popp, M. and Sadaka, S. (2017). Chemical properties of Biochar materials manufactured from Agricultural products common to the Southeast United States. *Hortechnology 27(1):1-16*

Jones DL, Rousk J, Edwards-Jones G, DeLuca TH, Murphy DV. Biochar-mediated changes in soil quality and plant growth in a three-year field trial. *Soil Biol. Biochem.*2012; 45, 113–124.

Lehmann J, Joseph S. (2009) Biochar for environmental management. Earthscan, Sterling,VA 16-2. 17:23

Messiaen, C.M.(1992). The tropical Vegetable Garden:Principles for improvement and increased production with application to the main vegetable types514pages

Njoku, J.C., Okpara, D.A and Asiegbu, J.E. (2006). Growth and yield response of Sweet potato to inorganic Nitrogen and potassium in a tropical ultisol. Nig. Agric. J. 32:30-41.

Obasi, A. I. Ejpe, I. I., Igwe, E. O. and Nnachi, Enwo, E. (2015).The physical properties of soils within major dumpsites in Abakaliki Urban, southeastern Nigeria and their importance to groundwater contamination.*International Journal of Agriculture and Forestry.* 5(1):17-22.

Ogeh, E.S. (2010). The performance of maize in acid infertile soil amended with municipal tree leaves residue and phosphorus. *Nigerian Journal of Soil Science* 20 (2): 76- 81.

Ojeniyi, S. O. and Adeniyan, N. O. (1999). Effect of poultry manure and NPK fertilizer on soil fertility, nutrient content and yield of maize at Akure southwest. In: management of soil resources of Nigeria for sustainable production in the 21st century. Proceedings of the 25th Annual conference of the Soil Science Society of Nigeria (SSSN), Benin City. Pp 185-191

Onwuka, M.I., Osodeke, V.E. and Okolo, N.A.(2007). Amelioration of soil acidity using cocoa husk ash for maize production in Umudike area of southeastern Nigeria .Tropical and Subtropical Agroecosystem 7:41-45.

Osodeke, V. E. (1996). Effects of rainfall and land-use on the management of the highly degraded soils of southeastern Nigeria. Proceedings of the 5th Annual conference of the Nigerian Society of Biological conservation, Umudike.

Pansu, M. and Gautheyrous, J. (2006). Handbook of Soil Analysis: Mineralogical Organic and Inorganic Methods. Springer, p995.

Sanchez P.A. and Logan, T.L (1992). Myths and science about the chemistry and fertility of soils in the Tropics. In:R. Lal and P.A. Sanchez. *Myths and Science of Soils of the Tropics*. Soils Science Society of AmericaSpecial Publication Number 29, Madison, Wisconsin.

Simiele M, Argentino O, Baronti S, Scippa GS, Chiatante D, Terzaghi M, Montagnoli A.(2022) Biochar Enhances Plant Growth, Fruit Yield, and Antioxidant Content of Cherry Tomato (Solanum lycopersicum L.) in a Soilless Substrate. Agriculture.; 12, 1135. https://doi.org/10.3390/ agriculture12081135

Simmone, E. N., Jones, J. B., Mills, A. H., Smittle, A. A. and Hussey, C. G. (1994). Comparison of analytical methods for nitrogen analysis in plant tissues. *Common Soil Science,* 24:1609-1616

Udo, E J., Ibia, T.O. Ogunwale, J.O. Ano, and. Esu, A.O. (2009). *Manual of Soil, Plant andWater Analysis*. Sibon Books Ltd. Lagos.

Utietiang L. Undie' Michael A. Kekong and Tom O. Ojikpong[3] (2013) Moringa *(Moringa Oleifera* Lam.) Leaves Effect on Soil Ph And Garden Egg (Solanum Aethiopicum L.) Yield In Two Nigeria Agro- Ecologies *European Journal of Agriculture and Forestry Research, Vol No. 1, pp. 17-25*