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INFLUENCE OF COMBINED BIOCHAR AND POULTRY MANURE ON SELECTED SOIL CHEMICAL PROPERTIES AND GINGER YIELD IN AN *ULTISOL* OF UMUDIKE, SOUTH-EAST NIGERIA

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Abstract
The study was carried out to examine the effect of different ratio combinations of biochar (0, 2, 4, 6 and 8 t/ha) and poultry manure (0, 4 and 8 t/ha) in an ultisol of South-East, Nigeria. The 8 treatments were laid out in a randomized complete block design (RCBD) in the field. Surface (0-30 cm) soil properties were determined before and after planting, and ginger yield (t/ha) taken at harvest. Results showed that all the selected soil chemical properties and fresh rhizome yield of ginger significantly ($p<0.05$) improved by the combined application of biochar and poultry manure. The combination of biochar (8t/ha) and poultry manure (8 t/ha) gave the highest yield (13.23 t/ha), followed by 6t/ha biochar + 8t/ha poultry manure with yield of 9.17t/ha. The study therefore, recommends treatment combination of biochar and poultry manure at the ratio of 8t/ha each for use in ginger production in ultisol or similar soils and for improving soil properties.

Keywords: Ginger, poultry manure, biochar, soil chemical properties

Introduction

The decreasing yield trend of ginger in the tropics has been attributed to low soil nutrient especially, nitrogen and phosphorus (Nwaogu *et al*., 2011). According to Srinivasan *et al.* (2012), the major reasons for low productivity of spices such as ginger are low- soil pH, high clay, -sand content, -CEC, - nutrient reserve, and -levels of manure and mineral fertilizer applications. The soils of the South-East Nigeria are strongly weathered, have predominantly kaolinite in the clay fractions, low CEC, low nutrient reserve and may suffer from multiple nutrient deficiencies (Enwezor, *et al*, 1990). This soil may not sustain intensive ginger production, considering the high nutrient demand of ginger. Ginger removes an average of 400, 32 and 394 kgha-1 of N, P and K, respectively from the soil (Lujiu *et al.* 2004). Improving the fertility status of the ginger growing soils requires the judicious use different organic manure sources, either sole or in combination. Biochar is a stable, recalcitrant organic carbon (C) compound that is produced by thermochemical alteration of biomass (feedstock) for the purpose of soil amendment and carbon sequestration (Jeffery *et al.* 2011). It is considered to be relatively stable in soil with mineralization rates that are slower than that found in the original biomass (Spokas *et al.* 2010). This makes biochar attractive as a carbon sequestration option in addition to its potential for enhancing soil quality and minimizing the release of environmental pollutants (Clough and Condron 2010). Application of biochar could improve soil Cation Exchange Capacity (CEC), influence the base saturation, decrease soil pH and reduce nutrient leaching; to improve fertility efficiency (Van Zwieten *et al*., 2010). In addition, biochar can increase the biological activity of soil by providing living environment and suitable water and nutrient conditions for microorganisms in soil (Lehmann *et al*., 2011) and can as well act as a liming agent (Liu, *et al.* 2012). Despite the demonstrated potentials of biochar on improving soil fertility and crop yield, sole application of biochar is not recommended due to its low nutrient content and resistance to degradation (Adekiya *et al,* 2020; Adekiya *et al*. 2019). Many studies have been carried out on the use of poultry manure and other organic manure sources on ginger production in South-East, Nigeria. However, information is lacking on the effect of complementary use of biochar and poultry manure in South-East Nigerian soils and hence, the need for this study.

Materials and Methods

The experiment was carried out at the Research farm of National Root Crops Research Institute (NRCRI), Umudike, South-East, Nigeria. Umudike is located on latitude 05˚ 27'N and longitude 07˚ 32'E. The treatments comprise of five levels of biochar (0, 2, 4, 6, and 8t/ha) applied in complementary with 0, 4 and 8t/ha of poultry manure, giving a total of 8 treatments laid out on manually prepared seedbeds of 1m x 2m, arranged in RCBD and replicated 3 times. All the agronomic practices recommended for ginger production were carried out. The biochar used was produced from sawdust using pyrolysis drum. Poultry manure (deep litter) was sourced from the poultry unit of NRCRI, Umudike. Pre-planting and post planting soil samples were collected at the depth of 0-30cm. The samples were air dried, grinded and screened through a 2mm sieve and analyzed in the laboratory for some physical and chemical properties using standard analytical methods following Udo *et al*. (2009). Yield data was taken at harvest. Statistical analysis of data generated was done using Genstat software package and significant means separated using Fishers' least significant differences at 5% level of probability.

Results and Discussion

Properties of the soil at the experimental site

The physical and chemical properties of the soil before the application of the treatments are presented in Table 1. The soil was sandy loam in texture with pH value of 4.2, indicating very strong acidity, according to Fulhage, (2000). Acidic soils potentially reduce plant growth, fix plant nutrient by increasing H^+ and Al^{3+} ion toxicity and reducing available Ca, Mg, and P. Available phosphorous, organic matter, calcium and potassium were low, indicating poor soil fertility and hence, the need for amendment for increased crop yield.

Table 1: Properties of the experimental site before planting

Soil properties	Values
Sand (%)	79.60
Silt (%)	6.40
Clay (%)	14.00
Textural class	Sandy loam
Soil pH (H_20)	4.2
Organic matter (%)	1.79
Total nitrogen (%)	0.028
Available phosphorous(mg/kg)	10.6
Exchangeable acidity (cmol/g)	1.40
Calcium (cmol/kg)	3.20
Potassium (cmol/kg)	0.043
Magnesium (cmol/kg)	0.80
Sodium (cmol/kg)	0.092
ECEC (cmol/kg)	5.54
Base saturation (%)	74.72

Table 2: Chemical properties of the Biochar and Poultry manure used for the study

Property	Poultry manure	Biochar
pH (H_20)	6.55	8.10
Organic carbon (%)	19.8	60.1
N (%)	3.32	0.67
P (%)	1.81	0.56
K (%)	1.98	1.24
Na (%)	0.80	0.39
C:N ratio	7.21	75.3
Ca (%)	0.81	1.00
Mg (%)	0.68	0.28
Na (%)	0.30	0.39

Influence of Combined application of Biochar and Poultry manure on selected Soil chemical properties

The results of the influence of combined application of biochar and poultry manure on the selected soil chemical properties are presented in Table 3. The treatments significantly ($p<0.05$) improved all the soil chemical properties studied relative to the control. The pH of the soil increased from 4.45-6.93 and increased generally with increase in the rate of the treatment applications. The increase in the pH of the soil might be due to the high pH values of the added biochar. This confirms the liming effects of biochar and animal manure as reported by Van Zwieten *et al*. (2010) and Ano and Ubochi (2007). Similarly, the significant increase in soil pH as seen in this study agrees with the findings of Li *et al.* (2021), Adekiya *et al.* (2020) and Gul *et al*. (2015). The organic carbon content of the soil increased from 0.90-2.85%. The increase in the organic carbon content of the soil might be due to the addition of poultry manure and carbon rich biochar to the soil as reported by Li *et al.* (2021), Adekiye *et al.* (2020) and Adekiye *et al*. (2016). The N and P contents of the soil increased from 0.095-0.395 and 12.6-25.63 respectively. This might be because of the greater multiplication of microbes caused by the addition of organic materials for the conversion of organically bound N to inorganic form. Also, the appreciable build up in available P in the amended plots might be attributed to the influence of organic manure in increasing the available P in soil through complexing of cations like Fe^{2+} and Al^{3+} which are mainly responsible for the fixation of phosphorus. Zsolamey and Gorlitz

(1994) reported that incorporation of manure and crop residues have been shown to increase the rate of desorption of P and thus improve the available P content of the soil. The Ca, Mg, K and Na contents of the soil increased from 2.83-7.30, 0.63-4.47, 0.092-0.465 and 0.083-0.380Cmol/kg respectively. The observed increase in these cations might be due to the improvement in soil pH which has a positive relationship with the availability of basic cations; the presence of cation exchange sites on the surface of biochar (Jones *et al.,* 2012, Sohi *et al*., 2010) and the presence of carboxyl group in biochar which is indicated by high oxygen and carbon ratios on the surface of the biochar after microbial degradation (Preston and Schmidt, 2006, Liang *et al*., 2006). Mucheru *et al.* (2007) noted that increasing the pH of acidic soils through organic amendments improves the plant availability of macronutrients (such as Ca, Mg, K and Na), while reducing the solubility of elements (such as Al and Mn). The soils exchangeable acidity (EA) reduced from 1.82-0.18, while the percentage base saturation of the amended soil increased from 66.66-98.54%. The reduction in the exchangeable acidity and increase in soil percentage base saturation might be due to the improvement in soil pH and lowering of Al^{3+} and Fe^{2+} concentration in the soil following the biochar and poultry manure applications. The soils' ECEC increased from 5.46-12.76 and can be attributed to the better buffer capacity of the soil as a result of the organic amendments and the rise in organic matter content, which increased the net negative charges in the exchange complex (Mutegi *et al.,* 2012).

Table 3: Effect of treatment on selected soil chemical properties

Treatment	pH (H_2O)	Av.P (mg/kg)	N (%)	OC (%)	Ca	Mg	K	Na	EA	ECEC	BS %
					……. cmol/kg ……….						
Control	4.45	12.6	0.095	0.90	2.83	0.63	0.092	0.083	1.82	5.46	66.66
B1P1	5.06	14.73	0.233	1.02	4.03	1.03	0.233	0.203	1.45	6.96	79.10
B1P2	5.31	15.70	0.277	1.64	4.70	1.43	0.271	0.240	1.36	8.00	83.01
B2P1	5.55	18.53	0.263	1.70	4.96	1.83	0.310	0.280	1.27	8.66	85.31
B2P2	5.80	19.86	0.307	1.84	5.73	2.17	0.365	0.295	1.07	9.30	88.85
B3P1	6.10	21.53	0.288	1.96	6.07	2.63	0.386	0.309	0.88	10.28	91.43
B3P2	6.38	22.20	0.371	2.27	6.53	3.13	0.397	0.326	0.73	11.12	93.40
B4P1	6.67	23.76	0.334	2.55	6.63	3.83	0.422	0.351	0.44	11.68	96.24
B4P2	6.93	25.63	0.395	2.85	7.30	4.47	0.465	0.380	0.18	12.76	98.54
Mean	**5.81**	**19.39**	**0.285**	**1.85**	**5.42**	**2.35**	**0.327**	**0.274**	**1.02**	**9.36**	**86.94**
LSD (0.05)	0.12	0.33	0.014	0.04	0.38	0.08	0.002	0.001	0.04	0.42	0.85

NB: B1P1=2t/ha biochar+4t/ha PM, B1P2=2t/ha biochar+8t/ha PM, B2P1=4t/habiochar+4t/ha PM, B2P2=4t/ha biochar +8t/ha PM, B3P1=6t/ha biochar+4t/ha PM, B3P2=6t/ha biochar+8t/ha PM, B4P1=8t/ha biochar+4t/ha PM, B4P2= 8t/ha biochar+8t/ha PM. PM=Poultry manure, Control= no treatment

Influence of Combined application of Biochar and Poultry manure on the fresh rhizome Yield of Ginger

Combined application of bochar and poultry manure significantly ($p<0.05$) increased the yield of ginger relative to the control. The yield increased with increase in treatment combinations on application of 8t/ha biochar +8t/ha poultry manure, giving the highest yield of 13.23t/ha, followed by application of 6t/ha +8t/ha poultry manure with yield of 9.17t/ha relative to the control. The increase in the yield of ginger in this study might be as a result of improvements in soil properties. The results obtained corroborates the findings Lima *et al.* (2021), who reported a significant increase in the yield of common bean with combined application of biochar and poultry manure. Similarly, Adekiya *et al.* (2020) reported a significant increase in ginger rhizome yield with combined application of biochar and poultry manure in an *alfisol* of South-West, Nigeria.

Table 4: Effect of treatment on the fresh rhizome yield of Ginger

Treatment	Values
Control	2.50
B1P1	6.50
B1P2	8.47
B2P1	8.00
B2P2	7.10
B3P1	7.27
B3P2	9.17
B4P1	9.13
B4P2	13.23
Mean	**7.93**
LSD (0.05)	2.55

NB: B1P1=2t/ha biochar+4t/ha PM, B1P2=2t/ha biochar+8t/ha PM, B2P1=4t/habiochar+4t/ha PM, B2P2=4t/ha biochar +8t/ha PM, B3P1=6t/ha biochar+4t/ha PM, B3P2=6t/ha biochar+8t/ha PM, B4P1=8t/ha biochar+4t/ha PM, B4P2= 8t/ha biochar+8t/ha PM. PM=Poultry manure, Control= no treatment

Conclusion

Results of this study showed that all the selected soil chemical properties and fresh rhizome yield of ginger were significantly ($p<0.05$) improved by the combined application of biochar and poultry manure. The yield increased with increase in treatment combinations with combined application of 8t/ha biochar +8t/ha poultry manure, giving the highest yield of 13.23t/ha, followed by application of 6t/ha biochar +8t/ha poultry manure with yield of 9.17t/ha relative to the control. Therefore, the yield of ginger in South-East, Nigeria can be improved by complementing poultry manure with Biochar. Application of 8t/ha biochar +8t/ha poultry manure is hereby recommended for ginger farmers in South-East, Nigeria.

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