SOIL AMENDMENT WITH BIOCHAR BLEND PRODUCED FROM SELECTED WASTE

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ABSTRACT

Agricultural performance of biochar blend prepared from waste on the properties of soil supporting the oil palm was investigated. The biochar from the waste produced from coconut coir and chicken dung at 300°C for three hours were characterized in terms of pH, attrition, porosity, bulk density, ash content, conductivity, surface charge, nutrient value, yield% and surface area. Soil samples collected at the Nigeria Institute for Oil Palm Research (NIFOR) main station were prepared and analyzed for physico-chemical properties in the laboratory using standard techniques. The physico-chemical properties of the biochar blend –soil mixture samples in which sprouted oil palm seedlets have been planted were measured as a function of biochar blend and loading and compared with the values obtained in the control without biochar. The biochar blend showed significant ($p<0.05$) improvement in soil properties and growth of the oil palm seedlets.

KEYWORDS: Biochar; Soil; Coconut coir, Chicken dung

INTRODUCTION

The continued threat to the world's land resources is exacerbated by the need to reduce poverty and unsustainable farming practices. During the last decade, food security was not a global priority, but studies such as the 2020 vision and the World Food Summit[1] have shown that food security is one of the main global concerns in the new decade[2].

Food security encompasses food scarcity as well as the inability to purchase food. Although food insecurity occurs throughout the developing world, it is most acute in sub-Saharan Africa, where the attainment of food security is intrinsically linked with reversing agricultural stagnation, safeguarding the natural resource base, and reducing population growth rates[3], Low soil fertility, particularly nitrogen and phosphorus deficiencies, is one of the major biophysical constraints to optimize the management of the oil palm plantations.

One such approach is the use of biochar, a carbon-rich product obtained when biomass, such as wood, manure, or leaves, is heated in a closed container with little or no available air. Biochar has unique properties that make it not only a valuable soil amendment to sustainably improve soil health and productivity, but also an appropriate tool for sequestering atmospheric carbon dioxide in soils for the long term in an attempt to mitigate global warming. The recent broad interest in biochar has been chiefly stimulated by the discovery that biochar is the primary reason for the sustainable and highly fertile dark earths in the Amazon Basin, Terra Preta de Indio. The present communication describes the investigation of soil amendment with the biochar blend

MATERIALS AND METHODS

Materials

Coconut coir and the Chicken dung were obtained from the Nigerian Institute for Oil Palm Research community, Benin City, Nigeria.

The Coconut coir were separated from the coconut pod, reduced to small sizes, while the chicken dung was dried, and used. Eight samples (of four each) of weight: 1.0, 2.0, 3.0 and 4.0kg each were pyrolyzed at 300oC for three hours using the METM-525 Muffle furnace. The biochar obtained were then milled to fine powder and sieved through a mesh size of 150µm. The biochar particles that passed through the screen were collected, characterized and used for further analysis.

Soil samples (0-30cm) collected using auger, used for the study were obtained from the fields in NIFOR and prepared for further analysis. All the reagents used for analysis were of analytical grade and were used without further purification.

Characterization of the Biochar and the soil samples

The biochars were characterized in terms of %yield on pyrolysis of the biomass, obtained from the weight difference, ash content determined according to the method described by ASTM D1762-84[4], the bulk density determined according to the method described by Ahmedna *et al.*,[5], the pH determined using ASTM D1512[6] method, the method used for surface area measurement was determined by iodine adsorption number, Ishak and Baker[7], conductivity by using the conductivity meter. The total surface functional group was carried out by the method described by Boehm[8]. Attrition was determined using the method described by Marshal *et al.*,[9]. The calcium and Magnesium contents by EDTA titration, while the sodium and potassium contents were determined by flame photometry and the nutrient value, carbonates, carbon, nitrogen and total phosphorus were determined using standard methods. Heavy metals present were determined using the atomic absorption spectrophotometry (AAS).

The soil samples were characterized as follows: bulk density was measured by core method[10]. Soil pH measured in 1:1 soil-water ratio[11], while total nitrogen was obtained by microkjedahl method. Cation exchange capacity was measured using ammonium acetate leaching at pH 7.0[12]. Available phosphorus was determined by the method of Olsen[13] and soil heavy metal content was determined using the AAS.

Preparation of Biochar blend-soil mixture, experimental details

The resulting biochar blends were applied in blended nixture and singly at 1.0, 2.0, 3.0. and 4.0% by wt with 2kg of the soil, placed in five-liter polyethylene containers. One sprouted seedlet of the oil palm was planted in the centre of each pot. The soil was irrigated with water to field capacity and the volume of water required to saturate the soil was recorded. The control was prepared using 3kg soil without biochar blend; one sprouted seedlet of the oil palm was planted at the centre of the pot. The volume of water required for field capacity was also recorded.

In all, 7 treatments, four replications in complete randomized design in a green house, biometric observation and condition of experimental plant were recorded at monthly intervals.

Soil samples were collected at the beginning and last month and analyzed for important chemical and physical parameters using recommended procedures. Determinations of plant plant height, and leaf area) were carried out during harvest. Relative water content (RWC) of leaves was measured on fully expanded leaves at end of second month after sowing (WAS). Leaves were cut and collected at midday to determine fresh weight (FW). Leaf blades were then, placed with their cut end pointing down into a tube containing about 15 ml of 1 mM $CaCl_2$. The

$CaCl_2$ was used to increase leaf cell integrity, with the aim of reducing cell lysis due to excessive rehydration. The turgid weight (TW) was then, recorded after overnight rehydration at 4°C. For dry weight (DW) determination, samples were oven-dried at 70°C for 48 h. Relative water content was calculated according to Schonfeld *et al.*,[14] thus:

$$RWC\ (\%) = [(FW - DW) / (TW - DW)] \times 100 \quad (1)$$

The growing plant height was measured as the distance from soil surface to upper end of the longest leave taken on a ruler, and leaf area was measured on the summation of areas of demarcated portions of leaf. At maturity, a sample from each pot was harvested for root/shoot ratio determination and data were taken after oven drying at 70°C for 72h.

The fresh leaves were grounded in 80% acetone as quickly as possible at room temperature, and the chlorophyll (Chl) contents (Chla, Chlb and Chla/b) were determined using a UV spectrophotometer at 420, 645 and 664 nm and by the calculations described by Wellburn[15].

$$\text{Chlorophyll a} = 10.3E664 - 0.918\ E645 \quad (2)$$

$$\text{Chlorophyll b} = 19.7\ E645 - 3.870\ E\ 664 \quad (3)$$

The average data obtained for soil and biochar physio-chemical properties and the water holding capacity of the soil-biochar mix were analyzed by ANOVA F-test and the means compared with the least significant differences (LSD) at the 5% level of probability using the Genstst 12 software.

RESULTS AND DISCUSSION

Table 1 shows the characterization of the biochar materials before and after blending; these properties have fundamental importance for a range of effects of biochar on soil properties. From the table, the iodine number of 87.3mg/g for the blend, 78.8mg/g for coconut coir biochar (CCB) compared to 52.5mg/g for chicken dung biochar (CDB) elicits the amount of surface area available for surface reactions with nutrient elements such as adsorptive reactions with ions or element transformations[16]. The greater the surface area, the more effective biochar will be in relation to affecting soil properties (although the nature of the surfaces plays an equally important role). Macropores, in the surface area are also relevant to the movement of roots through soil and as habitats for a vast variety of soil microbes[17].

Table 1: Characteristics of Biochar samples

Parameters/Samples	Coconut coir biochar (CCB)	Chicken dung biochar (CDB)	Biochar blends (BB)
Yield (%)	53.4±0.6	38.7±0.4	49.7±0.1
pH of slurry at 28oC	6.1±0.1	8.2±0.1	6.7±0.1
Conductivity (µs)	15875±20	11700±18	18670±05
Bulk Density (g/ml)	0.62±0.02	0.68±0.05	0.64±0.02
Surface area (Iodine ads) mg/g	78.8±1.8	52.5±1.5	87.3±0.5
Ash Content (wt.%)	0.8±0.1	1.5±0.1	2.3±0.2
Surface Charge (mmolH+eqv./gc)	0.61±0.01	0.28±0.02	0.75±0.05
Potassium content (mg/kg)	2400±08	2210±15	2400±10
Magnesium content (mg/kg)	530±5	130±8	567±10
Calcium Content (mg/kg)	480±16	260±08	581±05
Sodium Content mg/kg)	180±05	260±01	281±5
Carbon (g/kg)	0.69±10	0.38±07	0.885±12
Nitrogen (g/kg)	9.4±0.3	20±01	25.9±0.1
Phosphorus (mg/kg)	50±2	252±20	272±25

From the Table 1, the electrical conductivity of the blend is higher than that of CCB and CDB showing a tendency for high amount of electrolytes added to soil which could affects its flocculation[17]. However, it can be expected that this has an effect on soil only at very high application rates, but may be a factor to consider with some crops that are sensitive to increased salt concentrations or soils with unstable soil structure.

More important is the pH of biochar, which from the Table 1 range from 6.1 for CCB, 6.7 for the blend , to 8.2 for CDB. It has been reported that pH can be high or low depending upon feedstock and production conditions. A high pH can be a key feature of biochar in improving acid soils, Cheng et al.,[20], which is a characteristic feature of the soil supporting the oil palm.

Bulk density of the blend is lower than that of CDB from the table which means higher transport properties of blend, therefore, the resulting bulk density of soils after biochar blend addition, would show improve penetrability, drainage and aeration of soils that are essential for good plant growth[17].

The higher value of surface charge for blend compared to CCB and CDB shows the high level of functional group on the surface of the biochar blend.

Carbon content of blend is higher than that of CCB and CDB from the Table 1. The total carbon provides a measure of the total amount of organic carbon that is added to the soil and is therefore relevant to the carbon balance and sequestration aspect of biochar management. It also provides a good indicator (along with knowing the ash composition) of the composition of the parent biomass and the process conditions under which the biochar is produced[18]. It supplies a baseline to determine the rate of removal of carbon from the biochar as a function of time in the environment.

From the Table 1 the nutritive value of the blend is higher compared to that of the CCB and CDB due to high values of the magnesium, potassium, sodium, calcium and nitrogen content, which influence the cation exchange capacity (CEC) of soil when the biochar blend is added, which are not in the control. CEC is a measure of the surface charge in soil or biochar. CEE increases as the biochar ages[19] and this has been attributed to an increase in some of the oxygenated functional groups on the surface of the biochar[20], However, in the control, the absence of biochar enables an assessment of its impact both on the soil and the seedlet.

The biochar blend shows higher ash content compared to CCB and CDB, obviously due to the high CEC. However, two factors, feedstock and process conditions, control the amount and distribution of mineral matter in biochars.

The composition of biochars, however, depends upon the nature of the feedstocks and the operating conditions of pyrolysis.

Table 2: Physico-chemical properties of the soil sample

Properties			Value
Depth, cm			0-15
pH			5.4±0.1
Conductivity, µs			2720±602
Bulk density, g/ml			1.58±0.05
Moisture Content			6.4±0.1
Particle size	%	Clay	6.38±0.57
		Silt	1.40±0.01
		Sand	92.22±0.45
Total acidity			5.4±0.2
Total organic carbon g/kg			1.568±0.152
Total Nitrogen, g/kg			0.104±0.001
Phosphorus, mg/kg			33.76±2.68
Potassium Content, mg/kg			987±25
Sodium content, mg/kg			718±11
Magnesium content, mg/kg			499.2±28.1
Calcium content, mg/kg			608±33
CEC			2792.2±98.1

Table 3: Physico-chemical properties of the soil –biochar blend mix for the first month

Sample	Biochar (%)	pH	TOC (g/kg)	BD (g/ml)	CEC (mg/kg)	P(mg/kg)
Soil –CDB	1	7.8	0.68	0.68	3014.2	258
Soil-CCB	1	6.3	1.36	0.60	2895.5	54.0
Soil-BB	0	5.4	1.57	1.58	2792.4	33.7
	1	5.6	1.88	1.63	3243.0	78.2
	2	6.4	1.90	1.63	3997.4	95.06
	3	6.6	1.91	1.61	4381.5	116.78
	4	6.8	2.40	1.60	5115.1	266.22
	Mean	6.35	2.02	1.62	4184.3	139.07
	LSD (0.05)	0.87	0.42	0.80	1296.5	143.3

BD: Bulk density, TOC: Total organic carbon, CEC: Cation exchange capacity, p: Phosphorus, LSD: Least square difference. Different letters in the columns indicate significant differences between treatments at $P < 0.05$ level.

Table 4: Physico-chemical properties of the soil –biochar blend mix for the last month

Sample	Biochar (%)	pH	TOC (g/kg)	BD (g/ml)	CEC (mg/kg)	P(mg/kg)
Soil –CDB	1	7.4	0.98	0.60	3308.5	258
Soil-CCB	1	6.8	1.44	0.71	3011.8	54.0
Soil-BB	0	5.2	1.64	1.56	2913.3	40.12
	1	6.2	2.22	1.61	3588.6	63.61
	2	6.6	2.46	1.60	3801.5	106.01
	3	6.5	2.90	1.60	4470.0	199.08
	4	6.8	3.32	1.61	5116.7	296.23
	Mean	6.525	2.725	1.605	4244.2	166.38
	LSD (0.05)	0.33	1.18	0.0095	1150.5	171.8

BD: Bulk density, TOC: Total organic carbon, CEC: Cation exchange capacity, p: Phosphorus, LSD: Least square difference. Different letters in the columns indicate significant differences between treatments at $P < 0.05$ level.

The result Table 2 shows that the soil is acidic and the nutritive value is low, hence the need for improvement in the quality of the soil for increase yield and productivity.

Table 3 and 4 summarizes the effect of biochar blend on the properties of soil supporting the oil palm plantation and on the growth rate as well as the saturated water volume of sprouted seedlets of the oil palm for a two month period.

The result showed a significant improvement ($p<0.05$) on the soil cation exchange capacity, total organic carbon, available phosphorus and nitrogen in the soil leading to a significant growth rate of the sprouted seedlets compared to the control, also the saturated water volume over the period showed the tendency for biochar to enhance the water retention capacity of the soil. However, there is a remarkable reduction in the total acidity of the soil obviously due to the high level of CEC of the blend.

The tables show the immediate positive effect of the blend in the properties of the soil over a period of two months. The probable reason for these is due to the high value of CEC of the blend.

However, a close look at the result reveal a tendency for prolong positive impact of the blend over that of the control which could be explained in terms of the composition and nature of the feedstock.

Table 5: water used by sprouted seedlets soil –BB treatments at various week intervals

Treatment/Wks	2	4	6	8
Soil-BB				
(1 %)W_1	420	285	245	200
(2%)W_2	475	405	340	275
(3%)W_3	550	460	345	375
(4%)W_4	750	570	440	400
Soil -CDB	400	315	255	200
Soil-CCB	375	305	285	275
Control	325	285	265	250
Mean	548.8	430	342.5	312.5
LSD (0.05)	239.9	197.0	132.3	153.6

LSD: Least square difference. Different letters in the columns indicate significant differences between treatments at $P < 0.05$ level.

Table 6: Effect of soil amendment with biochar blend on oil palm seedling height, root/shoot ratios under different biochar blend treatments at 2 months harvest.

Treatment	Plant height (cm)	Root/shoot ratios	Leaf area (cm^2)	RWC	Chlorophyll a/b
Control	38.44±0.98	0.25±0.5	285.56±2.2	88.8±0.5	2.13±1.08
Soil-CDB	42.56±1.08	0.18±0.6	272.88±0.6	90.4±1.1	2.01±1.05
Soil-CCB	40.05±1.25	0.16±0.8	258.05±1.9	92.3±0.8	2.00±1.88
1% (W1)	42.98±1.33	0.26±1.1	305.18±1.3	93.7±1.5	1.81±1.68
2% (W2)	43.55±1.37	0.28±0.6	311.57±2.2	95.6±0.3	1.79±0.88
3% (W3)	46.25±2.21	0.31±1.5	335.12±2.0	98.3±1.5	1.63±0.47
4% (W4)	60.02±2.10	0.34±1.2	358.56±0.5	98.8±0.8	1.48±1.54
Mean	75.7	0.298	327.6	96.6	1.68
LSD (5%)	5.34	0.058	40.4	3.97	0.26

RWC: Relative water content of the leaves, LSD: Least square difference, LSD: Least square difference. Different letters in the columns indicate significant differences between treatments at $P < 0.05$ level.

Tables 5 and 6 summarizes the effect of biochar blend on the growth rate of the oil palm spouted seedlets and the saturation water volume of soil supporting the oil palm plantation over a period of two months.

The table shows a significant growth rate expressed in terms of the height, stem diameter, leaf number, relative water volume of the leaves and leaf area of the oil palm sprouted seedlets for both biochars, however, the blend showed a significant effect on growth compared to that of the control over the period[21].

The probable reason for this is the high nutritive value of the blend over that of the control, which has a significant effect on the soil supporting the oil palm.

The result of the saturation water volume which is the amount of water applied to the soil at filed capacity, showed that the application of blend to the soil enhances the water retention capacity of the soil and hence enhanced the growth of the sprouted seedlets.

CONCLUSION

The main aim of this work is to evaluate the performance of biochar blend on the physico-chemical properties of the soil supporting the oil palm

The results show that biochar blend prepared from chicken dung and coconut coir influenced the physico-chemical properties of soil supporting the oil palm and that the growth rate of the sprouted seedling compared to the control is better in soil amended with biochar blend than when the soil was not amended. Biochar blending with soil improve the water retention capacity of the soil

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