

Effect of Indigenous Palm Fronds and Cow dung Biochar and its Blends on Soil Properties

II. Growth Assessment of Oil Palm Seedlets

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Abstract: Biochar being an important tool to addressing a wide range of the major challenges of soil degradation and food insecurity, climate change, sustainable energy generation and waste management is a carbon rich product obtained when biomass such as wood, manure or leaves is heated in a closed vessel with little or no air. The objective of this study was to determine the effects of biochar and its blends on soil properties and its effects on the growth assessment of oil palm seedlets. The palm fronds and cow dung biochar produced at 300°C for three hours and the soil prepared were analyzed for physico-chemical properties in the laboratory using standard techniques. The growth, soil physico-chemical properties and water holding capacity of the biochar–soil mixture samples in which sprouted oil palm seedlets have been planted were measured. The biochars showed good improvement in the soil water holding capacity at 20-35% more with 40tha⁻¹ dry biochar application than the control. The results of the soil-biochar analysis on the growth of the oil palm and physico-chemical properties of the biochar–soil mixture samples showed significant ($p < 0.05$) improvement.

Keywords: Biomass, Oil Palm Seedlets, Food Security, Soil Amendment, Productivity.

1. Introduction

Severe hunger and poverty affects nearly billions of people around the world particularly people in the developing world are more battered and malnourished. Three-quarters of the world's poorest people get their food and income from farming small plots of land. They deal with diverse and challenging farming systems, facing diseases, pests, and drought, as well as unproductive soil, with limited access to inputs [1]. For some time, the research community has recognized low soil fertility, particularly nitrogen and phosphorus deficiencies, as one of the major biophysical constraints affecting the oil palm plantations due to continuous soil-fertility depletion. The urgency to address these threats creates an increasing demand for solutions that can be implemented now or at least in the near future. These solutions need to be implemented both locally by individuals and the government in order to produce effects on a global scale. One of such approach is the use of biochar [2]. Biochar has unique properties that make it a valuable soil amendment to sustainably increase health and productivity. Even though biochar has been the subject of scientific investigation for 10 years, efforts have been isolated or regionally focused, [3]. It is undisputed that biochar is much more persistent in soil than any other form of organic matter that is commonly applied to soil. Therefore, associated benefits with respect to nutrient retention and soil fertility are longer lasting than with alternative management.

The present study presents an investigation of the effect of palm frond and cow dung biochar and its blends on soil water holding capacity, soil physico-chemical properties and growth performance of the oil palm seedlets, under varying loading concentrations.

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2. Methodology

2.1. Materials

Fronds of the African oil palm tree (*Elaeis guineensis*) and the dung of domesticated Cow (*Bos taurus*) were obtained from the premises of the Nigerian Institute for Oil Palm Research, Benin City, Nigeria. The sprouted oil palm seedlets and the soil were from the institute.

2.2. Preparation of the Biochar

The palm fronds were separated from the palm stalk, reduced to small sizes for ease of handling and processing, while the cow dung was dried at 75°C for 3h before use for further analysis. Two samples of 4.0 kg from each organic source were pyrolysed at 300 °C for 3h. The biochar obtained were then milled to fine powder using a mechanical grinder, and sieved through a mesh size of 150 µm. The biochar particles that passed through the screen were collected, characterised and used for further analysis.

2.3. Characterization of the Biochars and the Soil Samples

The biochars were characterized as follows: % yield (dry weight basis) on pyrolysis was obtained from the weight difference pre- and post pyrolysis, ash content was determined using the method described in ASTM D1762-84, (1983); the bulk density was determined using the method described by Ahmedna et al. [4]; the pH was determined using ASTM D 1512(1983) method; the method used for surface area measurement was iodine adsorption[5]; conductivity of biochar was determined using the conductivity meter. The total surface functional group was carried out by the method described by Boehm [6]. Attrition was determined using the method described by Marshal et al. [7]; porosity was determined using the method described in ASTM D1584 (1983). Calcium and magnesium concentrations were determined by EDTA titration, while the sodium and potassium concentrations were determined by flame photometry (Model 410, Sherwood, England) and the nutrient values were determined using AOAC standard methods.

Soil samples from surface to a depth of 30 cm were collected using auger and prepared for further analysis. All the reagents used for analysis were of analytical grade and were used without further purification. The soil samples were analyzed as follows: bulk density was measured by core method, [8], Soil pH was measured in 1:1 soil-water ratio,[9]. Soil organic carbon was estimated by combustion at 840 °C [10], while total nitrogen was obtained by microKjeldahl method. Cation exchange capacity was measured using ammonium acetate leaching at pH 7.0; [11]. Available phosphorus was determined by Olsen method[12].

2.4. Experimental Design and Method

Measured quantities of each of the biochar samples (0, 10.0, 20.0, 30.0 and 40.0 t ha⁻¹, dry biochar, designated as W₀-W₄) were thoroughly mixed with uniform quantities of soil, placed in polythene containers. Sprouted seedlets of the oil palm were planted at the centre of each pot. The soil was irrigated to field capacity and the volume of water required to saturate the soil was recorded. The experiment was green house studies which consist in all, 13 treatments (4 palm frond biochar (PFB), and 4 cowdung biochar (CDB) concentrations; 1 control, 4 biochar blends) laid out in a complete randomised design (CRD) in three replications. Measurements of the plant height, leaf area, pigment values, relative water content (RWC) and root to shoot ratio, were taken at two-week intervals after planting for eight weeks. The water holding capacity was evaluated as: weight of water retained by treatment = weight of water treatment– weight of water in control. Results of treatment with highest performance are presented.

2.5. Statistical Analysis

The results presented are the mean values ± standard errors obtained from at least three replicates. Significant differences between the treated and control plants were determined using ANOVA F-test (P < 0.05). Statistical analyses were conducted using the statistical software package Genstat 12.

3. Results and Discussion

3.1. Results of Growth Performance of the Oil Palm Seedlets

The results of the physio-chemical properties of the biochar and the experimental soil were presented in previous work [13].

The greater the surface area, the more effective the biochar in relation to affecting soil properties (although the nature of the surfaces play an equally important role). Biochar macropores are also relevant to the movement of roots through soil; they store water and act as habitats for a vast variety of soil microbes, [14]. Two factors, feedstock and pyrolysis conditions, control the amount and distribution of mineral matter in biochar [3]. Table 1 shows that the amount of water used increases significantly ($p < 0.05$) with the amount of amendments. This is expected because the more the amount of biochar added the more water the soil takes because of the ability of the biochar to absorb water, [3]. However, Table 1 shows that subsequent addition of water in subsequent weeks significantly decreases ($p < 0.05$) from the initial amount of water absorbed due to the storage ability of the biochar to hold water for plant use. This translates to more water for the plant particularly considering the drought nature of the soil in sub-Saharan Africa. The initial water demand of the soil-BB was higher by 19.1% when compared to the soil PFB and CDB treatments.

Table 1: water (ml) used by sprouted seedlets treatments at various week intervals

Treatment/Wks	2	4	6	8
PFB				
W ₁	380a	285a	245a	220a
W ₂	425a	375b	300b	245a
W ₃	510b	450c	375c	305b
W ₄	680c	550d	450d	375c
CDB				
W ₁	400a	325a	275a	200a
W ₂	475b	400b	325a	275b
W ₃	550c	425b	375a	300b
W ₄	750d	550c	480b	400c
Control				
BB	325	285	250	200
	741	594	490	305
PFB				
Mean	498.75	415	342.50	286.25
LSD(0.05)	128.3	109.1	86.6	67.0
SEM	46.78	39.76	31.57	24.43
C.V%	26.53	27.10	26.07	24.13
CDB				
Mean	543.75	425	363.75	293.75
LSD(0.05)	146.0	90.7	85.0	80.1
SEM	53.22	33.07	30.97	29.20
C.V%	27.68	22.00	24.08	28.12

C.V: coefficient of Variation, SEM: Standard error of the mean, LSD: Least square difference. Different letters in the columns indicate significant differences between treatments at $P < 0.05$ level. BB: biochar blends

Table 2 summarizes the effect of the biochars on the growth performance of the oil palm spouted seedlets. The table shows a significant growth performance expressed in terms of the height, root/shoot ratio, leaf area, relative water capacity of the leaves and pigment values. However, the blend showed a significant effect on growth compared to that of the control and other treatments over the period. The probable reason for this is the high nutritive value of the blend over the others, which has a significant effect on the properties of soil supporting the oil palm [2].

Table 2: Effect of soil amendment with biochar on oil palm seedlets height, root/shoot ratio under different biochar treatments

Treatment	Plant height (cm)	Root/shoot ratios	Leaf area (cm ²)	RWC (%)	Chlorophyll a/b
Control	38.44 ± 1.06	0.25 ± 0.01	285.56 ± 41	88.8 ± 2	2.13 ± 0.04
Soil-BB(1:1)	58.25 ± 2.88	0.42 ± 0.15	360.11 ± 56	98.6 ± 1	1.57 ± 0.04
Soil-PFB(W ₄)	42.56 ± 1.56	0.18 ± 0.05	272.88 ± 11	90.4 ± 2	2.01 ± 0.02
Soil-CDB(W ₄)	40.05 ± 1.89	0.16 ± 0.01	258.05 ± 25	92.3 ± 2	2.00 ± 0.04

RWC: Relative water content of the leaves.

Table 3: Physico-chemical properties of the soil-biochar mix at the end of the first two weeks

Sample	Biochar	TN(g/kg)	pH	TOC (g/kg)	BD (g/ml)	CEC (mg/kg)	P(mg/kg)
Control	0	0.10 ± 0.05	5.4 ± 0.1	1.57 ± 0.15	1.58 ± 0.05	2792.2 ± 98.1	33.76 ± 2.7
Soil-PFB	W ₄	0.28 ± 0.02	5.8 ± 0.1	1.88 ± 0.06	1.68 ± 0.05	2814.2 ± 14	48.0 ± 1.4
Soil-CDB	W ₄	0.42 ± 0.06	6.3 ± 0.1	2.16 ± 0.11	1.80 ± 0.01	2895.5 ± 154	54.0 ± 1.2
Soil-BB	1:1	0.60 ± 0.05	6.5 ± 0.1	2.40 ± 0.08	1.98 ± 0.03	3092.4 ± 164	66.7 ± 1.1

TN: Total Nitrogen TOC: Total organic carbon, BD: Bulk density, CEC: Cation exchange capacity, P: Phosphorus.

Table 4: Physico-chemical properties of the soil –biochar mix at the end of the last two weeks

Sample	Biochar	TN(g/kg)	pH	TOC (g/kg)	BD (g/ml)	CEC (mg/kg)	P(mg/kg)
Control	0	0.15±0.01	5.9±0.1	1.77±0.05	1.51±0.01	2854.1±54.2	39.1±1.3
Soil –PFB	W ₄	0.34±0.05	6.4±0.1	1.98±0.15	1.20±0.02	3308.5±148	58.0±1.5
Soil-CDB	W ₄	0.55±0.01	6.8±0.2	3.44±0.05	1.71±0.05	4311.8±106	64.0±1.4
Soil-BB	1:1	0.78±0.06	7.2±0.1	3.64±0.25	1.86±0.01	4913.3±118	80.1±1.2

Table 3 and Table 4 summarize the effect of the biochars on the properties of soil supporting the oil palm for a two month period. The results 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 performance of the sprouted seedlets compared to the control. However, there is a remarkable reduction in the total acidity of the soil obviously due to the high level of CEC of the soil-biochar mix.

The tables show the immediate positive effect of the biochars on the properties of the soil, water retention capacity of soil and growth rate of the seedlets over a period of two months, which corroborates the earlier assertion of Liang et al., [15]. These point to the ability of biochar to increase the plant available water in the soil which enables the plants to survive longer under water stress, increase soil fertility and agricultural yields, improve soil structure, aeration & water penetration, reduce use of synthetic fertilisers and pesticides, reduce nitrous oxide and methane emission from soil, reduce nitrate and farm chemicals leaching into watersheds, convert green and brown wastes into valuable resources, reduces the evapotranspiration rate of the plants and induce a significantly higher growth rate in plants [2]. However, a close look at the results reveal tendency for prolonged positive impact of the biochars in the soil and on the plant.

4. Conclusion

The results show that biochar prepared from cow dung and palm fronds influenced the growth rate of the sprouted seedlets more as blends compared to the control, in terms of obvious differences in the biometric data. The results indicate that there is an improvement in the ability of the soil to hold water with the introduction of the biochar. The results further show that the biochar blends formulation is recommended because it influenced the physico-chemical properties of soil supporting the oil palm and the growth rate of the sprouted seedlets better than the individual biochars and the control by 28%. This increase in plant growth and soil improvement will no doubt increase yield and productivity, which would also contribute in no small measure to solving the challenge of feeding our growing population in the continent. However, more research needs to be conducted in determining the best quality of biochar and its output in view of the influence of pyrolysis time, temperature and modes of application.

5. References

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