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Influences of Cocoa Pod Husk, Cocoa Pod Husk Biochar and NPK Fertilizer on Soil Properties and Growth Performance of Plantain (*Musa Paradisiacal* L) in Ile-Oluji, Ondo State, Nigeria

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Abstract

Field experiment was carried out during 2018 cropping season at Ile-Oluji in the rain forest zone of Nigeria to study the effects of cocoa pod husk (CPH), cocoa pod husk biochar (CPHB) and NPK fertilizer (NPKF) on soil properties and growth performance of plantain (Musa paradisiacal L). The trial involved the application of cocoa pod husk (CPH), cocoa pod husk biochar (CPHB) at 5, 10, 15 and 20 t ha^{-1} and 300 kg ha^{-1} NPK fertilizer (NPKF), Soil physical properties and growth parameters of plantain were evaluated. The amendments improved soil porosity, bulk density, pH and OM relative to the control. The result also revealed that growth components of plantain treated with 20 t ha^{-1} CPH and CPHB were similar to the plants treated with 300 kg ha^{-1}. NPKF and they were significantly higher than those of the control. Number of leaves, leaf area, Pseudostem height and girth increased with increased rate of amendments relative to the control, 300 kg ha^{-1} NPKF, 5, 10, 15 and 20 t ha^{-1} CPH and CPHB improved soil physical condition. Cocoa pod husk biochar at 20 t ha^{-1} is recommended for the production of Plantain as substitute for an expensive and scarce NPK fertilizer in the study area.

Keywords: Plantain; growth performance, cocoa pod husk, cocoa pod husk biochar; soil physical properties.

Introduction

Plantains (*Musa* ***paradisiacal*** **L)** are plants producing fruits that remain starchy at maturity (Marriot and Lancaster, 1983; Robinson, 1996). The fruits are eaten boiled, roasted, fried or baked. The rate of plantain consumption has risen tremendously in Nigeria in recent years because of the rapidly increasing human population, urbanization and demand for easy and convenient foods by the non-farming population. Plantain is a delicacy and favored snack for people even in other ecologies. A growing industry, mainly plantain chips, is believed to be responsible for the high demand being experienced now in the country. Though fruits are produced all year round, the major harvest comes in the dry season (November to February), when most other starchy staples are unavailable or difficult to harvest. Thus, it plays an important role in bridging the hunger gap (Wilson, 1986) as well as assisting farmers in having cash at hand through sales of plantain. Management of soil fertility for high productivity of plantain farm remains a challenge due to continuous use of soil nutrients without replenishment particularly in the south western Nigeria. Continuous cultivation and cropping with chemical fertilizer reduce organic matter content and hence decrease granulation compared to virgin soils. Crop yield efficiency depends on the available nutrient status of the soil (Khan *et al.,* 2009). Plant residue is rapidly available at the farm level which can be utilized as bio fertilizer and soil amendment, but the bulkiness and slow mineralization among other factors contribute to its underutilization; Pyrolysis is the process of chemically decomposing or transforming a material into one or more recoverable substances by heating it to very high temperatures in an oxygen-free environment, it could also be described as a thermochemical process where biomass is heated in the absence of oxygen in which the resulting char is a primary stabilized carbon (Yaman, 2004). The net effect of biomass pyrolized to biochar is to remove carbon dioxide and storing it instable soil carbon called sinks. When char is intentionally produced for agricultural use, it is called biochar (Lehmann, 2009). Pyrolysis is one of the most attractive alternative options among the bioenergy conversion technologies to produce soil conditioners from plant residues. Biochar application has multiple benefits for soil fertility improvement. It can act as a source of nutrients and sequester carbon (C) in the soil. Akanbi *et al.,* (2013) recognized the need to intensify studies into locally sourced, cheap, adoptable organic sources of plant nutrients. In order to alleviate the problems of low soil fertility and soil quality affecting yield of crop with continuous cultivation of crops, there is the need to develop an organic soil management for sustainable production of plantain. It is already established that total dependence on chemical fertilizer has failed to sustain crop production in the tropics (Ojeniyi, 2000; Ano and Agwu, 2005). The aim of this research was to restore the productivity of plantain plantations by improving the physical, chemical and biological characteristics of soil through carbon sequestration which serves as a C-substrate for soil macrofauna and microorganisms.

Materials and Methods

The study was conducted during 2018 cropping season at the Teaching and Research Farm, Federal Polytechnic Ile Oluji, Ondo State located in the rainforest Zone of Nigeria on latitude 7 ° 20` N and longitude 4 ° 87` E and Altitude of 247 metres. The location has a bimodal rainfall of 1250 to 1460 mm with mean annual rainfall of 1367 mm and average number of rainy days of about 112 per annum. Temperature is almost uniform throughout the year 21 – 33 ^{o}C with little deviation from mean annual of 27 °C. February and March are the hottest months with mean temperature of 28 and 27 °C, respectively. The mean total sunshine hour is about 2000 hours with mean annual radiation of about 130 kcal cm^{-3} year^{-1}. The area falls within the high forest zone where the rich tropical forests once thrived. The location has a tropical humid climate with distinct wet and dry seasons. The wet season is from late March to October with little dry season in August (meteoblue.com).

Experimental design and treatments

The experiment was arranged in a randomized complete block with each treatment replicated four times. The area used was 24 m x 51 m (1224 m^{2}) in total. Each plot measured 3 m x 3 m with discard of 3 m within the plots and 4m between the block. The trial involved the use of cocoa pod husk (CPH), cocoa pod husk biochar (CPHB) and NPK fertilizer (NPKF). Prior to planting, plantain suckers were raised through sucker multiplication method at nursery, transferred to polythene pots. Suckers with equal height and number of leaves were selected and planted on well prepared land at a spacing of 3 x 3 m and this was followed by application of CPH and CPHB at 0, 5, 10, 15, 20 t ha^{1} and 300 kg ha^{1} NPKF to cover the soil. Weeding operation was done manually as at when due. Determination of certain soil physical properties in all plots at the site commenced one month after treatments application and this was done on four occasions at two months' interval. Six samples were collected at 0-10 cm depth from each plot using a steel cone sampler and were used for evaluation of bulk density, total porosity and gravimetric water content after oven-dried at 100ºC for 24 hrs. Total porosity was calculated from the values of bulk density and particle density. Soil temperature was determined at 15.00 hr with a soil thermometer inserted to 10 cm depth. Six readings were made per plot at each sampling time and mean data were computed. Prior to commencement of experiment, soil samples randomly collected from 0 – 20 cm depth were thoroughly mixed inside a plastic bucket to form a composite which was later analyzed for physical and chemical properties. Another set of composite samples were collected per plot basis before maturity and similarly analyzed for routine chemical analysis as described by Carter (1993). The soil samples were air-dried and sieved using a 2 mm sieve before making the determinations. Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996), Soil pH was determined in soil water (1:2) medium using the digital electronic pH meter. Particle size analysis was done using Bouyoucos hydrometer method (Sheldrick and Hand Wang, 1993). Soil bulk density was determined using the core method (Campbell and Henshall, 1991).

Data collection and statistical analysis

Two plantains were randomly selected from each plot across the four blocks for growth determination. The parameters assessed included number of leaves, pseudostem height, pseudostem girth, and leaf area. The data collected were subjected to analysis of variance (ANOVA) using the SPSS package (version 16) and treatment means were compared using the Duncan's multiple range test (DMRT).

Results

Pre-Planting Soil properties

Table 1 shows soil properties of the experimental site at Ile Oluji Nigeria prior to planting. The values of soil Bulk density was 1.43 g/cm^3, Porosity - 41.4 %, Soil temperature - 36.1 °C and Soil moisture - 6.31 % The result revealed that the soil at the location was sandy loam, acidic, low in N, available P, exchangeable K and OM in accordance with the rating of Akinrinde and Obigbesan (2000). Therefore, the results revealed that additional soil conditioner would be needed before the soil could effectively produce crop.

Table 1: Pre-Planting Soil properties

Property	Value
Sand (%)	71
Silt (%)	14
Clay (%)	15
Textural Class	Sandy Loam
Bulk density g/cm^3	1.43
Total porosity (%)	41.4
pH (H_20)	5.8
Organic Matter (%)	2.26
Total N (gkg^{-1})	0.14
Available P (mgkg^{-1})	9.21
Exchangeable K (cmolkg^{-1})	0.17
Exchangeable Ca (cmolkg^{-1})	2.41
Exchangeable Mg (cmolkg^{-1})	1.09

Table 2: Effect of cocoa pod husk, cocoa pod husk biochar and NPK Fertilizer, on selected soil properties

Treatment	pH	OC (%)	Moisture (%)	Temperature (^{0}C)	Porosity (%)	Bulk density (g/cm^3)
Control	5.08i	1.11j	5.53j	31.83a	30.48a	1.42a
5 t ha^{-1}. CPH	6.39g	2.69h	7.86h	29.68c	37.53a	1.19d
10 t ha^{-1} CPH	6.48e	2.83g	8.93f	29.21e	43.48a	1.17f
15 t ha^{-1} CPH	6.78c	3.41d	9.42c	28.53g	47.93a	1.15h
20 t ha^{-1}CPH	6.78c	3.89b	10.61a	27.84i	52.84a	1.13j
5 t ha^{-1} CPHB	6.47f	3.03f	7.63i	29.82b	34.84a	1.21c
10 t ha^{-1} CPHB	6.59d	3.32e	8.25g	29.47d	41.73a	1.18e
15 t ha^{-1}CPHB	6.81b	3.87c	8.98e	28.68f	45.16a	1.16g
20 t ha^{-1} CPHB	6.94a	4.38a	9.69b	28.31h	47.92a	1.14i
300 kg ha^{-1} NPKF	5.82h	1.24i	9.37d	29.82b	33.96a	1.28b

Data followed by the same alphabet along the columns are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). CPH =Cocoa Pod Husk, CPHB = Cocoa Pod Husk Biochar, NPKF = NPK 15:15:15 Fertilizer

Table 2 presents data on effect of amendments on some selected soil properties, the result revealed that soil moisture content and porosity increased with increase in rate of amendments irrespective of amendment types. CPH applied at the rate of 20 t ha^{-1} had highest value of moisture and it was significantly different from the value recorded for other soil amendments. All the soils treated with amendments recorded a significant higher value compared with the control. Soil moisture content under 20, 15, 10 and 5 t ha^{-1} CPH and CPHB were (10.61, 9.42, 8.93, 7.86 %), (9.69, 8.98, 8.25, and 7.63 %) respectively. Effect of CPH and CPHB were significantly higher than the values obtained for NPKF and control. The values of porosity were not significantly different from one another although were slightly varied considering nutrient sources and rates. Temperature and soil bulk density were reduced with increase in rate of amendments irrespective of type. 20 t ha^{-1}.CPH had the least temperature value of 27.84°C and was significantly lower than the closest value of 28.31°C recorded for 20 t ha^{-1}. CPHB. The control had the highest value of temperature followed by soil treated with 300 kg ha^{-1} NPKF, 5 t ha^{-1} CPHB, 10 t ha^{-1} CPH and 10 t ha^{-1} CPHB respectively. Soil bulk density under 20 t ha^{-1}. (CPH and CPHB) were 1.13 g/cm^3 and 1.14 g/cm^3 while the control obtained highest value of bulk density and was significantly higher than others. Both CPH and CPHB reduced soil temperature and bulk density irrespective of rates relative to the control.

Table 3: Effect of cocoa pod husk, cocoa pod husk biochar and NPK Fertilizer, on number of leaves of plantain at weeks after treatments application (WATA)

Treatment	Weeks After Treatments Application (WATA)									
	2	4	6	8	10	12	14	16	18	20
Control	5.61d	6.17j	6.98j	8.02j	8.96j	9.73j	10.53j	11.41j	12.38j	13.06i
5 t ha^{-1} CPH	5.43j	6.48i	7.65i	8.74i	9.88i	10.57i	11.41i	12.48i	13.41i	14.21f
10 t ha^{-1} CPH	5.72b	6.85f	8.02g	9.24g	10.47g	11.21g	12.13g	13.15g	14.11g	14.96d
15 t ha^{-1} CPH	5.60e	6.87d	8.14e	9.39e	10.79e	11.53f	12.39f	13.27f	14.24f	15.13cd
20 t ha^{-1} CPH	5.52g	6.86e	8.26c	9.73c	11.01c	11.97c	12.98c	14.02c	15.00c	15.98a
5 t ha^{-1} CPHB	5.51h	6.58h	7.84h	8.92h	9.97h	10.83h	11.79h	12.80h	13.73h	14.62.e
10 t ha^{-1} CPHB	5.48i	6.83g	8.12f	9.31f	10.78f	11.81e	12.69e	13.71e	14.68e	15.37bc
15 t ha^{-1} CPHB	5.53f	6.89c	8.22d	9.48d	10.93d	11.96d	12.84d	13.92d	14.74d	15.59b
20 t ha^{-1} CPHB	5.71c	6.92b	8.31b	9.87b	11.14b	12.03b	13.09b	14.11b	15.07b	16.01a
300 kg t ha^{-1} NPKF	5.93a	7.08a	8.49a	10.13a	11.79a	12.64a	13.52a	14.38a	15.21a	16.19a

Data followed by the same alphabet along the columns are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). CPH =Cocoa Pod Husk, CPHB = Cocoa Pod Husk Biochar, NPKF = NPK 15:15:15 Fertilizer

The effects of amendments on number of leaves are shown in Table 3. Soil treated with varying rates of cocoa pod husk (CPH), cocoa pod husk Biochar (CPHB) and 300 kg ha^{-1} significantly ($p < 0.05$) increased number of leaves from 2 to 20 WATA. Plot treated with 300 kg ha^{-1} NPKF had the highest number of leaves in most observation except at 20 WATA in which number of leaves obtained for 20 t ha^{-1}CPH was not significantly different. Number of leaves recorded for CPH was significantly lower than 300 kg ha^{-1} NPKF but significantly higher than others.

Table 4 presents data on effects of cocoa pod husk (CPH), cocoa pod husk biochar (CPHB) and NPK fertilizer (NPKF) on pseudostem of plantain. The fertilizer types increased the height of plantain from 2 to 20 WATA irrespective of fertilizer type and rates relative to the control. Highest pseudostem height of plantain, vine length, number of branches and leaf area were recorded for plant treated with 300 kg ha^{-1} NPKF followed by 20 t ha^{-1} CPHB and 20 t ha^{-1} CPH with little difference. The least value of pseudostem height was recorded for the control and it was significantly lower than all amendment tested.

Table 4: Effect of cocoa pod husk, cocoa pod husk biochar and NPK Fertilizer, on pseudostem height of plantain weeks after treatments application (WATA)

Treatment	Weeks After Treatments Application (WATA)									
	2	4	6	8	10	12	14	16	18	20
Control	47.62a	56.34j	62.64j	73.08j	79.37i	91.51j	98.69j	102.11j	111.13j	118.27j
5 t ha^{-1} CPH	46.87d	57.72i	69.83i	82.83i	92.03h	103.92i	116.97i	127.13i	142.93i	144.53i
10 t ha^{-1} CPH	47.48b	59.12g	72.88g	89.03g	102.81e	110.98g	120.93g	131.52g	147.30g	147.02h
15 t ha^{-1} CPH	45.93g	59.42f	74.73e	92.75e	108.37d	115.67e	128.01e	136.21e	151.41e	156.11e
20 t ha^{-1} CPH	46.33e	61.81c	78.61c	96.91c	111.39c	124.01c	132.74c	139.99c	154.08c	162.41c
5 t ha^{-1} CPHB	44.96j	58.02h	70.82h	83.26h	92.81g	104.73h	117.83h	128.81h	144.74h	148.32g
10 t ha^{-1} CPHB	46.08f	60.12e	73.96f	89.68f	99.04f	112.97f	122.18f	133.72f	149.92f	151.47f
15 t ha^{-1} CPHB	47.39c	60.93d	75.68d	93.27d	107.83d	118.73d	129.01d	138.47d	153.21d	157.59d
20 t ha^{-1} CPHB	45.68h	62.46b	79.42b	98.94b	114.29b	126.31b	136.05b	143.21b	157.61b	165.91b
300 kg t ha^{-1}NPKF	45.50i	63.73a	84.63a	101.52a	119.74a	131.03a	140.51a	148.49a	161.23a	173.05a

Data followed by the same alphabet along the columns are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). CPH =Cocoa Pod Husk, CPHB = Cocoa Pod Husk Biochar, NPKF = NPK 15:15:15 Fertilizer

Table 5 presents data on effects of amendments on pseudostem girth of plantain from 2 to 20 WATA. The result revealed all the amendments tested significantly increased the girth of plantain irrespective of types and rates from 2 to 20 WATA relative to the control. Highest value of pseudostem girth of plantain was obtain for 300 kg ha^{-1} NPKF which was closely followed by 20 t ha^{-1} CPHB and CPH respectively.

Table 5: Effect of cocoa pod husk, cocoa pod husk biochar and NPK Fertilizer, on pseudostem girth of plantain weeks after treatments application (WATA)

Treatment	**Weeks After Treatments Application (WATA)**									
	2	**4**	6	**8**	**10**	**12**	**14**	**16**	**18**	**20**
Control	12.36bc	16.10fg	19.96g	22.93j	25.62i	28.47j	31.01j	34.26j	38.15j	43.02i
5 t ha^{-1} CPH	12.09abc	16.08ef	20.08f	23.97i	28.47h	32.71i	36.27i	39.83i	43.45i	48.27h
10 t ha^{-1} CPH	12.38a	16.37d	21.24e	24.48g	30.58f	34.02g	39.03g	42.37g	47.36g	52.11f
15 t ha^{-1} CPH	11.92c	17.06c	23.24c	27.21e	33.79d	38.01e	41.06e	46.02e	51.62e	55.03d
20 t ha^{-1} CPH	12.40a	18.41a	25.91b	30.85c	36.98b	40.36c	44.31c	49.97c	55.24c	57.34c
5 t ha^{-1} CPHB	12.37a	17.91b	21.41e	24.08h	29.21g	33.21h	36.93h	40.93h	44.56h	49.73g
10 t ha^{-1} CPHB	11.98c	15.69g	21.85d	25.62f	31.71e	35.01f	39.72f	44.36f	49.22f	53.38e
15 t ha^{-1} CPHB	11.79c	16.14de	23.22c	28.37d	34.52c	38.73d	42.01d	47.92d	52.41d	57.36c
20 t ha^{-1} CPHB	12.32ab	17.96b	25.89b	31.94b	37.21b	41.86b	45.61b	51.01b	57.23b	59.14b
300 kg ha^{-1} NPKF	12.39a	18.62a	26.48a	33.31a	39.19a	43.21a	47.58a	52.71a	58.63a	61.19a

Data followed by the same alphabet along the columns are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). CPH =Cocoa Pod Husk, CPHB = Cocoa Pod Husk Biochar, NPKF = NPK 15:15:15 Fertilizer

Table 6: Effect of cocoa pod husk, cocoa pod husk biochar and NPK Fertilizer, on leaf area of plantain weeks after treatments application (WATA)

Treatment	Weeks After Treatments Application (WATA)									
	2	**4**	6	**8**	**10**	**12**	**14**	**16**	**18**	**20**
Control	953.6b	1062.4h	1201.3j	1958.4j	2721.4j	3115.3j	4013.2j	4683.1j	5251.4j	5752.2j
5 t ha^{-1} CPH	913.8f	1012.1j	1284.7i	2103.2i	3691.6i	4107.5i	5024.7i	7421.0i	8538.7i	9579.3i
10 t ha^{-1} CPH	937.1e	1126.3f	1396.2g	2287.1g	3892.5g	4378.4h	6321.4g	8362.6g	9562.2g	9937.2g
15 t ha^{-1} CPH	942.5c	1193.7b	1417.5e	2375.9e	4103.6e	5821.7e	7526.9e	9541.7e	10351.8e	10671.8e
20 t ha^{-1}CPH	939.7d	1191.5c	1589.2c	2592.5c	4228.2c	6110.4c	7814.2c	9763.2c	10493.6c	10879.6c
5 t ha^{-1} CPHB	964.1a	1013.4i	1382.6h	2159.3h	3782.4h	4512.6g	5786.5h	7601.4h	8597.4h	9637.4h
10 t ha^{-1} CPHB	897.8i	1096.2g	1407.3f	2295.8f	3946.2f	4836.8f	6784.9f	8573.5f	9603.2f	10211.5f
15 t ha^{-1} CPHB	906.4h	1182.7e	1583.1d	2483.2d	4168.3d	5984.3d	7793.8d	9642.4d	10375.7d	10689.3d
20 t ha^{-1} CPHB	894.8j	1185.3d	1615.8b	2697.4b	4312.7b	6212.7b	7923.6b	9831.7b	10528.4b	10941.1b
300 kg ha^{-1} NPKF	911.3g	1312.6a	1893.4a	2921.5a	4627.9a	6401.3a	8157.3a	10028.2a	10731.6a	11217.4a

Data followed by the same alphabet along the columns are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT). CPH =Cocoa Pod Husk, CPHB = Cocoa Pod Husk Biochar, NPKF = NPK 15:15:15 Fertilizer

Table 6 presents data on leave area of plantain from 2 to 20 WATA. All the amendments imposed significantly increased leaf area of plantain irrespective of the source and rate. Highest leaf area of plantain was recorded for the plot treated with 300 kg ha^{-1} NPKF and it was closely followed by 20 t ha^{-1} CPHB and CPH. The value of leaf area obtained for the control was the least throughout the observations and was significantly lower than other.

Discussion

This work shows that CPH and CPHB improved soil physical properties by reducing soil temperature and bulk density which reduced with increase in amendments rate irrespective of nutrient sources. While soil porosity, soil moisture content increased with increase rates of soil amendments. Returning organic waste to the soil is known to improve soil quality and productivity through favourable effects on soil properties (Lai and Stewart, 1995). Favourable effects of organic manure on soil organic carbon, water retention and aggregate stability have been reported on soil surface layer (Duicker and Lai, 1999). Conservation of soil moisture is one of the major advantages of organic materials incorporated into soil. Organic materials bind the soil, serve as major barrier against moisture losses from soil, slow surface runoff and increase infiltration. Hence this work found that soil moisture content increased with rate of cocoa pod husk (CPH) and cocoa pod husk biochar (CPHB). The increase in moisture content expectedly reduced soil temperature (Agele *et al.,* 1999). The increased porosity and reduced soil bulk density recorded in this study could be attributed to increased microbial activities and mineralization of nutrients and it is consistent with the findings of Noltidge *et al.,* (2005) and Akanbi and Ojeniyi (2007). The number of leaves, pseudostem height and girth of plantain increased with the application of 300 kg ha^{-1} NPKF and other amendments irrespective of rates relative to control. This is attributed to the ability of the amendments to release nutrients for the quick utilization by plants and improving the root environment which translated to high growth performance obtained. This indicated that plantain can be cultivated using both cocoa pod husk (CPH) and cocoa pod husk biochar (CPHB) with significant growth performance. The maximum and higher growth were given by CPH and CPHB relative to the control., 20 t ha^{-1} CPH and CPHB gave a close value of number of leaves, pseudostem height and girth compared with plant treated with 300 kg ha^{-1} NPKF. The differences noticed between NPKF and other amendments are not adequate to justify the cost of synthetic fertilizer used coupled with other constraints being experienced by farmers as a result of its usage. It was also observed that plantain can be produced with cocoa pod husk (CPH) and cocoa pod husk biochar (CPHB) with significant improvement.

Conclusion

It is concluded that 20 t ha^{-1} CPH and CPHB are suitable for the production of plantain in the agro ecological Zone; as they are highly advantageous to ensuring improved soil physical properties and performance of plantain. Cocoa pod husk Biochar at 20 t ha^{-1} is recommended for the production of plantain since it can be substitute for an expensive and scarce NPK fertilizer in the studied area.

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