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Comparative Assessment of Cocoa Pod Husk Biochar Fortified with NPK Fertilizer Formulations on Kola Seedling Nutrient Uptake and Soil Properties in Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author OSI designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author OSOA managed the literature searches, statistical analysis of the study and authors OSI and OSOA managed the experimental process. Both authors read and approved the final manuscript.

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ABSTRACT

A greenhouse trial was carried out at Cocoa Research Institute of Nigeria, Ibadan in 2013 to evaluate the effect of cocoa pod husk (CPH) biochar fortified with NPK fertilizer formulations on kola seedling nutrient uptake and soil properties. The treatments consisted of a control, NPK (3 g) + Biochar (5 g), NPK (Liquid – 3 mls/L of water) + Biochar (5 g), Biochar (5 g), NPK (Solid-3 g), NPK (Liquid – 3 mls/L of water). The six treatments were replicated three times in a completely randomized design and data on nutrient uptake of kola seedlings and soil properties were taken for seven months. Results showed that all the fertilizers irrespective of rates of application and types of NPK formulations enhanced the nutrient uptake of kola seedlings relative to control.
The leaf and root nitrogen uptake of kola seedlings was significantly ($p<0.05$) enhanced as a result of CPH biochar applied singly (T4) or in combination with NPK liquid fertilizer (T3) compared to when biochar was applied with NPK solid fertilizer. The leaf and stem P-uptake of Kola seedlings was not significantly influenced by CPH biochar and NPK fertilizer formulations. Conversely, the P-

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uptake of root of kola seedlings was significantly ($p<0.05$) improved as a result NPK (liquid) fertilizer compared to NPK (solid) applied alone. The pH of the soil was significantly ($p<0.05$) affected due to application of CPH biochar in combination with liquid NPK (T3) and CPH biochar alone (T4) compared to the control and NPK solid (T5). The exchangeable K in the soil was significantly ($p<0.05$) influenced as a result of CPH Biochar application and NPK fertilizer formulations. CPH biochar alone (T4) significantly ($p<0.05$) improved the exchangeable potassium in the soil compared to the control. The positive influence of CPH biochar applied either alone or in combination with NPK fertilizers on nutrient uptake of kola seedlings and soil nutrients indicated that integrated use of organic and inorganic fertilizers holds the ace for crop production and soil fertility management in Nigeria. Kola farmers across the growing regions have the privilege of using biochar fortified with NPK fertilizer (liquid) for improved productivity.

Keywords: Biochar; dry matter yield; growth; kola seedlings; NPK fertilizer.

1. INTRODUCTION

Kola is a tropical African genus that belongs to the family Sterculiaceae and has long history in West Africa [1]. The genus comprises of about 140 species [2] of which fifty species have been described in West Africa [3]. *Cola nitida* and *Cola acuminata* are the two major cultivated species in Nigeria. Despite the strong cultural importance of kola in West Africa, research interest on the crop has been very tardy. The use of fertilizer on kola at early stage or fruiting stage has not received much attention of Research Scientists probably because previous attempts indicated that the crop did not show consistent response to fertilizer application [4]. Previous efforts were concentrated on the use of inorganic fertilizer such as NPK 15-15-15, urea, MOP and SSP. The response of kola to fertilizer application in terms of yield and growth had been very inconsistent; this makes kola research unattractive to most scientists. In addition, long term use of inorganic fertilizer has been implicated in soil acidification, loss of organic carbon, nutrient imbalance deficiency of secondary and micro-nutrients [5]. Over the years, little effort had been made on the use of organic fertilizer for Kola cultivation. The use of organic fertilizers either as composted or made into biochar could be used to promote the growth and productivity of kola. Biochar is a carbon-rich product obtained when a biomass wood or crop residues is heated in a closed container with little or no oxygen [6]. Biochar is important for supplying organic materials for soil fertility improvement, adsorption of applied mineral fertilizers, converting them into organic form, stabilization of soil organic matter as biochar is very stable in the soil and improves crop productivity [7].

In CRIN, very few systematic fertilizer trials on kola have been conducted. Previous fertilizer trial indicated that only potassium increased the yield of kola by 7.5%. However, Egbe et al. [8] reported the results of a 2^3 NPK factorial trial on ramets showed that PK produce more pods than NPK, N, NP and NK applied alone. Ayodele [4], reported that P, K, NK and PK treatments had higher average yields than the control on ramets. Afolami and Egbe, [9] showed that N depressed yield. P, K, NP, KP and NPK had no significant effect on yield while NK increased the yield of the nuts. Recent trials on the use of organic fertilizer by Ipinmoroti et al. [10] indicated positive responses of kola seedlings to organic fertilizer, however; the results are yet to be confirmed in the field. The present study was to assess the effect of cocoa pod husk (CPH) biochar fortified with different NPK fertilizer formulations (solid and liquid) on kola seedling nutrient uptake and soil properties.

2. MATERIALS AND METHODS

A greenhouse trial was carried out at Cocoa Research Institute of Nigeria, Ibadan in 2013 to evaluate the effect CPH biochar fortified with NPK fertilizer formulations on the nutrient uptake of kola seedlings and soil properties in Ibadan, Southwestern Nigeria. The treatments consisted of a control, biochar (5 g) + NPK (3 g), Biochar (5 g) + NPK (Liquid - 3mls/L of water), Biochar (5 g), NPK Solid (3 g), NPK Liquid (3 mls/L of water). The six treatments were replicated three times in a completely randomized design (CRD) and data on nutrient uptake of kola seedlings and soil properties were taken for seven months. The kola nuts used for the trial were induced using incision method with very sharp blade and planted in the germinator and were pre-germinated in the germinator for sixty days before germinated seedlings were transferred into five-litre plastic buckets filled with top soil. The liquid NPK fertilizer was foliarly applied by spraying on kola leaves while the solid fertilizer was applied in a ring form at the base of the seedlings. Watering was carried out thrice per week throughout the period of the trial. The top soil (0 – 30 cm) was collected from the Kola plot within the Institute and processed for routine analysis according to IITA, [11] manual. The kola plants were harvested, washed, separated into leaf, stem and root. They were oven-dried to constant weight and milled. The milled samples were subjected to laboratory analysis using the procedures described below to determine N, P and K concentration.

2.1 Phosphorus Determination in Plant Samples

The oven-dried samples were milled in an electric mill and nutrient analysis carried out for major nutrients in the leaves, stems and roots. Milled plant sample (0.55 g) was digested using tecator digestion system in a 70 ml Pyrex digestion tube. Five millilitres of $HNO_3.HCO_3$ reagent (2:1 v/v) were added into each tube under a fume chamber and allowed to stand overnight at room temperature. The tubes were then transferred into aluminium digestion block inside the fume chamber at a temperature of 150ºC. The digestion was allowed for one and a half hours and the tubes removed, allowed to cool and 30 ml of distilled water was added into each tube. Stirring was done with vortex mixer and the content of each tube made up to 75 ml mark with distilled water. Phosphorus concentration was measured colorimetrically using vanado-molybdate method with a Jennway model colorimeter at 882 μm wavelength.

2.2 Total N Determination in Plant Samples

Total N determination was carried out by weighing 0.24 g of milled plant samples into 75 ml digestion tubes, a tablet of kjeldahl catalyst, 3.0 ml conc. H_2SO_4 and 2.0 ml of H_2O_2 were added. The mixture was allowed to stand till the reaction ceased. The reaction tubes were placed on pre-heated digestion block at 370ºC for 20 minutes with full end plates. After cooling, 20 ml distilled water was added to make up to 70 ml mark. Thorough shaking was done by inverting the digestion tube end-to-end. Total N (NH_4-N) was determined colorimetrically using the Technicon Autoanalyser II [11].

2.3 K Determination in Plant Samples

Finely ground plant samples (0.55 g of leaf, stem and root) were placed in 30-ml porcelain crucible. The samples were ignited for 7 hours at a temperature of 450ºC and not exceeding 500ºC. Greyish-white ashes were cooled on top of asbestos sheet and 5ml of 1 N HNO_3 solution was added. This was evaporated to dryness on a steam bath and returned to the furnace and heated at 400ºC for 10 minutes until a perfectly white ash was obtained. Ten millimetres 1 N HCl three times and made up to volume with 0.1 N HCl solutions. The K-content of the sample was read on a Jennway (PFP7 model) at 766 μm wavelength

2.4 Nutrient Uptake of Kola Seedlings

The nutrient uptake was calculated as the product of the nutrient concentration and dry matter yield: Uptake = Nutrient conc. X dry matter yield [12].

2.5 Soil Sample Analysis

Soil samples collected within the kola plantations were analyzed for both physical and chemical properties using the methods described in International Institute of Tropical Agriculture Manual [11]. The soil samples were air-dried, ground and sieved using 2.0 mm mesh. Soil pH was measured in water (1:1). Particle size distribution was carried out using the hydrometer method; while organic carbon was determined using chromic acid method. The regular microkjehldal method was used to analyse for total nitrogen. Available P in the soil was determined using ascorbic acid method. The Cation Exchange Capacity (CEC) of the soil was determined by using pH 7.0 buffer solution of calcium ammonium acetate, while EDTA titration was used to measure Ca^{2+}, Mg^{2+} and K^{+}.

2.6 Chemical Analysis of the Organic Materials Used

Two (2) grams each of the processed forms of the organic material used were analysed for nutrient composition using the standard procedure as described by Udo and Ogunwale [13]. Analysis of variance was performed on all data to test the treatment effect on different parameters measured using a GenStat 8th Edition. Least Significant difference (p<0.05) was used to separate the means.

3. RESULTS AND DISCUSSION

The physic-chemical properties of the soil indicated that the sand, silt and clay fractions were respectively 694, 150 and 156 gkg^{-1} soil (Table 1). The clay + silt content of 306 gkg^{-1} soil were sufficient to hold enough water for sustainable kola plant growth and to guard against short duration drought [8,10]. The pH, organic carbon, total N and available P were 6.66, 1.81 gkg^{-1}, 0,65 gkg^{-1} and 8.87 $mgkg^{-1}$ soil respectively. The pH of the soil falls within the acceptable range of 5.5-7.5 according to Egbe et al. [8]. The organic carbon is low and hence organic fertilizer may have effect on the crop. Previous effort has shown that soils that already have a high organic matter content, biochar will show little or no effect on crop response in the first year [14]. The exchangeable cations (K^+, Ca^{2+} and Mg^{2+}) of the soil were 0.67, 2.1 and 2 $cmolkg^{-1}$ soil respectively. The soil is sandy loam. The pH of the soil was adequate for kola production. The soil is marginal in terms of nutrient compositions particularly N, P and K [8]. The CPH biochar used for this study contained 1.5% N, 0.5% P, 6.9% K, 1.4% Ca, 0.6% Mg and 3.3% organic carbon while the NPK liquid fertilizer had 20%, 2% and 4% for N, P and K respectively. The solid NPK fertilizer had 15% N, 15% P and 15% K (Table 2). Application of sole or combined CPH biochar positively and significantly ($p<0.05$) enhanced the nutrient uptake of kola seedlings.

The leaf and root nitrogen uptake of kola seedlings was significantly ($p<0.05$) enhanced as a result of CPH biochar applied alone (T4) or in combination with NPK liquid fertilizer (T3) compared to when biochar was applied with NPK solid fertilizer (Table 3). The improvement on N uptake in the kola leaf and stem might be due to the fact that CPH biochar is rich in plant nutrients especially N, P and K. This result is in agreement with the findings of Ajayi et al. [15] that cocoa pod husk used alone or in combination with NPK fertilizers enhanced kola growth and nutrient uptake. However, CPH biochar and NPK fertilizer formulations did not significantly affect the stem nitrogen uptake of kola seedlings. CPH biochar and NPK liquid fertilizer depressed nitrogen uptake by 35%. Similarly, the leaf and stem P-uptake of kola seedlings was not significantly influenced by CPH biochar and NPK fertilizer formulations. Conversely, the P-uptake of root of kola seedlings was significantly ($p<0.05$) improved as a result of NPK liquid fertilizer compared to NPK solid fertilizer applied alone. The K-uptake of kola seedlings was consistently ($p<0.05$) enhanced as a result of CPH biochar in combination with liquid NPK (T3) and CPH biochar alone (T4) compared to NPK solid (T5) (Table 3).

Table 1. Physical and chemical characteristics of Onigambari-Ibadan soil

Soil properties	Unit	Value
Physical		
Sand	gkg^{-1}	694.00
Silt	"	149.55
Clay	"	156.45
Textural class		Sandy loam
Chemical		
$pH(H_2O)$ 1:1	-	6.66
Organic carbon	gkg^{-1}	1.81
Total Nitrogen	"	0.65
Available phosphorus	$mgkg^{-1}$	8.87
Exch. Bases		
K^+	$cmolkg^{-1}$	0.67
Ca^{2+}	"	2.07
Mg^{2+}	"	2.01
Na^+	"	0.55
Exch. Acidity		
Mn^{2+}	$mgkg^{-1}$	0.03
Al^{3+}	"	0.13
H^+	"	0.04
ECEC	"	5.14

The improvement in the uptake of nutrients by kola seedlings is consistent with the findings of [16,17,18] and in which they recorded significant improvement in the nutrient uptake of coffee seedlings and pepper respectively. The textural fractions (sand, clay and silt) of the soil were not significantly affected as a result of Biochar application and NPK fertilizer formulations (Table 4). The mean values of sand, clay and silt fractions of the soil were 710, 190 and 100 gkg^{-1} soil respectively. The pH of the soil was significantly ($p<0.05$) affected due to application of CPH biochar in combination with liquid NPK (T3) and CPH biochar alone (T4) and compared to the control and NPK solid (T5). This observation is consistent with the earlier findings by [19,20] in which organic manure increased soil pH and soil nutrients (organic matter, Mg, Ca, K, P and N). However, the organic carbon and total nitrogen of the soil were not significantly affected by CPH biochar application and NPK fertilizer formulations. The organic carbon ranged from 1.50 gkg^{-1} in NPK solid (T5) and NPK liquid (T6) to 2.58 gkg^{-1}soil under the control. The reason for this phenomenon could not be easily deciphered. In contrast, the exchangeable potassium in the soil was significantly ($p<0.05$) influenced as a result of CPH biochar application and NPK fertilizer formulations compared to the control (Table 4). The high K content is attributable to the fact both the biochar and inorganic fertilizers contained K. Application of CPH biochar either with or without inorganic fertilizer reduced significantly ($p<0.05$) the C:N ratio of the soil. This implies that microbial activities would greatly improve under CPH biochar application with or without NPK fertilizer formulations than the control. This is consistent with the submission of Agbede [21] that activities of microbes are impaired when the C:N ratio is greater than 30:1 which could lead to immobilization of soil N.

Table 2. Chemical composition of fertilizer materials used for the study

Fertilizer materials	Chemical composition (%)					
	N	P	K	Ca	Mg	Org.C
CPH Biochar	1.55	0.55	6.86	1.42	0.64	3.28
NPK(Liquid)+ TE	20	2	4	-	-	-
NPK(Solid)	15	15	15	-	-	-

TE- Trace Elements

Table 3. Kola seedling nutrient uptake as influenced by NPK fertilizer formulations and CPH Biochar in Ibadan, Southwestern Nigeria

Treatment	Leaf nutrient uptake (mg/plant)			Stem nutrient uptake (mg/plant)			Root nutrient uptake (mg/plant)		
	N	P	K	N	P	K	N	P	K
T_1	198.20	2.60	230.60	150.54	1.97	175.20	81.60	1.07	94.96
T_2	173.50	3.18	282.70	97.20	1.51	160.00	82.96	1.51	135.20
T_3	293.20	3.23	351.00	163.68	1.80	194.64	127.40	1.40	151.44
T_4	313.30	2.03	349.00	136.98	1.15	152.58	137.60	1.15	152.64
T_5	199.10	2.30	124.90	120.18	1.40	75.42	68.52	0.80	43.00
T_6	208.40	3.63	262.40	115.68	1.98	145.62	86.68	1.52	109.12
LSD(0.05)	122.70	Ns	67.70	Ns	Ns	40.62	21.24	10.76	25.60
CV (%)	11.68	12.40	10.90	10.20	10.89	8.90	10.68	0.27	10.96

T1- Control, T2- Biochar (5 g) + NPK (3 g), T3 – Biochar (5 g),+ NPK (Liquid – 3 mls), T4 - Biochar (5 g), T5 - NPK (Solid-3 g),T6 - NPK (Liquid – 3 mls)

Table 4. Soil physical and chemical properties as influenced by NPK fertilizer Formulations and CPH Biochar in Ibadan, Southwestern Nigeria

Treatment	Soil physical properties			Soil chemical properties				
	Sand gkg^{-1}	Clay gkg^{-1}	Silt gkg^{-1}	pH	Org. C gkg^{-1}	Total N gkg^{-1}	Exch. K $cmolkg^{-1}$	C:N
T_1	718.40	205.60	76.00	5.19	2.58	0.10	0.18	26.80
T_2	702.70	201.30	96.00	5.32	2.27	0.10	0.26	22.00
T_3	720.30	190.40	89.30	5.83	1.63	0.11	0.31	15.40
T_4	725.10	172.30	102.60	5.87	1.85	0.10	0.40	17.50
T_5	705.10	178.90	116.00	4.94	1.50	0.09	0.35	17.40
T_6	711.70	165.60	122.70	5.67	1.50	0.09	0.20	16.70
LSD(0.05)	Ns	ns	Ns	0.27	ns	Ns	0.04	3.94
CV (%)	4.20	10.70	11.00	6.00	13.30	16.90	9.60	12.00

T1- Control, T2- Biochar (5 g) + NPK (3 g), T3 – Biochar (5 g), + NPK (Liquid – 3 mls), T4 - Biochar (5 g), T5 - NPK (Solid-3 g),T6 - NPK (Liquid – 3 mls)

4. CONCLUSION

The positive influence of CPH biochar applied either alone or in combination with NPK fertilizers on nutrient uptake of kola seedlings and soil nutrients indicated that integrated use of organic and inorganic fertilizers holds the ace for crop production and soil fertility management in Nigeria. Kola farmers across the growing regions have the privilege of using biochar fortified with NPK fertilizer (liquid) for improved productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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