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Research Article

Modification of Soil Reaction using Different Plant Residue Sources on an Ultisol in a Derived Savannah Zones of Uhonmora, Nigeria (Incubation Study)

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Abstract

An incubation study was conducted at the Laboratory of Cocoa Research Institute of Nigeria headquarters, Ibadan, Oyo state in 2011 to evaluate soil reaction modification using different plant residues on an Ultisol in a derived Savannah zone of Uhonmora in Edo state. Three different plant residue materials milled cocoa pod husk (CPH), cocoa pod husk ash (CPHA), Oil palm bunch ash (OPBA) were applied at a rate equivalent to 10 $kgNha^{-1}$. Each of the sources of plant residue was added 10kg of soil in 10litres plastic containers and replicated three times. The soil pH (H_20) was determined on the incubated samples at 0, 4, 8, 12, 16 and 20 weeks of incubation using standard Laboratory procedures. The results indicated that all the plant residue materials irrespective of source significantly ($p< 0.05$) increased the pH values of soil relative to the control. However, cocoa pod husk ash (CPHA) was better than other materials throughout the period of the incubation. There was a sharp and consistent increase in pH value from zero (0) up to 8 weeks of incubation for all the plant residue materials used in the study and dropped afterwards. The CPHA contributed between 20.24-27.63% pH value increases while OPBA contributed between 10.84-22.43% increases to soil pH value of Uhonmora soil during the incubation period. CPH on the other hand, recorded the least percent contribution of between 6.19-12.84% increases to soil pH value. It could therefore be concluded that CPHA has great potential as good remediating agent for an acidic soil.

Keywords: *Acidic soil; Incubation study; Plant residues; Modification; Evaluation*

Introduction

A soil is said to be acidic when the hydrogen and aluminum ion in the soil is high leading to reduction in the pH value of the soil [1]. It has been observed that most soils from the Southern Nigeria are acidic due to high rate of leaching and weathering as a rate of high rainfall regime and the nature of their parent materials [2]. Also, the soils suffer from nutrient deficiencies [3].

Soil acidity causes non availability of essential nutrient elements while the micro nutrient or trace elements are more readily available to be assessed by plants when there is a large amount of active acidity in the soil. However, addition of plant residue ash of varied source had been noted to remediates active acidity especially in the Southern Nigeria [4-7].

Crop residue ash materials serve as liming materials, nutrient sources, although their effects may vary with their nature and composition [7-9] and soil types. CPH, CPHA and OPBA increases soil organic carbon contents, improves fertility status of soil and enhances the activities of soil microbes [6-8]. The study therefore, sought to evaluate soil reaction modification using different plant residue sources on an Ultisol in a derived savannah zones of Uhonmora, Nigeria.

Materials and Methods

An incubation study was conducted at the laboratory of Cocoa Research Institute of Nigeria, Ibadan, Oyo state in 2011 to evaluate soil reaction modification using different plant residue ash. The plant residues used for this experiment included unash cocoa pod husk (CPHU), cocoa pod husk ash (CPHA) and oil palm bunch ash (OPBA). Three organic materials and the control (i.e., without organic materials) given four treatments were replicated three times to give twelve experimental units altogether arranged in a completely randomized design (CRD). Approximately 50g of soil (which included 40g top soil + 10g of river sand) sieved to pass through 2 mm sieve were weighed into each of the 72 sterilized plastic cup and 1.25g of each organic material was added into the plastic cup corresponding to each row except for the control plastic cups. The content of each sterilized cups were throughly mixed together, the containers were clearly labeled. Distilled water was added periodically to keep the sterilized plastic containers and the contents at 60% field capacity at all times. Watering was carried out twice weekly. The sterilized cups were allowed to remain on the laboratory bench at room temperature for twenty weeks. Three cups were retieved per row at 1st day, 4th week, 8th week, 12th week, 16th week and 20th week after treatment application.

Organic Materials Collection and Preparation

The Oil palm bunch and Cocoa pod husk were collected from the Oil palm plantation and cocoa processing unit of the Cocoa Research Institute of Nigeria, Ibadan. The organic materials were sun dried and later burnt into ashes to get the Cocoa pod husk and Oil palm bunch ash (CPHA and OPBA), the unash cocoa pod husk (CPHU) was produced by milling the dried husk using Glen Cremson Mill.

Soil Sample Collection and Processing

Prior to the commncement of the incubation study, soil samples were collected from a highly leached, degraded and acidic soil, air-dried, crushed and sieved to pass through a 2 mm sieve and prepared for a routine laboratory analysis. Particle size analysis was conducted using a Bouyouocos hydrometer method as described by [10]. The values of the soil separate obtained were then used to determine soil texture using USDA textural triangle. Flame photometry was used to determine potassium and sodium contents while EDTA titration method was used to Calcium and Magnesium [11]. Organic carbon was determined using Walkley-Black wet combustion method [12]. The samples were treated with potassium dichlomate and sulphuric acid and then titrated against ferrous-sulphate. Total nitrogen was determined using Micro kjedahl digestion distillation method [13]. Available phosphorus was determined using Bray No. 1 method [14]. The changes in pH at each stage of releases was determined in water at a of 1:2 (Soil/Water) using a pH meter with glass electrode as described by [13].

Results and Discussion

Table 1 shows initial analysis of nutrient content of the soil used for the incubation study and chemical composition of the various organic materials (CPHU, CPHA and OPBA).

Soil properties	Unit	Critical level	Ibadan	Uhon-mora
Chemical properties				
pH (H_2O)	-	5.0-6.5	5.11	5.53
Organic C	gkg^{-1} soil	30.0	11.05	14.95
Nitrogen	gkg^{-1} soil	1.0	0.60	0.70
Available P	$mgkg^{-1}$ soil	10.0	4.61	3.56
Calcium	$cmolkg^{-1}$ soil	50.0	7.15	6.37
Magnesium	$cmolkg^{-1}$ soil	0.8	0.60	0.73
Potassium	$cmolkg^{-1}$soil	0.30	0.59	0.41
Sodium	$cmolkg^{-1}$ soil	-	0.51	0.67
Al_3^+	$cmolkg^{-1}$	-	0.13	0.10
H^+	$cmolkg^{-1}$	-	0.04	0.27
CEC	$cmolkg^{-1}$	-	8.85	8.18
BS	%	-	98.08	94.50

Physical properties				
Sand	gkg^{-1} soil	-	113.00	152.85
Silt	gkg^{-1} soil		673.00	610.00
Clay	gkg^{-1} soil		214.00	237.15
Textural class	-		SL	SCL

***Table 1:** Physical and Chemical Properties of Ibadan and Uhonmora Soil Prior to the Field Experiments.*

SL= sandy loam; SCL= Sandy clay loam

The soil is acidic (5.49) deficient in N contents and organic carbon (OC) respectively.

The low level of total N in the soil could be attributed to rapid microbial activities leaching of nitrates and crop removal. The values for K, P and Ca were low and fall below the required value for sustainable tree crop production in Nigeria since they are lower than the critical level determined for optimal and profitable crop production. The acidic nature of the soil may be attributed to high rainfall which could have leached out basic cations from the soil surface, such soil condition can induce phosphate fixation and reduce the ability of microorganism to fix atmospheric nitrogen [15]. The low soil pH coupled with the deficiency of major nutrient elements in the soil agrees with the results of [16] that low soil pH or high soil acidity can reduce the availability of plant nutrients, this therefore, suggest that the soil requires nutrient supplementation and liming agents to correct the acidic nature and low soil fertility status of the soil.

The nutrient elements composition of the organic materials evaluated in the trial are presented in Table 2. The assay of the three organic residues materials revealed that the materials (CPHA, CPH and OPBA) contained varying amount of both macro (N, P, K, Ca, Mg) and micro nutrient elements (Fe, Mn, Zn, Cu, Na. etc.) based on the type of the materials in addition to the major nutrient elements possessed by most of the chemical fertilizers.

Properties	Units	CPH	CPHA	OPBA
Nitrogen (N)	%	2.35	0.10	0.06
Phosphorus (P)	%	0.19	1.00	0.80
Potassium (K)	%	1.83	5.88	4.75
Magnesium (Mg)	%	0.61	1.10	0.95
Calcium (Ca)	Ppm	0.79	4.17	2.79
Manganese (Mn)	Ppm	345.61	384.93	321.90
Iron (Fe)	Ppm	510.62	800.77	1300.41
Zinc (Zn)	Ppm	34.47	87.98	70.37
Sodium (Na)	Ppm	88.76	230.92	384.38
Copper (Cu)	Ppm	41.95	101.94	80.38
pH (H_2O)	-	6.80	10.80	11.20
pH (Kcl)	-	6.10	10.60	11.00

***Table 2:** Nutrient Composition of Organic Fertilizer Materials Used for the Study.*

CPH= cocoa pod husk; CPHA= cocoa pod husk ash; OPBA= oil palm bunch ash.

Macro Nutrients

Nitrogen (N): The result of the analysis of the organic materials revealed that CPH, CPHA and OPBA contained nitrogen (N) at varying amount based on the types of the materials involved (Table 2). The CPH, CPHA and OPBA contain 2.35, 0.24, 0.10 and 0.06% N respectively. The N concentration in the materials was in order of CPH (2.35) > CPHA (0.10) > OPBA (0.06%).

The relatively lower N values of CPHA and OPBA compared to CPH may be due to the burning during which complete oxidation and volatilization occurred and resulted to loss of N as oxides (gases) with decomposition of phosphates, oxides and carbonates of cations hence, its valuable liming quantity. This result corroborates the findings of [17,18].

Phosphorus (P): The P values of the various organic materials ranged from 0.19-1.00%. The highest amount of P was recorded by CPHA; this was followed by OPBA (0.80%) while CPH recorded the least P (0.19%) values. The amount of phosphorus (P) in the organic materials was more in CPHA (1.00%) compared to the rest. The milled or unash cocoa pod husk (CPH) is lower in P value compared to the burnt or ash types (CPHA and OPBA). The relatively high P contents of CPHA and OPBA make both a good source of P supply to soils that are noted to be low and deficient in P and for high demanding crops respectively.

Potassium (K): The K concentration in the organic fertilizer materials ranged between 1.83-5.88%. The K concentration was higher in the CPHA compared to either OPBA or CPH. The order of K concentration in the materials in decreasing order is: CPHA (5.88%) > OPBA (4.70%) > CPH (1.83%). The K contents in the materials followed similar trend with the P contents.

Calcium (Ca): The Ca contents of the organic materials presented in Table 2 showed that CPH; CPHA and OPBA vary in the amount of Ca values in all the fertilizer materials. The Ca contents ranged from 0.79-4.19 ppm per kg soil, with the lowest value in the CPH (0.79ppm) compared to those of OPBA (2.79 ppm) and CPHA (4.19 ppm) respectively.

Magnesium (Mg): The Mg (1.10 ppm) was more concentrated in the CPHA than the OPBA and CPH which had 0.95 and 0.61ppm. The occurrence of all the various cations (Ca, Mg) is an indication that these materials will serve as a good liming material for remediating the slightly acidic nature of the soils used for the study.

The alkaline nature of the ashes and the presence of basic cations (Ca^{2+} and Mg^{2+}) make them suitable as liming materials which will remediate the acidic nature of the soil. OPBA is relatively higher in Ca and Mg than CPHA and CPH while CPH is higher in OC and N relative to the CPHA and OPBA (Table 2). The C:N ratio values of 10.0 and 10.2 for OPBA and CPHA respectively are conducive enough for early mineralization of nutrients especially N for uptake by plant. Incorporation of organic amendments in form of CPH, CPHA and OPBA however, will help to raise the pH value of the soil since they are rich in both macro and micro nutrient elements [9].

Micro Nutrients Content

The Mn contents of the fertilizer materials used for the study ranged from 321.90-384.93 ppm per kg soil. The Mn is relatively higher in CPHA (384.93 ppm) compared to CPH (345.61 ppm) and OPBA (321.90 ppm). The Cu value of CPHA (101.84 ppm) is more than twice higher than what is found in the CPH (41.95ppm) and slightly higher than the value found in OPBA (80.38 ppm). The total Fe contents in the organic materials ranged from 510.62-1300.47 ppm. The Fe value in the OPBA (1300.47ppm) was higher compared with the other organic materials while zinc concentration was twice higher in CPHA (87.98 ppm) compared to CPH (34.49 ppm). The materials (CPHA; OPBA and CPH) therefore have the ability to meet the micro nutrients needs of Cocoa plants both in the nursery and on the field without necessarily in curring extra cost on chemical fertilizer which is scarce and expensive.

Effects of organic materials (CPHA, CPH and OPBA) on pH change during the 20 weeks of incubation study

The effects of the different organic materials on the soil pH change during the five months of the incubation study are presented in Figures 1-6. The organic materials (CPH, CPHA and OPBA) irrespective of source (s) increase the pH values of the soil significantly ($p > 0.05$) from the beginning of the study Figure 1 throughout the incubation periods relative to the control. Cocoa pod husk ash treated soil significantly ($p < 0.05$) increased the soil pH values (7.6) relative to the control (5.5) and other organic materials. This was followed by OPBA and CPH respectively with mean pH values of 7.09 and 6.31. The increases observed in the soil pH may probably because of basic cations contained in the ash materials which could have served as buffer against acidification of individual soil medium. These observations were consistent with the views of [5,19-21]. Similar responses were observed with the organic materials at 4th, 8th, 12th, 16th and 20th weeks of incubation Figures 2-6. Comparably with the control and the rest, CPHA maintained the highest mean pH values although the pH values dropped across the materials at the 12th week of incubation while control on the other hand, recorded the least pH value.

The CPHA reaches its peak mean pH value of 7.78 at 4WAI and drops afterwards while, OPBA and CPH reached peak values at 20WAI and 8WAI respectively. The increases were in the following order: CPHA > OPBA> CPH> Control. Generally, at each period of pH determination, the values for the organic materials treated soils were significantly ($p < 0.05$) higher than those obtained from control.

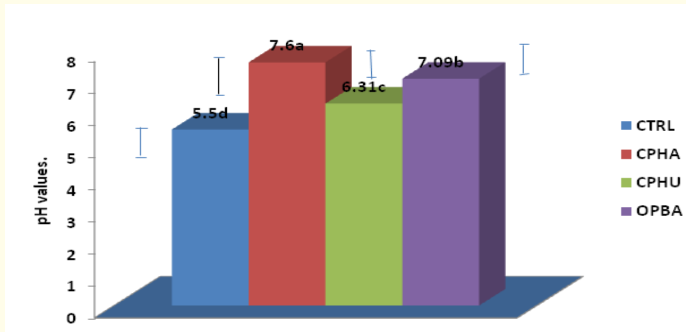

Figure 1: *Effects of Ash on soil pH (Water) at 1st day of incubation. CTRL= Control; CPH= Milled Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA= Oil Palm Bunch Ash.*

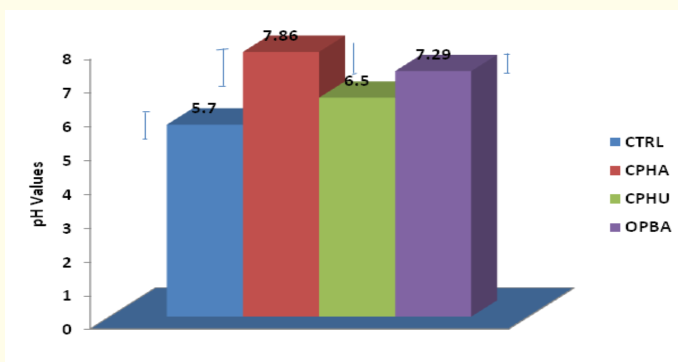

Figure 2: *Effects of Ash on soil pH (Water) at 4 weeks of incubation. CTRL= Control; CPH= Milled Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA= Oil Palm Bunch Ash.*

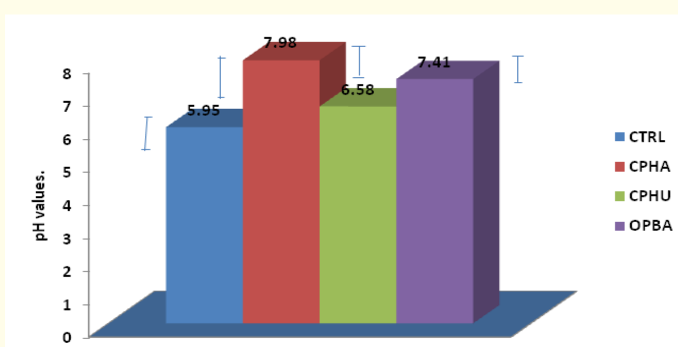

Figure 3: *Effects of Ash on soil pH (Water) at 8 weeks of incubation. CTRL= Control; CPH= Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA= Oil Palm Bunch Ash.*

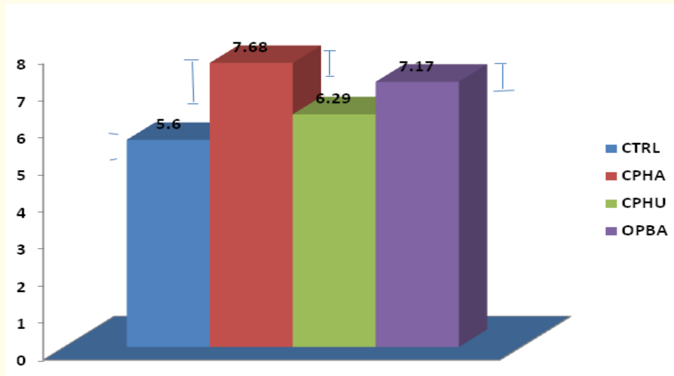

Figure 4: *Effects of Ash on soil pH (Water) at 12 weeks of incubation. CTRL= Control; CPH= Milled Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA= Oil Palm Bunch Ash.*

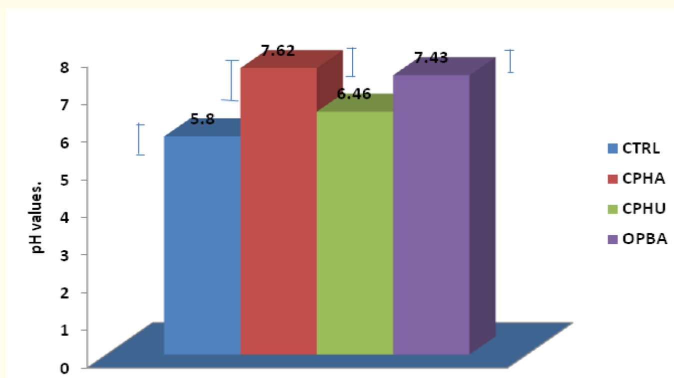

Figure 5: *Effects of Ash on soil pH (Water) at 16 weeks of incubation. CTRL= Control; CPH= Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA= Oil Palm Bunch Ash.*

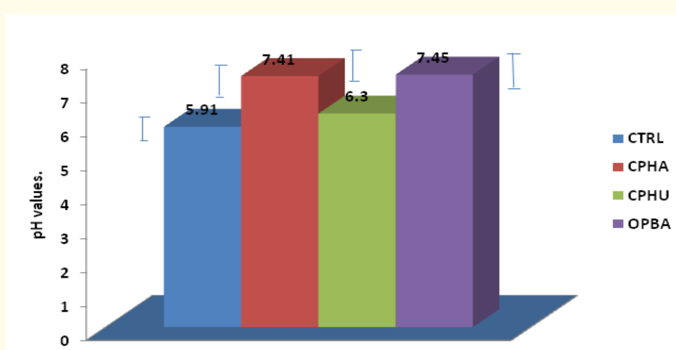

Figure 6: *Effects of Ash on soil pH (Water) at 20 weeks of incubation. CTRL= Control; CPH= Milled Cocoa Pod Husk; CPHA= Cocoa Pod Husk Ash; OPBA=Oil Palm Bunch Ash.*

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