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Effect of organic soil amendments on soil chemical properties in Sudan Savannah of Nigeria

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ABSTRACT

Composite soil samples were collected from irrigated maize fields, to study the effect of Bio char and Compost on post-harvest soil chemical properties in the Sudan Savannah of Nigeria. Laid on a completely randomized block design, the treatments used in the experiment were 5tha^{-1} Bio char, Compost, and Control. Pre-amendments application and post maize harvest soil characteristics obtained from laboratory were statistically analysed using R software (version 3.4.3). The results showed a post-harvest significant increase in pH, Organic Carbon, Total Nitrogen, Exchangeable Potassium, Exchangeable Calcium and Available Lead on plots amended with Bio char. It also showed a significant increase in Organic Carbon, Total Nitrogen, and Exchangeable Calcium on plots amended with Compost. It is concluded that addition of the organic amendments to the soil leads to a significant augmentation in some of the chemical properties of the experimental soil. Such amendments application could therefore be recommended to enable arable crops uptake of the augmented chemical properties, as advocates of organic farming.

1.0. Introduction

Several concerns have been raised on the use of inorganic Nitrogen (N) fertilizers due to its involvement in processes such as greenhouse gas emissions, Eutrophication, acidification, salinization, and losses of soil carbon (Khan et al.,2007). However, the use of soil amendments such as bio char and compost has been found to improve soil characteristics. The emerging picture for bio char and compost amendment use has shown potential significant benefits on the soils of the tropics, both in terms of soil properties and crops yield(Lehmann et al., 2003).

Bio char has been extensively studied in the past few years for its ability to enhance chemical properties and the nutrient level of soils (Schulz and Glaser, 2012), as well as its positive effect on plant growth (Sohi et al., 2010). Another unique ability of bio char is that it can increase Cation exchange capacity (CEC) and pH of the soil (Abrishamkesh et al., 2015), microbial biomass and activity (Lehmann et al., 2011), soil moisture, total nitrogen and phosphorus ions, promotes root development, soil surface area, and nutrient retention (Chan et al., 2008), in addition to minimizing soil erosion and nutrient leaching during drought (Lorenz, 2007). The increasing use of bio char as soil amendment was inspired by high fertility and organic C contents found in anthropic soils in the Amazon Basin referred to as *Terra Preta de Indio* (Lehmann et al., 2003). Potential negative impacts of bio char on soil quality include increasing soil pH in alkaline soils (Novak et al., 2009) and potential N immobilization (Lehmann et al., 2003). The increase of soil CEC as a result of bio char application can be caused by the inherent characteristics of bio char, such as high porosity and surface area. One very good feature of bio char is its ability to holds nutrients in the soil and hence leads to a reduction in nutrient leaching and the dramatic increase in nutrient uptake by plants with subsequent higher crop yield (Prins et al., 2007). Its use as soil amendment was found to increase soil pH, soil organic C, total N, and decreased soil bulk density (Zhang et al., 2010). The soil concentration of Phosphorus, K, Ca, and magnesium (Mg) was not affected by the use of bio char as an amendment (Laufer and Tomlinson, 2013). Bio char is characterized by high porosity which is sourced from the restructuring of carbon molecules and the release of organic matter, its pore sizes differ depending on the biomass used and pyrolysis process. It is also characterized with high surface which is greatly attributed to the micropores (Morrow, 2013).

Unlike bio char, Composting process is carried out by successive microbial population that function with increase in temperature to produce carbon dioxide, water, minerals and stable organic matter as product of decomposition of biomass (Evanylo et al., 2009). It has been suggested that organic matter be composted to increase C:N ratio prior to their application to the farms as it increases soil CEC. The process manipulates and speeds up the natural biological aerobic decomposition (Evanylo et al., 2009) through creating a suitable condition for the exponential microbial growth and reproduction (Campbell, 2012). The composting process is carried out by successive microbial population that function with an increase in temperature to produce carbon dioxide, water, minerals and stable organic matter as a product of decomposition of biomass (Evanylo et al., 2009). The process also lead to a reduction of the release of methane into the atmosphere which contrary to the anaerobic decomposition in landfills (Evanylo et al., 2009).

Sudan savannah region is an economically important belt of maize and other arable crops production in the tropics. But despite its economic importance, literature reports indicated inherent low soil fertility indices, organic matter content, as well as frequent variability in most of its soils' chemical properties with cropping and land use types. Coupled with the above facts, are the uncensored farmers' practices in relation to organic matter and organic amendments incorporation to the Sudan savannah soils. An understanding of the effects of organic amendments on soil chemical properties and hence crop performance will go a long way in informing decisions on cropping systems in the zone. The objective of this work is therefore; to study the effect of Bio char and Compost on post harvest soil chemical properties of irrigated maize fields in the Sudan Savannah of Nigeria.

2.0. Materials and methods

2.1. Study area

The research was conducted at the faculty of agriculture Bayero University Kano research farm, Kano state, during the dry season of 2016. The site is located in the Sudan savannah of northern Nigeria, having latitude of $11^0 59'$N and longitude of $8^0 25'$E.

2.2. Experimental treatments

Three sets of materials; bio char, compost and a control were used as experimental materials. The variety of maize that was used for the experiment was 2009 EVDT. The trial was laid out in Completely Randomized Complete Design, and replicated three times.

2.3. Soil sampling

Before the establishment of trial, a composite sample was collected from surface to 30 cm using auger. At the maize harvest, soil samples were also collected from bio char treated, compost treated and control plots. These samples were air-dried, gently crushed and sieved through a 2 mm sieve mesh and stored in an air tight container prior to soil analysis.

2.4. Production of bio char and compost

The Bio char used was produced from a grinded and well dried wood in a fabricated pyrolysis Kiln in the Department of soil science Bayero University, Kano as described by (Lehmann, 2007) prior to addition to the experimental plots.

The compost used in the experiment was produced from dried plant residues using a fabricated metal vessel as an improvising of bin composting technique described in USDA (2010).

2.5. Laboratory analysis

2.5.1. Soil analysis

The pH of the soil was determined in soil : water of 1:2.5 using glass electrode pH meter as described in Estefan et al.,(2013). Soil EC was determined in soil : water ratio of 1:5 soil : water as described by Estefan et al., (2013); Bower and Wilcox, (1965) and then converted to EC_e by using Slavich conversion factor (Slavich and Petterson, 1993).

Soil Organic Carbon (SOC) was determined using Walkley-Black wet oxidation method (Walkley and Black, 1934). Soil organic matter (SOM) was calculated by using a multiplier of 1.724.

Neutrally buffered ammonium acetate was used in the extraction of exchangeable bases. Ca^{2+} and Mg^{2+} were read using Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP), while Na^+ and K^+ were read using flame photometer (Jenway PFP 7) as described in Anderson and Ingram (1993).

Exchangeable acidity was extracted using IM KCl solution and determined by titration with NaOH as described in Anderson and Ingram (1993). Cation Exchange Capacity was determined by summation method as described by Chapman (1965).

Total nitrogen was determined using Micro Kjeldahl method as described in IITA (1979) and Bremmer (1996).

The soil available phosphorus was extracted using Bray 1 method (Bray & Kurtz, 1945) and determined using Blue method (Drummond and Maher, 1995; Murphy and Riley, 1962). Micronutrients were extracted using 0.1M HCl and read using Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP), (Estefan et al., 2013; IITA, 1979).

2.5.2. Organic amendments analysis

Portions of the two amendments were taken, sieved using 2mm sieve and preserved for analysis. The parameters analysed were:

The pH and EC of the bio char and compost were determined using amendment : water ratio of 1:10 as described by McLaughlin (2010) and USDA (2010) respectively.

Total Nitrogen was determined using micro Kjeldahl method as described in Bremmer (1996) and IITA (1979).

Total carbon in both of the amendments was determined by ignition method as described by Shuttle (1995).

Available phosphorus was extracted using Bray 1 method extractant (Bray and Kurtz, 1945) and then read using spectrophotometer (22PC MODEL) at a wavelength of 860nm (Murphy and Riley, 1962).

Exchangeable bases were extracted using NH_4Ac saturation method as described in Anderson and Ingram (1993) Ca^{2+} and Mg^{2+} were determined using AAS(BUCK SCIENTIFIC 210 MODEL) while Na^+ and K^+ were determined using flame photometer (JENWAY PFP 7) as described by Anderson and Ingram (1993).

Exchangeable acidity was extracted using IM KCl and then determined by titration with NaOH as described by Anderson and Ingram (1993). The Effective Cation Exchange Capacity was determined by summation method as described by Chapman, (1965).

Available forms of Fe^{2+}, Cu^{2+}, Zn^{2+}, Cr^{2+}, Co^{2+} and Pb^{2+} were extracted using 0.1M HCl and read using Atomic Absorption Spectrophotometer (BUCK SCIENTIFIC 210 MODEL) as described by Anderson and Ingram (1993)

2.6. Statistical analysis

The data was analysed using R Software (3.4.3) edition. Analysis of variance was carried out to determine if there is significance difference between chemical properties of the soil after the experiment.

3.0. Results and Discusion

3.1. Characteristics of the Experimental Soil

Table 1 shows the chemical characteristics of the soils of the experimental site. The soil has mean pH of 6.63, This indicates that the soil is neutral and falls within the optimum range for the growth of the experimental crop as described by Havlin et al., (2012). The EC_e with a mean 1.90dS/m, shows that it is non-saline based on FAO rating (FAO, 1999). The total organic carbon of the studied soil was 0.32%. The total Nitrogen of the studied soil was 0.13%. Its available Phosphorus was found to be between 3.24 and 11.07mg/kg with mean of 7.17mg/kg. The soil contains low Organic Carbon, Available Phosphorus and the Total Nitrogen based on ESU rating (Esu, 2010). The exchangeable bases of the experimental site were found to be 0.46cmol/kg K, 0.20cmol/kg Na, 2.72cmol/kg Ca and 1.15cmol/kg Mg. The Exchangeable Ca was found to be between 2 and 3.33cmol/kg while Mg was between 0.625 and 1.667cmol/kg. The values of Na and K were 0.118 to 0.275cmol/kg and 0.280 to 0.653cmol/kg respectively. The mean exchangeable acidity and ECEC were respectively 0.17 and 4.69cmol/kg. The ECEC ranges between 3.401 to 5.623cmol/kg. The soil has a medium content of Calcium and Sodium with a high content of Magnesium and Potassium, the Effective Cation Exchange Capacity (ECEC) of the soil rated medium (Esu, 2010). The mean concentrations of Fe, Zn, Mn, Cu, Cr, Pb and Co were 3.46, 7.88, 8.25, 6.38, 1.16, 0.83 and 0.97mg/kg respectively.

3.2. Characterization of the Organic Amendments Used in the Experiment

Table 2 shows the chemical characteristics of the two organic amendments used in the experiment. It shows that the pH of the compost was 6.490 while that of the bio char used was 7.717. The EC (1:5) of the compost was 1.78dS/m and that of the bio char was 0.62dS/m. The Total Nitrogen of the compost and the bio char were 11.2and 10.0gkg^{-1} respectively. The compost and the bio char were found to have available phosphorus of 171.76mg/kg and 33.06mg/kg respectively. The compost was found to have 2.06cmol/kg Ca, 1.60cmol/kg Mg, 0.90cmol/kg Na and 5.06cmol/kg K on its exchange sites where as bio char contains 1.39cmol/kg Ca, 1.39cmol/kg Mg, 0.08cmol/kg Na and 3.81cmol/kg K. The respective Effective Cation Exchange Capacity of the compost and the bio char was 10.47cmol/kg and 7.18cmol/kg. The concentration of available form

Table 1: Chemical characteristics of the pre amendment application soil

Soil property	Values
pH	6.45
EC (dSm^{-1})	1.56
TN (%)	0.07
OC (%)	0.24
K (cmolkg^{-1})	0.28
Na (cmolkg^{-1})	0.12
Mg (cmolkg^{-1})	0.63
Ca (cmolkg^{-1})	2.00
EA (cmolkg^{-1})	0.17
ECEC (cmolkg^{-1})	3.40
Av. P (mgkg^{-1})	3.24
Fe (mgkg^{-1})	2.92
Zn (mgkg^{-1})	4.06
Mn (mgkg^{-1})	4.17
Cu (mgkg^{-1})	3.33
Cr (mgkg^{-1})	0.68
Pb (mgkg^{-1})	0.49
Co (mgkg^{-1})	0.67

EC= Electrical Conductivity, TN = Total Nitrogen, OC = Organic Carbon, ECEC =Effective Cation Exchange Capacity, EA = Exchangeable acidity, and Av. P = Available Phosphorus of Fe, Zn, Cu, Mn, Cr, Co and Pb in the compost was found to be 2.22, 20.00, 10.67, 9.17, 1.29, 0.83 and 0.85mg/kg respectively while in the bio char it was 2.78, 32.78, 17.67, 12.17, 0.83, 0.72 and 1.46mg/kg respectively.

3.4. The Chemical Characteristics of the Experimental Soils at Harvest

The chemical properties of the soils after the harvest of maize in the experiment is presented in table 3. from the table, it can be the pH varies significantly as influenced by amendment (p=0.015) with bio char amended soil having the highest value, this is one of the unique ability of bio char; that it can increase pH of soil (Abrishamkesh et al., 2015),The lack of significant increase in the pH of the soil of compost amended soil could be attributed to the compost buffering capacity which makes it to resist changes in pH (McCauley et al., 2009). The EC_e of the soils also varied significantly (p=0.027) with highest value in compost amended soil, which is similar to the findings of Abrishamkesh et al., (2015). The organic carbon of the experimental soil also varied significantly (p<0.001) with highest in bio char amended soil, total nitrogen also varied significantly with amendments (p=0.005), the amendments were also found to statistically affect the exchangeable K of the experimental soils (p=0.020), the exchangeable Ca was also found to vary significantly (p<0.001), Their application noticeably increased SOC, total N, exchangeable Ca and K which is similar to the findings made by Agegnehu et al., (2016); Chan et al., (2008) However, changes in exchangeable Mg and Na contents were negligible relative to their initial values which is similar to the findings made by Agegnehu et al., (2016) The observed high exchangeable K content in the bio char amended soils could be attributed to high ash content of bio chars. The immediate release of K from the ash could result in higher K availability in the bio char amended soils (Abrishamkesh et al., 2015). The amendments also affect concentration of available Pb in the tested soil (p=0.012) with highest in the control. Exchangeable Na, exchangeable Mg, exchangeable acidity, ECEC, Fe, Zn, Mn, Cu, Cr and Co were found not have significant variation with the amendments. The separate or combined application of bio char and compost significantly increased soil nutrient status during the crop growth period indicating that their usage may prove beneficial for crop nutrition.

Table 2: Chemical Characteristics of the Organic Amendments

Property	CMP	BCH
Ph	6.49	7.72
EC (dSm^{-1})	1.78	0.62
TN (gkg^{-1})	11.2	10.0
OC (%)	26.8	65.6
K ($cmolkg^{-1}$)	5.06	3.81
Na ($cmolkg^{-1}$)	0.9	0.08
Mg ($cmolkg^{-1}$)	1.60	1.39
Ca ($cmolkg^{-1}$)	2.06	1.39
EA ($cmolkg^{-1}$)	0.85	0.51
ECEC ($cmolkg^{-1}$)	10.47	7.18
Av. P ($mgkg^{-1}$)	171.76	33.06
Fe ($mgkg^{-1}$)	2.22	2.78
Zn ($mgkg^{-1}$)	20	32.78
Mn ($mgkg^{-1}$)	9.17	12.17
Cu ($mgkg^{-1}$)	10.67	17.67
Cr ($mgkg^{-1}$)	1.29	0.83
Pb ($mgkg^{-1}$)	0.85	1.46
Co ($mgkg^{-1}$)	0.83	0.72
C:N ratio	25.24	60.18

EC= Electrical Conductivity, TN = Total Nitrogen, OC = Organic Carbon, ECEC =Effective Cation Exchange Capacity, EA = Exchangeable acidity, and Av. P = Available Phosphorus

4.0. Conclusion

The results of the experiment showed that bio char has the potential to significantly increase pH, Organic Carbon, Total Nitrogen, Exchangeable Potassium and Calcium while decreasing the concentration of available Lead. Furthermore, amending Sudan savannah soil with compost, lead to significant increase in Organic Carbon, Total Nitrogen and Exchangeable Calcium.

5.0. Recommendation

Following the results of this study, Organic amendments application could be recommended to enable arable crops uptake of the augmented chemical properties, as advocates of organic farming in Sudan Savannah of Nigeria.

Table 3: The Chemical Characteristics of the Experimental Soils at Harvest

Table 3: The Chemical Characteristics of the Experimental Soils at Harvest

AM	pH	EC	O.C	TN	K	Na	Ca	Mg	EA	ECEC	Fe	Zn	Mn	Cu	Cr	Co	Pb
		dS/m	gkg^{-1}		$cmolkg^{-1}$						$mgkg^{-1}$						
CNT	6.74b	3.08	2.2b	0.93b	0.41b	0.08	2.26c	2.22	0.34	5.29	2.92	7.81	8.06	7.78	1.74	0.72	1.95a
BCH	7.31a	2.81	3.7a	2.33a	0.57a	0.06	3.39a	2.64	0.34	6.91	2.64	10.10	7.92	6.94	1.06	0.67	1.14b
CMP	6.97ab	3.11	3.5a	1.98a	0.55a	0.06	3.39b	2.36	0.23	6.40	2.36	6.46	9.58	5.97	1.44	0.72	1.67a
SED	0.147	0.177	0.012	0.330	0.031	0.009	0.099	0.621	0.046	0.541	0.642	1.851	1.814	1.534	0.536	0.268	0.205

BCH = Biochar, CMP = Compost, CTR = Control
Means followed by the letter are statistically the same at 5% level of probability using Fischer's protected LSD

AMM = Amendments, BCH = Bio char, CMP = Compost, CTR = Control
Means followed by the letter are statistically the same at 5% level of probability using Fischer's protected LSD

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