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Biochar Amendments and Their Residual Effect on Soil Chemical Properties and Growth Components of Greenleaf (*Amaranthus caudatus)* In Nutrients Depleted soil

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Abstract

Soil nutrients depletion is often a problem associated with the Tropical soils. This study aims to investigate the effect of biochars produced from different feedstock on depleted soil nutrients, growth of Greenleaf (*Amaranthus caudatus)*, some nutrients uptake and their residual effect in the following year. Six types of biochar that originated from cow dung (CDB), goat dung (GDB), poultry dropping (PDB), rice husks (RHB), composted rice husks (CRHB), and mixed feedstock (MFB) (combination of the first named five feed stocks) constituted the treatment. There was also a control (C) that had no amendment. The six amendments were applied once at the rate of 3t/ha to the soil on a plot size of 3m x 3m each, at the research and training farm of Michael Okpara University of Agriculture, Umudike in 2014 planting season and the residual effect evaluated in 2015 planting season. Greenleaf was planted in each plot at 2014 and 2015 planting seasons. The treatments were arranged in a randomized block design with three replicates. Results of the study showed that MFB increased soil pH in water from the initial value of 5.10 before treatment application to 6.21 at the end of the experiment in 2014, while PDB had a residual effect on the pH with a value of5.93 in 2015. PDB showed a significant increase in available phosphorus with values of 68.70 mg/kg and 53.7 mg/kg in 2014 and 2015 respectively. CDB increased the organic carbon above the other treatments in 2015, while MFB increased the exchangeable potassium in the two planting seasons. The uptake of N and P were increased by MFB in 2014 and 2015 respectively. Application of MFB, PDB and CDB resulted in the replenishment of most depleted soil nutrients, Greenleaf growth and nutrients uptake. The three biochar sources could be a good alternative in the absence of fertilizers for soil nutrient improvement and increase crop yields as their residual effects last beyond the year of application.

Key words: Greenleaf*, biochar, depleted soil nutrients, feedstock, nutrient uptake and residual effect*

Introduction

Continuous crop cultivation on the same piece of land is one of the factors that results to soil nutrients depletion. Soil nutrient depletion occurs when most nutrients are lost from the soil; this may be through natural or human-induced practices. Soil nutrient depletion could be defined as a process by which the soil nutrient stock is diminishing due of continuous nutrient mining without sufficient replenishment of the nutrients harvested in agricultural products (Tilahun *et al.,* 2018). Apart from continuous crop cultivations, other factors that may lead to soil nutrient depletion include heavy rainfall, which causes intensive leaching that results to soil acidity (Lee *et al.,* 2018),soil water and wind erosions (Tan *et al.,* 2005; Niu *et al.,* 2015), changes in land use (Hartemink, 2010) among others. Effect of soil nutrient depletion, which includes reduction of soil quality and crop yield, poses a potential threat to global food security and agricultural sustainability (Tan *et al.,* 2005). Global food insecurity bears a direct impact on the human diets resulting to malnutrition (Barker *et al*., 2016).Depleted soil nutrient can be replenished through crop rotation, proper use of fertilizers, cover cropping and organic materials.

Organic materials can be applied in form of animal manure, live mulch, compost and biochar. Biochar, which is produced through pyrolysis of feed stocks can be used to replenish soil nutrients, especially in acidic condition where it acts as a liming material (Onwuka *et al.,* 2015). It can also improve soil fertility (Biederman and Harpole, 2013); reduce gaseous and leaching losses of nutrients such as carbon and nitrogen from the soil (Zhang *et al.,* 2010). Biochar can be produced from diverse feed stocks and each of these feed stocks has different nutrient contents which affect the soil fertility and crop yields (Onwuka and Nwangwu, 2016). One good thing with biochar is that it can be produced from locally available feed stocks. These feed stocks which may initially constitute or pose a threat to the health of the populace can be converted to useful agricultural inputs such as biochar.

Greenleaf or Amaranthus is one of the vegetables that produces the highest amount of protein and is a valuable source of fighting malnutrition (Messiaen, 1992 and Uwaegbute, 1989). Including amaranthus in diets especially for children will help in fighting malnutrition (Uwaegbute, 1989) therefore, it is important to increase the production of Amaranthus, which is becoming extinct in Umudike area of Abia State.

Biochar produced from different feed stocks has different nutrient contents (Onwuka and Nwangwu, 2016).It is vital to find the biochar produced from feedstock that will improve the amaranthus production in the absence of mineral fertilizer and as well as improve the soil fertility.

In this study, we evaluated the effect of biochar produced from different feed stocks on Greenleaf and soil nutrients content in Umudike area of Abia State. Our aim was to determine the effect of biochar produced from different feedstock and their effects as well as their residual effect on soil chemical properties, Greenleaf growth and nutrients uptake. We hypothesized that biochar from different feed stocks would differ from each other in relation to soil nutrient replenishment and Greenleaf growth.

Materials and methods

Biochar Types

Biochar types were produced from different feed stocks which included cow dung, goat dung, poultry dropping, rice husk, composted rice husk and a combined mixture of all the feed stocks. The feed stocks (cow dung, goat dung and poultry dropping) were collected from Michael Okpara University of Agriculture, Umudike livestock unit, while the rice husk was collected from the local milling unit at Uzuakoli village in Bende L.G.A. of Abia State. The feed stocks were converted into biochar by subjecting them to a slow pyrolysis method at a temperature of 450^0C using the pyrolysis drum unit.

Nursery preparation and transplanting

Greenleaf seeds were seeded into the nursery containers made of wooden material. The length, width and depth of the containers were 90 x 60 x 30 cm respectively. These were filled with a mixture of loamy soil, manure, and river sand, in a ratio of 3:2:1. The test crop- Greenleaf (*Amaranthus caudatus*) were sourced from National Agricultural Seed Service situated at National Root Crops Research Institute Umudike, Abia State. The seeds were transplanted to beds after two weeks of being raised in the nursery, at a spacing of 30cm x 30cm intra and inter-row spacing respectively, to give a plant population of 111,111plants per hectare.

Experimental setup

The experimental field was located at the Eastern Research Farm of Michael Okpara University of Agriculture (latitude 05° 29´ 15.6” and 05° 29´ 15.3”E, longitude 07° 32´ 55.9” and 07° 32´ 55.7”N; elevation of 143m above sea level, mean annual rainfall of 2117 mm which is distributed over nine to ten months in a bimodal rainfall pattern).The field was pre-cropped with cassava and after the cassava was harvested, the land was left to fallow for a short period of 6 months with *Mimosa pudica* and *Panicum maxima* as the dominant weed species. The field was cleared of existing vegetation and the debris was removed from the site manually.

Beds were made manually for the transplanting of the Greenleaf seedlings.

The experimental area had a total land area of 294m^2. Each experimental plot had a dimension of 3m x 3m with 1.0m buffer zone between plots and 0.5m within plots. The soil has a sandy clay loam texture (218 gkg^{-1} sand, 35 gkg^{-1} silt and 747gkg^{-1}clay) with pH (H_2O) of 5.10, 1.66% OM, 0.11 % N, 32.00 mgkg^{-1}P and 0.02cmolkg^{-1}K.

Table 1: The physiochemical properties of the soil used for the research study

Soil parameters	Values
Sand (g/kg)	747
Silt (g/kg)	35
Clay (g/kg)	218
Textural class	Sandy Clay Loam
pH (H_2O)	5.10
pH in (KCl)	4.40
Organic Carbon (%)	0.96
Organic Matter (%)	1.66
Total Nitrogen (%)	0.11
Available Phosphorus (mgkg^{-1})	35.70
Exchange. Potassium (cmolkg^{-1})	0.02
Exchange. Calcium (cmolkg^{-1})	2.40
Exchange.Magnesium (cmolkg^{-1})	0.80
Exchange.Sodium (cmolkg^{-1})	0.25
Exchange. Acidity (cmolkg^{-1})	1.52
ECEC (cmolkg^{-1})	5.00
Base Saturation (%)	69.58

Exchange = Exchangeable; ECEC = Effective cation exchange capacity.

Treatment

This comprised of six types of biochar as amendments and a control (C), which did not receive any biochar. The amendments were cow dung (CDB), goat dung (GDB), poultry dropping (PDB), rice husks (RHB), composted rice husks (CRHB), and mixed feedstock (MFB) (combination of CDB, GDB, PDB, RHB and CRHB at 1:1:1:1:1 ratio). The amendments were applied at the rate of 3t/ha (equivalent of

2.7kg/plot)on dry basis per plots. They were applied once in 2014 and allowed for the residual effect on the soil properties and re-planted Greenleaf growth in 2015.Thebiochar was analyzed and characterized according to Biochar material test categories and characteristic of the *IBI Biochar Standards* Version 2.0 (2014). The details of the chemical composition of the amendments are shown on Table 2 below. The treatments were laid out in a Randomized Complete Block Design and were replicated three times.

Table 2: Chemical composition of amendments used for the study

Properties	CDB	GDB	PDB	CRHB	MFB	RHB
pH (H_2O)	10.70	8.80	8.70	7.00	7.10	6.60
Av. P (%)	1.37	1.23	2.23	1.24	1.07	2.15
Nitrogen (%)	1.68	1.40	1.12	1.75	0.91	1.33
Potassium (%)	1.26	0.64	1.55	1.20	1.25	1.49
Sodium (%)	0.22	0.22	0.37	0.15	0.19	0.35
Calcium (%)	3.41	3.21	4.91	3.01	4.21	2.21
Magnesium(%)	0.55	1.10	0.49	0.67	0.37	0.31
Org carbon (%)	53.30	88.90	67.60	72.16	96.35	96.00

CDB= Cow dung biochar; GDB= Goat dung biochar; PDB =Poultry dropping biochar; CRHB= Composted Rice husk biochar; MFB= Mixed feedstock biochar; RHB= Rice husk biochar; Av.P= Available phosphorus; Org carbon= Organic carbon.

Soil properties determination

Pre-treatment soil samples were collected randomly using a soil auger from thirty spots in the field. The soils were sampled at the depth of 0-15cm to give a composite soil sample that was air dried, passed through a 2 mm sieve mesh size and used for the laboratory analyses. Likewise, after harvest, the soils were randomly collected from each of the plots separately and prepared for analyses.

Soil pH was determined in 1:2.5 soils to water ratio respectively using a glass electrode pH meter (Mclean, 1986). Organic carbon was determined using the wet oxidation method of Walkey and Black as described by Nelson and Sommers (1986). Total nitrogen was determined using the macro-kjedahl method as described by Jackson (1962). Available phosphorus was determined by Bray 1 method as described by Bray and Kurtz (1945). Exchangeable cation (K, Na, Ca and Mg) were extracted with 1N ammonium acetate (NH_4OAc) buffered at pH 7, afterwards sodium (Na^+), and potassium (K^+) were read using flame photometer, while magnesium and calcium were determined using the ethylene diaminetetracetic acid (EDTA) titration method as described by Page, *et al.*,(1982). Exchangeable acidity was determined by the method of Mclean (1986) as outlined by Udo, *et al.*, (2009).Effective cation exchange capacity was calculated as the sum of exchangeable basic cation (calcium, magnesium, potassium and sodium) and exchangeable acidity expressed in $cmolkg^{-1}$. Percentage base saturation was obtained by calculation using the formula below:

$$\%\text{Base saturation} = \frac{Total\ exchangeable\ bases}{Effective\ cation\ exchange\ capacity} \text{X } 100$$

Plant parameters measured

Six Greenleaf plants were tagged in each plot for the measurement of plant height (cm)at 5, 6, 7, 8 and 9 weeks after transplanting (WATP). The N,P and K uptake of the plant was determined by harvesting two plants from each plot at 6WATP. They were carefully washed with distilled water and oven-dried at 65^0C. The oven-dried plant samples were then milled and passed through a 0.25 mm mesh-size sieve. Wet oxidation method (AOAC 1984)was used to digest the sieved plant materials for the uptake of N, P and K nutrient in the plant. Perchloric acid 60% AR (Analar), HNO_3Conc, AR and H_2SO_4 conc, AR, were the extractants used. The amount of nutrient taken up by plant was calculated using the below formula:

$$\text{Nutrient uptake in biomass (kg/ha)} = \frac{Nutrient\ in\ biomass \times Dry\ matter\ of\ biomass}{100}$$

Statistical Analysis

The data generated were subjected to Analysis of Variance (ANOVA) for Randomized Complete Block Design (RCBD) using the GENSTAT package (17^{th} Edition). The means were separated using the Fisher's Least Significant Difference (LSD).

Results and Discussion

Effect of treatment on some soil chemical properties at harvest of Greenleaf in 2014 planting season

The treatments effect on some soil chemical properties is shown on Table 3. The pH varied from the control to MFB with values of 4.50 and 6.21 respectively. Mixed Feedstock Biochar (MFB) had a significantly ($P \leq 0.05$) highest value among the treatments. Poultry Dropping Biochar (PDB) showed a significantly ($P \leq 0.05$) highest value of 68.70 mg kg^{-1} for available phosphorus, this was followed by MFB with a of 60.38mg kg^{-1}. The control had the lowest value of 9.10 gkg^{-1} for organic carbon while RHB had the highest value of 24.51gkg^{-1} however; there was no statistically difference among the amendments in relation to organic carbon. There were no significant differences among the treatments for total nitrogen. All the amendments had reduced values for exchangeable acidity when compared with the value obtained for the control. Mixed Feedstock Biochar had 0.10coml kg^{-1}, which was the lowest value for exchangeable acidity while the control had the highest exchangeable acidity value of 0.47 coml kg^{-1}. The value of exchangeable calcium ranged from 1.74coml kg^{-1} in control to 5.61coml kg^{-1} in PDB. Poultry Dropping Biochar showed a significantly ($P \leq 0.05$) higher value for exchangeable calcium, followed by MFD. All the amendments increased the value of exchangeable magnesium over the control. Mixed feedstock Biochar significantly ($P \leq 0.05$) increased exchangeable magnesium with value of 1.31coml kg^{-1} as against the values of 0.52coml kg^{-1} and 0.93 coml kg^{-1} obtained for control and PDB respectively. Plots that received the amendments showed significantly ($P \leq 0.05$) higher values for exchangeable potassium over the control. The highest value for exchangeable potassium was 0.47coml kg^{-1} given by MFB while the control gave a value of 0.14 coml kg^{-1}. There were no significant differences among the treatments with regards to exchangeable sodium. Percentage base saturation was increased significantly in plots that received MFB with value of 91.66%; this was followed by plots that received PDB with a value of 91.46 %. The increase in soil pH by the application of biochar agrees with the result obtained by Onwuka *et al.* (2016). They observed that biochar applied to highly weathered tropical soils increased the pH. When the pH is increased to near neutral (6.21 and 6.11 in Table 3) as in the case of the present work, most of the soil macronutrients especially phosphorus, potassium, calcium and magnesium become available for plant utilization. As the pH was increased, the exchangeable acidity was decreased, this could be as a result of the neutralization and precipitation of aluminum and hydrogen by the high calcium (Table 2) contained in the biochar types. The amendments increased the soil pH, available phosphorus, organic carbon, exchangeable calcium and exchangeable potassium from their initial values before treatments application (Table 1) to the values obtained after treatment applications (Table 3). The reason for these increases could be that the amendments supplied the nutrients that replaced the depleted ones from the soil colloids before planting.

Table 3: Effect of treatments on some soil chemical properties at the end of harvest of Greenleaf in 2014 planting season

Treatment	pH (H_20)	Av.P mgkg^{-1}	Org.C gkg^{-1}	TN gkg^{-1}	Ex.Acid →	Ex.Ca →	Ex. Mg cmolkg^{-1}	Ex.K ←	Ex. Na ←	%BS
Control	4.50	13.50	9.10	0.60	0.47	1.74	0.52	0.14	0.27	66.58
CDB	5.32	38.21	23.80	1.80	0.25	2.53	1.08	0.25	0.28	81.98
GDB	5.23	48.04	16.91	1.90	0.31	2.78	1.00	0.31	0.26	82.29
PDB	6.11	68.70	19.13	1.00	0.28	5.61	0.93	0.38	0.26	91.46
CRHB	5.40	47.03	23.61	0.90	0.14	2.12	1.02	0.10	0.30	77.80
MFB	6.21	60.38	19.33	2.70	0.10	4.76	1.31	0.47	0.27	91.66
RHB	5.71	44.80	24.51	1.10	0.29	3.01	0.74	0.29	0.31	82.54
Lsd ($p\leq0.05$)	0.04	1.32	9.30	Ns	0.07	1.02	0.35	0.07	ns	10.21

CDB= Cow dung biochar; GDB= Goat dung biochar ; PDB= Poultry droppings biochar; CRHB= Composted rice husks biochar ; MFB= Mixed feedstock biochar ; RHB=Rice husks biochar ; Av. P= Available phosphorus , Org.C= Organic carbon ; TN= Total Nitrogen; Ex. Acidi=Exchangeable acidity; Ex.Ca=Exchangeable calcium ; Ex. Mg =Exchangeable Magnesium; Ex. K= Exchangeable potassium ; Ex. Na= Exchangeable sodium; and %BS= percentage base saturation.

Residual effect of treatment on some soil chemical properties at harvest of Greenleaf in 2015 planting season

Soils in plots that were treated with PDB had the highest significant pH value of 5.93 (Table 4). The value obtained in PDB was higher than the value of 4.23 obtained in plots that received no amendments (control).All the amended plots had higher values over the control for available phosphorus. The values of available phosphorus for the amendments ranged from 38.2mg kg^{-1} in CDB to 46.7mg kg^{-1} in RHB with RHB showing significantly ($P \leq 0.05$) higher value. Plots that received CDB showed higher values of 1.73 $gkg^{-1}$for organic carbon compared, to the value gotten for MFB (1.39gkg^{-1}), which was the lowest among the treatments. The value for total nitrogen ranged between 0.05$gkg^{-1}$and 0.31gkg^{-1} in control and MFB respectively. All the amendments significantly ($P \leq 0.05$) increased the values of the soil total nitrogen over the control. The soil exchangeable acidity was reduced by the applied PDB with a value of 0.71cmol kg^{-1}. It was observed that 0.71cmolkg^{-1} was lower than the values obtained for the control (1.51comkg^{-1}) and the pre-treatment soil (1.52comlkg^{-1}) as shown in Table 1. Poultry Dropping Biochar gave a value of 4.08 comkg^{-1} for exchangeable calcium, which was significantly ($P \leq 0.05$) higher than the values of 1.43 and 1.79 obtained for the control and CRHB respectively. All the amendments had significantly higher values for exchangeable magnesium compared to the control. The highest value for exchangeable magnesium was obtained in plots that received MFB while the lowest were from plots that did not receive any amendment (control). All the treatments did not show any significant differences for exchangeable potassium and sodium. Poultry Dropping Biochar gave a significant value of 88.28 % for percentage base saturation while the value obtained from the control was 58.74 %.

Table 4: Residual effect of treatments on some soil chemical propertiesat the end of harvest Greenleaf in 2015

Treatment	pH (H_20)	Av.P $mgkg^{-1}$	Org.C gkg^{-1}	TN gkg^{-1}	Ex.Acid	Ex.Ca	Ex. Mg cmolkg^{-1}	Ex.K	Ex. Na	%BS
Control	4.23	37.5	1.60	0.05	1.51	1.43	0.48	0.09	0.15	58.74
CDB	5.00	38.2	1.73	0.11	0.98	2.05	0.93	0.22	0.22	77.73
GDB	5.02	43.0	1.48	0.09	0.95	2.29	0.97	0.25	0.19	79.57
PDB	5.93	53.7	1.45	0.13	0.71	4.08	0.83	0.24	0.17	88.23
CRHB	4.81	43.0	1.42	0.14	1.20	1.79	0.79	0.07	0.23	70.59
MFB	5.65	41.6	1.39	0.31	0.74	2.84	1.18	0.31	0.21	85.98
RHB	5.11	46.7	1.48	0.11	1.04	2.11	0.62	0.22	0.20	75.18
Lsd ($p \leq 0.05$)	0.32	2.53	0.53	0.03	0.17	1.00	0.28	Ns	Ns	7.15

CDB= Cow dung biochar; GDB= Goat dung biochar ; PDB= Poultry droppings biochar; CRHB= Composted rice husks biochar ; MFB= Mixed feedstock biochar ; RHB=Rice husks biochar ; Av. P= Available phosphorus , Org. C= Organic carbon ; TN= Total Nitrogen; Ex. Acidi=Exchangeable acidity; Ex.Ca=Exchangeable calcium ; Ex. Mg = Exchangeable Magnesium; Ex. K= Exchangeable potassium ; Ex. Na= Exchangeable sodium; and %BS= percentage base saturation.

Effect of treatment on Greenleaf plants heights in 2014 planting season

The treatments effect on Greenleaf height is shows on Fig 1. No significant differences were recorded among the treatments at 5 weeks after transplanting (WATP). At 6WATP, the plots treated with CDB recorded the tallest plants with a mean height of 13.30cm.

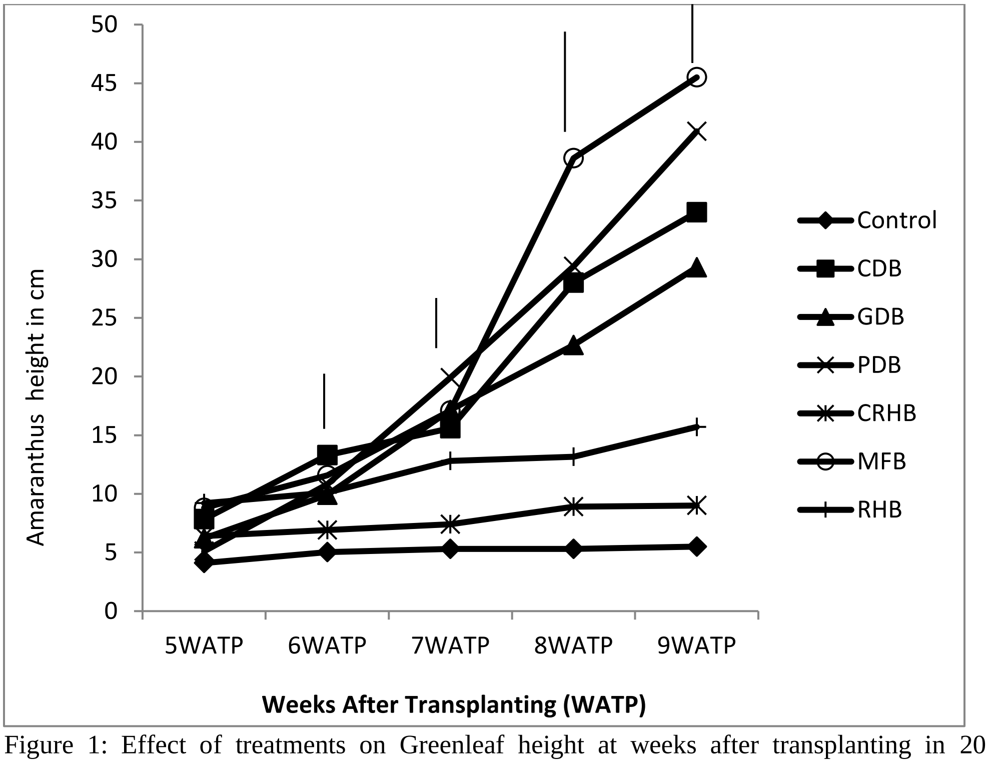

Figure 1: Effect of treatments on Greenleaf height at weeks after transplanting in 2014 planting season.
Vertical bars represent lsd at p≤ 0.05.

At 7 WATP plots amended with PDB significantly (P≤ 0.05) increased the plant height with a value of 19.9cm. All the amendments increased the plant heights over the control at 7 and 8 WATP. MFB significantly (P≤ 0.05) increased the plant height at 8 and 9 WATP with values of 36.6cm and 45.5cm respectively while the lowest plant heights of 5.3 and 5.5 respectively, were gotten from the control. The increase in the plant heights by the amendments over the control is in line with the findings of Graber *et al.*,(2010), who recorded an increase in the plant height of tomato and pepper, following the application of biochar. The increase in plant height could be as a result of the nutrients in the amendments (Table 2), which the plant would have been assimilated and hence the growth occurred.

Residual effect of treatment on Greenleaf plants heights in 2015 planting season

Figure 2 shows the residual effect of treatments on the height of Greenleaf (*Amaranthus caudatus*). At 5, 6, 7, 8 and 9 WATP, PDB significantly ($P \leq 0.05$) increased the plant heights with values of 30.14cm, 36.50cm, 41.50cm, 47.11cm and 50.73cm respectively. It was observed that there was no statistical difference among PDB, MFB, GDB and CDB though PDB had the highest values for plant heights at 5, 6, 7, 8 and 9WATP. The better plant height performance recorded in PDB could be as a result of increase in the rate of mineralization as the months progressed.

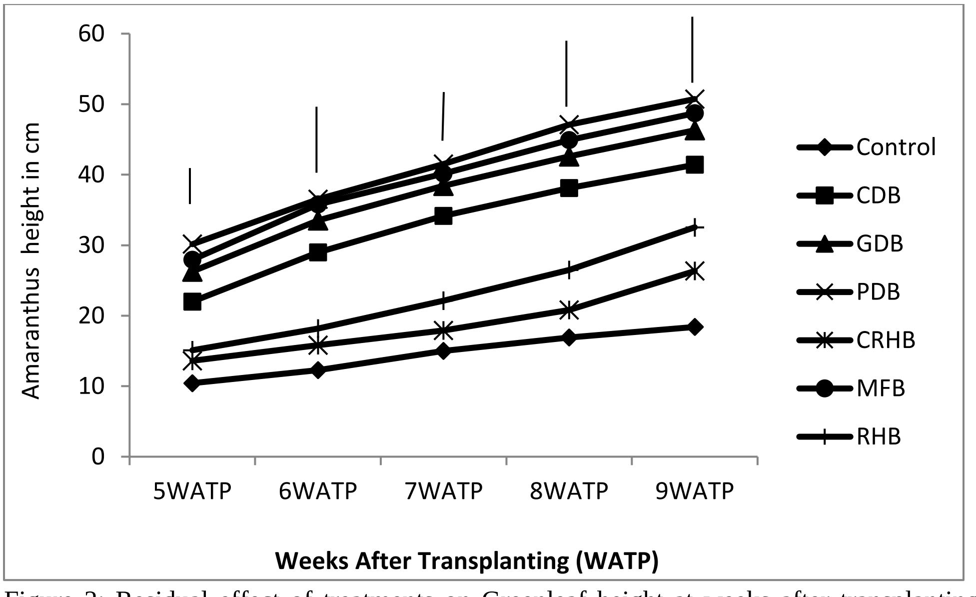

Figure 2: Residual effect of treatments on Greenleaf height at weeks after transplanting in 2015 planting season.
Vertical bars represent LSD at p≤ 0.05.

Effect of treatment on NPK uptake by Greenleaf plants in 2014 planting season

The applied amendments increased N, P and K uptake over the control (Table 5). Whereas MFB showed the highest N and P uptake values of 2.10 kg ha^{-1} and 0.96 kg ha^{-1} respectively, CDB gave the highest K uptake of 1.06 kg ha^{-1}. This result agrees with the findings of Lehmann and Joseph (2009).

Table 5: Effect of treatments on NPK uptake in 2014 planting season

Treatment	N	P	K
	→	kg ha^{-1}	←
Control	0.05	0.04	0.01
CDB	1.59	0.47	1.06
GDB	1.41	0.52	0.74
PDB	1.45	0.40	0.61
CRHB	0.29	0.14	0.15
MFB	2.10	0.96	0.96
RHB	0.42	0.20	0.20
$LSD_{(0.05)}$	0.89	0.28	0.47

CDB = Cow dung biochar; GDB = Goat dung biochar; PDB = Poultry dropping biochar; CRHB = Composted rice husk biochar; MFB =Mixed feedstock biochar; RHB =Rice husk biochar

They reported that there were significant differences in nutrients uptake in biochar-amended plots over the control. The reason for the increase of nutrients uptake on the plots that received amendments, could be a result of higher bioavailability of nutritional elements in the amendments which led to their uptake by the Greenleaf. The better performance showed by MFB in relation to N and P uptake, could be as a result of synergistic effect from the combination of the different biochar feedstock sources that gave rise to MFB.

Residual effect of treatment on NPK uptake by Greenleaf plants in 2015 planting season

The residual effect of the treatments on nitrogen showed that plots that received the amendments had higher nitrogen uptake residual effect values over the control as shown in Table 6. MFB had significantly ($P \leq 0.05$) highest N uptake value (1.93%), while the control had the lowest value of 0.03%. The highest value of .96% for the phosphorus uptake was recorded on plots that received MFB, this was followed by the value of 0.47% given by plots that received CDB; the control had the least value of 0.04. The residual effect of the treatment on potassium was more significant in plots that received CDB with a value of 0.95kg ha^{-1}, while the control had the least value of 0.02 for K uptake.

Table 6: Residual effect of treatments on NPK uptake in 2015 planting season

Treatment	N	P	K
	→	kg ha^{-1}	←
Control	0.03	0.04	0.02
CDB	1.51	0.47	0.95
GDB	1.28	0.07	0.70
PDB	1.35	0.07	0.56
CRHB	0.27	0.07	0.14
MFB	1.93	0.96	0.94
RHB	0.44	0.22	0.16
$LSD_{(0.05)}$	0.84	0.38	0.41

CDB = Cow dung biochar; GDB = Goat dung biochar; PDB = Poultry dropping biochar; CRHB = Composted rice husk biochar; MFB =Mixed feedstock biochar; RHB =Rice husk biochar

Conclusion

Application of biochar significantly increased the soil properties and Greenleaf growth parameters tested in the present work. Biochar applied in the form of mixed feedstock biochar (MFB) and poultry droppings biochar (PDB),significantly increased the soil pH, available P, exchangeable Ca, exchangeable Mg, exchangeable K, percentage base saturation, plant heights and N, P and K uptake in 2014 planting season. Poultry dropping biochar (PDB) and Cow dung biochar (CDB) had a significant residual effect on soil pH, available P, exchangeable Ca, organic carbon, plant height and K uptake respectively. It will be concluded that the effect of MFB was mostly noticeable on the year of the amendment application, which was evident from most of the properties and parameters tested. Similarly, the PDB and C DB effect lasted in the soil in the second year planting. Mixed Feedstock Biochar, Poultry Dropping Biochar and Cow Dung Biochar are recommended for replenishing of the depleted soil nutrients and growth of Greenleaf in the study area. Further research work is on the optimal rates of combining MFB, PDB and CDB in order to harness their potentials in the year of application and the following year will be appropriate.

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