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Potentials of Biochar to Improve Productivity of Automobile Wastes Contaminated Ultisol under Mound Tillage Practice Using Cocoyam (*Xanthosoma sagittifolium*) as Test Crop in Abakaliki Southeast Nigeria

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Abstract: A field experiment was conducted in 2018 and 2019 cropping seasons to evaluate the effect of *biochar on the physicochemical properties of* automobile waste contaminated soil, yield , soil heavy metal (Cu, Zn, Fe, Pb) content and uptake by Cocoyam (*Xanthosoma sagittifolium*) in a mound tillage practice. The treatments were; Contaminated automobile waste soil (CO-control), contaminated soil amended with 5 tha-^{1} biochar (BO_5), contaminated soil amended with 10 t ha-^{1}(BO_{10}) and contaminated soil amended with 20 tha-^{1}biochar (BO_{20}). There was significant decrease in soil bulk density and increased soil hydraulic conductivity in biochar amended plots compared to the control. Exchangeable bases (Ca, Mg, K, Na), effective cation exchange capacity (ECEC), total N, available P, organic carbon and pH levels were significantly higher in biochar amended plots relative to the control. The significantly higher cocoyam yield was recorded in the biochar amended plots compared to control plots. Biochar amendment reduced the levels of Pb, Fe, pb and Cu to tolerable limits in soils. Similarly, uptake of Fe, Zn, cu and Pb by cocoyam in biochar amended soil was within acceptable limit for human consumption. It is recommended that agronomic practices that increases soil nutrient and decrease heavy metal uptake be used in automobile waste contaminated soils to obtain high crop yield and safe produce.

Keywords: Underutilized crops, Food security, Rural farmers, Acceptable limit, Mechanic village

Many indigenous plant species are in regular use by both human and non-humans. However, most of these plant species cultivated for food across the world have largely been neglected, unrecognized and underutilized. According to Agulana (2020) these indigenous and underutilized crops help in improvement and enhancement of health status of local population. In a study on food security; the challenge of feeding 9 billion people, Godfray et al (2010) reported that those indigenous and underutilized crops all over the world promote food security, enhance nutrition and help in generation of income for poor rural farmers. Cocoyam (one of the popular crops in Nigerian in late 1960's and early 1970's) is one of these neglected indigenous and underutilized plant species. At present it is at the verge of being forgotten. Ojenuga et al (1996) showed that heavy metals are naturally present in soils. In a study on transport of heavy metals in surface runoff from vegetable and citrus fields. He et al (2004) reported that anthropogenic activities result in high concentration of heavy metals in the environment. Poorly managed automobile workshops popularly called 'sites' abound in Abakaliki, the study area. These “sites” according to Ugoh and Moneke (2011) are source of constant release of used spent oil discharged from crank cases of cars, motorcycles and generators. Researches on heavy metal uptake by crops grown in automobile waste contaminated soils are few or non-existence in the study area. Similarly, studies on theeffects of biochar on Nigerian soils are very few and scanty. Fagbenro et al (2015) observed that available literature on biochar in Nigeria indicated that nearly all the biochar researches were potted/green house experiments. There is therefore, the need to carry out biochar studies in the field for an understanding of its effect on soil properties and crop yield. The aim of this research was to examine the effect of different rates of biochar on the properties of automobile waste contaminated soil and their impact on the yield and heavy metal uptake of cocoyam. The study will create awareness on the suitability of such soils for crop production especially cocoyam- an important, indigenous and underutilized crop that is almost being forgotten. Farming is the major activity of the people of the study area while the tillage system used by the farmers is mound tillage.

MATERIAL AND METHODS

Study area: The study was carried out on abandoned land that used by mechanics for workshop and disposal of automobile wastes for many years and adjacent to the Teaching and Research Farm of Faculty of Agriculture and Natural Resources Management, Ebonyi state university Abakaliki, Abakaliki is located by latitude 06^{0}4'N and longitude 08^{0}65'E in the derived Savannah zone of the Southeast agro-ecological area of Nigeria. The rainfall pattern is bimodal (April – July and September – November) with a short dry spell in August normally referred to as "August break". The total annual rainfall in the area ranges from 1500 -2000 mm, with a mean of 1,800 mm. At the onset of rainfall, it is torrential and violent, sometimes lasting for one to two hours (Okonkwo and Ogu 2002). The area is characterized by high temperatures with minimum mean daily temperature of 27^{0}C and maximum mean daily temperature of 31^{0}C throughout the year. Humidity is high (80%) with lowest (60%) levels occurring during the dry season between December to April, before the rain season begins. Geologically, the area is underlain by sedimentary rocks derived from successive marine deposits of the cretaceous and tertiary periods. According to the Federal Department of Agriculture and Land Resources (FDALR 1985), Abakaliki agricultural zone lies within 'Asu River group' and consists of olive brown sandy shales, fine-grained sandstones and mudstones. The soil is shallow with unconsolidated parent materials (shale residuum) within 1m of the soil surface. It belongs to the order, ultisol and is classified as Typic Haplustult (FDALR 1985). The vegetation of the place is primarily derived savannah with bush growth and scanty economic trees. The site has history of previously being used for mechanic workshop and disposal of automobile wastes for over twenty years before it was reclaimed. Existing grasses in some portions were cleared manually using cutlass. The debris left after clearing was removed before seedbed preparation. Farming is the main occupation of people of the study area.

Land preparation and application of treatments: The land used for the study measured 13.5 m by 15 m equivalent to 0.0203 ha. The experiment was arranged as Randomized Complete Block Design (RCBD) with four treatments and five replications. A total of 20 plots measuring 3 m x 3m each were used for the study. Plots were separated by buffer of 0.5 m and each replicate 1 m apart. The treatments were; Control (automobile waste contaminated soil-(CO) , 5 t ha-^{1}of biochar (BO_5) ,10tha-^{1}biochar (BO_{10}) and 20 t ha^{-l} biochar (BO_{20}) equivalent to 0,6,12, and 20 kg plot^{-1}. The treatments were spread uniformly and incorporated into their respective plots during cultivation. Mounds 16-20 cm high were prepared using hoe. Cocoyam sett weighing 20-25g was planted 30 cm apart and at a depth of 5cm to give a planting population of 834 corms/ha. Weeding was done manually at interval of 6 weeks with hoe. At maturity (18 months after planting) ten plants were harvested from each plot by shelling up the plant and uprooting it. This brings out the corms while the remains in the soil were dug out. The corms were dried in the sun for 2-3 days, weighed and the yield expressed in t ha-^{1}. The dried corn was ground in food processor with stainless cutter. Approximately 1g of the sample was digested with Conc HNO_3. The digest was analysed for heavy metal (Cu, Fe, Zn, Pb) content by subjecting it to flame AAS according to APHA (1985). The same procedure was repeated in the second cropping season without application of amendments to test the residual effect.

Soil sample collection: Initial soil samples were collected randomly from 8 observation points in the study site at 0-15 cm depth before the study. Auger samples were collected from 4 observation points at 0-15 cm .after harvest. The soil samples were thoroughly mixed to form a composite sample and used for routine analysis. Core samples were collected from four observation points at a depth of 6 cm in each plot at 45 and 90 days after planting (DAP) and used for the determination of soil physical properties. Biochar was collected from two different species of hard wood viz Oil palm (*Elaeis guineensis*) and Gmelina (*Gmelina arborea*) bought from a local distributor. The hardwood was pyrolysed at 350°C, manually crushed to particles smaller than 2 mm and thoroughly mixed together. Later, characterization was carried out according to biochar material test categories and characteristic of the IBI Standards version 2.0 (2014). At the end of the end of each cropping season (after harvest) undisturbed core samples were collected and used for the determination of soil physical properties. Similarly, auger samples were collected from the plots air dried, sieved and used for determination of soil chemical properties.

Plant sample collection: At maturity eight cocoyam plants per plot were sampled and tagged. The corms were harvested, air dried and weighed to get the yield per plot. The yield data was expressed to hectare equivalent. The dried corm was analysed for heavy metal (Cu, Zn, Fe, Pb) content.

Laboratory methods: Bulk density (bd) was determined using the core method described by (Blake and Hartage, 1986).Hydraulic Conductivity was determined by the constant head technique (Klute and Dinken 1986). Exchangeable bases (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}) were determined by the method of Thomas (1982) and effective cation exchange capacity (ECEC) determined by summation. Soil reaction was measured according to the procedure of Henderson et al (1993). Total nitrogen was determined using the micro-Kjeldhal distillation method of (Bremner 1996). Available P was determined by the Bray-2 method as described by (Page 1982) while organic carbon was determined using the method described by Nelson and Somners (1982).

Determination of heavy metals: The corm heavy (Cu, Fe, Pb, Zn) metal content was determined using the analytical procedure by APHA et al (1985).

Statistical analysis: Data was analysed using Statistical Analysis System (SAS 1985).

RESULT AND DISCUSSION

Selected properties of the automobile waste contaminated soil and biochar: The soil texture is sandy clay loam . The soil pH was extremely acidic (USDA-SCS 1974). Higher values of Avail. P, total N and organic carbon (OC) were observed in the biochar compared to the soil (Table 1).

Effects of biochar on soil bulk density (bd) Mgm-^{3} and hydraulic conductivity (Cm hr-^{1}): Significantly lower bd values were observed inbiochar amended plots at 45 DAP in both cropping seasons compared to control (Table 2). Brady and Weil (2004) observed that biochar has lower bd (0.3 Mgm-^{3}) than mineral soils (1.3 M gm-^{3}) and thus can reduce soil bd. In a study on the effect of mechanic village activities on the soils of Abakaliki south eastern Nigeria, Njoku et al (2021) reported higher bd in spent oil contaminated soil relative to the control. Nellison et al (2015) reported decreased soil bd relative to the control when they studied the effect of woody biochar on the properties of a sandy loam soil and spring barley in a two year field experiment. Atkinson et al (2010) and Ndor et al (2015) also reported lower bd values in biochar amended plots compared to control as in present study.The significantly higher levels of hydraulic conductivity (HC) in biochar amended plots relative to control in both cropping seasons (Table 2). In the first cropping season HC ranged between 8.29-25.11 Cm hr^{-1}. In the second cropping season the order of increase in HC wasCO< BO_5< BO_{10}<BO_{20}. Nwite (2013) reported decreased HC in plots contaminated with automobile lubricant oil compared to non-lubricant oil contaminated soil. Njoku et al (2015) and Busscher et al (2011) showed increased HC in biochar amended plots relative to control plots.

Table 1. Selected properties of the automobile waste contaminated soil and biochar

Parameter	Soil (g kg^{-1})	Biochar
Coarse sand	364	Nd
Fine sand	200	Nd
Silt	366	Nd
Clay	70	Nd
Texture	Sand clay loam	-
pH	3.82	7.4
Ash content	Nd	23
Total N %	0.12	0.89
Avail. P mg kg^{-1}	5.30	28.0
OC (%)	3.60	23.9

Nd= Not determined

Effect of biocharon soil exchangeable bases and effective cation exchange capacity (ECEC) (Cmol kg^{-1}): The significantly (p=0.05) higher values of exchangeable bases and ECEC in amended plotsrelative to CO in both cropping seasons were observed (Table 3). In the first cropping seasonCa, K, Mg and Na ranged between, 0.11-0.27, 0.11-0.21, 0.10-0.23 and 0.09-0.24,respectively. In both cropping seasons the least exchangeable cation values were in the control. Mbah and Ezeaku (2009) characterized the physicochemical conditions of farmland affected by automobile waste and reported decrease in exchangeable bases and ECEC. Uchendu and Ogwo (2014) in a study on the effect of spent engine oil discharge on soil properties in automobile mechanic village reported decrease in exchangeable bases relative to non-spent engine oil discharged soil. Inal et al (2013) reported increase in exchangeable bases and cation exchange of soils amended with biochar and processed poultry droppings. Glaser et al (2002) opined that biochar inherently containing ash adds nutrients such as K, Ca and Mg to the soil solution thereby increasing the pH of the soil and providing readily available nutrients for optimum plant growth.

Effectbiocharon soil organic matter (OM%), pH ,available P (mg kg-^{1}) and total N (%): The significantly high

Table 2. Effect of biochar on soil bulk density (gcm^{-1}) at 45 and 90 days after planting (DAP) and Hydraulic conductivity (HC)

Treatment	2018		2019		HC	HC
	45 DAP	90 DAP	45 DAP	90 DAP	2018	2019
CO	1.47	1.51	1.49	1.52	8.29	5.09
BO_5	1.37	1.49	1.38	1.51	20.14	15.04
BO10	1.35	1.48	1.36	1.50	18.20	13.44
BO_{20}	I.33	1.37	1.35	1.49	25.11	18.70
FLSD (0.05)	0.02	NS	0.02	NS	2.23	1.02

pH values in biochar amended plots relative to the control were observed in the two cropping seasons respectively (Table 4). Similarly, significantly higher values of avail P, total N and OM was observed in amended soils relative to the control in both cropping seasons. The improvement in soil pH following application of the amendments corroborates the study of Chan et al (2008a).Using biochar as soil amendment, Vaccari et al (2011) reported elevated levels of pH in amended plots compared to control plots. Improvement in soil contents of available P, total N and organic matter observed in the study could be attributed to higher levels of these nutrients in the amendment in line with the observations of Peston and Schmdt (2006). Similarly Angst et al (2014) observed significantly higher values of SOC in soils amended with biochar compared to control.

Effect of biochar on the yield of cocoyam (Mg ha^{-1}): The significantly (p=0.05) higher Cocoyam corm yield in amended plots relative to control was observed (Table 5). The highest cocoyam corm yield (28.4) in the first cropping season was obtained in BO_{20} plots. This value (28.4) was 13%, 6% and 65% higher than yield values in BO_5, BO_{10} and CO, respectively. The order of yield increase in the second cropping season was $CO<BO_5<BO_{10}<BO_{20}$. The low yield obtained in CO plots is in line with the report of Vuoto et al (2005) that lubricant oil contaminated soil has serious fertility problems. The higher cocoyam corm yield in amended plots could also be due to high nutrient content of biochar and (Table 1) Blackwell et al (2008) reported that biochar can be used as amendment to improve soil quality and crop productivity. Yilangai et al (2014) reported significantly higher tomato yield in beds treated with charcoal than without charcoal. Similarly, Vinh et al (2014) observed increased vegetable yield following application of biochar. However, the result of this study differed from that of Jay et al (2015) who reported that short time application of biochar has no yield benefit.

Heavy metal uptake by cocoyam corm after the study: Heavy metal uptake by cocoyam corm differed significantly among the treatments in both cropping seasons (Table 6). In the first cropping season Cu varied between 1.04 and 2.52 with the highest value observed in CO. In the same season Zn, Fe, and Pb content of cocoyam corm varied between 8.08-28.5, 19.3-36.1 and 0.001-0.011, respectively. The highest corm content of Cu (1.90) was observed in CO in the second cropping season. Plants growing in a polluted environment can accumulate toxic metals at high concentration causing serious risks to human health if consumed Vahter et al (2007). Vousta et al (1996) reported higher levels of heavy metals in vegetables grown in contaminated soil relative to uncontaminated soil. Furthermore, Nwiko and Eguobi (2002) carried out a study

Table 5. Effect of biochar on the yield of cocoyam (Mg ha^{-1})

Treatment	2018	2019	Mean
CO	10.0	6..12	8.0
BO_5	26.6	13.7	20.1
BO_{10}	24.6	16.6	20.6
BO_{20}	28.2	18.4	23.3
FLSD (0.05)	1.96	1.67	

Table 3. Effect of biochar on soil exchangeable bases and effective cation exchange capacity –ECEC (Cmol kg-^{1})

Parameter	2018					2019				
	Ca	Mg	Na	K	ECEC	Mg	Na	K	Ca	ECEC
CO	0.11	0.10	0.09	0.11	0.41	0.06	0.05	0.08	0.07	0.26
BO_5	0.20	0.25	0.19	0.18	0.82	0.13	0.16	0.11	0.13	0.53
BO_{10}	0.23	0.28	0.16	0.21	0.78	0.18	0.13	0.16	0.15	0.50
BO_{20}	0.27	0.23	0.24	0.16	0.90	0.21	0.18	0.11	0.14	0.54
FLSD (0.05)	0.03	0.13	0.02	0.02	0.12	0.03	0.04	0.01	0.04	0.12

Table 4. Effect of biochar on soilorganic matter (OM), pH, available P and total N

Parameter	2018				2019			
	pH	Available P	TN	OM	pH	Available P	TN	OM
CO	3.76	1.02	0.10	0.09	3.65	0.09	0.06	0.07
$B0_5$	5.80	4.05	0.23	0.27	5.40	1.08	0.10	0.16
BO_{10}	5.50	5.O1	0.28	0.37	5.42	1.98	0.14	0.19
$B0_{20}$	6.01	5.06	0.29	0.40	5.50	1.65	0.19	0.23
FLSD (0.05)	0.12	0.03	0.01	0.03	0.02	0.40	0.10	0.30

Table 6. Heavy metal uptake by cocoyam corm after the study

Parameter	2018				2019			
	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe
CO	2.52	28.5	0.011	36.1	1.90	16.8	0.009	22.0
BO_5	1.11	7.20	0.002	19.7	1.00	6.72	0.001	16.0
BO_{10}	1.04	8.05	0.002	20.0	1.01	7.56	0.002	18.1
BO_{20}	1.23	9.24	0.001	19.3	1.12	7.61	0.001	16.0
FLSD (0.05)	0.11	0.32	NS	1.23	0.22	0.14	NS	1.31

Table 7. Heavy metal content of the soil after the study (Mg kg-^{1})

Parameter	2018				2019			
	Cu	Fe	Zn	Pb	Cu	Fe	Zn	Pb
CO	270	76	400	380	252	362	60	302
BO_5	162	33	298	198	230	108	30	120
BO_{10}	191	30	203	180	103	186	27	98
BO_{20}	153	28	198	142	98	169	20	102
FLSD(0.05)	10,3	6.9	12,5	16.3	8.9	10.2	4.5	1.8

on lead contamination of soils and vegetations in an abandoned battery factory in Ibadan and revealed that edible plants grown in polluted soils are susceptible to heavy metal uptake. Crop content of heavy metals is dependent on crop uptake and its availability in soils. High levels of heavy metals in crops above critical limit cause human hazards. Ware (2007) showed that the recommended daily allowance for Cu is 900 ug (meq) a day for adolescence and adult. The observed Cu value in the study is within acceptable limit. According to US National Institute of Health (2018) the recommended average intake of Fe in foods and supplement is 19-20.5 mg/day. Result of this study showed that Fe toxicity is possible in cocoyam grown in automobile soil since it is above acceptable limit for human beings. The range of Zn concentration/consumable in food samples according to World Health Organization) (WHO-2011) is 5-15 mg/kg. Ajiwe et al (2018) reported that the average human intake of Zn is 7-16.3 mg/day. The observed Zn content of the corm in automobile soil constitute human health hazard since it is above acceptable limit. According to Park et al (2011) plants readily bio-accumulate large quantity of pb through their roots without much changes in their total yield. Nnabo (2015) reported that pb accumulation above permissible level causes body ailments and easily leads to weariness of the body tooth and bones. The total pb burden according to Bersenyi (2008) is 90-400 mg.

Soil heavy metal content after the study (Mgkg-^{1}): The present study indicated that significant higher heavy metals in the CO plots (Table 7). The higher levels of soil heavy metal content in CO could be attributed to the effect of spent lubricant oil discharge by the mechanics. Duru (2019) reported that monitoring of heavy metal levels in soil is of great concern because of their toxicity and ease of leaching into surface and ground water. Majolagbe et al (2014), Palm et al (2013) and Oti (2018) showed higher levels of heavy metals in automobile waste soil than non-automobile waste soil. Orjiakor and Atuanya (2015) observed that the daily activities of auto-mechanic battery have negative impacts on soil physico-chemical properties. Demie (2015) showed extremely high levels of heavy metals (above USEPA regulation standard) in soil contaminated in garage and auto-mechanic workshop of Shasheme city. Njoku et al (2021) and Oti (2016) reported higher levels of heavy metals compared to the control. The result of the study showed that pb toxicity in automobile waste soil is possible since it is above acceptable limit.

CONCLUSION

The application of biochar improved the physicochemical properties of automobile waste contaminated soil. It also increased cocoyam yield and decreased heavy metal (Cu, Zn, Pb, Fe) uptake by cocoyam to acceptable limits that does constitute health hazard. Results also showed that heavy metals (Pb, Zn, Cu and Fe) content in automobile waste contaminated soil was decreased to non-toxic limit when biochar was uses as amendment. The use of biochar as an agronomic practice to increase crop yield and ensure safe produce from automobile waste contaminated soil was recommended.

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