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COMPARATIVE ASSESSMENT OF PHYSIOLOGICAL PERFORMANCE AND YIELD OF MAIZE VARIETIES TO BIOCHAR AMENDED METAL POLLUTED SOIL

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ABSTRACT

This study determined the chemical properties of biochar amendments and the performance of two maize varieties grown on the soil. The seeds of two improved varieties of OLOYIN /SW1 and SWAN-1-SR-Y were used while the local breed was obtained from a local market. Treatment consisted of two soil amendment of biochar from 100% Maize residue (MAS) and 100% African Teak (AFT) applied at same rate (10tha^{-1}) with zero biochar application as the control. Results were analyzed using Analysis of Variance (ANOVA) and their treatment means were separated by Duncan's Multiple Range Test at $p < 0.05$.The organic carbon, total nitrogen and phosphorus for the two amendments used were 47.60, 3.70, 47.81 g kg-^{1} for maize residue, and 44.30, 3.20 and 23.76 g kg-^{1} for African Teak. Highest mean plant height, stem girth and number of leaves were 112 cm, 4.90 cm and 9.00 cm were obtained in the OLOYIN when equal proportion of maize residue and African Teak biochars was applied. However, lower growth component values were obtained for the local variety. The highest mean maize grain yield of 279.4 (g) in OLOYIN followed by 243.3 (g) in SWAM -1-SR-Y while the least yield was recorded in the local variety. Also, highest protein (99.7 %), (93.4 ± 0.12%) and vitamin C (27.43, 27.25 mg kg-^{1}) were obtained for the harvested two improved varieties when compared with the local one.

Keywords: Biochar, Contamination, Environment, Metal Proximate, Physiology Yield

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INTRODUCTION

Maize (*Zea mays* L.) is a member of grass family P*oaceae*. It is originated from South and Central America. It was introduced to West Africa by the Portuguese in the 10th century. It is one of the world's most important cereal, which is primarily grown for grains and fodder. In Nigeria, maize cultivation is gaining popularity. Its production has increased tremendously over the years. Maize can be grown on a wide variety of soils, but performs best on well-drained, well aerated, deep warm loams and silt loams containing adequate organic matter and well supplied with available nutrients. Although it grows on a wide range of soils, it does not yield well on poor sandy soils, except with heavy application of fertilizers on heavy clay soils, deep cultivation and ridging is necessary to improve drainage (Ahmad *et al*., 2010). Maize can be successfully grown on soils with pH of 5.0 - 7.0 but a moderately acid environment of pH 6.0 - 7.0 is optimum. Outside this range results in nutrient deficiency and mineral toxicity. High yields are obtained from optimum plant population with appropriate soil fertility and moisture.

Biochar is a carbon rich charcoal that is formed by the pyrolysis (thermal decomposition) of organic biomass or agricultural residues which is used as soil amendment (Xiao *et al*. 2014). Furthermore, Biochar can also be seen as the carbonaceous product obtained when plant or animal biomass is subjected to heat treatment in an oxygen-limited environment and when applied to soil as an amendment. Biochar made from diverse biomass species (feedstock) are characterized by different morphological and chemical properties but also characteristically differ based on specific pyrolysis conditions (i.e. final pyrolysis temperature or peak temperature, rate of charring or ramp rate, and duration of charring time). It is produced by incomplete pyrolysis of biomass, or sometimes as a co-product of pyrolysis and thus commonly occurs as a component of soil organic matter (SOM) where slash-and-burn agriculture is widely practiced, and in soils of the fire-prone eco regions. metal contamination of soil is a major environmental problem worldwide and biochar application to soil contaminated with metals has emerged as a potential cost-effective and environmentally sustainable technique for immobilization of toxic metals from soils (McGrath and Zhao, 2003; Tanvir and Siddiqui, 2010). On account of anthropogenic activities our natural habitats are endangered, therefore the restoration of such degraded habitats using sustainable, low input cropping systems with the aim of maximizing yield of crop plants is the need of the time. Thus, incorporation of the natural roles of the beneficial micro-organisms as well as introduction of biochar in maintaining soil fertility and plant productivity is gaining much more attention.

In general, biochar may not support microbial activity due to the refractory nature of Carbon and thus, can represent a long-term Carbon sink in soil (Tanvir and Siddiqui, 2010). The use of biochar as soil additives has been proposed as a means to simultaneously mitigate anthropogenic climate change while improving soil fertility. These soils have low pH levels and result in increased nutrient loss especially nitrogen through leaching. The soils are generally becoming sandy with reduced organic matter content (Ahmad *et al*., 2010). Biochar application helps farmers in several ways: less fertilizer is needed because biochar absorbs and slowly releases nutrients to plants; biochar improves soil moisture retention and conserves water, securing the crops against drought; farmers spend less on seeds as emergence percentages increases; biochar reduces the methane emissions from paddy fields and farm yard manures; it increases the soil microbes and other soil-life density; it lessens the hardening of soils; it supports better growth of roots and helps in reclaiming degraded soils. Another advantage of biochar is that it can be used in all types of agricultural systems (organic, chemical, mixed farming, natural farming) (Cushion *et al*., 2010). Currently, very little biochar material is being used in agriculture in Nigeria and elsewhere. Therefore, in the future development of agricultural markets for biochars, agronomic values of these products in terms of crop response and soil health benefits need to be quantified.

Biochars can be produced from a range of organic materials and under different conditions resulting in products of varying properties (Baldock and Smernik 2002; Nguyen *et al.*, 2009; Guerrero *et al.,* 2005). Little research has been published elucidating the mechanisms responsible for the reported benefits of the biochars on crop growth, production, and soil quality. Such understanding is essential for development of agricultural markets for biochars and for the future development of technology for the production of biochar products with improved quality and value. Shinogi *et al.* (2003) found, however, that biochar produced from sewage sludge in Japan did not show harmful levels of heavy metals. Agricultural activities and soils emit greenhouse gases, and emissions occur in the conversion of land. Agricultural soils have lost a large portion of their antecedent soil organic carbon storage, becoming a source of atmospheric carbon-dioxide. Biochar is charcoal, optimized with characteristics deemed useful in agriculture, interest in biochar stems from its potential agronomic benefits and carbon sequestration ability. As a soil amendment, biochar can stabilize carbon belowground and potentially increase agricultural and forest productivity, which appear to be sensitive to the conditions prevailing during its formation. Proposed mechanisms evidence points to added environmental function in the mitigation of diffuse pollution and emissions of trace gases from soil; precluding the possibility of contaminants accumulating in soil from the incorporation of biochar. Biochar alters soil properties, encourages microbial activity and enhances sorption of inorganic and organic compounds. Research studies point to their ability to increase the plant available water in the soil which enables the plants to survive longer with water shortage, increase soil fertility and agricultural yields, improve soil structure, aeration and water penetration, and land reclamation. Biochar stability depends on the molar ratio of oxygen to carbon in the resulting black carbon and appears to provide, at minimum, a 1000-year biochar half-life. The major consequences of agricultural intensification are a transfer of carbon (C) to the atmosphere in the form of carbon (IV) oxide (CO_2), thereby reducing ecosystem carbon pools. Agriculture contributes 10–12% of the total global anthropogenic greenhouse gas emissions. To meet the challenges of global climate change, greenhouse-gas emissions must be reduced. Diminishing increased levels of carbon (iv) oxide (CO_2) in the atmosphere is the use of pyrolysis to convert biomass into biochar, which stabilizes the carbon (C) that is then applied to soil. Biochar contains high concentrations of carbon that can be rather recalcitrant to decomposition, so it may stably sequester carbon (Glaser *et al.,* 2002).

Heavy metals are a dangerous group of soil pollutants as they cause serious toxicity problems in plants, animals and human beings. Metals are classified as "heavy" or "light" based on their specific gravity, atomic number, atomic mass and position in the periodic table. Generally, the term "heavy metal" refers to a selected group of metals and metalloids (*i.e.*, Cu, Zn, As, Pb, Cr and Cd) that are toxic to the environment. Metals cannot be degraded naturally like organic pollutants and accumulate in different parts of the food chain. Soils highly contaminated with metals lack proper structure and aeration and are low in soil fertility that can result in small biomass, together with poor plant growth in these soils (Clemente *et al*., 2006). Organic amendments, like compost, peat, farmyard manure, biosolids, chelates and most importantly biochars have been used recently in different research studies for the revitalization of soils contaminated with heavy metals (Clemente *et al*., 2007).

Tordoff *et al.,* (2000), however, reported that organic materials comprised of high concentrations of stabilized humic acid influenced the bioavailability of heavy metals by adsorption and forming stable complexes. For this reason, organic material addition permits the restoration of vegetation on contaminated sites. These materials increase plant production by mobilizing essential nutrients and by changing availability of toxic heavy metals. Meanwhile the heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilised by root exudates. Although plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other non-essential metals. As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly. Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes, restriction in the development of the roots and damage to cell structures due to oxidative stress. An example of indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants. Further, the negative influence of heavy metals on the growth and activities of soil microorganisms may also indirectly affect the growth of plants. For instance, a reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to decrease in organic material decomposition leading to a decline in soil nutrients. Enzyme activities useful for plant metabolism may also be hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decline in plant growth performance which may sometimes results in the reduction in the yield and eventually the death of plants.

The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process. For metals such as

Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, adverse effects have been recorded at very low concentrations of these metals in the growth medium. For instance, mercury level in cereals ranges between 0.004 - 0.008 (µg/g). Most of the reduction in growth parameters of plants growing on polluted soils can be attributed to reduced photosynthetic activities, plant mineral nutrition, and reduced activity of some enzymes. For other metals which are beneficial to plants, "small" concentrations of these metals in the soil could actually improve plant growth and development.

However, at higher concentrations of these metals, reductions in plant growth have been recorded. The exposure of plants to toxic levels of heavy metals triggers a wide range of physiological and metabolic alterations (Dubey, 2011; Villiers *et al.*, 2011). However, as different heavy metals have different sites of action within the plant, the overall visual toxic response differs between heavy metals. Contamination of agricultural soil by heavy metals has become a critical environmental concern due to their potential adverse ecological effects. The most widespread visual evidence of heavy metal toxicity is a reduction in plant growth (Sharma and Dubey, 2007) including leaf chlorosis, necrosis, turgor loss, accumulation of anthocyanin pigment in the shoot and root regions especially in maize plant due to the deficiency of phosphorous in the soil, a decrease in the rate of seed germination, and a crippled photosynthetic apparatus, often correlated with progressing senescence processes and untimely ageing or with plant death due to their widespread occurrence and their acute and chronic effects on plant. Therefore, this study will provide information on the growth performance and yield of the two maize varieties when biochars are used as soil enhancers. It will also provide information on the effect of biochar on soil properties.

MATERIALS AND METHODS

Study Area

The study was conducted in the screen house of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria. The site is located on latitude**:** 7° 27' 59.99" N, longitude 4° 33' 59.99" E and on the altitude of 244m above sea level. In Ile-Ife, the wet season is oppressive and overcast, the dry season is muggy and partly cloudy, and it is hot year-round. Over the course of the year, the temperature typically varies from 66°F *to* 93°F and is rarely below *60°F* or above *98°F*.

Experimental procedure

The viable seeds of the two improved maize varieties; OLOYIN/SW1 and SWAN-1-SR-Y were obtained from the Institute of Agricultural Research and Training (IAR & T), Ibadan, Nigeria. The following information was also obtained from the Seed Processing Unit of the Institute; germination percentage 94, 92 and the life cycle 75 days and 80 days for the two improved varieties respectively while no information was gathered as regards the local variety.

Bulk surface soil samples were collected from a farmland within the Obafemi Awolowo University Ile-Ife, Nigeria, air-dried and sieved using 2 mm mesh. In all, there were four treatments, each was replicated four times and laid out in a Randomized Complete Block Design (RCBD). The biochar treatment consisted of soil amendment [100% Maize residue (MAS), 100% African Teak (AFT) and 50% MAS + 50% AFT] applied at same rate (10 tha^{-1}) while zero biochar application to serve as control. Particulate matter was obtained from the Iron Smelting Industry, Ibadan road, Ile-Ife, Nigeria. Ten kilograms of air-dried soil was filled into 32 plastics pots per variety perforated at the bottom for aeration making a total of 96 pots. The biochar amendment treatments were applied to the soil simultaneously with the sowing of maize seeds. Particulate matter collected from the metal recycling plant was applied at the same rate as in the case of biochar (10%). Maize seeds were sown at 3 seeds per hole and thinned to two stands two weeks after sowing.

Growth parameters measurement

The growth parameters collected were plant height, number of leaves and stem girth. This was done at two weeks interval starting from two weeks after sowing to ten weeks after sowing. Five maize plants were selected at random from the pots and tagged for growth measurements.

Plant height was measured using a tape measure from the ground level to the apical portion of the stem and plant stem girth was measured by using the measuring tape around the first node of the stem while the numbers of leaves were visually counted and recorded accordingly.

Soil sampling

Initial soil samples were collected from the two different locations per pot at random while samples were also collected after harvest for post-cropping soil analysis. For texture; (Bouyoucus hydrometer method), pH; (1:1 soil-1M Kcl suspension), and Nitrogen; (Macro-Kjeldahl method), Phosphorus; (Murphy and Riley method), Organic carbon; (Walkley and Black method), exchangeable acidity; (Mclean and USDA), and the selected metals; (Mn, Fe, Cu and Zn) were analysed by Atomic Absorption Spectrophotometer (AAS) as follows; Soil samples (10 g) each were weighed into a 100 ml beaker and 20 ml of 0.01 N HC1 was added as an extractant. This was shaken for 30 minutes and filtered through Whatman No. 1 filter paper. Readings were taken on the Buck Scientific Atomic Absorption Spectrophotometer Model 210/211 VGP at various wavelengths (wavelength for Cu-324.8nm, Fe-248.3nm, Mn-279.5nm, Zn-213.9nm).

Data analysis

Data were analyzed using Graphpad 5.1 software, Statistics Analysis Software (SAS 9.2) using Duncan's Multiple Range Test ($p < 0.05$) to separate the means. Results were presented in tables**.**

RESULTS

Physical and chemical properties of soil used in the study

The physical and chemical properties of the soil used in the study are shown in the Table 1 and 2. The soil had 11.60 % clay, 75.4 % sand and 13.0 % silt, thus the soil was loamy sand in texture. The soil pH in 1:1 soil to water suspension was 5.63 indicating a slightly acidic condition. The soil organic carbon was 1.392 g kg-^{1}, the total nitrogen of the soil was 0.144 g kg^{-1} while the available phosphorous was 5.090 mg g-^{1}. The cation exchange capacity (CEC) (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) of the soil was 14.994 cmol kg$^{-1;}$ exchangeable acidity was 0.40 cmol kg^{-}1$^{.}$ Other values are: Mn 91.40; Fe 100.60; Cu 7.91 and Zn 1527.50 mg g^{-1}.

Table 1 Physical and chemical properties of the pre-cropped soil

Property	Value
pH (1:1 soil/water)	5.30
Organic carbon (g kg^{-1})	0.94
Nitrogen (g kg^{-1})	0.10
Available phosphorous (mg g^{-1})	4.45
Exchangeable acidity (cmol kg-^{1})	4.00
H^{+}	0.40
Al^{+++}	0.00
Exchangeable Basicity (cmol kg^{-1})	8.30
Ca^{2+}	5.94
Mg^{2+}	1.46
K^{+}	0.15
Na^{+}	0.75
ECEC (cmol kg^{-1})	15.12
Mn (mg g^{-1})	55.80
Fe (mg g^{-1})	133.80
Cu (mg g^{-1})	9.81
Zn (mg g^{-1})	787.75
Clay (g kg-^{1})	116.00
Silt (g kg-^{1})	130.00
Sand (g kg-^{1})	754.00
Textural class	Loamy sand

The chemical compositions of the two biochars are presented in Table 2. The values for total nitrogen in maize stover and *Milicia exelsa* were 3.70 and 3.20g kg^{-1} respectively. Total Phosphorous in maize stover was 47.81 mg kg^{-1} and in *M. exelsa* was 23.26 mg kg^{-1}; Values for potassium was 1.62 cmol kg^{-1}and was higher in maize stover. Also, in organic carbon, maize stover had higher value of 47.60 g kg^{-1}; and pH values were 9.44 and 9.08 for the two biochars respectively indicating an alkaline medium, while the ash content for maizestoverwas 38.40 % and 40.40 % for *M. exelsa*. The exchangeable acidity was high in maize stover with the value 5.90 and; 4.70 c mol kg^{-1} in *M. exelsa*.

Table 2: Chemical compositions of the biochars used

Property	Maize residue	African teak
pH	9.44	9.08
Organic carbon (g kg-^{1})	47.60	44.30
Total Nitrogen (g kg-^{1})	3.70	3.20
Carbon: Nitrogen	12.1	13.1
Total phosphorous (mg kg-^{1})	47.81	23.26
Potassium (cmol kg-^{1})	1.62	0.25
Calcium (cmol kg-^{1})	2.19	13.38
Magnesium (cmol kg-^{1})	0.15	0.03
Sodium (cmol kg-^{1})	0.18	0.24
Ash (%)	38.40	40.40
Exchangeable acidity (cmol kg-^{1})	5.90	4.70
Moisture content (%)	89.20	89.7

The mean and the standard error for the proximate composition of maize variety ART 98/SW1 is presented in Table 3. Maize variety ART 98/SW1 with treatment A (100% maize stover) had the highest weight (0.43 ± 0.28 t ha-1). The lowest weight of (0.13 ± 0.08 t ha-1) was recorded in the same variety in the control plant (C). Treatment B (100% Milicia exelsa) and treatment AB (50% maize stover + 50% African teak) had very close weights of (0.36 ± 0.32 t ha-1) and (0.37 ± 0.23 t ha-1) respectively. In the same vein, for maize variety Br-9928-DMR-SR-Y, treatment B (100% Milicia exelsa) was observed to have the highest weight of (0.39 ± 0.24 t ha-1) while the control plant had the lowest weight of (0.23 ± 0.14 t ha-1). Plant treated with AB (50 % maize stover + 50% Milicia exelsa) was also noted to have the weight of (0.38 ± 0.23 t ha-1) which was a bit higher than plant with treatment A (100% maize stover) with the weight of (0.33 ± 0.20 t ha-1) all at the same application rate of 10 t ha-1

Table 3: Proximate composition of the maize varieties

Treatment	A: OLOYIN/SW1	B: SWAN-1-SR-Y;
A	0.430.28^{a}	0.330.20^{a}
B	0.360.32^{a}	0.390.24^{a}
AB	0.370.23^{a}	0.380.23^{a}
C	0.130.08^{b}	0.230.14^{b}

Mean with the same letters in each column are not significantly different by Bonferroni Multiple Comparison Test at $p < 0.05$ Legend: A = 100% maize stover; B = 100% Milicia exelsa; AB = maize stover 50% + 50% Milicia exelsa; C = Control.

The Organic carbon, nitrogen and phosphorous concentrations in the soil after harvest of the maize are presented in Table 4. Values for O.c ranged from 0.94 – 18.82 g kg^{-1}, for the first site cultivated with variety ART 98/SW1, while for variety Br-9928-DMR-SR-Y ranged from 0.98 – 19.94 g kg^{-1},Soils with treatment AB (50% maize stover + 50% *Milicia exelsa*) had highest values and the least values were recorded in the control of the two varieties respectively. Nitrogen values ranged 0.10 - 0.43 g kg^{-1}for ART 98/SW1 and 0.09 – 0.41 g kg^{-1} for the second variety. Soils with treatment B (100% African teak) had the highest value in ART and treatment AB (50% maize stover + 50% *Milicia exelsa*) in the other variety while both control had lowest values. Phosphorous concentration in the soil also ranged from 4.45 - 17.99 mg g^{-1} in ART and 4.41 - 14.61 mg g^{-1} in the Br-DMR-SR–Y. Soils with treatment B had the highest value in ART and treatment A (100% maize stover) had the highest value in the other variety while the controls of the two varieties had the lowest value respectively.

The pH values and exchangeable acids (H^+ and Al^{3+}) concentrations in the soil after harvest of the maize are presented in Table 4. pH values ranged from 4.87 – 5.47 and treatment A (100% maize stover) had the highest value while the treatment AB (50% maize stover + 50% *Milicia exelsa*) had the lowest value in the variety ART 98/SW1, but in the variety Br 9928-DMR-SR-Y, the pH values ranged from 5.31 – 6.94, the control had the lowest value while treatment A (100% maize stover) had the highest. The concentrations of H^+ and Al^{3+}in the soil made up the exchangeable acids. $Al^{3+}$was not detected in the post-soil test. Therefore, H^+Values ranged from 0.40 – 0.70cmol kg^{-1} with the treatment AB (50% maize stover + 50% *Milicia exelsa*) having the highest value and the control the lowest the value in variety ART 98/SW1. The H^+ concentration in the soil cultivated with maize variety Br-9928-DMR-SR-Y also ranged from 0.40 – 0.90 cmol kg^{-1}, treatment B (50% *Milicia exelsa*) had the highest value while the control had lowest value.

Calcium, magnesium, potassium and sodium concentrations in the soil after harvest of the maize are presented in Table 4. Values for calcium ranged from 5.93 – 10.85 cmol kg^{-1}, magnesium from 1.45 – 3.04 cmol kg^{-1} and potassium had values ranged from 0.14 – 0.39 cmol kg^{-1}. Soils with treatment A (100% maize stover) had the highest values while the control had the least values in the three in them except for in sodium where the treatment B (100% *Milicia exelsa*) ranged between 0.57 – 0.83 cmol kg^{-1} had the highest value and the control the lowest, All this were recorded for the maize variety ART 98/SW1.

In the second variety Br-9928-DMR-SR-Y, the values for calcium ranged from 5.93 – 19.01 cmol kg^{-1}, magnesium from 1.45 – 3.18 cmol kg^{-1} with the highest values in the soils with treatment AB (50% maize stover + 50% *Milicia exelsa*) and the least values were recorded in the controls. While value for potassium ranged from 0.14 – 0.34 cmol $kg\text{-}^{1}$ and for sodium ranged from 0.72 – 0.78 cmol $kg\text{-}^{1}$ with the highest value in soils with treatment A (100% maize stover) while lowest was in the control and treatment AB (50% maize stover + 50% *Milicia exelsa*) in the case of potassium and sodium respectively.

The concentrations of manganese, iron, copper and zinc in the soils after harvest for the two maize varieties are presented in Table 4. The value of manganese for the first variety ART 98/SW1 ranged from 57.85 – 109.60 mg g^{-1} and the highest was in the soil with treatment AB (50% maize stover + 50% *Milicia exelsa*) and the control with the lowest value, concentration of iron also ranged from 82.85 – 133.80 mg g^{-1} with the control having the least value. The concentration of copper was in the range of 4.44 – 9.80 mg g^{-1}, with the highest value in the control and the lowest in the treatment AB (50% maize stover + 50% *Milicia exelsa*) while zinc concentration ranged from 112.60 – 787.30 mg g^{-1} with the highest value in the treatment B (100% *Milicia exelsa*) and the lowest in the treatment AB (50% maize stover + 50% *Milicia exelsa*).

Meanwhile in the second variety Br-9928-DMR-SR-Y, the value of manganese ranged from 55.80 – 125.50 mg g^{-1} and the highest was in the soil with treatment B (100% *Milicia exelsa*) and the control with the lowest value, concentration of iron in the soil also ranged from 82.85 – 123.80 mg g^{-1} with the control having the least value as in the case of manganese. Copper concentration was in the range of 3.70 – 9.90 mg g^{-1}, with the highest value in the control and the lowest in the treatment AB (50% maize stover +

50% *Milicia exelsa*) while zinc concentration ranged from 84.00 – 337.80 mg g^{-1} with the highest value in the control B and the lowest in the treatment B (100% *Milicia exelsa*).

TABLE 4: Post-cropped soil test results of the two maize varieties

Properties	Improved varieties				Local varieties			
	A	B	AB	C	A	B	AB	C
pH(1:1) H_2O	5.47^{a}	5.37^{a}	4.87^{a}	5.31^{a}	6.94^{a}	6.67^{a}	6.68^{a}	5.31^{b}
O.C (%)	14.90^{a}	7.88^{b}	18.82^{a}	0.94^{c}	13.70^{ab}	8.64^{b}	19.94^{a}	0.98^{c}
Total N (%)	0.41^{a}	0.43^{a}	0.39^{a}	0.10^{b}	0.38^{a}	0.37^{a}	0.41^{a}	0.09^{b}
Available P(mg g^{-1})	13.76^{b}	17.99^{a}	17.35^{a}	4.45^{c}	14.61^{a}	8.87^{b}	11.00^{ab}	4.41^{c}
Ca^{2+}(mg kg^{-1})	10.85^{a}	8.95^{a}	7.04^{a}	5.93^{a}	7.77^{b}	7.58^{b}	19.01^{a}	5.93^{c}
Mg^{2+} (mg kg^{-1})	3.04^{a}	2.82^{a}	2.66^{a}	1.45^{b}	2.75^{a}	2.62^{a}	3.18^{a}	1.45^{b}
K^{+} (mg kg^{-1})	0.39^{a}	0.37^{a}	0.25^{ab}	0.14^{b}	0.34^{a}	0.25^{a}	0.27^{a}	0.14^{a}
Na^{+}(mg kg^{-1})	0.74^{a}	0.83^{a}	0.72^{a}	0.57^{a}	0.78^{a}	0.78^{a}	0.72^{a}	0.75^{a}
Acidity (mgkg^{-1})	0.60^{b}	0.60^{b}	0.70^{a}	0.40^{c}	0.44^{bc}	0.90^{a}	0.50^{b}	0.40^{c}
Al^{3+} (mg kg^{-1})	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
CEC (mg kg^{-1})	15.63^{a}	13.49^{a}	12.25^{a}	15.10^{a}	12.28^{c}	12.15^{c}	18.68^{a}	15.11^{b}
Mn (mg g^{-1})	89.06^{b}	109.50^{a}	84.57^{b}	103.60^{a}	140.60^{a}	122.30^{c}	134.50^{b}	140.20^{a}
Fe (mg g^{-1})	66.26c	82.85b	70.42bc	93.70a	83.46a	80.26a	81.86a	84.57a
Cu (mg g^{-1})	4.39b	7.32ab	4.59b	9.82a	7.66a	6.36d	6.85c	7.55b
Zn (mg g^{-1})	114.10b	163.10b	130.40b	362.80a	192.60c	185.20d	196.30b	297.60a
Cd (mg g^{-1})	0.75a	1.07a	0.63a	0.71a	0.34a	0.31a	0.32a	0.40a
Pb (mg g^{-1})	54.47b	84.06b	50.55b	156.30a	85.26b	77.54d	79.06c	98.56a
Ni(mg g^{-1})	9.80a	13.62a	9.80a	17.82a	11.25b	9.36d	9.95c	12.22a

Means with the same letters in each row per crop variety are not significantly different by Duncan's Multiple Range Test at $p < 0.05$
Legend: A = 100% maize residue; B = 100% African teak; AB = maize residue 50% + 50% African teak; C = Control.

DISCUSION

The soil amendment influenced the yield of the two improved maize varieties compared to the local one. This was in agreement with results of Rachael (2008), that there was an improvement in the yield of corn when biochar was used as soil amendment. OLOYIN variety had the highest mean yield followed by the second improved variety SWAN-1-SR-Y which showed improved growth performance and yield when compared to the local maize variety meanwhile the lowest mean yields were recorded in the control. This showed that application of the soil amendment positively influenced the yield of the maize.

The mean of the proximate composition of the two maize varieties indicates that the carbohydrates and total sugar were very high when compared to the reducing sugar in the two maize varieties, the dry matter was also high while the protein, fat and crude fibre were low when compared with the values obtained in the carbohydrates and total sugar in the two maize varieties, this was in agreement with the findings of Ijagbadeniyi and Adebolu (2005), who worked on the proximate composition of some maize grown in Nigeria using the same routine chemical analytical methods of Association of official analytical chemists (A.O.A.C, 2003). The results indicated that grains of the maize varieties vary greatly in terms of protein, fats and crude fibre contents. Maize variety OLOYIN and SUWAN-1-SR-Y had a high protein content compared to the local variety.

Application of soil amendment had a significant influence on the yield of maize and improved the properties of the soil. It had a significant improvement on the organic carbon, nitrogen and phosphorus contents of the soil compared to the control, this is due to the fact that the amendments used in this study contain more organic carbon, phosphorous and ash, this agreed with the findings of Freddo *et al*., (2012). Mohammed *et al*., (2014) also noted that the mineralization rate of carbon in a biochar amended soils was very low, thus making it a better option for carbon sequestration due to its slow carbon mineralization. The pH of the two biochar was alkaline while that of the soil was slightly acidic, the addition of biochar could only bring slight changes in the pH and increase the mobility of the cations in the soil due to reduced competition between H^+ and metals for cation exchange sites either directly on the surface of the biochar or as a general liming effect on the soil matrix. Meanwhile the biochar application to the soil had significant impact the calcium, sodium, magnessium and effective cation exchange capacity (ECEC) of the soils across all the treatment, because the values were high across the treatments when compared to their concentration in the pre-cropping analysis except in the control (Table 4.). When biochar is incorporated into the soil it reduces the size pores thereby increases the water holding capacity of the soil and providing a medium for adsorption. Also, it had been reported that long-term application of biochar may increase the levels of phosphorous and potassium in the soil (Rodon, 2006).

The concentrations of the metals (iron, zinc, manganese and copper) in the soil were very high in the pre-cropped soil analysis but with the amendment they were being immobilised because they were able to form complex metal ions on their surface and therefore increased the bioavailability of the metals because of the moderately acidic nature of the soil. So, with the application of biochar the metal was more available on the soil matrix.

CONCLUSION

The results showed that the growth performance and yield of the improved varieties were better compared to the local type. In addition, the yield of the treated local variety was better than the controls of the improved varieties which are indications of the positive impact of the amendments.

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