academicJournals

Vol. 8(1), pp. 11-16 January 2017
DOI: 10.5897/JSSEM2016.0566
Articles Number: 577E2DC62191
ISSN 2141-2391

http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Influence of wood charcoal from Chlorophera excelsa on soil properties and yield components of maize

Nweke, I. A.

Soil Science Department, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.

Received 2 March, 2016; Accepted 30 September, 2016

Wood charcoals were mainly used for smoking of fish, meat and frying of corns and many times dump off as wastes in southeast, Nigeria. Their nutrient recycles and release when used as soil amendment has not been considered and evaluated by farmers in the southeast, Nigeria. This study was therefore carried out to assess the efficiency of wood charcoal technology in improving soil productivity. Influence of wood charcoal from *Chlorophera excelsa* on soil properties and yield components of maize were evaluated. Four different rates of wood charcoal (6, 4, 2 and 0 tha^{-1} that received no treatment application) were used. The treatments were laid out in randomised complete block design (RCBD) and treatment means were compared using least significant difference (LSD). The findings from the study showed non-significant ($P<0.05$) differences in most of the growth and yield components of maize tested. Significant differences were recorded in all the soil properties assessed except for percentage nitrogen (N). Higher values were observed in 4 tha^{-1} rates except for the values of pH, available phosphorus and percentage base saturation, where higher values were observed in 6 tha^{-1} rates of wood charcoal than the other rates of wood charcoal. The percentage increase in calcium content of the soil relative to the values obtained in 0 tha^{-1} rate was 13.04% (2 tha^{-1}), 11.76% (4 tha^{-1}) and 7.69% (6 tha^{-1}). While the percentage increase in the value of Mg^{2+} obtained in 4 tha^{-1} plots relative to control (0 tha^{-1}) plots was 28.5%. The data generated from both growth and yield component and soil properties showed that the values of parameters tested increased as the rate of wood charcoal applied increased, though this was not consistent in the growth and yield parameters and few cases in soil parameters. In comparison of the four different rates of the wood charcoal applied, 4 tha^{-1} rate seems to be an ideal than the other rates as it performed competitively better and were able to liberate plant nutrients more than the other rates of wood charcoal though these liberated nutrients were not reflected in most of the growth parameters assessed.

Key words: *Chlorophera excelsa* , crop growth, soil properties, wood charcoal.

INTRODUCTION

The availability of soil mineral nutrients in non-fixed and toxic form is natural requirement for crop growth. Crop plants require them for healthygrowth and good yield. Agricultural soils show mineral deficiency problems

E-mail: nwekson@hotmail.com.

merely after short period of cultivation, especially in the south eastern soils of Nigeria. They are very fragile and delicate due to nature and prevailing environmental conditions. Hence,they suffer rapid decline in mineral nutrients after short cultivation and these are soils that tend to harbour crop production. The soils of this area are usually influenced by high rainfall and temperature coupled with the climatic change that have influenced greatly the periodic cycle of the rainfall with heavy downpour. This situation invariably causes low nutrient content and soil organic matter mineralisation.

Also with accelerated decrease in cation exchange capacity (CEC) resulting to increase in acidity of the soils. Hence, agricultural sustainability in the area faces a large constraint. Farmers, therefore, in their quest to improve their crop yield then sought to supply additional plant nutrients by application of organic or inorganic chemical fertilizers so that yield of crops will no longer be limited by the amount of plant nutrients that the natural system can supply. Thus, both the organic manure and chemical fertilizers are common forms of soil amendment that are routinely used in agricultural soils. Though their impact on soil mineral nutrients differ remarkably when they are surface applied or incorporated into the soil. Also because of the high rainfall observed in the study area, the efficiency of applied mineral fertilizers is very low.

In addition, many farmers in the study area cannot afford the cost of regular application of chemical fertilizers. Hence, nutrient deficiency is very prevalent in many crop production systems of the area. The application of organic wastes or manure in its own case have frequently been shown to increase soil fertility, but have not fared better because, according to Tiessen et al. (1984), under tropical conditions organic matter is usually mineralised very rapidly and from the work of Fearnside (2000) only a small portion of the applied organic compounds will be stabilised in the soil in the long term but successively released to the atmosphere as carbon iv oxide (CO_2).

Therefore, under this circumstance, the use of more stable compounds such as carbonised materials or their extract becomes useful both in availability and cost for agricultural sustainability. The works by Glaser (1999) and Glaser et al. (2000), showed that carbonised materials from the incomplete combustion of organic material (charcoal, black C, pyrogenic C) are responsible for maintaining high levels of soil organic matter and available nutrients. The works of Radlein et al., (1996) equally showed that coal from geological deposit (coal) and from various specialised procedure were successfully used for soil amelioration as carbonised materials comprised a wide range of materials from partly charred materials to graphite and soot particles. Therefore, the objective of this study is to examine the influence of wood charcoal from C. excelsa (Iroko) on soil properties and yield components of maize.

MATERIALS AND METHODS

The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria. The experimental site is located within latitude 06°14’N and longitude 06°45’E. The total annual mean rainfall ranges between 1800 and 2000 mm while the temperature range during the rainy season is between 21° and 24°C and an estimated relative humidity range of 64 to 90%.

Land preparation and treatment allocation

The experimental site was manually cleared and debris removed. The plots were then laid out in a randomised complete block design (RCBD) with four treatment materials and four replications to give 16 plots. The size of each plot measured 3 m × 4 m (12 m^2) with a distance of 1 m between the blocks and 0.5 m pathway between plots. The treatment consisted of the appropriate rate of wood charcoal made from *C. excelsa* (Iroko) which were applied to their respective plots. The treatment summaries are:

2 tha^{-1} wood charcoal equivalent to 2.4 kg/ha
4 tha^{-1} wood charcoal equivalent to 4.8 kg/ha
6 tha^{-1} wood charcoal equivalent to 7.2 kg/ha
0 tha^{-1} control (CO) that received no treatment

Each of these rates of wood charcoal were grounded and applied evenly on the plot and incorporated into the soil one week before sowing to allow mineralisation of nutrients in the treatment. Maize hybrid seeds (Oba super II) were planted two per hole at the spacing of 76 cm × 25 cm, which was done one week after the incorporation of the wood charcoal. The seedlings were thinned down to one plant per stand two weeks after germination, while empty stands were supplied. The experimental field was kept relatively weed free till harvest. Soil samples prior to treatment application was collected from different locations after field preparation and bulked together and analysed for the physical and chemical parameters of the soil (Table 1). At the end of the study, soil samples were collected from individual plots and used for the determination of physical and chemical parameters of the soil according to the procedure described by Black (1965). Five maize plants were randomly selected and used to measure plant height and leave area at 2, 4, 6 and 8 weeks after planting as well as length of cob/plant, numbers of cob/plant and cob’s diameter.
Data collected from the study was tested on analysis of variance based on randomised complete block design (RCBD) according to Steel and Torrie (1980), while least significant difference (LSD) at 5% was used to compare treatment means.

RESULTS

The initial soil properties of the study area in Table 1 showed that the soil is sandy with low contents of organic carbon (0.71%) and organic matter (1.23%) as well as low values in major plant nutrients tested. Hence, the soil of the experimental site was found to be deficient in the major plant nutrients.

The result of the growth parameter recorded in Table 3 showed that the rates of wood charcoal applied have no effect on the plant height and leaf area tested for 2 to 8 weeks after planting (WAP) except for plant height at 2 WAP. The plant height and leaf area result obtained equally showed that the plots that received different rates

Table 1. Physical and chemical properties of the studied soil prior to treatment application.

Parameter	Values
Coarse sand	46%
Fine sand	43%
Silt	7%
Clay	4%
Textural class	Sandy
pH H_2O	6.8
OC	0.71%
OM	1.23%
N	0.06%
Na^+	0.15 $cmolkg^{-1}$
K^+	0.19''
Ca^{2+}	0.13 ''
Mg^{2+}	2.00 ''
CEC	18.4 ''
BS	82.29 ''
Avail. P	5.60 $mgKg^{-1}$
H^+	0.80 $cmolkg^{-1}$

Table 2. Nutrient content of the wood charcoal used for the study.

Parameter	Value
pH H_2O	10.4
OC	10.47%
OM	18.06%
N	0.084%
Na^+	0.19 $cmolkg^{-1}$
K^+	0.21 $cmolkg^{-1}$
Ca^{2+}	0.06 $cmolkg^{-1}$
Mg^{2+}	0.10 $cmolkg^{-1}$
Avail. P	0.07 $mgkg^{-1}$

Table 3. Effect of wood charcoal on the growth and yield component.

Treatment (tha^{-1})	2WAP		4WAP		6WAP		8WAP		Length of cob/plant (cm)	Numbers of cob/plant	Cob's diameter (cm)
	PH (cm)	LA (cm^2)	PH (cm)	LA (cm^2)	PH (cm)	LA (cm^2)	PH (cm)	LA (cm^2)			
0	8.16	6.42	21.34	33.65	36.17	59.73	48.92	70.94	5.82	1.9	3.96
2	7.25	5.67	19.08	24.34	30.17	41.44	43.25	60.45	5.70	2.1	3.87
4	7.17	6.50	21.60	31.92	35.00	54.42	50.42	84.36	5.82	2.1	3.62
6	7.42	6.00	19.75	29.54	32.42	46.15	48.92	76.64	5.17	1.5	3.43
LSD0.05	0.04	NS	NS	NS	NS	NS	NS	NS	NS	0.33	NS

WAP = Weeks after planting; PH = Plant height; LA = Leaf area; LSD = Least significant difference; NS = Not – significant.

of wood charcoal did not perform better than the control plots except at 8WAP where the treated plots especially the 4tha^{-1} wood charcoal gave the highest plant height and leaf area followed by 6 tha^{-1} wood charcoal, but they

Table 4. Effect of wood charcoal on the chemical properties of the soil.

Treatment (t/ha)	pH H_2O	OM (%)	N (%)	P ($mgkg^{-1}$)	BS (%)	CEC ($cmolkg^{-1}$)	EA ($cmolkg^{-1}$)	Na^+ ($cmolkg^{-1}$)	K^+ ($cmolkg^{-1}$)	Ca^{2+} (%)	Mg^{2+} (%)
0	6.20	0.94	0.04	3.73	75	18.40	0.80	0.121	0.147	12.0	2.0
2	6.40	1.08	0.07	3.73	77	18.40	0.60	0.133	0.164	13.8	0.4
4	6.50	1.14	0.08	4.66	78	19.20	0.80	0.146	0.182	13.6	2.8
6	6.60	1.08	0.08	8.39	87	19.20	0.80	0.133	0.173	13.0	1.4
LSD0.05	0.27	0.02	NS	0.08	1.29	0.11	0.14	0.014	0.013	0.97	1.49

Table 5. Effect of wood charcoal on the particle size of the soil.

Treatment (t/ha)	Coarse sand (%)	Fine sand (%)	Clay (%)	Silt (%)	Textural class
0	45	44	4	7	Sandy
2	46	43	4	7	Sandy
4	43	46	4	7	Sandy
6	40	51	4	5	Sandy
LSD0.05	0.62	0.40	NS	0.66	

were not significantly (P<0.05) different. The result of the length of cob/plant and cob's diameter showed non-significant (P<0.05) difference among the treatments. While number of cob/plant show significant difference among the treatments, with the values obtained from 2 and 4 tha^{-1} being statistically similar, but significantly (P<0.05) better than the 6 tha^{-1} plots. Critical observation of the data obtained for the growth parameters showed that the plots treated with 4 tha^{-1} wood charcoal performed better than the other treatments. Though its effectiveness were minimally observed in plant height at 2 and 4 WAP and leaf area at 4 and 6 WAP as well as cob's diameter.

The values obtained for soil chemical properties recorded in Table 4 indicated that the wood charcoal from the *C. excelsa* influenced the chemical properties of the soil. All the parameters tested show significant (P<0.05) difference among the treatments with the exception of total nitrogen result.

The result of the soil pH showed that the soil pH increased gradually as the rates of wood charcoal application increased and the order of increase were 6 > 4 > 2 > 0 tha^{-1}. The highest organic matter (OM) content was observed in 4 tha^{-1} plots compared with the other treated plots and was significantly (P<0.05) different with the other treatments. The values obtained in 2 and 6 tha^{-1} treated plots were statistically similar but significantly (P<0.05) better than the values obtained in 0 tha^{-1} plots. The result of available P and base saturation (BS) showed that the plots treated with 6 tha^{-1} gave the highest value and were significantly (P<0.05) different from the other treatments. The next in rank is 4 tha^{-1} treated plots of which its available P value is significantly better than the 2 and 0 tha^{-1} results. The base saturation (BS) values indicated that as the rate of wood charcoal application increased the value of BS increased and the order were 6 > 4 > 2 > 0 tha^{-1}. The result of cation exchange capacity (CEC) and exchangeable acidity (EA) recorded in Table 4 showed significant difference among the treatments. The values of CEC indicated that 4 and 6 tha^{-1} values were statistically similar, but significantly better than the values obtained in 2 and 0 tha^{-1}, while values of EA showed that the values obtained in 0, 4 and 6 tha^{-1} are statistically similar, but significantly better than the values obtained in 2 tha^{-1} rates of wood charcoal applied.

The result of Na^+ and K^+ showed significant (P<0.05) difference among the treatments. The highest value in Na^+ and K^+ was observed in 4 tha^{-1} treated plots of which its Na^+ value was significantly better than the other treatments. While its K^+ value was statistically similar with 6 tha^{-1} value but significantly better than the value obtained in 0 and 2 tha^{-1}. The exchangeable Ca^{2+} and Mg^{2+} result in Table 4 were significant (P<0.05) and the order of increase for Ca^{2+} were 2 > 4 > 6 > 0 tha^{-1} while Mg^{2+} order of increase were 4 > 0 > 6 > 2 tha^{-1}.

The percentage increase in Ca^{2+} relative to the values obtained in 0tha^{-1} was 13.44% (2 tha^{-1}), 11.76% (4 tha^{-1}) and 7.69% (6 tha^{-1}). The percentage increase in the value of Mg^{2+} obtained in 4tha^{-1} relative to the value obtained in control plots were 28.57% while its percentage decrease relative to 2 tha^{-1} plots were 600%. The soil chemical parameter results showed that the wood charcoal applied at 4tha^{-1} performed competitively better and were able to liberate mineral nutrients better than the other rates of wood charcoal applied, though it is not true for soil pH, available P, BS and Ca^{2+} contents of the soil studied. Nonetheless, the release of these chemical nutrients was not adequately reflected in the growth and yield parameters of the tested crop.

The result of the particle size analysis of the soil in (Table 5) indicated significant differences in coarse and fine sand particles and silt content of the soil, but showed non-significant differences as well as non-change (as the values are the same) in the clay content of the soil. Thus, with regard to the clay content of the soil the influence of the different rates of wood charcoal are the same and equal. The influence of 0, 2 and 4 tha^{-1} rates of wood charcoal on the silt content of the soil were equal and statistically similar, but significantly better than silt content of 6 tha^{-1} rate of wood charcoal. The influence of wood charcoal on the sand particles showed that 6 tha^{-1} rates had more sand particles than the other rates. While the rates of 0, 2 and 4 tha^{-1} the same values of sand particles on the average were observed.

DISCUSSION

The soil analysis result in Table 1 showed that the studied soil is very deficient in major mineral nutrients; the values are below the fertility classification of Ibedu et al. (1988) and Landon (1991). Hence, the soil is deficient in plant nutrients. The nutrient content in wood charcoal (Table 2) applied indicated that the organic matter, organic carbon, pH and some other nutrients tested are higher relative to quantity of the nutrients available in the soil before treatment application.

The effect of wood charcoal on the growth and yield component of maize was observed to be non-significant. This problem may be attributed to the amount present in the individual rates applied and their slow release as well as non-synchronisation of nutrient released within the short period of growth of the maize plant. The differences in values of these parameters tested, however, may be as a result of differences in plant nutrient in the rate of treatments applied.

However, non-significant values in growth and yield component of crops have been reported in the works of Nweke and Nsoanya (2013a,b), Nweke and Obasi (2013) and Nweke et al. (2014) following organic waste application in soil, the post-harvest soil analysis result of this study show that wood charcoal from *C. excelsa* when used as soil amendment has the capacity of increasing the pH level thereby reducing the acidity levels of the soil required for crop production as was observed in Table 4. This increase in soil pH level is good omen for agricultural production as low pH value limits soil productivity, since it affects availability and uptake of nutrients by plants because at low pH, acid soils are normally flocculated (Haynes and Naidu 1998). The wood charcoal at rate of 4 tha^{-1} was observed to have being a good estimate of amount required significantly to improve soil properties and enhance growth and yield components of maize (Table 3).

Using cocoa pod ash and wood ash, by Ayeni et al. (2008) and Mbah et al., (2010) respectively, as soil amendment reported increased soil pH relative to non-ash treated soil. The OM and TN content of the treated plots were observed to be improved relative to the control plots. This improvement could be attributed to the higher level of OM and TN in wood charcoal applied than the soil. Organic matter according to Tisdale et al., (1993) and Brady and Weil (2006) play important roles in essential nutrient availability and soil improvement.

The influence of the wood charcoal on the soil available P, BS% and CEC values varied among the rates and appreciated relative to the control rate. The level of soil available P and other nutrients might have been influenced by the changes in soil pH due to application of wood charcoal since the availability of P and its solubility is pH dependent. In line with the findings of this study, Mbah et al. (2010) and Nweke and Nsoanya (2013b) reported significant increase in available P and plant nutrients in soils amended with wood ash and organic wastes respectively relative to control plots. Kayode and Agboola (1983) attributed the increased CEC in wood ash amended soil to increased cations Ca, K and Na as was observed in the present study. In support of the findings of this study, previous study like Ayeni et al. (2008), Adele et al. (2010), Nweke and Nsoanya (2013b) and Nweke et al. (2014) had shown that organic wastes increased soil OM, N, pH, P, CEC, exchangeable base and reduced soil exchangeable acidity (EA).

The post-harvest soil analysis showed that the rates of wood charcoal applied significantly influenced the particle size distribution but did not affect the textural class of the soil. There were more sand fraction which indicates good aeration and will not present problem with drainage and plant root penetration. There were no differences between the clay contents of the different rates of wood charcoal and the silt contents of 0, 2 and 4 tha^{-1} rates of wood charcoal. Nweke and Nsoanya (2012) observed no difference between the clay and silt content of soils of the same locality.

Conclusion

The findings from the study have shown that wood charcoal from *C. excelsa* is capable of improving soil properties and crop production. The values obtained from 4 and 6 tha^{-1} wood charcoal in most of the soil and plant parameters tested were statistically similar. This placed 4 tha^{-1} in this particular study as the optimum rate of wood charcoal application for soil fertility improvement and maize growth. The material is cheap, available and can be sourced by poor resource farmers and used for soil and crop improvement.

Conflict of interests

The authors have not declared any conflict of interests.

REFERENCES

Adeleye EO, Ayeni LS, Ojeniyi SO (2010). Effect of poultry manure on soil physico-chemical properties, leaf nutrient contents and yield of yam (*Dioscorea rotundata*) on Alfisol in southwestern Nigeria. J. American Science 6 (10):509-516.

Ayeni LS, Adetunji MT, Oyeniyi SO (2008). Comparative nutrient release from cocoa pod ash, poultry manure and NPK 20:20:20 fertilizer and their nutrient combination incubation study Nig. J. Soil Sci. 18:114-123.

Black CA (1965). Method of soil analysis II chemical and microbiological properties. Am. Soc. Agron. Madison, Wisconsin. 157 p.

Brady NC, Weil RR (2006). Nature and properties of soil, 13th edition London, Prentice Hall. pp. 595-624.

Fearnside PM (2000). Global warming and tropical land use change, green house gas emissions from biomass burning, decomposition and soils in forest conversion, shifting cultivation and secondary vegetation, Climatic Change. 46:115-155.

Glaser B (1999). Ergenschaften und stabilch des Humuskrpers der indianerschwar zerden Amazon iens Bayreuther Bodenkunliche Berichte. 68.

Glaser B, Haumaier L, Guggenberger G, Zeck W (2001). The terra preta phenomenon a model for sustainable agriculture in the humid tropics naturwissenschaften 88:37-41.

Glaser B, Balachov E, Haumaier L, Guggenberger G, Zech W (2000). Black carbon in density, fractions of anthropogenic soils of the Brazilian Amazon region. Org. Geochem. 31:669-678.

Haynes RJ, Naidu RC (1998). Influence of lime fertilizer and manure application on soil organic matter content and soil physical conditions, a Rev., Nutrient Cycling in Agrosys. 51:123-137.

Ibedu MA, Unambra RPA, Udealor A (1988). Soil management systems in relation to farming systems development in the southeastern agricultural zone of Nigeria. Paper presented at the National Farming System Research Workshop, Jos, Plateau State, Nigeria. pp. 26 -29.

Kayode GO, Agboola AA (1983). Investigation on the use of macro-and micro-nutrients to improve maize yield in South Western Nigeria. Fertilizer Research 4(3):211-221.

Landon JR (1991). Booker tropical soil manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics, Longman Scientific and Technical New York. P 33.

Mbah CN, Nwite JN, Njoku C, Nweke IA (2010). Response of maize (Zea *mays* L.) to different rates of wood ash application in acid ultisol in southeast Nigeria. Afr. J. Agric. Res. 5(7):580-583.

Nweke IA, Nsoanya LN (2012). Inventory of physico-chemical characteristics of soils of the Teaching and Research Farm, Faculty of Agriculture, Anambra State University, Igbariam Campus, Nigeria. In Proceedings of International Agricultural Conference 6th - 9th May, 2012, held at Anambra State University, Igbariam Campus, pp. 488-493.

Nweke IA, Nsoanya LN (2013a). Effect of Poultry Manure and Inorganic Fertiliser on the Performance of Maize (Zea Mays) and Selected Physical Properties of Soils of Igbarian Southeastern Nigeria. J. Agric. Rur. Dev. 16(1):1348-1353.

Nweke IA, Nsoanya LN (2013b) Effect of different rates of rice mill waste on soil chemical properties and grain yield of maize (Zea Mays). J. Agric. Rur. Dev. 16(1):1431-1436.

Nweke IA, Obasi MN (2013). Effect of different levels of pig manure on the growth and yield of okra (*Abelmoschus esculentus* Ush). In proceedings of the 47th annual conference of the Agricultural Society of Nigeria, Ibadan 2013. pp. 23-26.

Nweke IA, Okoli PSO, Enyioko CO (2014). Effect of different rates of poultry droppings and plant spacing on soil chemical properties and yield of cucumber. Elixir Agriculture 70(2014):23934-23940.

Radlein D, Piskorz JK, Maher P (1996). Method of producing slow-release nitrogenous organic fertilizer from biomass. European patent application 0716056AI.

. Steel GD, Torrie JN (1980). Principles and Procedures of Statistics. A Biometrical Approach 2nd ed. McGraw Hill Book Co., New York. P. 633Tiessen H, Stewart JWB, Cole CV (1984). Pathways of phosphorous transformation in soils of differing pedogenesis. Soil Sci. Soc. Am. J. 48:853-858.

Tisdale SL, Nelson WL, Beaton JD, Havlin A (1993). Soil Fertility and Fertilizers. 5th edn. Macmillan Publishing Company New York USA.