Effect of Charcoal on Soil Physico-Properties in Ndele, Rivers State: Implication for Organic Farming

Ukpong, G. U.[*1] and Egbulefu, G. U.*[2]

[1]Department of Agricultural Education, Federal College of Education (Technical), Omoku, Rivers State Nigeria
[2]Department of Agricultural Science, Faculty of Vocational/Technical Education, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State.

KEYWORDS

Heavy metals,
Immobilization,
Organic carbon,
pH,
Total nitrogen,

*CORRESPONDING AUTHOR

godonwin@gmail.com

ABSTRACT

The study was aimed at evaluating effect of charcoal on the Physico-chemical properties of Ndele soil .The study was conducted during the first farming season at the Teaching and Research Farm Ignatius University of Education Ndele Campus. The design adopted was randomized complete block design (RCBD) , topography was block , five treatments, 0,2, 4,6 and 9 tonsha-1 charcoal . The experimental area was cleared, seed beds were constructed before grounded charcoal was measured and applied in each of the experiment units and each treatment was replicated three times. The duration for experiment was six weeks and soil samples were collected using soil augur at the depth of fifteen centimeters (15cm). The collected samples were taken to laboratory for analysis. The data generated were subjected to analysis of variance using SPSS version and means separated with Duncan multiple range test. It was observed that organiccarbon, moisture, phosphorus (P), Manganese (Mn), Magnesium (Mg) and Iron (Fe) content of the soil increase as the level of treatment increased from 2 ton ha^{-1} to 6 tons ha^{-1} charcoal. Potassium (P), Zinc (Zn) Calcium (Ca), Boron (Bo) and Chlorine (Cl) content of the soil reduce as the quantity of treatment increased. It was also observed that Fe was not significantly ($p \leq 0.05$) different among treatments .Higher treatment 8 tons ha^{-1}had no significant effect on Physico- chemical properties measured. Finally it was observed that the range of 4 tons ha^{-1} and 6tons ha^{-1}charcoal gave the best concentration of the tested Physico- chemical properties of the soil. It concluded that charcoal should be used to improve the fertility of the soil in Ndele but higher application of 8 tons ha^{-1} should be avoided.

INTRODUCTION

Man has direct and indirect relationship with soil. Animals including man feed from plant that utilizes soil nutrients. The nutrients by nature are subject to depletion over time as a result of utilization.This depletion may also influence other physical and chemical properties of the soil. According to O'Neil *et al.* (2009), as the content of soil organic matter decreases, the bulk density of soil also decreases. Bulk density and course fragments are integrated into a soil quality. Furthermore, from the study of soil properties such as the soil texture of soil, depends on the amount of the sand or clay or silt particles, the most advantageous physical properties of soil is soil texture, the reason being that all necessary components including soil nutrient, water and aeration are mostly dependent on it(O'Neil *et al*. 2009),.Similarly, writing on the chemical properties of soil, Nelofer *et al* (2016), reported that it is very difficult to discriminate between chemical, physical and biological properties of soil. Because of vivacious inter – link with each other. For Bockheim (2015), the soil quality indicators like chemical and biological properties have prominent connection between them. Many researchers consider the similar attribute in any sort. According to him the Physico-chemical properties of soil is directly affected on all those microbiological properties that can encourage the water holding capacity, nutrient cycling, accessibility of water, pH buffering, leaching and ion exchange capacity of soil. According to Bockheim (2015), chemical indicators of soil are same for farming and woodland soils. Schaetzl and Thompson, (2015), reported that soil organic matter is also a major key chemical indicator for assessing soil quality and in aggregate stability. To them soil chemistry determines the availability of nutrients, microbial growth, corrosively and stability of water it should therefore be concluded that physical and chemicalproperties of soil are significant and the components that are a combination of characteristics including soil carbon and soil quality index.

Today, sustainable agriculture or farming totally or partially nullifies the use of agro- chemicals because of their long term effect on the ecosystem and man (Food and Agricultural ORganisation, FAO, 2016; Urban2008). Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity (FAO,2016; Littcerick and Watson,2017). It emphasizes the use of management practices in preference to the use of off-farm inputs, takinginto account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system (Codex, 2007).Organic farming implies recycling of waste and residue to the native soil itself, replenishing the nutrients depleted from the soil during the crop growth, encouraging the growth of microorganisms which could regulates phased release of stored nutrients in the soil to the crop growth in right proportion, maintaining soil health by balancing the soil moisture and soil aeration and ensuring soil fertility by firmly binding the nutrient elements in the complex organic molecules (Patel, Choudhary andSwarnakar, 2013). Organic farming implies zero agro-waste, waste from a particular farm produce is a start off pack in another produce. Organic farming has numerous advantages to ecosystem and man; it improves the soil fauna and flora thereby enhancing soil performance and fertility; reduces pollutions and prevents man from suffering residual health effect of harmful substances.

There are numerous organic resources that may be used to fortify or amend the soil, one of which is charcoal. Charcoal a product of partial or complete combustion of wood. It is very common in communities where energy or fuel wood is used for cooked. It is also common in areas where traditional farm still persist, clearing and burning farm land lead to charcoal production and crop are sowed with them on farmlands. Some farmers are commonly seen in local community burning wood on special site for special crops such as pepper, cucumber and amarathus to mention but a few .

Charcoal works as a highly effective slow release fertilizer. According to Keller (2017), the type of charcoal used, however, is important; emphasizing that natural charcoal formed from biomasses such as wood will give the best results. This natural charcoal from natural alternative outlets or made by slow - burning wood will release vital nutrients into the soil aiding the growth of plants (Keller, 2017). The importance of charcoal dates back to its use as fuel for cooking and steam engines etc. However, Glaser *et al.* (2001), reported that charcoal apart from its primary function as fuel, it has long ago been used as a soil improver in many parts of the world. But Nishio and Okaw (1991), reported that only recently was the application of charcoal to the soil practiced. According to Ogawa andOkimori (2010), the effects of charcoal vary according to the raw materials, production methods and types of charcoal and the period of its application to the soil. For them bio-char shows a positive effect on certain physical, chemical and biological properties of soils. Laird *et al*, (2010), reported the advantages of charcoal, emphasizing that because charcoal been a porous material with high water and air retention capacities, its addition to agricultural soils leads to increases in water holding capacity and decreases in nutrient leaching. Steiner *et al*, (2007) reported that less attention was given to quantifying nutrient leaching from agricultural soils treated with charcoal despite the fact that a lot of plant and soil scientists' have recommended the use of charcoal for soil improvement, and to achieve better plant growth. According to Steiner *et al*,*(*2007), a review of literature showed no previous comparative study of the most suitable quantity of charcoal grains to simultaneously promote plant growth and reduce nutrient leaching. For Major *et al* (2009), nutrient leaching and retention of agricultural land is greatly influenced by soil texture. Ketterings and Bigham (2000), reported that charcoal addition to the soil have positive effect on soil properties and enhance soil fertility and productivity. For Glaser *et al*, (2002), increased soil acidity pH, addition of free bases such as ca, k, and mg and enhancement of the cation exchange capacity showed that added charcoal is not only a soil conditioner but also acts as a fertilizer. In addition, putting charcoal to the soil will positively affect seed germination, crop growth and yields (Ketterings and Bigham 2000). Glaser *et al*, (2002), in a recent review demonstrated that crop yields can be increased when chemical is added to the soil especially in the tropics. The significance of charcoal to plant growth is so much that apart from increasing the amount of water a soil can hold and improvement to soil acidity pH) so that plants can get more nutrients from the soil, evidences show that charcoal which has tiny pores that looks like sponge can equally absorbs pesticides and chemicals secreted from the roots of anxious weeds and enhance special fungi that infect a plant root and assist the plant to get more nutrient from the soil. The soil in Ndele has been continuously expose to gents of soil degradation factors and nutrient losses such as rainfall, leaching, erosion, nutrient uptake by plants and crop removal . Therefore, the study was aimed at determining the effect of charcoal on the Physico-chemical properties of the soil.

MATERIALS AND METHODS

The experiment was carried out at the Teaching and Research farm of IgnatiusAjuru University of Eduction, NdeleCompus in 2022 and the experiment lasted six (6) weeks. The design of adopted was complete randomized block design (CRBD) with five (5) treatments replicated three (3) times. The land was cleared mapped out and seed bed constructed. The bags of charcoal were purchased from local producers, grounded, measured and applied on the seed beds. The treatments applied were 0, 2, 4, 6 and8ton ha-1. The soil samples were collected for Physico- chemical properties test of the soil 6 weeks on application of the treatments using soil auger at a depth of 15 cm and taken to the laboratory for analysis using standard procedures. The Physico-chemical properties test for were pH, moisture, organic carbon,P,K,S,Zn,Mn, Cu,Fe,Bo and Cl of the soil. The generated data were subjected to analysis of variance and mean separated using Duncan Multiple RangeTest (DMRT).

RESULT AND DISCUSSION

Table 1 showed the summarized effect of different rate of application of charcoal on soil Physico-chemical properties of the soil.The organic carbon content was 34.45, 47.99, 47.50, 48.30% and 43.18 for 0,2,4,6 and 8 tonha-1 of charcoal respectively

Table1 Effect of Charcoal Application on soil Physico-chemical Properties

Charcoal Rates	OC	pH	Moisture	Total N	P	K	Ca	Mg	S	Zn	Mn	Cu	Fe	Bo	Cl
O	34.43^{a}	5.25^{a}	16.03^{a}	13.68^{d}	0.15^{a}	0.80^{b}	0.73^{b}	0.06^{a}	0.049^{b}	0.10^{a}	0.036^{a}	0.42^{c}	3.79^{a}	0.083^{a}	0.176^{b}
2 ton	47.99^{c}	5.67^{b}	16.50^{a}	13.94^{e}	0.15^{a}	0.81^{b}	0.74^{b}	0.06^{a}	0.011^{a}	0.093^{a}	0.039^{a}	0.146^{c}	4.24^{a}	0.083^{a}	0.152^{b}
4 ton	47.50^{c}	5.77^{b}	16.60^{b}	13.33^{b}	0.17^{a}	0.79^{a}	0.73^{b}	0.059^{a}	0.11^{a}	0.073^{a}	0.038^{a}	0.130^{b}	4.29^{a}	0.070^{a}	0.139^{a}
6 ton	48.30^{c}	5.77^{b}	16.60^{b}	13.16^{a}	0.18^{a}	0.77^{a}	0.73^{b}	0.055^{a}	0.012^{a}	0.077^{a}	0.038^{a}	0.130^{b}	4.12^{a}	0.080^{a}	0.110^{a}
8 ton	43.18^{b}	6.25^{c}	17.39^{c}	13.52^{c}	0.16^{a}	0.77^{a}	0.57^{a}	0.251^{b}	0.074^{b}	2.57^{b}	0.033^{a}	0.100^{a}	4.14^{a}	0.25^{b}	0.215^{c}
SE df=14	3.68	0.285	0.033	0.079	0.12	0.009	0.003	0.043	0.016	0.554	0.003	0.012	0.21	0.27	0.022

Mean with same superscript is not significantly different (0.≤05)ph,N,P,K,Ca,Mg,S,Zn,Mn, Cu,Fe,Bo,Cl means soil pH, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, manganese, copper, iron, boron and chlorine respectively.

The organic carbon content of the soil showed a numerical increase in the treatment rates of charcoal from the control (0ton) to 6 tons per hectare which were significantly different at 0.05. Treatments 2, 3 and 4 were not significantly different and treatment 1 and 5 were not significantly different. The observed pattern may be due to the following factors / method of processing, age of trees and charcoal, handling procedures and season of application of the charcoal.

The pH of the soil for charcoal treatment rates are 5.77, 5.67, 5.25, 5.77 and 6.25 respectively for 0, 2, 4, 6 and 8 tonsha^{-1}of charcoal. The charcoal treatment rates were significantly different P≥0.05, 0 and 2 tons ha^{-1} application were not statistical different but showed numerically deduction pH of the soil as the application increases from 0ton (control) to 4 tons ha^{-1} and the pH rises again from 6 tons ha^{-1} that is from 8.25 when 4 ton ha^{-1} was applied to 5.77 and 6.25 respectively for 6 and 8 tons ha^{-1}. This indicates that higher application may change soil to slightly acidity instead of alkaline

The soil water holding (content) capacity for charcoal treated soil are 16.60, 16.50, 17.39, 16.50 and 18.03 respectively for 0, 2, 4, 6 and 8 tons ha^{-1}. There is no significant difference among treatments. The soil water holding at 4, 6 and 8 tons ha^{-1} of charcoal treatment were higher than numerically than 0 and 2 tonsha^{-1} treatments respectively. It could be deduced that charcoal has poor ability to absorb water from the air to soil. Total nitrogen of the treated soil is 13.68, 13.94, 13.33, 13.16 and 13.32 for 0, 2, 4, 6 and 8 tonsha^{-1} of charcoal. There was numerical increase in the total nitrogen of the soil among treatments. These numerical increase were significant (P≤0.05). The soil phosphorus (P) is 0.16, 0.15, 0.17, 0.18 and 0.16 ppm for 0, 2, 4, 6 and 8ton ha^{-1} of charcoal. There was numerically a difference as a result of quantity applied but there was no significant difference. The soil potassium (K) are 0.80, 0.81, 0.79, 0.77 and 0.71 ppm for 0, 2, 4, 6 and 8 ton-ha of charcoal. The soil potassium for treatments 0 and 2 ton/ha^{-1} of charcoal were not significant but significantly different for 4, 6 and 8 tons ha^{-1} were not significantly different from each other. The soil calcium (Ca) are 0.73, 0.74, 0.73, 0.75 and 0.57ppm for 0, 2, 4, 6 and 8 tons/ha of charcoal respectively. There was significant difference among treatments. Treatment 0, 2, 4 and 6 tons/ha were not significantly different but significantly different from treatment 8 ton/ha of charcoal. Magnesium (Mg) due to charcoal application is 0.066, 0.59, 0.055 and 0.25 ppm for 0, 2, 4, 6 and 8 tons ha^{-1} respectively. Application of charcoal led to reduction in quantity of Mg.

Charcoal application indicates the soil sulphur (S) as 0.049, 0.011, 0.012 and 0.074ppm for 0, 2, 4, 6 and 8 tonsha^{-1}. The application showed initial reduction in soil sulphur from 0.049ppm in 0ton ha^{-1} to 0.011ppm in 4kgha^{-1} of charcoal. There was an increase in quantity of S from application of 6tons ha^{-1} to 8 tons ha^{-1}

Zinc (Zn) content of soil due to charcoal application indicates 0.10, 0.093, 0.073, 0.077 and 2.57 ppm 0, 2, 4, 6 and 8 tons ha^{-1}. The application of charcoal reduces the quantity of 2 in the soil from 0.10 ppm in 0 ton ha^{-1} to 0.077 ppm in 6 tons ha^{-1} but 8 tons/ha^{-1} shows 2.57 ppm. There was no significant difference among 0, 2, 4 and 6 tons ha^{-1} of charcoal but differ from 8 tons/ha^{-1}. It could be deduced that higher application of charcoal from 8 tons ha^{-1} could be beneficial to soil Zn.

Mn content of the soil treated with charcoal indicates 0.036, 0.039, 0.038, 0.038 and 0.033 ppm for 0, 2, 4, 6 and 8 tons ha^{-1} respectively. There was both increment and reduction as the application quantity increased Mn increases from 0.036 ppm application. From there, reduction was observed as 4, 6 and 8 tons ha^{-1} were applied. The various treatments 0, 2, 4, 6 and 8 tons/ha^{-1} were not significantly difference. This may show that charcoal is very low in Mn and could also prevent reaction which involves mobilization of Mn from the soil for crop uses.

Copper (Cu) content of soil as treated by charcoal indicates 0.142, 146, 0.130, 0.130 and 0.100 for 0, 2, 4, 6 and 8 tons ha^{-1} respectively. Application of charcoal led to the initial increase in the quantity of Cu, from 0.142 ppm in the control to 0.146 ppm in the application 2 tons ha^{-1}. When 4 tons ha^{-1} is applied, there is a reduction in quantity of Cu to 0.130 ppm and continued application of 8 tons ha^{-1}indicates 0.100 ppm of Cu. There was a significant difference among treatments. Control (0 tons ha^{-1}) and treatment of 2 tons ha^{-1} do not differ significantly. In similar way, 4 tons ha^{-1} and 6 tons ha^{-1} do not differ significantly. The observed may be due to the soil reactions which immobilized Cu.

Iron (Fe) content of the soils treated with charcoal indicates as3.79,4. 24,4.29, 4. 12 and 4.14 ppmfor 0, 2, 4, 6and 8 tonsha^{-1}respectively. The application of charcoal showed initial increase in the Fe of soil but higher application above 4 tons ha^{-1} led to reduction in the soil Fe. The increase or reduction due to application was not significantly different. It could be reduced moderate application of charcoal could be applied to soil. The application of charcoal indicates the Bo content of treated soils as 0.083, 0.083, 0.070, 0.074 ppm and 0.25 for 0, 2, 4, 6 and 8tons ha^{-1} respectively. The increase in the Bo level was not uniform but there was a significant difference among treatments. Treatments 0, 2, 4 and 6 tons ha^{-1} are not significantly different.

Chlorine (Cl) content of soil indicates 0.176, 0.52, 0.139, 0.110 and 0.215 ppm for 0, 2, 4, 6 and 8 tons ha^{-1} of charcoal treatment. There was gradually reduction in the Cl content of the soil from control to 6 tons ha-1then increase to 0.215 ppm for 8 tons ha^{-1}

There was gradual increase in organic carbon, soil pH, total nitrogen moistureandmineral were positively increased. Organic carbon content of the soil though increase was not significant among treatments. Total nitrogen, moisture, pH and mineral in the soil are major indicators of soil fertility. Soil fertility is built with these components substances and is derived from organic and chemical sources. These findings are in consonant with the report of Nelofer *et al.* (2016),that the Physico-chemical properties of the soil determine the comfort easily uptake water by plants volume of oxygen and other gases and their movement with the soil. These findings are similar to the report of Kelterings and Bigham (2000) that charcoal addition to the soil have positive effect on soil properties and enhance soil fertility and productivity. The findings are also in line with result from Bijisma and Lambers (2000) who reported that charcoal introduction into the soil affects the amount of mineral nitrogen, organic carbon availability of the soil. The results also reflect the report of Aduayi *et al.* (2002) that the major elements in fertilizer are known to be deficient in most Nigeria soils.

CONCLUSION

From data analyzed, the application of charcoal has positive influence on soil Physico –chemical properties. Application of 4tons ha-1 of charcoal improves the organic content, soil acidity structure, texture and nutrient contents of Ndele's soil. It is recommended that charcoal should be applied at least 4 to 6 tonsha^{-1} to fortify the soil Physico-chemical properties and enhance crop yield in eroded soil like Ndele. Also charcoal should be used as substitute for NPK or any other organic fertilizer.

REFERENCES

Aduayi, E.A, Chude, V.O., Adebusuyi, B.A. and Olayiwola, S.O. (2002).Fertizer use and Management practices for crops in Nigeria. Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja Nigeria. 16

Bijlsma, R.J. and Lambers, H. (2000).A dynamic whole plant model of integrated metabolism of nitrogen and carbon.Plant and soil. 220: 71-87.

Bockheim,J.G. (2015). The soil of America.World soil book series, springer International publishing, Switzerland, 322.

Codex, A. (2007).Organically produced foods, 3rd Ed. Codex Alimentarius Commission, World Health Organization (WHO)/Food and Agriculture Organization ofthe United Nations (FAO), Rome, 51 pp.

Food Agricultural Organisation,FAO (2016). Organic farming. Technologies and practices for smallholder farmers. Available http//www.organic agriculture . Retrieved on 20/02/2023.

Glaser, B., Haumaier, L.M, Guggenberger, G. and Zech, W. (2001). The Terra preta' phenomenon: a model for sustainable agriculture in the humid tropics. Naturwissenschaften. 88(1), 37-41.

Glaser. B., Lehmann .J. and Zech, W.(2002). Ameliorating physical and chemical properties of highly weathered soils. 35: 219 – 230.

Keller, M. (2017).How to use charcoal as fertilizer. Available at www charcoal asfertilizeruse.com. Retrieved on November 20th 2019.

Ketterings, Q. and Bigham, J.M.(2002). Soil color as an indicator of slash – and – burn fire severity and soil fertility in sumatra, Indonesia, soil Sic. Soc. AmJ 64:1826 – 1833.

Laird, D.A, Fleming, P.M Davis, D.D., Horton, R.., Wang, b. and Karlen, D.L. (2001).*Impact of biochar amendments on the quality of a typical Midwestern agricultural soil*.Geoderma 158(3-4); 443-449.

Littcerick, A.M and Watson, C.A (2017).Crop systems. *Encylopedia of Applied Plant Science*. ELSEVIER books

Major, J. Steiner, C., Downie, A.mLehmann,J. (2009) Biochar effects on nutrient leaching. In Biochar for environmental management, science and technology.(Eds J. Lehmann, S. Joseph); 271-288.Earthscan; London.

Nashio, M. and Okaw, S. (1991).Stimulation of the growth of alfalfa and infection of roots with indigenous vesicular-arbuscularmycorrhizal fungi by the application of charcoal. Bulletin of the national Grassland Research Institute 45: 61-71.

Nelofer, J.mHumaira, A. and Naheed, S. (2016). Physical and chemical properties of soil quality indicating forests productivity: A review. https.//www.researchgate.net/publications

O'Neill, B.J., Grossman, M.T., Tsai, J.E., Gomes. J.E, Lehmann, J., Peterson, J., Naves, E. and this, J.E. (2000) Bacterial Community composition in Brazilian Anthrosols and Adjacent soils characterized using culturing and molecular identification.Microbial Ecology, 58:23 – 35.

Ogawa, M. and Okimori, Y. (2010). Pioneering works in biochar research, Japan. Australian.*Journal of soil Research*, 48; 489-500.

Patel, M.N; Choudhary, SandSwarnakar, V. K. (2013). Study on Adoption of Eco-Friendly Management Practices by Vegetable Growers in Indore Block of Indore District (M.P.) *IOSR Journal of Agriculture and Veterinary Science 2(4): 22-25.*

Schaetzl, R.J. and Thompson, M.l., (2015).Soils Genesis and Geography, 2^nd^edition Cambridge university press, New York USA, 795.

Steiner, C., Blum, W.E.H; Zech, W., de Macedo J.L.V. Teixeira, W.G., Lehmann, J., and Nehls, T. (2007) long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered control Amazonian upland soil, plant and soil. 291(1-2), 275-290.

Urban, M.S (2008). Organic farming. *Encyclopedia of Ecology*. ELSEVIER books