Nig J. Biotech. Vol. 25 (2013) 53 -59
ISSN: 0189 17131
Available online at www.biotechsocietynigeria.org.

NIGERIAN JOURNAL OF BIOTECHNOLOGY

Changes in Rheological Properties and Heavy Metal Content of an Ultisol Amended with Ash and its Effect on Maize Yield

Mbah, C. N.[1], Oguejiofor, C. U.[1], Idike, F. I.[1], Nwovu, I.G.[2] and Attoe, E. E.[3]

[1]Department of Soil and Environmental Management, Ebonyi State University, Abakaliki.
[2] St Monic Model academy Izzi, Abakaliki, Ebonyi State
[3]Department of Agronomy, Cross River State University of Technology, Calabar.

(Received 11.01.13, Accepted 09.04.13)

Abstract

This study investigated the effect of ash from wood (WA), rice husk (RHA) and coconut (CA) on soil liquid limit (LL), plastic limit (PL), sodium absorption ratio (SAR), exchangeable sodium percent (ESP), exchangeable potassium percent (EPP) and contents of Cu, Fe, Bo and Pb in an Ultisol in Southeastern Nigeria. The experiment was laid out as completely randomized block design with four treatments and five replications. The treatments were applied at the rate of 4t ha-^{1} and maize used as a test crop. Results of the study showed significant increase (p=0.05) in LL,PL, EPP and ESP. Observed LL values were 6%,12% and 11% higher in CA, RHA and WA amended plots, respectively, relative to the control. Results of the study also showed decreased soil contents of Bo and Cu and increased Pb content to non-toxic level. Results also showed significantly (p=0.05) higher maize height and yield in ash amended plots relative to the control. Ash application is recommended since it improves soil properties and increase maize yield.

Keywords: Ash, rheological properties, heavy metal, maize yield.

Correspondence*:* *cnmbah10@yahoo.com*

Introduction

There is increasing interest in using waste materials (WMs) to improve soil productivity in agricultural system in topical areas. Result of researches by Njoku and Mbah (2012), Mbagwu *et al*. (1994), Okonkwo *et al*. (2011) and Hadas *et al*. (2004) showed that application of WMs to soil have beneficial effects on soil nutrients, soil physical conditions, soil biological activity and crop performance. In Nigeria WMs are sometimes used after crop harvesting, since a lot of WMs is left in the field after harvest. Government and private sectors have tried to promote the utilization of those wastes e.g, applying them as compost or soil amendment but most farmers do not use these WMs. Onpreasert (1991) observed that this residue are usually burnt after harvest leading to production of ash.

In southeast Nigeria, soil acidity is a problem hindering proper agricultural production since most of the crops grown are susceptible to dangerous effects of acidic soils. To make the soil less acidic it is common practices to apply lime to agricultural soils. However, the unavailability and high cost of lime materials has led to research into low cost, affordable and adoptable organic and inorganic material like wood ash (Igbokwe *et al*., 1981). Giovannini *et al*. (1993) reported that the addition of ash in one form or another to soil has been done for years through burning of agricultural residues but only in recent years has research begin to focus on the effects of application of ash on agricultural soils. Mbah *et al*. (2011) reported improved soil properties and increased maize grain yield when they tested the response of maize (*Zea Mays* L) to different rates of wood-ash application in acid ultisol in southeast Nigeria. Oditte the *et al.*

*(*2005) and Ojeniyi *et al*. (2007) reported increased crop yield when ash was used as soil amendment.

Similarly, research result by Odedina *et al*. (2003), Adetunji (1997) and Owolabi *et al*. (2003) showed reduced acidity and increased nutrient availability in soil of southwest Nigeria amended with different types of ash relative to the control. However, research interests on the potential hazards associated with the use of ash as soil amendment have not been taken into account. The objective of this study was to find out the contribution of ash used as amendment to soil heavy metal contents, sodium adsorption ratio (SAR), Exchangeable sodium percent (ESP), Exchangeable potassium percent (EPP), and changes in soil rheological properties (liquid limit (LL) and plastic limit (PL) of an ultisol in southeast Nigeria. The assumption is that heavy metal concentration in excess of critical levels could lead to agronomic and environmental problems.

Materials and Methods

Location: The study site is Teaching and Research Farm of Faculty of Agriculture and Natural Resources Management, Ebonyi state university, Abakaliki. Abakaliki is bounded by latitudes $06^0 4^1$N and longitude $108^0 65^1$E. It is within the humid tropics. Temperatures are high and change slightly during the year (mean daily temperature ranges between 27-31^{0}C. The average annual rainfall is 1700mm distributed between April and November. Soils of the study site have been classified as Typic Haplustult (FDALR, 1985). They are acidic, have low cation exchange capacity, low base saturation and low fertility status. Farming is the major economic activity even in urban areas where pockets of subsistence farmers are found.

Field studies: An area of land measuring 15m x 12 m (equivalent to 0.180 t ha^{-1}) was marked out, slashed, cleared of grasses and used for the experiment in 2011 cropping season. The experiment was laid out in randomized complete block design (RCBD) with plot sizes measuring 2 m x 3 m replicated five times. The field was divided into four blocks with each block having five experimental units giving a total of 20, plots. The experimental units were demarcated by 1m alley.

The land was cleared of vegetation and manually tilled. The treatments comprising 4 t ha^{-1} each of burnt coconut ash (BA), burnt rice husk ash (BHA) and wood-ash (WA) were incorporated into the soil during tillage. A control was also included. Maize (variety Oba super 11) was used as a test crop and planted at 2 grains per hill with a spacing of 0.5 m x 0.5 m inter and intra-row, respectively. This was thinned to one plant hill ten days after germination to give a plant population of 53,333 plants. At maturity maize grain was harvested, air dried and the dry weight taken and expressed on a 12.5% moisture basis. Soil samples were collected at a depth of 20 cm from the experimental units before and after the study. The soil samples were air dried and sieved using 2 m sieve in readiness for various laboratory analysis. Six plants were sampled from each plot for plant height. At maturity, 6 plants were uprooted per plot and the roots cut off, air dried and weighed to determine the dry shoot and root weight.

Laboratory studies:

Rheological properties: The liquid limit (LL) and plastic limit (PL) were determined by the standard Casagrande method (Sowers, 1965) plastic number or index was calculated using the formula;

LL-PL = PN.

Sodium adsorption ratio (SAR) was calculated using the equation of Richard (1954) as follows:

$$SAR = Na^+ / [(ca^{2+} + Mg^{2+}/2)]^{½}$$

Exchangeable potassium percent (EPP) was calculated as follows:

$$EPP = K^+ / CEC \times \frac{100}{1}$$

Exchangeable sodium percent (ESP) was obtained using the following formula:

$$ESP = \frac{Na^+}{CEC} \times \frac{100}{1}$$

The pH was determined using 1: 25 solid – liquid ratio (Thomas 1996). Exchangeable basic cations were estimated by inductively coupled plasma atomic emission spectrometer (KP – AES) (Integra XMO, GBC, Arlington Heights, IL, USA). Total

Heavy metal: Heavy metal (Cu, Pb, Zn, Bo) were determined from the soil sample using atomic adsorption spectrometer after digestion with conc. HNO_3 (Alloway, 1996).

Data analysis: Data obtained from the study were subjected to analysis of variance (ANOVA) and means separated using Fishers least significance difference (FLSD-0.05) according to the procedure outlined by Steel and Torrie, (1980).

Nitrogen was determined by Kjeldah digestion with Keltec Auto 1030 system (Tecator, Hoganas, Sweden) while particle size distribution was determined by hydrometer method according to Gee and Orr (2002).

Results and Discussions

The properties of the soil and the different types of ash (WA, CA, BHA) are shown in Table 1. Total sand dominated the other size particles in the study site. Organic matter (OM%) was generally higher in the ash compared to the soil. Higher levels of exchangeable bases were observed in the soil. Similarly the soil has an acidic pH compared to the observed basic pH in the ash. Analysis of the ash showed higher values of heavy metals (Cu, Fe, Pb) in the ash relative to the soil.

Table 1. Initial properties of the soil and different types of ash.

Parameters	Unit	Soil	WA	BHA	CA
Clay	%	16			
Silt	%	19			
Total sand	%	65			
Texture		5L			
pH (H_2O)		5.80	9.8	7.5	9.9
Total N	%	0.11	0.13	0.05	1.50
OM	%	3.13	6.00	7.68	4.12
Ex Na^+	Cmolkg^{-1}	0.17	0.008	0.05	0.011
Ex Ca^{2+}	‘’	4.00	3.88	0.52	0.72
Ex. K^+	‘’	0.15	0.016	0.014	0.72
Ex. Mg^{2+}	‘’	2.00	1.82	1.91	0.29
CEC	‘’	15.20			
Pb	Mgkg^{-1}	0.21	2.67	1.44	1.07
CU	‘’	0.66	40.65	11.40	5.19
Fe	‘’	9.91	45.36	17.36	15.94
Bo	‘’	5.94	-	-	7.13

Table 2: Effect of ash on heavy metal contents, plant height (cm) and root dry matter yield.

Parameter	Cu	Pb	Bo	Fe	Plant Height	Root Yield
Co	0.30	0.12	5.94	3.92	81.0	0.17
BHA	0.41	0.14	4.75	3.92	77.5	0.14
WA	0.27	0.13	3.63	2.92	80.2	0.18
CO	0.43	0.11	7.13	2.82	73.8	0.11
Mean	0.35	0.13	5.36	3.39	78.1	0.15
LSD (0.05)	NS	NS	0.27	NS	1.02	0.5

CA = coconut ash, BHA = burnt rice husk ash, CO = Control, WA = Wood ash.

Application of ash reduced Cu and Bo contents of the soil (Table 2). The table also showed higher values of Pb and Fe in ash amended plots relative to the control. Reduction in soil Cu content relative to the control could be attributed to the effect of soil pH on Zn and Cu absorption. According to Rocio *et al*. (2011) Cu and Zn are less available and less absorbed when soil pH increases or is between 5-7. The increase in Pb and Bo contents of the soil is in line with the observations of Jacobson (2011) and Demeter et al. (2001). The observed values of heavy metals were within the FAO (1976) permissible limits of 5.0 (Fe) and 5.0 (Pb). However observed values of Cu and Bo exceeded the permissible limits of 0.2 and 1.0 respectively.

The maximum critical levels of these heavy metals and uptake by crops may depend on crop type (Kabata- Pendias and Pendias (1992), metal form and soil type (He et al., 2004) and soil management (Chen and Lee, 1999). Table 2 also showed significantly higher maize plant height and root dry matter yield relative to the control. The observed maize plant height was 1.98 (CA) 1.05 (BHA) and 1.87 (WA) times higher that the observed value in the control. Root dry matter yield increased in the order WA> CA> BHA>CO. The higher plant height and root dry matter yield observed in ash amended plots could be attributed to the reduction of soil pH following addition of ash. In a study on the response of maize to wood-ash application in acid ultisol in south-east Nigeria Mbah *et al*. (2010) reported that application of ash at 4 t ha^{-1} reduced soil acidity to levels required for maize production. Similarly, Adetunji (1997) observed that ash derived from wood reduced soil acidity and increased cations/nutrient availability in the soil. Studies by Awodun *et al*. (2007) Mbah *et al*. (2012) and Ayeni *et al*. (2008) showed the positive effects of ash application on soil improvement and crop yield.

Table 3. Effect of ash on soil rheological properties, SAR, EPP and ESP.

Parameters	LL	PL	PN	SAR	ESP	EPP
CA	23.90	17.21	6.69	0.079	1.64	1.54
BHA	25.06	18.09	6.97	0.076	1.54	1.98
WA	24.94	19.85	5.09	0.077	1.52	2.05
CO	22.45	14.90	7.55	0.107	1.42	1.08
LSD(0.05)	1.04	0.69	0.11	0.01	0.03	0.04

LL = liquid limit, PL = Plastic limit, PN = Plastic Number, SAR = Sodium adsorption ratio, EPP = Exchangeable Potassium Percent, ESP=Exchangeable Sodium Percent,.

Application of ash as soil amendment significantly (P=0.05) increased the soil LL and PL. Liquid limit (LL) was 1.06, 1.116 and 1.111 times higher for CA, BHA and WA, respectively, relative to the control. The order of increase in plastic limit (PL) was WA > BHA >CA>CO. Table 2 also showed significantly (P=0.05) higher levels of EPP and lower levels of SAR in ash amended plots relative to the control. MAFF (1967) reported that soil EPP above 25% has adverse effect on soil permeability and structure. Similarly, Longe (1967) observed that ESP above 15% causes soil to become sodic leading to undesirable characteristics especially weak structure. SAR to a lesser extent causes problems with soil structure, infiltration and permeability. Stewart and Meek (1977) reported that the SAR tolerance limits for sensitive fruits and field crops are 4 and 8-18 respectively. The observed ESP, EPP and SAR values in this study is within tolerance limit. In a study on the effect of animal wastes application on soil sodicity and sulphate concentration of an ultisol in southeast Nigeria, Mbah *et al*. (2005) observed that animal waste application increased soil SAR and ESP to non- threshold values for sodicity.

Results from the study showed that ash application to soil increased maize growth and yield. The result also showed that ash application as soil amendment does not constitute agronomic and environmental problems since observed values of heavy metals, SAR, EPP and ESP are within tolerance limits.

References

Adetunji, M. T. (1997). Organic residue management and nutrient cycling. *Agro-ecosyst*. 47 8 1 195.

Alloway, B.J. (1996). Heavy metal in soil. Haslted press. John Wiley and sons Inc. London. PP 339.

Awodun, A.M., Otani, M .S. and Ojeniyi, S. O. (2007). Effect of saw-dust ash plus urea on maize performance and nutrient status. *Asian J. Agric Res*. 12; 27-30.

Ayeni, L.S., Adetunji, M.T. and Ojeniyi, S.O. (2008). Comparative nutrient release from cocoa pod ash, poultry manure and NPK 20%10% 10% fertilizer and their nutrient combinations inoculation study*. Nig. J. Soil Sc*. 18:114-123.

Chen, Z.S. And Lee, T.M. (1999). The effect of chemical remediation treatment on the extractability of cadmium and lead by wheat growing in contaminated soils. Proceedings of the 2nd Int. conf. on contaminants in the soil environment in the Australia –pacific region. New Delhi, India.

Demeter, A.M., Voundi-Nkana, J.C. and Verloo, M. G. (2001). .Characteristics of wood ash and influence on soil properties and nutrient uptake. An overview. *Biores Technol*. 77:287-285.

FAO, (Food and Agricultural Organization) (1976). Soil survey investigation for irrigation. Soil bull, Rome.

FDALR, (1985). Reconnaissance soil survey of Anambra state of Nigeria. Soil Report 1985. Federal department of agriculture and land Resources (FADLR), Lagos Nigeria.

Gee, G. W. and Orr. D. (2002). Particle size Analysis. In Dane D.H; Topp G.C (Eds). Methods of soil analyses part 4: physical methods soil Sc. Am Book series No 5 ASA and SSSA, Madison, WI. P. 255-293.

Giovanni, G., Benvenuti, S., Lucchesi, S. and Giachetti, M. (1993). Weed reduction by burning straw and stubble in the field; positive response and potential. *Journal of Agric Sc*. 2 (4) 11-16.

Hadas, A., Kantsky, L., Goek M. and Kara E.E. (2004). Rates of decomposition of plant residues and available nitrogen in soils related to residue composition through stimulation of carbon and nitrogen turnover. *Soil Biol. Biochem*. 36: 2550266.

He, Z.L., Zhamg, M.K., Calvert, D.V., Stopella, P.J., Yany, X.E. and Yu, S. (2004). Transport of heavy metals in surface run off. from vegetable and citrus fields. Soil Sc. SOC, AM J. 68 :1662-1669.

Igbokwe, M.C., Njoku ,B.O. and Odurukwe, B.O. (1981). Lining effects on the response of maize on a ultsol in Enugu Nigeria. *Soil Sc*. 11:120-130.

Jacobson, K.S. (2001). The effect of fly ash/sewage slued mixtures and application rates on coco mass production. Journal of Environ. Science and Health 30:1322-1337.

Kabata- Pendias, A. and Pendias, H. (1992). Trace elements in soils and plants (zinc ed). CRC press, Inc., Boca ration Florida USA.

Longe, S. (1967). Hand book of chemistry 10th addition MC. Grew hill book company N.X PP 822-824.

MAFF. (1967). Soil potassium, and magnesium. Technical bulletin no 4 Hm SD

Mbah, C.N., Anikwe M. and Mbagwu, J,S,C. (2005). Effect of animal wastes on soil sodicity and sulphate concentration of an ultisol in south east Nigeria. *Nig Journ. of Soil Sc*. 15 (2) 93-100.

Mbah, C.N., Nwite, J.N., Njoku., C. and Nweke, A.I. (2010) Response of Maize (*Zea mays* L) to different rates of wood –ash application in acid ultisol in southeast Nigeria. *African Journal of Agric Res.* S (7), 580 – 583.

Mbah, C.N., Njoku, C., Ngene, P. and Oludare, C.G. (2012). Use of ash to improve the nutrient content of an ultisol and its effect on maize growth and dry matter yield. *Agric Sc. Res Journal:* 2 (3) 1-5.

Mbagwu, J.S.C., Unamba – Oparah. 1. and Nevoh, G.O. (1994). Physicochemical properties and productivity of two tropical soils amended with dehydrated swine waste. *Biores Technol*, 49; 163-171.

Njoku, C . and Mbah, C.N. (2012). Effect of burnt and un-burnt rice husk dust on maize yield and soil physicochemical properties of an ultisol in Nigeria. *Biological Agriculture and Horticulture firs*t 1-2.

Odedina, S.S., Odedina, J.N., Ayeni, S., Arowojolu, S.A, Adedeye S.O. and Ojemyi, S.O. (2003). Effect of types of ash on soil fertility, nutrient availability and yield of tomatoes and pepper. *Nig. Journ. of Soil Sc*. 13:66-67.

Odiette, I., Chude, V.O., Ojeniyi S.O., Okozi, A.A. and Assaini, G.M. (2005). Response of maize to nitrogen and phosphorus sources in guinea savanna zone of Nigeria. *Nig. Journal of Soil Sc. 15:90-101.*

Ojeniyi, S,O, Awodun, M.A. and Odedina, S. (2007). Effect of animal manure amended spent grain and cocoa husk on nutrient- status, growth and yield of tomato. *Int. Journ. of Agric Res*. 2 (4) : 406-410.

Okonkwo, C.I., Onyibe, C., Nwite. J. N., Igwe, T.S., Njoku, C. and Mbah, C.N. (2001). Physical characteristics and maize grain yield in an ultisol in south east Nigeria amended with four animal manures. *Int. Res. Journal of Agric Sc. and Soil Sc.* Vol. 2 (2) 077-080.

Orgprasert, B. (1991). Utilization of waste material from soil bean and peanut for soil improvement in Dynamics and its control of soils in tropical monsoon regions. Report of Soil survey and Research in Thailand. 180-186.

Owolobi, O., Ojeniyi S.O., Awodu, A.O. and Hazzan, K. (2003). Response of Okra and tomatoes to saw dust ash manure . *Moore J. Agric* Res: 4 (2). 178-182.

Richards, L.(1954) diagnosis and improvement of salme and alkali soils USDA, Agric. Hand book No 60.

Rocio, V.I., Jorge, L., Ricardo, M., Maria, U.E. and Hilda, Z . (2001). Effect of sewage sludge and sewage sludge compost amendments on soil properties and *zea mays* L plants. (heavy metals quality and productivity). *Rev. Int. Contains Ambie*. 27 (4) 303-311.

Sowers, G.F. (1965). Consistency limits In C.A. Black (ed). Methods of soil analysis. ASA monograph No 9 part 1:391-399.

Steel, R.G. and Torrie J.H. (1980). Principles and procedure of statistics. A biometrical approach. 2nd edition. Mc Grew. New York P. 1033.

Stewart, B.A. and Meek, B.O. (1977). Soluble salt considerations with waste applications Inc. soil for management of organic wastes and was Waters. ASA, CSSA, ASSA, Wisconsin, USA PP. 219-221.

Thomas, G.W, (1996). Soil pH and soil acidity. In methods of soil analysis part 3: Chemical methods SSSA book series No 5,SSA and ASA, Madison; WI P 475-490.