RESPONSE OF LIME AND BIOCHAR FOR ACIDIC SOIL REMEDIATION, GROWTH AND MACRO-NUTRIENTS UPTAKE OF MAIZE *(Zea mays L.)* IN IMO STATE, NIGERIA

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ABSTRACT

The study was conducted at the green-house of Alvan Ikoku Federal College of Education, Owerri, Imo State, Nigeria during the wet season of 2016. To explore the potential of using biochar as a substitute for chemical lime for remediating acidic soil and also evaluate effect of biochar on macro-nutrients uptake. The treatment consisted of two rates of dolomite lime (0, and 4g/5kg of soil) and three rates of rice husk biochar (0, 60,1 20g/5kg of soil). Treatments were factorial combined and laid out in a Randomized Complete Block Design and replicated three times. The results showed that application of dolomite lime and rice husk biochar rates had a significant (P=0.05) increased on soil pH and all the other chemical properties of the soil except exchangeable acidity. A reverse trend was observed in exchange acidity, where increased application of biochar resulted to a significant (p=O.O5) decrease in soil exchange acidity. Application of 4g/pot of dolomite lime and 120g/pot of rice husk biochar produced the highest levels of soil pH 7.25 in water and 7.09 in 0.01MKC1 were obtained. While, the control in lime and rice husk biochar produced the lowest level of 0.11 and 1.19 exchangeable acidity respectively. Lime and rice husk biochar had a significant (P = 0.05) effect on growth height, fresh, dry weight and macro-nutrients uptake of maize plant. Lime at 4g/pot and rice husk biochar at 1 20g/pot produced significantly taller maize of 40.32cm and 43.92cm height, fresh and dry plant weight of 13.50g;
79.79g and 3.55g: 17.92g respectively compare to other rates. Application of 4g/pot of lime and 120g'pot of rice husk biochar produced the highest value of maize uptake of N (1.86% and 2.87%); P (48.92 $mgkg^{-1}$ and 63.l2$mgkg^{-1}$) and K (3.93cmolkg' and 5.74cmolkg1) respectively compare to the other rates and control Therefore, it is recommended that lime material is also useful to soil acidity for better macro-nutrients uptake by plants.
KEY WORDS: biochar**.** Lime, growth, macro-nutrients, uptake, soil

INTRODUCTION

Soil acidity is a serious problem facing crop production in many regions of the world. The conventional method of correcting soil acidity is the addition of chemical lime (Opala, 2011). Mamo et al (2009) mentioned agricultural lime (Calcium Carbonate). burnt lime (Calcium oxides), Dolomite (Calcium magnesium Carbonate), Magnesite (Magnesium Carbonate), Burnt Magnesite (Magnesium oxides) as the major types of chemical lime used by farmers for correction of soil acidity. The addition of chemical lime predictably increased the plant growth by increasing soil pH and lowering Aluminum; thus the soil becoming non-toxic to crops. Soil acidity affect the solubility of plant nutrients in the soil. thus their availability for plant's uptake may not be guarantee.

Phosphorus deficiencies and aluminum toxicities often occur simultaneously in many acid soils in the tropics and are thought to be responsible for poor crop yields in such soils (Agbede, 2009). Indeed, soil acidity can be ameliorated with application of chemical lime. However, there are many other soil amendment materials that are used to improve soil properties; these materials include: chemical fertilizers, organic fertilizers, sawdust, wood shaving, biochar, ashes etc. The liming effect of some agricultural residues and other plant materials has been reported (Tang and Yu, 1999). Also, the potential of biochar as a soil amendment in agricultural fields is recently recognized and yet it is underutilized technology especially in Nigeria. Biochar, (also commonly known as charcoal or agrichar) is defined as a carbon (C) rich product derived from the pyrolysis of organic material at a temperatures bellow 1000 °C (Lehmann and Joseph, 2009). Biochar stores carbon for long time, ameliorates degraded soils and reduces soil acidity for better crop production (IBI, 2012); and also improves crop yield when applied as a soil amendment (Major et al., 2010). Biochar application improves crop productivity through enhancing water holding capacity, cation exchange capacity (CEC), adsorption of plant nutrients and creates suitable condition for soil micro-organisms (Lehmann et al., 2011). Hence, addition of liming materials, such as biochar, may offer a possible solution to manage acidity of the agricultural soils. The effect of biochar in increasing soil pH in highly weathered tropical soils had been confirmed (Glaser et al., 2001; 2002). Other studies also showed that the alkalinity of biochar was a key factor affecting their liming potential (Yuan et al., 2011b) and also showing an increase of pH when biochar with higher pH value was applied to the acidic soil (Yuan et al., 2011c). Soil fertility depletion and accelerated soil acidification are the factors that aggravate crop yield reduction. Due to increasing costs of lime and other farm inputs, poor smallholder farmers cannot afford to buy chemical lime in the shop. Therefore, there is increase interest in the use of cheap available organic materials as alternative to use **o**f chemical lime. The objective of this study is to explore the potential of using biochar as a substitute for chemical lime in remediating acidic soils and evaluate the effect of biochar soil amendment on macro-nutrient uptake by maize.

MATERIALS AND METHODS

The pot experiment was conducted during the wet season of 2016 at the green house of Alvan Ikoku Federal College of Education, Owerri, Imo State, Nigeria. The study area falls within southeast agro ecological zone of Nigeria. Rainfall period is usua1I from March October and the average monthly rainfall figures range from 400 mm-350 mm. The months of July and August usually record heavy rainfall and also have August break (low rainfall). The daily maximum temperature ranges from 20.0°C- 38.5°C. The months of February to early April are the months that have the highest maximum temperature while the lowest maximum temperature are recorded in December and January because of the prevailing cold harmattan wind. The relative humidity rises from April to a maximum of about *75*- 90 percent in July (NIMET, 2015).

Biochar production

Rice husk was collected from rice mill in Ihitte Uboma in Imo State for the production of biochar. An improvised kiln was produced which was an empty drum that was perforated but had a cover. The rice husk materials were poured inside the drum half full, then fired was ignited inside the drum and more materials were added and the drum lid was covered to encourage slow burning. Then the content in the drum was consistently stirred to enhance uniformity of burning. After 3-4hours the content of drum is poured out and quenched with water (by sprinkling water on the hot char) and dried in the sun for 2 days.

Soil samples Collection

Top soil was collected at a depth of 0-15 cm with soil auger, 5kg of soil per pot from the teaching and research farm of Department of Agricultural Science Education, Alvan Ikoku Federal College of Education, Owerri, Imo State, Nigeria for green house pot experiment.

Treatment and Experimental Design

The experimental design used was Completely Randomized Design (CRD) and the treatments consisted of three rates of rice husk biochar: 0. 60. 120 g per pot and two rates of dolomite lime materials [$CaMg(C0_3$]: 0. 4g per pot; factorially combined to form 18 treatments and laid out in the screen house. 15cm plow layer of one hectare of soil weight is 2,242,000 kg ha^{-1} (Harper. 2001). Therefore, the three application rates 0, 60, 120g of biochar are equivalent to 0 t ha^{-1}, 26.90 t ha^{-1} and 53.81t ha^{-1} respectively. While 0, 4g rates of dolomite lime are equivalent to 0, and 1.8 t ha^{-1}

Data Collection

After filling the pots with soil, water was also applied into the pots and allowed to stay for one week two maize seeds (Oba super II) were planted into each pot as the test crop. 35 g of NPK 20:15:15 fertilizer was applied in each pot and other agronomic practices were carried out. The following parameters were taken after five weeks of planting: plant height, number of leaves, fresh and dry biomass weight. Maize from each plastic bucket was harvested and oven dried at 45°C for tissues analysis. The N P and K uptake by maize were determined by nutrient concentration in the plant tissue multiply by total plant dry matter (Mahadi 2014). Finally, sample of top soil collected and post harvest soil were taken for routine laboratory analysis. Data collected were subjected to analysis of variance using GENSTAT and where there was a significant difference; the means were separated using F-LSD at 5% probability level

RESULTS AND DISCUSSION

The soil was slightly acidic in nature (pH 5.22 in H20 and 5.09 in 0.O1MKCL), very sandy and low in nitrogen, phosphorus, potassium, organic carbon and cation exchange capacity (Table 1) Also, the pH of rice husk biochars used was almost neutral (7.25) and had higher quantities of total nitrogen of 7.00 gkg', organic carbon 20.7 gkg1. The C/N ratio of rice husk biochar was 8.05, the cation exchange capacities of rice husk biochars was very low; but the percentage base saturation is very high (98%).

Table 1: Chemical properties of soil and biochar before used for the trials

Chemical composition	Soil	Rice husk
pH(H20)	5.22	7.25
pH(KCI)	5.09	7.10
Ashes(gkg^{-1})	Nd	35.6
TN(gkg^{-1})	0.40	7.50
OC(gkg^{-1})	7.50	20.7
C N(gkg^{-1})	Nd	8.05
Ay. P($mgkg^{-1}$)	4.57	6.01
K($cmolkg^{-1}$)	0.31	0.31
Mg($cmolkg^{-1}$)	1.78	1.34
Ca($crno1kg^{-1}$)	3.41	3.01
Na($cmolkg^{-1}$)	0.67	0.52
Exch. A($cmolkg^{-1}$)	1.83	0.20
CEC($cmolkg^{-1}$)	6.17	5.18
%Base Saturation	87	98

Nd — Not determined

Lime and rice husk biochars application had a significant (P 0.05) increased soil pH and all the other chemical properties of the soil except on exchangeable acidity (Table2). A reverse trend was observed in exchange acidity, where increased application of biochars resulted to a significant (P = 0.05) decrease in soil exchange acidity. Application of 4g/pot of dolomite lime and 120g/pot of rice husk biochar produced the highest levels of soil pH 7.25 in water and 7.09 in 0.01MKC1 were obtained. While, the control in lime and rice husk biochar produced the lowest level of 0.11 and 1.19 exchangeable acidity respectively. Nitrogen was 0.12% and 1.14%; available phosphorus of 3.03 $mgkg^{-1}$ and 6.69 $mgkg^{-1}$ and potassium of $0.28cmolkg^{-1}$ and 0.31 $cmolkg^{-1}$ respectively in the soil. Interaction between lime and biochar also showed significant (p = 0.05) effects on soil pH and exchanged acidity (Table 4). The combination between 4g/pot of dolomite lime and 1 20g/pot of rice husk biochar gave the highest soil pH of 7.25 in water and 7.09 in 0.01MKC1 and lowest soil exchangeable acidity of 0.10cmolkg was obtained.

Table 2: Effect of lime and biochar on amendment of acidic soil

Treatment	**pH**		**%**	**$mgkg^{-1}$**	**<…………………… $Cmolkg^{-1}$**				**>**	
Lime(g/pot)	(H_2O)	(0.01mk cl)	TN	Av P	Ca	Mg	K	Na	EA	CEC
0	5.28	5.11	0.07	2.53	2.53	1.03	0.24	0.20	0.89	4.76
4	7.25	6.64	0.12	3.03	3.23	1.08	0.28	0.32	0.74	5.96
LSD(0.05)	0.08	0.10	0.03	0.21	0.13	0.02	0.02	0.03	0.10	0.16
RHB(g/pot)										
0	5.24	5.12	0.52	6.23	0.78	1.18	0.23	0.52	1.29	2.88
60	6.87	6.20	1.01	6.68	0.81	1.20	0.28	0.56	1.23	2.88
120	7.05	6.87	1.14	6.69	0.83	1.24	0.31	0.60	1.17	2.90
LSD(0.05)	0.12	0.06	0.03	0.12	0.08	0.22	0.02	0.02	0.04	0.01
Interaction										
Lime X RHB	*	*	NS	NS	NS	NS	NS	NS	*	NS

RHB = Rice husk Biochar *Significant at 5% probability level

Table 3: Interaction effect of lime and biochar on soil pH and exchange acidity

	pH H_2O			pH(0.01MKCI)			Exchange acidity ($cmolkg^{-1}$)		
			Biochar(g/pot)					Biochar(g/pot)	
Lime (g/pot	**0**	**60**	**120**	**0**	**60**	**120**	**0**	**60**	**120**
0	6.78	6.91	6.93	6.64	6.77	6.83	1.7	0.98	0.72
4	7.08	7.12	7.21	6.83	6.92	7.05	0.64	0.56	0.10

Lime and rice husk biochar had a significant (P = 0.05) effect on height, fresh and dry weight of maize plant (Table 14). Lime applied at 4g/pot produced significantly taller maize of 40.32cm height, fresh and dry plant weight of 12.53g and 2.54g respectively compare to control treatment. Also, Rice husk biochar applied at 120g/pot was significantly the best in promoting maize height of 43. 93 cm, fresh and dry weight of 79.79g and 17.79g compare to rate and control. N P and K uptake by maize plant were also significantly (P = 0.05) increased by application of lime and rice husk biochar. Application of 4g/pot of lime and 120g/pot of rice husk biochar produced the highest value of maize uptake of N (1.86% and 2.87%); P (48.92 $mgkg^{-1}$ and 63.12$mgkg^{-1}$) and K (3.93$cmolkg^{-1}$ and 5.74$cmolkg^{-1}$)

respectively compare to the other rates and control. Interaction between lime and rice husk biochar did not showed any significant effect.

Table 4: Effect of lime and biochar soil amendment on maize growth and macro-nutrient uptake at six weeks after planting

Treatments	Growth parameters				Macro-nutrient uptake		
(Biochar)	**No. Leaves**	**Plant Height (cm)**	**Fresh Weight(g)**	**Dry Weight(g)**	**(%) N**	**(mgkg) P**	**(Cmol/kg) K**
Lime(g/pot)							
0	5.24	33.78	56.67	10.21	0.71	25.83	2.65
4	7.56	40.23	75.67	15.34	1.86	48.92	3.93
LSD(0.05)	0.23	3.21	13.50	3.55	0.41	12,24	2.12
RHB(g/pot)							
0	5.67	34.42	55.34	10.53	1.44	40.61	3.90
60	6.11	38.80	74.67	14.96	1.98	42.92	3.95
120	6.67	43.93	79.79	17.92	2.87	63.12	5.74
LSD(0.05)	0.84	3.80	16.46	2.06	0.45	7.47	0.76
Interaction							
Lime X RHB	NS	NS	NS	NS	NS	NS	NS

RHB = Rice husk Biochar

Discussion

The study revealed that both dolomite lime and rice husk biochar used in this trial had significantly increased the soil pH. This confirmed the earlier findings of Ndor et al., (2015) who reported a proportional increase in soil pH values as a result of increased biochar rates applied in degraded soils of southern guinea savanna agroecolgical zone of Nigeria. This happened because of higher concentration of ashes (liming agent) content in the biochar (Table 1) and also presences of calcium magnesium in dolomite lime which replaces both hydrogen and Aluminum in the soil. This also explained the significant reduction in exchange acidity (Al + H) of the soil after incorporating dolomite lime and rice husk biochar in the trial. There was a general improvement in soil nutrients (nitrogen, phosphorus, and potassium) availability because of the increase solubility of plant nutrients in the soil as a result of lowering the soil acidity, thus their availability for plant's uptake. The increased nutrient availability discovered in this study is consistent with the results of previous studies by (Novak et al., 2009).

The vigorous growth performance of maize planted on dolomite lime and rice husk biochar amended soils could be attributed to the fact that the soil of these study area was slightly acidic and poor in macro-nutrient content (Table 1). When dolomite lime and rice husk biochars were incorporated into the soils it reduces the soil acidity and sizes of the soil pores thereby reducing leaching and increases solubility and availability of these macro-nutrients and provided a medium for adsorption of minimal plant nutrients and improved conditions for activities of soil micro-organisms (Sohi et al., 2009). This is in tandem with the result of Van Zwieten *et al.,* (2010) who reported similar effect of biochar on N uptake in which it was observed that application of biochar significantly increased N uptake in plant. This explains why amending the soil with biochar brought about this visible improvement in the growth and macro- nutrients uptake of maize plant.

CONCLUSION

In conclusion, this study revealed that biochar is also a potential liming material that can be use to reduce acidity of the soil and it also showed that when dolomite lime or biochar is incorporated into an acidic soil, there will be a general improvement in soil nutrients (nitrogen, phosphorus, and potassium) availability because of the increase solubility of plant nutrients in the soil as a result of lowering the soil acidity, thus plant's uptake of these macro-nutrients will also increase.

RECOMMENDATIONS

It is recommended based on the study that:

1. Biochar is a potential liming material that can be use to reduce soil acidity for better macro-nutrient uptake by plaints.
2. Famers should be encouraged to use biochar for both soil acidity reduction and for nutrient enhancement.

REFERENCES

Agbede, O.O. (2009). *Understanding Soil and Plant Nutrition:* Salmon Press and Coy Keffi, Nigeria. Pp147-156

Glaser, B., Haumaier, L., Guggenberger, G., & Zech, W. (2001). The 'terra preta' phenomenon: A model for sustainable agriculture in the humid tropics. *Naturwissenschaften, 88,* 37-41. http://dx.doi.org/10.1007/ Soo1140000193

Glaser, B., Lehmann, J., & Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with bio-char: A review. *Biology and fertility of soils, 35,* 2 19-230. http://dx.doi.org/l0.l007/s00374- 002-0466-4.

Harper, W.S. (2001). Fundamentals of Soil Science. Recitation Problem Sets 2000. University of Vermount. Plant and Soil Science Department.

IBI (International Biochar Initiative). (2012). Recent research on biochar's potential in soils. International biochar initiative (IBI). Retrieved June, 2012, from www.biochar-international.org.

Lehmann, J., Rillig, M. **C.,** Thies, J.. Masiello, C. A., Hockaday, W. C., & Crowley, D. (2011). Biochar effects on soil biota: A review. *Journal Soil biology and soil chernistiy, 43,* 1812-1836.

Lehmann, J., & Joseph, S. (Eds.). (2009). Biochar for environmental management: science and technology. Earthscan. London & Sterling, VA.pp45-67

Mahadi, M. A., (2014) Growth, Nutrient uptake and Yield of maize (zea mays 1.) as influenced by Weed control and Poultry manure. *International journal of science and nature,* 5 : 1 : 94-102

Major, J., Rondon, M., Molina, D., Riha, S. J., & Lehmann, J. (2010). Maize yield and nutrition during 4 years after biochar application to a Colombian Savanna oxisol. *Plant and soil,* 333*,* 117-128. http://dx.doi.org/l0.l007/sl1104- 010-0327-0.

Mamo, M., Wortmann, C. & Shapiro, C. (2009). Lime Use for Soil Acidity Managements. NebGuide G1504. University of Nebraska Extension, Lincoln, NE.

Ndor, E.; Amana, S. M. & Asadu, C. L. A. (2015). Effect of Biochar on Soil Properties and Organic Carbon Sink in Degraded Soil of Southern Guinea Savanna Zone, Nigeria. *International Journal of Plant & Soil Science* 4(3): 252-258

NIMET (2015) Nigerian Meteorological Agency; Laf a Station

Novak, J.M., Busscher ,W.J., Laird, D.L., Ahmedna, M., Watts, D.W, & Niandou, M.A.S. (2009). Impact of Biochar Amendment on Fertility of a Southeastern Coastal Plain Soil. *Soil Science.* 174:105-112.

Opala, P. A. (2011). Comparative effects of lime and organic materials on selected soil chemical properties and nutrient uptake by maize in an acid soil. *Archives of Applied Science Research,* 3 (1):96-107

Sohi, S., Lopez-Capel, E., Krull, E. S. & Bol, R. (2009). Biochar, climate change and soil: A review to guide future research. *CSIRO Land and Water Science Report* 05/09.

Tang, C. & Yu, Q. (1999). Impact of chemical composition of legume residues and initial soil pH on pH change of a soil after residue incorporation. *Plant and Soil,* 215: 29-38.

Van Zwieten, L., Kimber, S., Morris, S., Chan, K.Y.. Downie, A., Rust, J., Joseph. S., & Cowie, A. (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant and Soil* 327: 23 5—246.

Yuan, J. Xu, R. Qian. W. & Wang. R. (20lla). Comparison of the ameliorating effects on an acidic ultisol between four crop straws and their biochars. *Journal of Soil. Sediment,* 11: 741—750.

Yuan. J., Xu, R., Wang, N. & Li, J. (2011b). Amendment of acid soils with crop residues and biochars. *Pedosphere,* 21: 302—308.

Yuan, J., Xu. R. & Zhang, H. (2011c). The forms of alkalis in the biochar produced from crop residues at different temperatures. *Biores. Technol.,* 102 :3488—3497.