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Research Paper

Effects of Rice Bran Ash in Ameliorating Acidity in the Soils of Southeastern Nigeria under Upland Rice

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A field experiment was conducted at the National Cereals Research Institute Amakama to evaluate rice bran ash in ameliorating acidity in highly weathered and leached soils of Southeastern Nigeria. This study investigated the effectiveness of rice bran ash which is a waste product of rice mills in ameliorating acid soils in upland rice. Treatments included control, 2, 3, and 4 t h^{-1} of rice bran ash. The results indicated that there was a significant increase in the soil pH, Ca, Mg and ECEC. However, there was a decrease in exchangeable acidity. Similarly, there was also a significant increase in plant height, tiller count and grain yield of the upland rice when compared with control. This indicates that rice bran ash material is a potential alternative for the resource poor small scale farmers.

Keywords: Rice bran ash, Acid soils, Upland rice.

INTRODUCTION

Growing rice in acidic soils (pH less than 4.0) commonly encounters relatively severe mineral stresses. The H^+ associated with soil acidity has indirect effects on mineral elements in low pH soils so that deficiencies of P, Ca, Mg, K, and Zn and toxicities of Al and Mn commonly appear (Clark *et al*., 1999). Among the deficiencies and toxicities that plants may encounter when grown in acidic soils is aluminum toxicity which is considered to be a major disorder (Foy, 1992). Aluminum is highly soluble at low pH and is toxic to plants at low concentrations. It also interacts with other mineral nutrients essential to plant growth, especially P, Ca, and Mg, so that these essential nutrients often become more limiting. The surplus of Al causes damage to the root growth and development (Foy,1992) as well as Fe oxides which are prevalent in acidic soils (Manning and Goldberg, 1996) where they adsorb P and make it available to the plants. Poor fertility of acid soils is due to a combination of mineral toxicities (aluminum and manganese) and deficiencies (P, Ca, Mg, and Mo).

A liming material is defined as a material whose Ca and Mg compounds are capable of neutralising soil acidity (Barber and Adams, 1984). The bulk of agricultural lime comes from ground limestone and can be calcite ($CaCO_3$), dolomite ($CaCO_3$, $MgCO_3$), or a mixture of the two. Other materials used to neutralise soil acidity include marl, slag from iron and steel making, flue dust from cement plants, and refuse from sugar beet factories, paper mills, wood ash, calcium carbide plants, rock wool plants, and water softening plants (Thomas and Hargrove, 1984). However, total use of these materials is relatively small, and they are generally applied only in areas close to their source. The application of lime to acid soils can affect biological, chemical, and physical properties of the soils. The increase in soil pH resulting from the application of lime provides a more favourable environment for soil microbiological activity which increases the rate of release of plant nutrients, particularly Nitrogen (N).

Reduced soil acidity following liming also increases the availability of several other plant nutrients, notably P (Attanandana et al., 1981). Only about 20% of fertilizer phosphorus is taken up by a crop in the application year (Attanandana et al., 1981). The remainder is fixed in the soil in various degrees of availability to succeeding crops. On acid soils (pH less 6.0) the fixed phosphorus is retained in less available forms than on slightly acid and neutral soils (pH 6.1 to 7.5). Therefore one of the benefits of liming acid soils is the increased utilization of residual fertilizer P by crops.

The application of lime can also improve the physical properties of some soils, reduce soil crusting, improve emergence of small seeded crops such as canola, and reduce power requirements for tillage. Studies using pot experiments have shown that liming is the simplest way of increasing the soil pH of the soil (Attanandana et al., 1981).

Attanandana and Vacharotayan, (1986), reported that the beneficial effects of leaching and liming on the rice yield on two flooded acid sulphate soils. Another advantage of using liming suggested by Attanandana and Vacharotayan (1986), showed the availability of most plant nutrients, in which, P, K, Ca, and Mg increased while Na, S, Al, Fe in the plant decreased due to liming. Annual yields of barley in a trial increased by 0.67t/ha when 2 tonnes per hectare of lime was applied to raise the soil pH from 5.3 to 6.5. This yield increase was based on 19 years of data (Attanandana and Vacharotayan 1986).

The yield on the limed treatment continued to be higher than on the control treatment which suggests lime addition increases the pH, reduces soil crusting and improves soil aeration. The objective of this study is to evaluate rice bran ash in ameliorating soil acidity.

MATERIALS AND METHODS

Site description

The experiment was conducted at the National Cereals Research Institute Amakama experimental farm (Lat 05° 28N Long 07°29 E and Alt. 154 .25 m) during the growing seasons of 2015 and 2016. The annual average rainfall was 2672.30 mm and the mean annual minimum and maximum temperature of 20°C and 35°C respectively. The soil is typical to those used by farmers in the Southeastern Nigeria and the texture is sandy loam in the tropical rainforest zone (Igwe et al.,1995). Its limiting factors are principally P deficiency, Al and Mn toxicities. The soil is highly weathered and leached (Igwe et al.,1995). Table 1 shows the characteristics of the used soil.

Soil sampling and analysis

Soil samples were collected from the surface (0–15cm) using an auger. The soil was collected randomly from within the experimental plots. Samples were thoroughly mixed, air-dried and passed through a 2 mm sieve. The distribution of particle sizes in the soil was determined by the pipette method (Day, 1965). Organic carbon was determined using the Walkley-Black wet oxidation procedure (Allison, 1965). Total N was determined by Kjeldahl digestion method as described by Bremmer, (1965). Soil pH was determined using a glass–calomel electrode in a 1:2.5 soil:1 M KCl suspension. Ca, Mg and exchangeable acidity (Al, H) were extracted by 1M KCl solution, using a soil to solution ratio of 1:10. Ca and Mg were determined by atomic absorption and Al, H by titration to the phenolphthalein end point with 0.005 M NaOH (Farina and Channon, 1991) .P, K, Zn and Mn were extracted with Ambic-2 solution containing 0.25 MNH4CO3, 0.01 M EDTA, 0.01 M NH4F and 0.05 g Superfloc (N100), adjusted to pH 8. This solution is the standard extractant used for P and K. It has been shown to remove quantities of K comparable to those removed by neutral normal NH4OAc in highly weathered soils (Farina, 1981).

Phosphorus was determined on a 2 ml aliquot of filtrate using a modification of the Murphy and Riley molybdenum blue procedure (Farina, 1981). K was determined by atomic absorption on a 5-ml aliquot of the filtrate after dilution with 20-ml deionized water, while Zn and Mn were determined also by atomic absorption but on the remaining undiluted filtrate. Effective CEC (ECEC) was calculated as the sum of KCl-extractable Ca, Mg, acidity and Ambic-2 extractable K. Acid saturation was calculated by dividing the exchangeable acidity with the sum of the exchangeable bases (Ca, Mg, K, Na) plus exchangeable acidity.

Material for soil amendment

The material for soil amendment representing resource that is readily available to small-scale farmers was used viz: rice bran ash.

$CaCO_3$ equivalence of amendment

The $CaCO_3$ equivalence of the of rice bran ash was determined by a titrimetric method of Erich and Ohno (1992). Briefly 0.5–1 g of material was ashed in 50 ml HCl. Excess acid was titrated with NaOH using phenolphthalein as an indicator. The percent $CaCO_3$ equivalence of the materials was calculated as % $CaCO_3$ equivalence = 2.5 (ml HCl – ml NaOH) /2

Experimental treatments and design

The experiment was laid out in a randomized complete

Table 1. Physical and chemical properties of the used soil before planting.

Property	Value
Particle size (g kg^{-1})	-
Sand	814
Silt	38
Clay	14.8
Textural class	Sandy loam
Total N (g kg^{-1})	1.40
Organic C (g kg^{-1})	20.6
P (mg l^{-1})	3.60
Exchangeable bases (cmol kg^{-1})	
K	0.07
Ca	1.65
Mg	0.88
Na	0.09
Exchangeable acidity(cmol kg^{-1})	1.40
Base saturation (%)	38
pH	4.5
CEC	6.29

Table 2. Chemical composition of rice bran ash.

Element	%
Total N	0.96
P	0.60
K	0.50
Ca	6.20
Mg	1.25
Na	0.06
pH(H_2O)	9.85
$CaCO_3$ Equivalence	15.45

Table 3. Effect of rice bran ash on chemical properties of the soil at harvest.

Treatment	pH	Exchangeable acidity (cmolkg^{-1})	ECEC (cmol kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
Control	4.50^{c}	2.58^{a}	3.60^{c}	105^{c}	30^{b}
2t/ha	4.65^{b}	2.05^{b}	4.00^{b}	250^{b}	50^{b}
3t/ha	4.80^{a}	1.05^{c}	4.70^{a}	431^{a}	71^{a}
4t/ha	4.85^{a}	1.05^{c}	4.75^{a}	432^{a}	72^{a}
SE	0.5	1.2	1.5	0.8	0.5
CV (%)	1.5	2.5	1.2	3.0	3.5

block design (RCBD) with 3 replications Experimental treatments consisted of one amendment (rice bran ash) and different rates of application. The different rates of application were: 2, 3, 4 and 0t ha^{-1} (control) Data were subjected to analysis of Variance (ANOVA) using SAS statistical package.

RESULTS AND DISCUSSION

Table 2 shows the chemical composition of rice bran ash used in ameliorating the acid soil. The analysis showed that the material used as amendment had a high content of Ca and Mg and the pH were alkaline and the % of $CaCO_3$ equivalence was also high. This makes the material for soil amendment good for resource poor farmers in the absence of agricultural lime which is expensive (Materechera and Mkhabela, 2002).

The analysis showed that increasing the application of rice bran ash as soil amendment increased the pH and reduced the acid saturation and the exchangeable acidity of the soil (Table 3). The rice bran ash amendment significantly increased the concentration Ca and Mg compared to the control. The efficiency of the rice bran ash amendment to ameliorate acidity and increase soil exchangeable cations were made by comparing the

Table 4.Effect of rice bran ash on the yield and yield components of upland rice.

Treatments	Plant height (cm)	Tiller number 5 hills	Grain yield (t/ha)
0t/ha	68^{c}	10^{c}	0.98^{c}
2t/ha	78^{b}	14^{b}	2.00^{b}
3t/ha	1.0^{a}	20^{a}	3.10^{a}
4t/ha	9.8^{a}	20^{a}	2.98^{a}
SE	1.5	2.0	1.3
CV (%)	5.8	9.3	2.5

magnitude of change in the soil properties. Application of rice bran ash increased soil pH by 7 %. Exchangeable acidity was reduced by 59%. The efficiency of the rice bran ash to raise soil pH to 0.35, while that of exchangeable acidity was 0.53. These indicate that rice bran ash was efficient in raising soil pH, compared to the control in reducing the exchangeable acidity of the soil. This may imply that exchangeable acidity of the soil which in most mineral soils is comprised almost entirely of exchangeable aluminum being neutralized by the alkalinity of the ash.

Although the mechanism by which this amendment ameliorates acidity may be controversial, it may likely be the cumulative result of several mechanisms. The main mechanism by which ash raised the soil pH acid is likely to be cumulative results associated with the high alkalinity and content of the basic cations (Ca, K, Mg, and Na), When these cations were released from the amendment the cation content and ionic strength of the soil solution would greatly be increased as would the exchangeable cation concentrations. Soil salinity induced by a heavy application had been attributed to the high concentration in soil solution (Sims and Wolf, 1994). The high cation concentration in soil solution could also explain the increase in ECEC of the ash amended soils compare with the control (Table 3).

Vance (1996) had observed that wood ash materials consisted of highly reactive fractions (oxides and hydroxides) and more slowly reactive fractions (carbonates) that are responsible for neutralizing acidity in the soil. This characteristic has made wood ash as an excellent amendment material for increasing pH and reducing Al and Mn of acid soils (Demeyer et al., 2001; Ohno and Erich, 1990; Lerner and Utzinger, 1986). However, Clapham and Zibiske (1992) had shown that the oxides, hydroxides and carbonates in the ash are very soluble and thus react quickly than calcite. They explained that; because of the high solubility the high increase in pH which does not persist for a long time in the soil but lasts for a relatively short period. The alkalinity of ash from the material provides an estimate of the organic anion content of the material (Slattery et al., 1991). As the organic amendment is decomposed organic anions are decarboxylated which causes both proton consumption and release of Co_2 (Yan et al., 1996).

However, rice bran ash would not only reflect organic acid anion but it also indicates that use of such material is a poor resource alternative for resource poor small scale farmers who cannot afford lime due to its high cost.

Grain yield and yield components of the upland rice were also affected by the applied treatments. All applied treatments significantly increased plant height, tiller numbers and grain yield compared with the control (Table 4). There was no significant difference in the application of the amendment at 3t ha^{-1} and 4t ha^{-1}. This shows that application of 3t ha^{-1} satisfies the requirement of the soil at the study site.

Conclusion

The conducted research has shown that rice bran ash can be effective in ameliorating acidity of highly weathered acid soils of the Southeast. The alkalinity of the amendment is presumed to be the major mechanism of ameliorating acidity. This finding is of particular interest because it indicates that the use of such material is a potential poor resource alternative for small scale farmers who cannot afford agricultural lime due to its high cost. It should be noted that liming alone is not adequate soil management technology for ameliorating acid soils. A mixture of management options such as judicious use of fertilizer, and selection of crops tolerant to acidity should also be evaluated.

REFERENCES

Allison LE (1965). Organic carbon. In: Black CA, Evans DD, White JL, Ensminger LE, Clark FE (Eds.), Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. Am. Soc. Agron. Madison, WI, Pp. 1367–1378.

Attanandana T, Vacharotayan S (1986). Acid sulphate soils. There characteristics, genesis, amelioration and utilization. Southeast Asian Studies 24(2):154-180.

Attanandana T, Demeyer A, Nkana JVC (1981). Characteristics of wood Ash and influence on soil properties and nutrien uptake. Biosource Tech 77: 287-297.

Barber SA, Adams F(1984). Liming materials and practices. Agronomy (EUA).

Bremmer JM(1965). Total N In: Black , C.A. et al (Eds) Method of soil analysis. Agron. Vol. 9. American Society of Agronomy. Madison WI. Pp. 1149-1178.

Clark RB, Zobel RW, Zeto SK (1999). Effects of mycorrhizal fungus isolates on mineral acquisition by Panicum virgatum in acidic soil. *Mycorrhiza, 9*(3):167-176.

Clapham WM, Zibilske LM (1992). Wood ash as a liming amendment. Commun. Soil Sci. Plant Anal. 23:1209–1227.

Day PR (1965). Particle fractionation and particle-size analysis. In: Black, Evans CA, White DD, Ensminger JL, Clark FE (Eds.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. Am Soc Agron, Madison, WI, Pp. 545–567.

Demeyer A, Nkana JCV, Verloo MG (2001). Characteristics of wood ash and influence on soil properties and nutrient uptake: an overview. Bioresource Technol. 77:287–295.

Erich MS, Ohno T(1992). Titrimetric determination of calcium carbonate equivalence of wood ash.Analyst 117:993–995.

Farina MPW (1981). The Hunter system of soil analysis. Fert. Soc.South Africa J. 1:39–41.

Farina MPW, Channon PA (1991). Field comparison of lime requirement indices for maize. Plant Soil. 134, 127–135.

Foy CD (1992). Soil chemical factors limiting plant root growth. *Advances in soil sciences (USA)*19:87-149.

Igwe CA, Akamigbo FOR, Mbagwu JSC (1995). Physical properties of soils in the Southeastern Nigeria. Soil science 160(6):114-120.

Lerner BR, Utzinger JD (1986). Wood ash as soil liming material. Hortscience 21:76–78.

Manning BA, Goldberg S (1996). Modelling competitive adsorption of arsenate with phosphate and molybdate on oxide minerals. Soil Science Society of America Journal, 60(1):121-121.

Materechera SA, Mkhabela TS (2002). The effectiveness of lime, chicken manure, and leaf litter ash in ameliorating acidity in a soil previously under black wattle plantation. Biosource Technology 85: 9-16.

Ohno T, Erich MS(1990). Effect of wood ash application on soil pH and soil test nutrient levels.Agric. Ecosystem Environ. 32:223–239.

Sims JT, Wolf DC (1994). Poultry waste management: agricultural and environmental issues. Adv.Agron. 52:1–83.

Slattery WJ, Ridley AM, Windsor SM (1991). Ash alkalinity of animal and plant products. Aust. J. Exp. Agric. 31:321–324.

Vance ED (1996). Land application of wood-fired and combination boiler ashes: an overview. J. Environ. Qual. 25, 937–944.

Yan F, Schubert S, Mengel K (1996). Soil pH increase due to biological decarboxylation of organic acids. Soil Biol. Biochem. 28:617–623.