Research Application Summary

Improving soil properties through use of unburnt local limes in acidic soils of Burera district, Rwanda

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Abstract

This study was carried out at Rwerere Research Station located in the highlands of Buberuka, Rwanda. Three local limes (Musanze, Rusizi and Karongi) were evaluated in a randomized complete block design (RCBD)) experiment established in September 2011 rainy season. Baseline information was established on soil properties and quality (CCE, Fineness factor, ECCE, Acidity and moisture) of lime materials. Soil pH, exchangeable Al and available phosphorus were monitored at 6, 12 and 16 weeks after lime application (WAP). However, nitrogen and base saturation were analysed at 16 WAP. Finding showed that application of 2.8t ha^{-1} of Musanze unburnt local lime and agricultural burnt lime had a similar effect on soil pH. They increased soil pH by 0.62 and 0.61 units, respectively. A lime application rate of 2.8t ha^{-1} of agricultural burnt lime, Musanze and Rusizi unburned local limes increased soil available phosphorus by 1.72, 1.71 and 1.65 mg/kg, respectively. On the other hand, agricultural burnt lime and Musanze unburnt local lime had a similar effect on Ca saturation. The application of 1.4 and 2.8t ha^{-1} of agricultural burned lime and Musanze unburnt local lime increased soil nitrogen by 0.12 and 0.24% of total nitrogen, respectively.

Key word: Available phosphorus, cation saturation, exchangeable Al, lime quality, soil pH, total nitrogen

Résumé

Cette étude a été réalisée à la station de recherche de Rwerere, située dans les montagnes de Buberuka, au Rwanda. Trois variétés de chaux locales (de Musanze, Rusizi et Karongi) ont été évaluées dans une expérience de conception en blocs complets aléatoire (RCBD) établie lors de la saison des pluies de Septembre 2011. L'information de base a été établie sur les propriétés et la qualité du sol (CCE, facteur de finesse, ECCE, acidité et humidité) de matériaux en chaux. Le pH du sol, l'Al échangeable et le phosphore disponible ont été suivis à 6, 12 et 16 semaines après l'application de la chaux (WAP). Cependant, l'azote et la saturation en bases ont été analysés à 16 semaines après l'application de la chaux. Les résultats ont montré que l'application de 2,8 t ha-1 de la chaux locale non calcinée de Musanze et celle de la chaux vive agricole ont eu un effet similaire sur le pH du sol. Elles ont augmenté le pH du sol de 0,62 et 0,61 unités, respectivement. Un taux d'épandage de la chaux de 2,8 t ha-1 de la chaux vive agricole, des chaux locales non calcinées de Musanze et de Rusizi a augmenté le phosphore disponible dans le sol de 1,72, 1,71 et 1,65 mg / kg, respectivement. Par contre, la chaux vive agricole et la chaux locale non calcinée de Musanze ont eu un effet similaire sur la saturation en Ca. L'épandage de 1,4 et 2,8 t ha-1 de la chaux vive agricole et de la chaux non calcinée de Musanze ont augmenté l'azote du sol de 0,12 et 0,24% de l'azote total, respectivement.

Mots clés: Phosphore disponible, saturation en cations, Al échangeable, qualité de la chaux, pH du sol, azote total

Background

Agriculture is the most important sector of the Rwandan economy, supporting 82% of the population (NISR, 2009) and contributing about 36% of GDP (World Bank, 2011). However, soil erosion, soil nutrient depletion and soil acidity with associated Al toxicities are the main soil related constraints to agricultural production (Van Straaten, 2002). It is estimated that acid soils comprise two-thirds of the cultivated soils of Rwanda, with about half of these experiencing serious problems due to aluminium induced low pH (Crawford *et al.*, 2008). It is estimated that acidic soils in Rwanda occupy approximately 45% of the total arable land, much of this with acidic soils with pH less than 5.5 (Beernaert, 1999).

Literature Summary

In highly acidic soils, nutrients availability, such as, nitrogen, phosphorus and potassium is generally reduced (Fageria and Baligar, 2008). Phosphorus is particularly sensitive to decreasing soil pH and can become a limiting nutrient in strongly acidic soils.Soil acidity also limits soil fertility through other nutrient deficiencies (P, Ca and Mg) and the presence of phytotoxic nutrients such as soluble Al and Mn (Awad *et al*., 1976). Thus, reduced crop performance as a result of high soil acidity has been reported in many studies (McFarland *at al.*, 2005; Fageria and Baligar, 2008; Ruganzu, 2009). Liming is one of the options of addressing low soil acidity because it improves nutrient availability and enhances overall microclimate of root system (Fageria and Baligar, 2008). In a study by Fageria and Stone (2004) in Brazil, liming was reported to raise soil pH, Ca and

Mg uptake and also reduced aluminium concentration. The application of lime also increase phosphorus uptake (Ruganzu, 2009; Black, 1992).

Study Description

This study was carried out in Burera District in the Northern Province of Rwanda. The average altitude of the district is 2100 meters above sea level; the relief is characterized by steeply sloping hills connected either by steep sided valleys or by flooded marshes. Annual rainfall ranges from 1400 to 1800 mm while the annual average minimum and maximum temperatures are 9°C and 25°C, respectively. Farming is done continuously on hills and mountains. Experimental soil was highly acidic with pH_W of 4.8 and exchangeable Al^{+3} of 2.8cmol kg^{-1}; ECEC of 4.8cmol kg^{-1} and 42.5% base saturation. Soil organic matter was 2.2%, while nitrogen and phosphorus were 0.11% and 3.63mg kg^{-1}, respectively. According to USDA texture triangle, soil texture was classified as loamy sand.

Limes quality (CCE, pH, Fineness, ECCE) were analyzed. The CCE (%) was calculated using the formula CCE (%) = (Ca+ Mg) x 2.5 (Hesse, 1971). The pH was determined using a pH meter at a 1:2.5 lime: water/KCl ratio (Page *et al.*, 1982). Fineness factor was determined by mechanically sieving the lime through a stack of 4 sieves of various sizes (2, 1, 0.5 and 0.2 mm) resulting in 5 classes of lime. The particles obtained were multiplied by an efficiency factor of 0, 0.5 and 1 as described by Halvin *et al.* (2005). The ECCE was determined following equation 1.

$$\mathrm{ECCE}\ (\%) = \frac{\mathrm{CCE} * \mathrm{Fineness\ factor}}{100}$$ (Peter *et al.*, 2006) .... (1)

The experimental design was a randomized complete block (RCBD) with 13 treatments replicated thrice and randomized within blocks. The treatments comprised of three local limes from different districts (Musanze, Rusizi and Karongi) applied at three levels: 1.4, 2.8 and 4.2t ha^{-1}. Agricultural lime was included as a reference and a control with no lime application was also included in the trials. Soil sampling was carried out at the start of the experiment, 6 weeks after lime application (WAP), 12WAP and after harvest (16 WAP). Composite soil samples from 0 – 20 cm depth were collected following the zigzag method (Carter and Gregorich, 2008). Soil pH was determined using a pH meter in a soil-water (1:2.5) suspension (Page *et al.*, 1982). Available P was determined using the Bray and Kurtz P-II method (Bray and Kurtz, 1945). Total N was determined by the Kjeldahl method (Page *et al*., 1982). All exchangeable cations including base cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) was determined by the atomic absorption spectrophotometer for Ca and Mg and flame photometer for K and Na (IITA, 1979).

Analysis of variance (ANOVA) for the data was done using GenStat 14th edition. Means separation was performed using Turkey's test at a 0.05 level of significance.

Research Application

The quality of limes was significantly different (Table 1). Agricultural burnt lime had a significantly higher pH compared to the three unburnt limes. The CCE (%) of the unburnt lime was also higher than the rest. The other lime quality parameters, i.e., fineness, ECCE (%), moisture (%), soluble $CaCO_3$ were significantly higher for burnt lime (Table 1). Musanze and Rusizi unburnt limes had similar effects on soil properties with local limes improving the total soil properties (Table 2).This study recommends local limes especially Musanze and Rusizi limes to replace the expensive burnt lime.

Table1. Summary of limes quality (CCE, ECCE, Fineness, pH, Moisture and soluble $CaCO_3$) from different mines in Rwanda.

Limes sources	Acidity (pH)	CCE (%)	Fineness (%)	ECCE (%)	Moisture (%)	$CaCO_3$ soluble
Agricultural burnt lime	12.45a	86.667a	70.567a	61.170a	32.498a	25.13a
Musanze unburnt local lime	8.72b	66.667c	63.033ab	47.810b	23.505ab	0.26b
Karongi unburnt local lime	7.92b	73.333ba	55.633b	41.847b	14.486b	0.10b
Rusizi unburnt local lime	8.33b	86.000a	56.900b	41.880b	18.466ab	0.33b
LSD	0.98	17.926	9.1318	9.1318	14.672	2.66
pValue	<0.001	0.018	0.0029	0.003	0.0214	<.0001

LSD = Least significant differences of means (5% level).
Means with the same letter in the same column are not significantly different.

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References

Awad, A.S., Edwards, D.G. and Milhan, P.J. 1976. Effect of pH on soluble soil aluminium and on growth and composition of Kikuyu grass. *Journal of Plant and Soil Sciences* 45: 531-542.

Table 2. Effect of different unburnt Rwanda limes on selected soil properties.

Treatments	pH			Exchangeable Al(cmol kg^{-1})			Available P (mg kg^{-1})			BS (%)	Ca (%)	N (%)
	6 W	12 W	16 W	6 W	12 W	16 W	6 W	12W	16W	16 W	16 W	16 W
Controls (0 t ha^{-1})	-0.03	-0.04	-0.03	-0.01	0.04	0.04	-0.03	-0.2	-0.24	0.54	27.98	0.01
Agricultural lime 1.4t ha^{-1}	0.1	0.25	0.44	-0.63	-1.85	-2.16	0.57	1.42	1.58	41.49	64.11	0.12
Agricultural lime 2.8t ha^{-1}	0.07	0.41	0.62	-0.62	-1.96	-2.39	0.49	1.59	1.73	49.49	62.6	0.24
Agricultural lime 4.2t ha^{-1}	0.15	0.61	0.84	-0.81	-2.22	-2.67	0.94	1.68	2.12	55.35	75.09	0.21
Karongi lime 1.4t ha^{-1}	-0.02	0.03	0.08	-0.46	-0.54	-1.08	0.04	0.27	0.34	27.39	35.04	0.02
Karongi lime 2.8t ha^{-1}	-0.02	0.05	0.14	-0.54	-0.49	-0.95	0.19	0.28	0.51	27.71	30.12	0.03
Karongi lime 4.2t ha^{-1}	-0.02	0.15	0.26	-0.42	-0.89	-1.6	0.15	0.74	0.81	37.26	34.21	0.06
Musanze lime 1.4t ha^{-1}	0.04	0.21	0.43	-0.54	-0.99	-2.07	0.42	0.77	1.12	39.74	59.94	0.18
Musanze lime 2.8t ha^{-1}	0.15	0.47	0.62	-0.76	-2.13	-2.42	1.16	1.55	1.71	48.94	68.34	0.21
Musanze lime 4.2t ha^{-1}	0.09	0.55	0.72	-0.69	-2.17	-2.52	0.42	1.62	1.85	51.62	69.31	0.18
Rusizi lime 1.4t ha^{-1}	0.01	0.27	0.17	-0.52	-1.18	-0.89	0.23	0.81	0.52	17.11	41.24	0.07
Rusizi lime 2.8t ha^{-1}	0.13	0.38	0.55	-0.75	-1.91	-2.36	0.94	1.49	1.65	46.97	64.84	0.14
Rusizi lime 4.2t ha^{-1}	0.18	0.62	0.86	-0.81	-2.32	-2.64	1.08	1.68	1.98	54.56	71.81	0.09
p value	0.897	0.326	0.004	<.001	<.001	<.001	0.67	<.001	<.001	0.001	<0.001	0.441
LSD	0.202	0.267	0.212	0.412	1.259	1	0.96	1.06	0.87	8.4	11.552	0.14

LSD= Least significant differences of means (5% level). W: Weeks after lime application. -: reduction.

Beernaert, F. 1999. Feasibility study of production of lime and or ground travertine for management of acidic soils in Rwanda. Brussels: Pro-Inter Project Consultants.

Black, A. 1992. *Soil Fertility Evaluation and Control*. London: Lewis Publisher.

Carter, M.R and Gregorich, E.G. 2008. Soil sampling and methods of analysis (2 Ed.). Taylor and Francis group.

Crawford, T.W., Singh, U. and Breman, H. 2008. Solving agricultural problems related to soil acidity in central Africa's great lakes region. Alabama: International Center for Soil Fertility and Agriculture Development.

Fageria, N.K and Stone, L.F. 2004. Yield of common bean in no-tillage system with application of lime and zinc. *Pesq. Agropec. Braas*. pp. 73-78.

Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L. 2005. Soil fertility and fertilizers: An introduction to nutrient managemnt (7 Ed.). New Jersey: Pearson prentice hall.

Hesse, J. 1971. A textbook of soil chemical analysis. London: John Murray.

IITA. 1979. Selected methods for soil and plant analysis. Ibadan, Nigeria: IITA Manual Services.

McFarland, M.L. 2001. Managing soil acidity. Texas: Texas agricultural experiment station.

NISR. 2009. National census. Kigali, Rwanda: National Statistical office of Rwanda.

Page, J. R., Miller, R.H., Keeney, D.R., Baker, D.E., Ellis, J.R. and Rhoades, J.D. 1982. Methods of soil analysis. II Chemical and microbiology properties (2 Ed.). Wisconsin, USA: Madison.

Peter, C., Quiline, K. and Hunter, M. 2006. Liming materials. USA: Nutrients Managements Spear program, Cornell University.

Ruganzu, V. 2009. Potential of improvement of acid soils fertility by incorporation of natural fresh plant biomass combined with travertine in Rwanda. Gembloux, Belgique: Agricultural University.

Soil Survey Division Staff. 1993. Soil survey manual. US Dept. of agriculture handbook. Washington, DC: US Govert. printing office.

Van Straaten, P. 2002. Rocks for crops: Agrominerals of sub-saharan Africa. Nairobi, Kenya: ICRAF.

World Bank. 2011. Rwanda economy update, Seeds for higher growth. Kigali, Rwanda: World Bank.