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Liming leads to high bean and maize yield on a strongly acid tea soil

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Abstract

Acid soils are very common in tea zones. These soils have a pH below 5.0. Below this pH, not only do the soils exhibit toxicity of aluminum and manganese but are deficient of calcium, magnesium, phosphorus and molybdenum, hence becoming chemically infertile. Liming is one cheap way of reclaiming these soils. The staple food crops in these tea soils are maize and beans. However the effect of different liming levels on bean (*Phaseolus vulgaris* L.) and maize (*Zea maiys,* L.) yield on acid tea-growing *ando-humic Nitisol* had not before been investigated. A study was therefore conducted to determine the crop response to liming and the appropriate liming level for maize and bean crops in a tea zone soils. The experiment was carried out in Embu County, Kavutiri and Kianjokoma areas, Agro-Ecological Zone (AEZ) UM1. A randomized complete block design with four replications of each lime treatment was used at each site. Lime at rates of 0 (L0), 2.4 (L1), 6 (L2), 8 (L3) t/ha was broadcasted on to 4m x 4m plots and mixed into 0-15cm of soil. There was a significant response to liming for both maize and beans. The maximum maize and beans yield was attained at around liming level L2 (pH 5.5). Above this pH, yields started to decline. The study clearly shows the benefits of soil liming on strongly acid tea soils and also the importance of accurate lime applications.

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Introduction

Strongly acid soils are very common in tea zones (Njeru *et al.*, 2012). Soil is termed acidic when its pH goes below 5.5 (Sombroek, *et al.*,1984) . Below this pH value, the soil not only exhibits toxicity of aluminium (Al) and manganese (Mn) but also is likely to suffer deficiency of calcium (Ca), magnesium (Mg), phosphorus (P) and molybdenum (Mo), hence becoming infertile chemically (Von Uexküll and Mutert, 1995). Bean yield has been shown to reduce significantly as a result of this infertility (mugai *et al.*, 2008). The application of high-input soil management technologies like expensive mineral fertilizers to increase food crop yields may not be feasible due to the low income levels of the farmers. Therefore the best approach should be a moderate input technology, like soil liming, which does not attempt to eliminate the use of fertilizers but rather complements them and maximizes their efficiency. Appropriate liming of acid soils eliminates Al toxicity, leads to supply of Ca andmg, and mobilises the fixed soil P and Mo (Njeru *et al.*, 2012; Mugai, 2008). This leads to increased yields without even application of expensive mineral fertilizers or with low applications of phosphorus (P) and nitrogen (N) (Quaggio *et al.*, 1995).

On the other hand the effect of different liming levels on bean and maize yield on acid tea growing soil had not been investigated. It was therefore not possible to authoritatively recommend the lime level that could be applied in beans and maize crop in tea zones. The study was therefore conducted to determine the response and the appropriate liming level for maize and bean crops in a strongly acid tea zone soil.

Materials and methods

Experimental site

The experiment was carried out in Embu County of Kenya, specifically at Kavutiri and Kianjokoma sites, Agro-Ecological Zone (AEZ) UM1 (Sombroek *et al.*, 1984) and at elevations of 1772m and 1795m, and coordinates 00° 24' 57"S, 37° 29' 3"E ; 00° 24' 26", 37° 29' 03" respectively. The two sites have a mean annual rainfall of 1736mm with mean monthly maximum and minimum temperature ranges of 19.9-27.8 °C and 11.5-14.3°C respectively (Warren and Kihanda, 2001). The soil type at both sites is *ando-humic Nitisols* (FAO-Unesco, 1988; FAO 2015) or *orthoxic Palehumult* (Soil Survey Staff-USDA, 1999). The soils have a topsoil Al saturation of more than 75%. Kavutiri site had slopes of 0-1% while Kianjokoma had about 10%. Though clayey in texture, the soils have loamy physical characteristics due to high content of kaolinitic and hydrous oxides (Mugai *et al.*, 2008).

Soil sampling and analysis

Before liming, a composite soil sample was taken at each experimental site and analyzed for soil chemical properties. Soil pH was determined by a pH meter (EYELA model pH M2000) in water 1:2.5 and 0.01M $CaCl_2$ 1:2.5 (Hinga *et al*, 1980). Exchangeable cations were determined following extraction by unbuffered ammonium acetate at pH 7.0; K^+ and Na^+ by flame photometry, and Ca^{++} andmg^{++} by atomic absorption spectrometry (Perkin-Elmer model 403) (Hinga *et al.*,1980). Al was extracted by unbuffered 1N KCl and determined colourimetrically by aluminon buffered to pH 4.0 at maximum absorption of 525mµ (Chapman and Platt, 1961). The effective CEC (ECCE) was calculated by the sum of exchangeable cations and extractable Al. Organic carbon was determined by the Walkley–Black procedure (Hinga *et al.*,1980).

The soils in the area are clayey in USDA textural classification and with a bulk density of 0.8 (KSS, 2007). Though clayey in texture, it has loamy physical characteristics due to high content of kaolinitic and hydrous oxides (Mugai *et al.*, 2008; KSS, 2007).

Lime

The lime used was purchased from agro-shops with trade name *Dolmax*. It is manufactured by the Athi River Mining Company of Kenya. It has a neutralizing equivalence value of 87 (Mugai *et al.*, 2008).

Experimental design and treatments

A randomized complete block design with four replications of each treatment was used at each site. Lime (dolomite) at rates of 0 (L0), 2.4 (L1), 6 (L2), 8 (L3) t/ha was broadcasted on to 4m x 4m plots and mixed into 0-15cm of soil. The blocks and plots were separated by 3 metres and 2 metres respectively.

After 3 weeks of liming, three soil sub-samples from every replicate were collected by augering at 0-15cm depth after which a composite sample for every treatment was obtained at each site and pH measured as above described. At the same time, maize (Hybrid 625) and beans (Red Haricot, GLP585) were planted at spacing of 60 x75cm and 75 x 20cm respectively.

At planting, maize was fertilized at 5g diammonium phosphate per plant (20kg N/ha and 50kg P_2O_5/ha) and later side-dressed at 5g calcium ammonium nitrate per plant (20kg N/ha) in the fourth week. The plots were weeded twice in 3rd and 6th weeks.

The beans were harvested after 12 weeks and subsequently threshed before weighing. In the 14th week the height of the three tallest and three smallest maize stalks were measured and their ear length and circumference determined in tandem. The maize crop was harvested after eight months, threshed and dried to 13% moisture content and weighed for each plot.

Data analysis

Costat software 5.034 was used to conduct analysis of variance (ANOVA) and separation of means using LSD by Turkey's procedure.

Results and discussion

Soil chemical analysis and pH changes

The soils at Kianjokoma site were chemically poorer in respect to higher aluminium saturation, lower pH, lower CEC (sum of cations), and lower organic carbon (Table 1). This is mostly likely due to soil erosion because of the higher slope at Kianjokoma site.

Table 1. Chemical characteristics of the test soils (0-20cm) at Kavutiri and Kianjokoma experimental sites.

Experimertal site	FAO mapping unit	pH Stillwater (1:2.5)	pH Soil: 1N KCI (1:2.5)	EC (dS/m) Stillwater (1:2.5)	Exchangeable cations (CMOI (+)/Kg)					ECEC (CMOI (+)/Kg)	Base saturation %	AI saturation %	OC %
Kavutiri	Ango-humic Nitisol	4.4	4.1	0.06	0.06	0.17	0.9	0.6	5.04	6.77	9.99	74.4	3.61
Kianjokoma	Ango-humic Nitisol	4.3	4.0	0.07	0.03	0.13	0.27	0.26	7.4	8.09	8.5	91.5	3.36

ECEC- Effective cation exchange capacity

OC – organic carbon

Table 2. Maize stalk height, ear length and ear circumference in response to liming. Means in the same row that are followed by the same letter do not differ significantly as separated by LSD (p≤0.05).

Sites	Parameter	L0	L1	L2	L3	Blocks	Liming
Kavutiri	Stalk height (mm)	328c	733b	1265a	1128a	ns	***
	Ear length (cm)	16.9 c	26.2 b	32.6a	31.7a	*	***
	Δ%	-	55	94	88		
	Ear circumference (cm)	16.9 c	26.2 b	32.6a	31.7a	*	***
	Δ%	-	55	94	88	-	-
Kianjokoma	Stalk height (cm)	466c	881b	1783a	1761a	ns	***
	Δ%	-	89	283	278		
	Ear length (cm)	16.7c	25.6b	32.8a	32.7a	*	***
	Δ%	-	53	96.4	96		
	Ear circumference (cm)	9.5c	13.3b	17.9a	17.4a	ns	***

Soil liming increased the pH as expected as shown in Fig.1. Dolomite is a mineral that contains calcium and magnesium carbonates ($CaMg(CO_3)_2$, and when applied in the soil, it dissociates into its cations (Ca^{++}) and (Mg^{++}) and carbonate ions (CO_3) with the latter reacting with H^+ to raise the pH. There was a slight increase of pH in the control most likely due to the seasonal rains which temporarily flooded the soils causing some reduction of $Fe^{(III)}$ and $Mn^{(iv)}$ oxides. Liming to L2 (6 t lime/ha) and above realized a more than pH of 5.0, i.e above the pH 4-5 where the monomeric species of Al species that are most toxic occur.

Bean and maize yield

In both sites, yields of maize and beans were higher at Kavutiri than at Kianjokoma because of soil differences articulated above and in Fig.1. Both beans and maize was highly impacted by liming (Fig. 2). Bean yield increased with increase in lime (Fig.3). There were clear differences from control (L0) and limed plots (L1, L2 and L3). However, L3 did not show clear differences from L2 and L1.

There was indication that L3 did not increase yield any further from L2, and on the contrary it appeared to be lowering it. Correspondingly though, another study on flora and fauna response to equivalent lime level (L3) in the same area, shown similar trend (Njeru *et al.*, 2012).

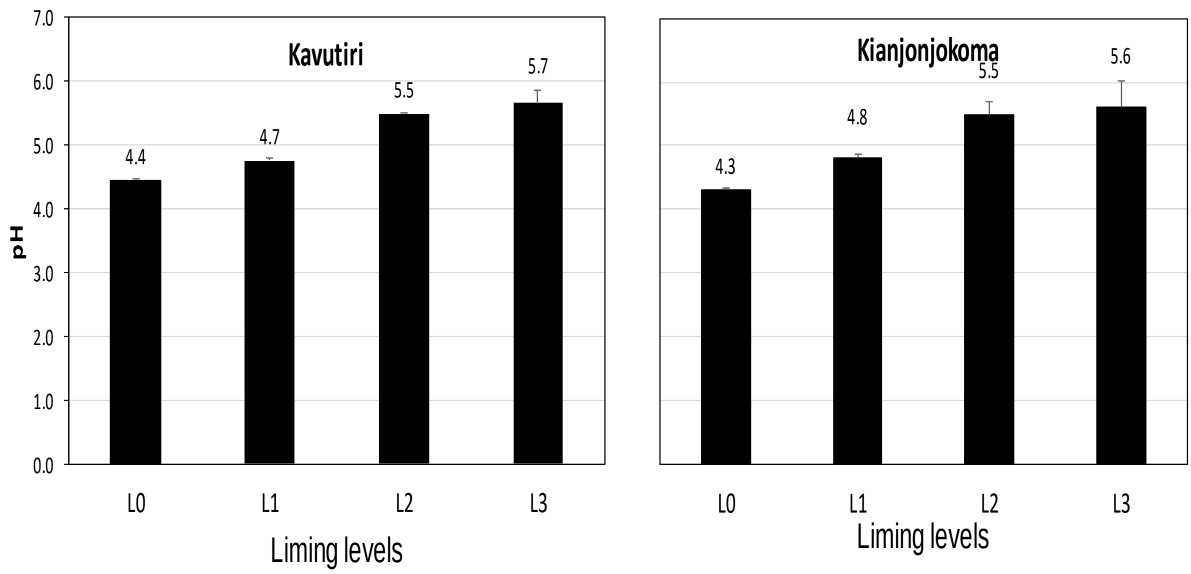

Fig. 1. Changes of soil pH after liming. Means in the bars followed by the same letter do not differ significantly as separated by LSD ($p \leq 0.05$).

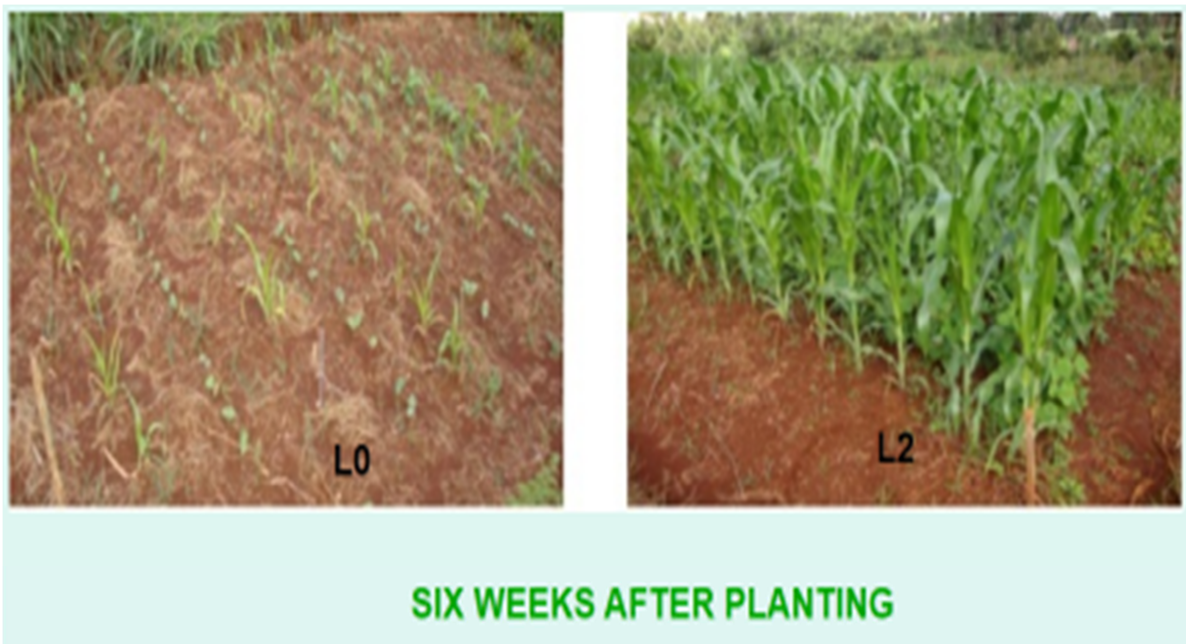

Fig. 2. The growth of maize without liming (L0) and with liming at L2 (pH 5.5) at Kavutiri site.

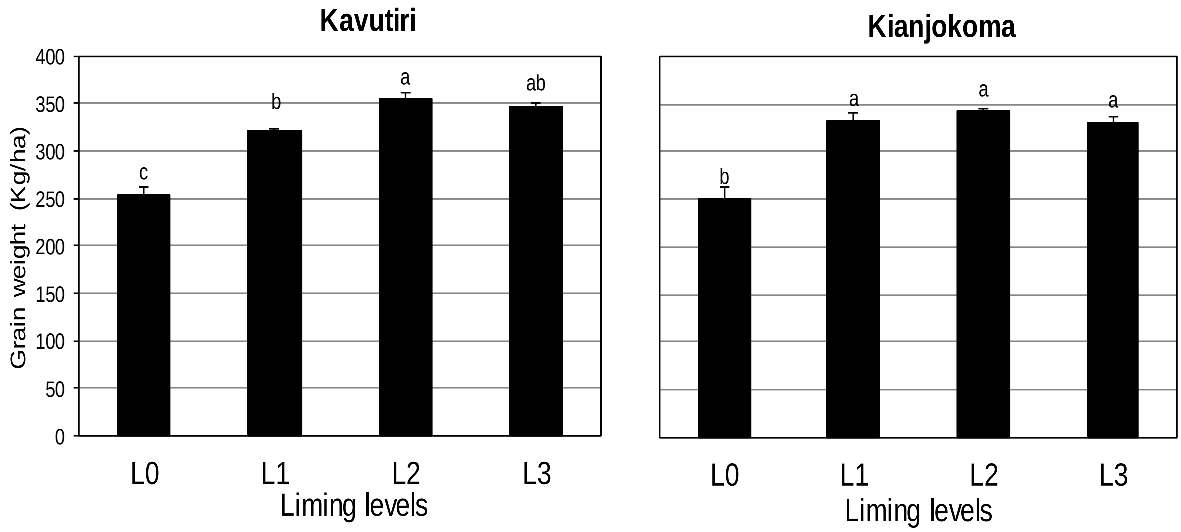

Fig. 3. The effect of liming on bean yield. Means in the bars followed by the same letter do not differ significantly as separated by LSD (p≤0.05).

There was a significant response to liming for both maize and beans. This was informed by the harvested yields for both maize and beans. The increase in grain yield from L0 to L2 and L3 as indicated on Fig. 4 may be explained through two possible scenarios. One is that liming was reversing the toxicity effects of elements such as Al and Mn as well as mobilizing fixed P (Mitchell, 1999). The second possibility may be the nutritive value of lime that contained Ca andmg (Mugai, 2008).

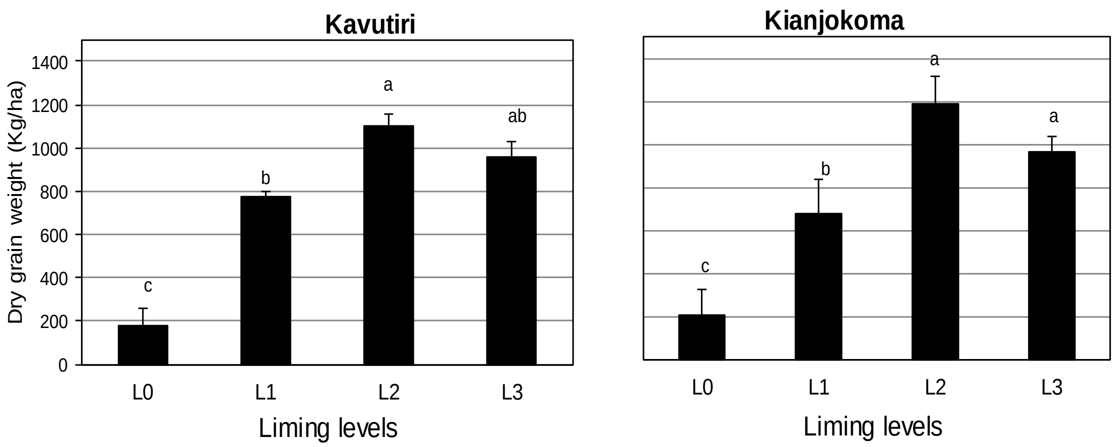

Fig. 4. The effect of liming on maize grain yield**.** Means in the bars followed by the same letter do not differ significantly as separated by LSD (p≤0.05.

The response to liming of beans was less than that of maize probably because of its shorter growing period and thus a benefitted less to the dissolving lime. The maximum maize and beans yield was around pH 5.5 which was initiated at L2. Maize yield started declining at higher liming of L3 which had given a pH 5.6. This was probably due to nutrient imbalance due to excess Ca andmg. Another possibility could have been micronutrient unavailability; however this was quite unlikely since micronutrients are not known to become unavailable at pH 5.6. Increase in harmful micro-organisms that are suppressed by Al may be another possibility for reduction in yield. This corroborates an earlier study on the effect of liming on bean (Mugai *et al.* 2008 and also the earlier work by Tessens and Shamshuddin,(1982) who showed that highly weathered soils rich in kaolinites and hydrous oxides do not increase their negative charge beyond pH 5.5. Njeru *et al.* (2012) speculated that the activity of some useful microorganisms that might have been adapted to acidity were disrupted by decreasing acidity above pH 5.5. Nevertheless, more research is required in this area to send more light on why yield declined at liming level above pH 5.5.

Conclusion

This work has shown that the correct level of liming in these strongly tea soils for cultivation of maize and beans is pH 5.5 and any liming above that is a waste of money and also leads to depressed yields. This optimal level of liming pH is arrived at around six tons of lime per hectare. Following dramatic response to liming in the tea zone acid soils, there is a need to educate farmers and extension workers on advantages of liming and disseminate the liming technologies to farmers and extension workers so that they can benefit from liming. Developing lime distribution networks in the country can help in making lime available to farmers.

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