SHORT, NON-REFEREED PAPER

EFFECTS OF SURFACE-APPLIED LIME AND GYPSUM ON SOIL PROPERTIES AND YIELDS OF SUGARCANE RATOON CROPS

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Abstract

Liming agents and gypsum are used to address aluminium (Al) toxicity and calcium (Ca) and magnesium (Mg) deficiencies in crops. However, the rate at which these materials react and their efficacy when surface-applied without soil incorporation remains uncertain; there are also concerns that gypsum may leach Mg, potassium (K) and Al into the subsoil. The effects on soil properties and yields of surface applications of ameliorants to ratoon crops were studied in field trials on the North Coast (Cartref sand; commenced December, 2011) and Zululand (Nomanci clay-loam; commenced September, 2014). Both dolomitic lime and gypsum significantly increased Ca levels and reduced acid saturation in the Cartref topsoil, with lime effects being greater than those of gypsum. However, after five years, the impact of lime was restricted to the top 40 cm, whereas gypsum had improved these properties to a depth of 80 cm. Preliminary findings on the Nomanci soil show that two years after the application of Calmasil and gypsum, their effects have been confined to the top 20 cm. In both trials there was no evidence of leaching of K, Mg and Al. Total sucrose yields on the Cartref soil were improved by the combined gypsum-plus-lime application. No effects of Calmasil and gypsum on sucrose yields on the Nomanci soil were yet apparent. This study highlights the benefits in terms of yields and soil chemical properties of surface-applied ameliorants on a sandy soil.

Keywords: soil acidity, soil ameliorants, lime surface-application, sucrose yields, sugarcane

Introduction

Soil acidity can limit sugarcane yields as it can cause poor rooting which will reduce the ability of the sugarcane crop to exploit moisture and nutrient reserves. Soil acidity is characterised by aluminium (Al) toxicity and calcium (Ca) and magnesium (Mg) deficiencies. These limiting factors are usually addressed by the application of lime and gypsum. Lime may require deep incorporation to reduce subsoil acidity due to its limited solubility and mobility (Farina *et al*., 2000). Concerns exist that gypsum, which has high solubility and mobility, may leach potassium (K), Mg, and Al into the subsoil, causing depletion of K and Mg in the topsoil (Ernani *et al*., 2006; Farina and Channon, 1988; Shainberg *et al*., 1989; Sumner, 1970). There are reports in the literature that a combination of lime and gypsum incorporated into the topsoil is an effective means of ameliorating subsoil acidity (Sumner, 2012). However, the rate at which these materials react and their efficacy when surface-applied without soil incorporation remain uncertain.

The aim of this study was to investigate the effects of surface applications of ameliorants to ratoon crops on soil profile chemical properties and sugarcane yields.

Materials and Methods

Investigations were carried out in two field trials on different soil forms:

- A trial on the North Coast was commenced in December 2011 on a first ratoon crop (N39) grown on an acid sandy (clay = 13%, pH_{CaCl2} = 4.27, organic C = 1.25%) Cartref soil. Treatments were the surface application of dolomitic lime (5 t/ha) and gypsum (5 t/ha) in factorial combination, with four replications. The trial was harvested four times.

- A trial in Zululand commenced in September 2014 on the fourth ratoon (N39) grown on an acid humic (clay = 33%, pH_{CaCl2} = 4.30, organic C = 4.49%) Nomanci soil. Treatments were the surface applications of Calmasil (12 t/ ha), gypsum (10 t/ha); and Calmasil plus gypsum (12 t/ha Calmasil plus 10 t/ha gypsum) in a randomized block design with three replications. At the time of writing the trial had been harvested only once.

In both trials nutrients not supplied as treatments were applied at rates deemed to be adequate for optimal growth. At harvesting, subsamples of stalks were taken to the millroom at the South African Sugarcane Research Institute (SASRI) for the measurement of sucrose contents. Soil sampling of both trials involved taking samples at intervals of 0-10, 10-20, 20-40, 40-60 and 60-80 cm. Soil and yield results were subjected to analysis of variance (Genstat version 18).

Results and Discussions

Effects on soil properties

Treatment effects on properties of the Cartref soil are shown in Figure 1. In keeping with its greater solubility (Sumner, 2012), gypsum reacted faster than lime. After five years, lime had markedly increased exchangeable Ca and Mg, and reduced exchangeable acidity and acid saturation in the topsoil. However, after five years the lime effects were restricted to the top 40 cm. Gypsum increased exchangeable Ca and reduced exchangeable acidity and acid saturation to a depth of 80 cm (Figure 1). This highlights the different mechanisms in which lime and gypsum react in the soil. Lime-induced increases in pH in the topsoil would increase negative charge on soil colloids (increased CEC); Ca is thus more strongly held. Gypsum, on the other hand, has little or no effect on pH, thereby allowing for the downward movement of Ca.

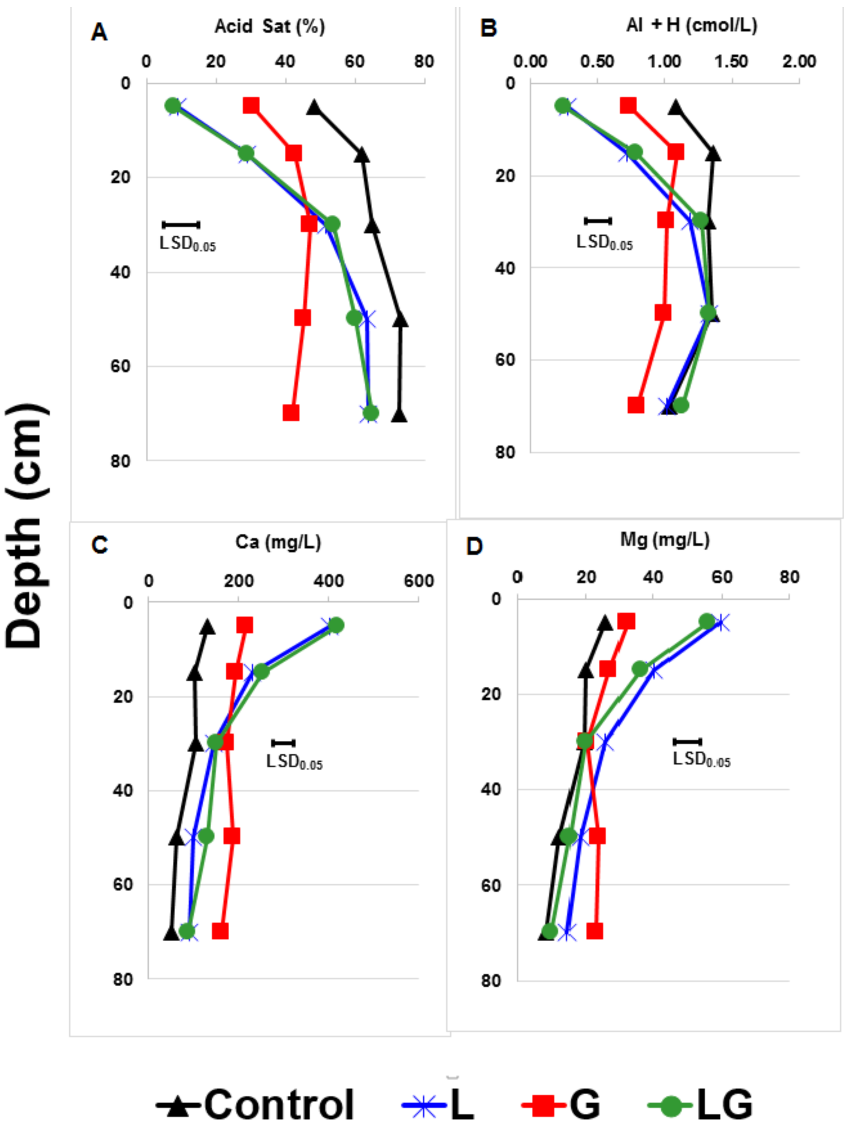

Figure 1: Variation in (a) acid saturation, (b) exchangeable acidity, (c) exchangeable Ca, and (d) exchangeable Mg with soil depth in response to lime and gypsum applications on the Cartref soil. (L = 5t /ha dolomitic lime; G = 5 t/ha gypsum; LG = 5 t/ha dolomitic lime + 5 t/ha gypsum). Soil samples were taken five years after the application of treatments.

In the Cartref soil, after five years there were essentially no differences in properties between the combination of lime plus gypsum and lime only treatments. Similar results were reported by Nixon *et al*. (2003) who found that after three years the effect on acid saturation of a combined 5 t/ha lime plus 5 t/ha gypsum on a Magwa soil form was similar to that of 5 t/ha lime alone. A satisfactory explanation for these observations cannot yet be proposed, but it would appear that movement of gypsum in the combined treatment was markedly retarded. Farina *et al.* (2000) have proposed that soils with mixed-layer clay components have large quantities of reserve acidity which can replenish Al^{3+} in soil solution and this will result in the retardation of gypsum movement. Precipitation of new amorphous sulphate minerals could also have contributed to the retardation of gypsum movement (Farina, 1997).

Preliminary findings on the Nomanci soil shows that, two years after the application of Calmasil and gypsum, effects have been confined to the top 20 cm.

In both trials there was no evidence of treatment-induced leaching of K, Mg and Al.

Effects on yields

Yield data on the Cartref soil (Figure 2) show that there was no significant response to the treatments for the first three harvests. However, lime plus gypsum treatments significantly increased sucrose yields in the fourth harvest and total sucrose yields over four harvests. Reasons for the muted responses to lime and gypsum are puzzling, given that the soil profile was severely acidic, with very low levels of calcium (Ca) and magnesium (Mg). Response to the combination of lime plus gypsum on the fourth harvest reflects a delayed response to this treatment. Nixon et al. (2003) also observed a delayed response to lime and gypsum during the first four crops of N12 grown on a Magwa soil form. Since the amendments were not incorporated in this study, it is expected that the delayed response could be longer than where incorporation took place.

No effects of Calmasil and gypsum on sucrose yields in the Zululand trial were yet apparent.

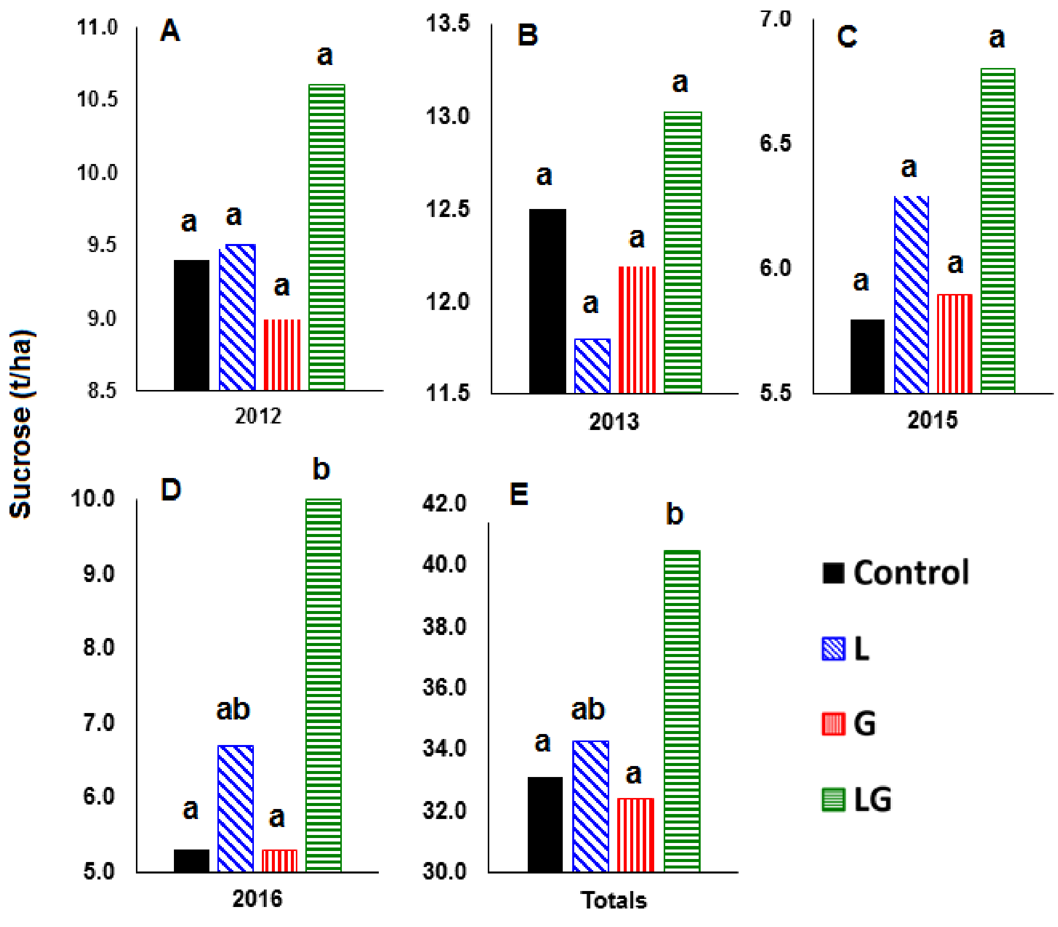

Figure 2: Treatment effects on sucrose yield for (a) 2012, (b) 2013, (c) 2015, (d) 2016 and (e) cumulative yield of all four harvests measured from sugarcane grown on Cartref soil. L = 5t /ha dolomitic lime; G = 5 t/ha gypsum; LG = 5 t/ha dolomitic lime + 5 t/ha gypsum; columns with the same letter above are not significantly different at P=0.05.

Conclusions

This study provides information on the mode of action of surface-applied ameliorants on acid soils. On a sandy Cartref soil, the lime treatment on its own was more effective in ameliorating topsoil acidity than gypsum. Gypsum, however, improved the whole soil profile chemistry to a depth of 80 cm within five years of treatment application.

A combination of lime plus gypsum significantly increased cumulative sucrose yields over four harvests on the sandy Cartref soil, but lime or gypsum on their own did not impact yields. At this stage treatment effects have not yet become apparent on the humic Nomanci soil.

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