SHORT, NON-REFEREED PAPER

THE MAGNESIUM STATUS OF SOILS SUPPORTING SUGARCANE PRODUCTION IN CENTRAL AND SOUTHERN AFRICA

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Abstract

Magnesium (Mg) is an essential plant macronutrient which plays a central role in the process of photosynthesis. Excess Mg in soils, however, contributes to structural instability which promotes soil crusting and erosion, and also restricts nutrient uptake. Using a previously published classification nomogram, the database of the South African Sugarcane Research Institute's Fertiliser Advisory Service (FAS) was used to assess the soil Mg status in southern and central African sugarcane producing soils. The nomogram, using exchangeable Mg (EMg) levels and exchangeable Mg percentage (EMgP) as criteria, classifies soils with >20 $cmol_c\ kg^{-1}$ exchangeable Mg and >40% EMgP as 'very magnesic' while those with between 2 and 20 $cmol_c\ kg^{-1}$ Mg and >40% EMgP are considered 'magnesic'. Below an EMg of 2 $cmol_c kg^{-1}$, a soil is 'magnesic', depending on the ratio of EMgP to EMg. In South Africa, magnesic soils occur mainly in the irrigated region, where Malelane had the highest percentage of magnesic (14%) soils compared to the other irrigated regions. In the rainfed regions of South Africa, Zululand North had the greatest proportion of magnesic soils (5% of samples from this region), while many soils in the other rainfed areas also had potentially excessive levels of Mg. For other African countries, less than 5% of the soils analysed were magnesic. The findings of this study highlight the extent of the soil magnesicity problem in and outside South Africa, and possible remedial measures, such as the appropriate use of gypsum and lime, are afforded consideration.

Keywords: magnesic, magnesium, nutrients, gypsum, sodic soils, soil structure

Introduction

Magnesium (Mg) is a frequently overlooked essential plant macronutrient which plays a central role in photosynthesis. Excess soil Mg in relation to calcium, however, contributes to soil structural instability which promotes clay dispersion (especially in sodic soils), crusting and erosion, and also restricts nutrient uptake (Dontsova and Norton, 1999). Soils with excess Mg are known as magnesic soils (MGS). Magnesic soils normally develop where (a) water with higher concentrations of magnesium in relation to calcium is used for crop irrigation and/or (b) continuous over-application of dolomitic lime has occurred (Dontsova and Norton, 1999). According to Rengasamy and Marchuk (2011), elevated levels of magnesium in soils may occur naturally and also as a result of irrigating crops with waste, effluent or recycled water. The Mg in MGS, either alone or combined with sodium may result in soil structural deterioration even though it is a divalent cation (Rengasamy and Marchuk, 2011). High levels of Mg in these soils weaken the attractive forces between the individual soil particles, leading to dispersion (Emerson and Bakker, 1973). A common feature of MGS, is the development, during ploughing, of massive clods that hinder the flow of water through the soil and across irrigated fields, leading to poor distribution of water. This problem is generally the characteristic of the irrigated soils where it is accelerated by the use of Mg-rich water. However, the existence and the distribution of MGS in the sugarcane growing regions remain uncertain. The aim of the present study was to use the Fertiliser Advisory Service (FAS) topsoil data to investigate the prevalence of MGS in and outside South Africa and to report on a preliminary study that tested gypsum and lime to ameliorate magnesicity in affected soils.

Materials and Methods

The current study used information relating to topsoils in the FAS database captured over the past six years (2012-2017). Exchangeable cations magnesium (Mg) and calcium (Ca) were measured using the Ambic (ammonium bicarbonate) extractant (van der Merwe *et al*., 1984), while pH was determined in 0.01 M calcium chloride at a 1:2.5 (soil: solution) ratio. To classify soils according to their magnesicity levels, exchangeable magnesium percentage (EMgP) was calculated as the ratio of exchangeable magnesium ($cmol_c$ kg^{-1}) to effective cation exchange capacity ($cmol_c$ kg^{-1}) and a nomogram was used (Cass and Baumgartner, 2010). The nomogram, using exchangeable Mg (EMg) levels and EMgP as criteria, classifies soils with >20 $cmol_c$ kg^{-1} exchangeable Mg and >40% EMgP as 'very magnesic' while those with between 2 and 20 $cmol_c$ kg^{-1} EMg and >40% EMgP are considered 'magnesic'. Below an EMg of 2 $cmol_c$ kg^{-1}, a soil may be 'magnesic' depending on the ratio of EMgP to EMg.

The topsoil samples from the Fertiliser Advisory Service (FAS) at the South African Sugarcane Research Institute (SASRI) database comprised of samples collected at 0-15, 0-20 and 0-30 cm depth. Soil samples (0-20 cm) used to measure the efficacy of lime and gypsum in the amelioration of magnesic soils (MGS) were taken from three cane fields that differed markedly in clay content (±5%, ±15% and ±35%) in the irrigated Malelane region of South Africa. These samples were treated with different rates of lime (equivalent to 0, 2, 4 and 6 t ha^{-1}) and gypsum (equivalent to 0, 2 and 4 t ha^{-1}), incubated for different time periods (1, 2, 5, 10, 20 and 50 days), and analysed for pH and exchangeable cations. Statistical analyses were carried out using GenStat Version 18 and Excel 2013.

Results and Discussion

Distribution of magnesic soils

Magnesic soils occur to varying extent in the sugarcane growing areas of South Africa and other African countries, with Malelane (14%) and Zululand North (5%) having the highest percentage of MGS in the irrigated and rainfed regions, respectively (Figures 1a and b).

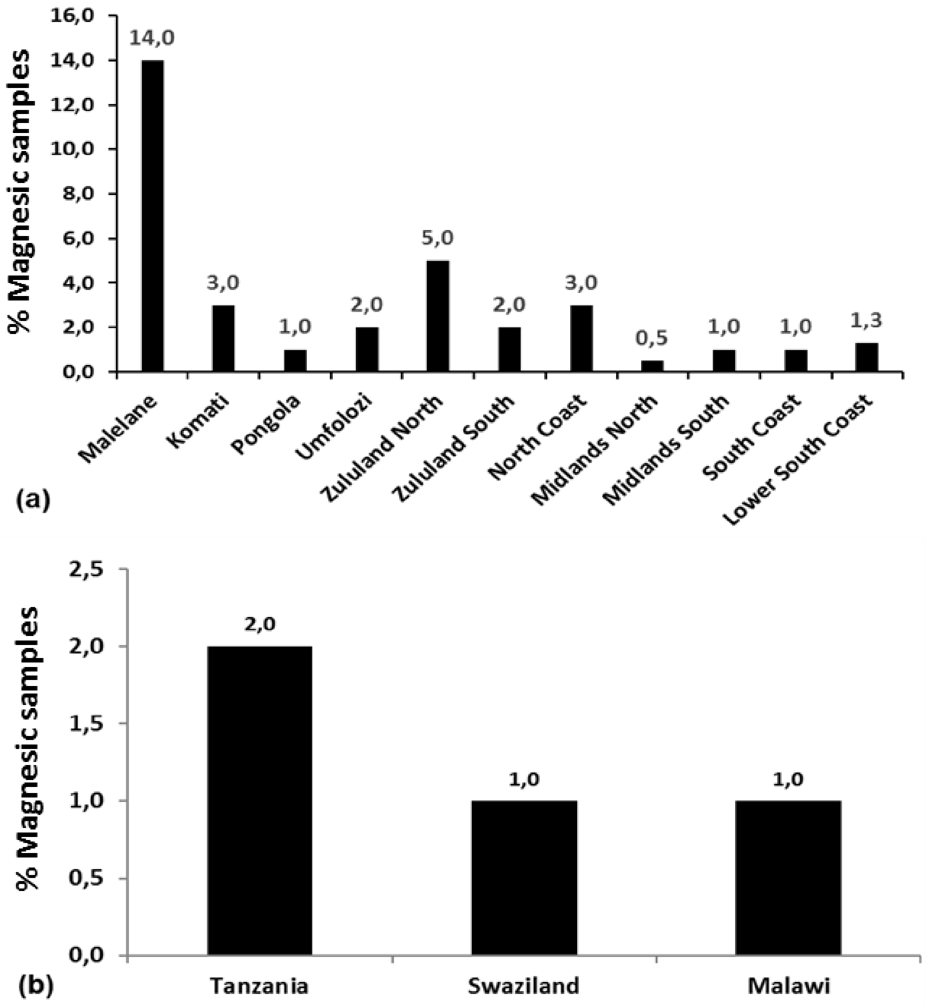

Figure 1. The percentage of magnesic soil samples submitted to the Fertiliser Advisory Service by sugarcane growers in (a) South Africa and (b) other African countries.

Remedial measures

Treatment effects on soil properties of the investigated soils are shown in Figure 2. Lime was generally more effective than gypsum in reducing soil magnesicity levels by reducing EMg levels as has been reported elsewhere (Edmeades, 1982). However, significant ($p<0.05$) effects were observed under both ameliorants compared to the control. According to Edmeades (1982), lime converts exchangeable Mg to non-exchangeable forms in high pH (>6.5) soils, as was the case in the present study. The significant ($p<0.05$) increase in pH ($CaCl_2$) measured in lime treated soils suggests that although lime performed better than gypsum, it might not be the best ameliorant for MGS with high pH, as further increases in pH may result in nutrients becoming less available for plant uptake (Figure 2e and f). Both lime and gypsum increased Ca:Mg ratio. Generally, the increase in the Ca:Mg ratio in MGS improves soil structural stability and thus reduces the risk of run-off and erosion (Rengasamy and Marchuk, 2011; Mthimkhulu, 2017).

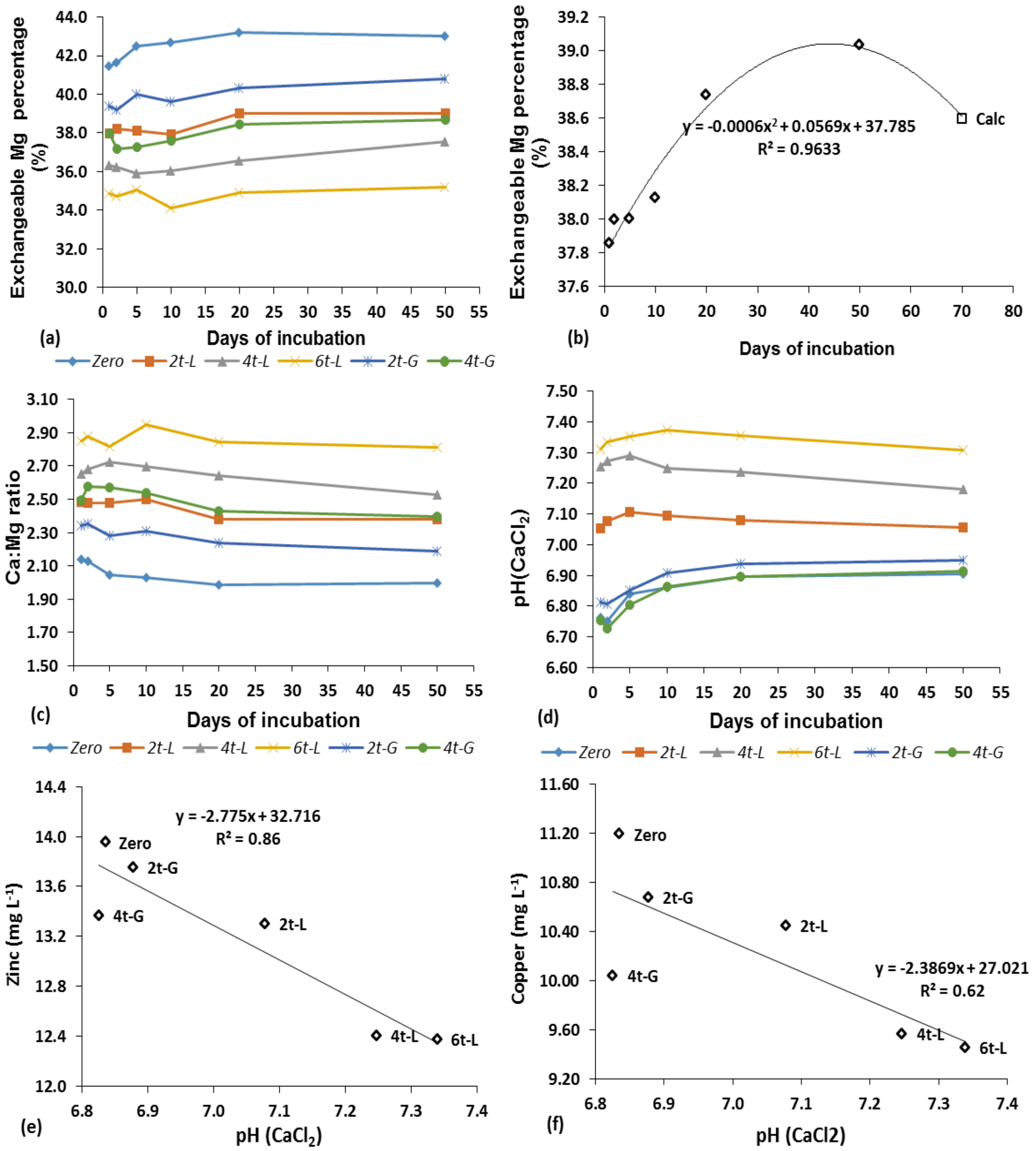

Figure 2: Impacts of lime and gypsum treatments and time of incubation on selected soil properties of three soils from the Malelane region of South Africa (presented data are means for the three soils). Mg: Magnesium, Ca:Mg; Calcium to Magnesium ratio, pH($CaCl_2$); pH measured in calcium chloride. Lime (L) and gypsum (G) are expressed in tons per hectare. Calc: calculated point from the equation shown in Figure1b).

Conclusion

This study provides information on the distribution of MGS in the sugar industry and possible remedial measures. The results show that MGS are present in all the sugarcane producing regions in South Africa and other investigated African countries, although their extent varied substantially from one region to another. A marked increase in pH($CaCl_2$) observed from lime-treated samples suggested that lime might not be suitable for treating high pH MGS, as it generally reduces the availability of plant nutrients. Gypsum seemed to be the most suitable ameliorant for high pH($CaCl_2$) MGS, although large amounts may be required.

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