SHORT NON-REFEREED PAPER

IMPACT OF CMS ON SOIL ACIDITY AND ALUMINIUM TOXICITY IN THE SUGARCANE INDUSTRY

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Abstract

Acid soils are a common phenomenon in the South African eastern regions, and topsoil and subsoil acidity are a serious concern in most regions of KwaZulu-Natal. Low soil pH restricts plant growth and in most cases it mobilises toxic metals, particularly aluminum (Al), which restricts plant growth. Condensed Molasses Stillage (CMS) is used in the SA sugar industry as a K fertiliser. However, farmers are concerned that the low pH of CMS (4.5) will acidify soils even further. The objective of this work was to evaluate the effect of CMS on the chemical properties (pH, exchangeable acidity and exchangeable Al) of acid soils. A column experiment was laid out in a 2-way factorial design (three soils and five treatments) replicated five times. The treatments were control (no applications), inorganic fertiliser (5:1:5 (46)), CMS applied at 3 and 5 t/ha and CMS fortified with N and applied at 3 t/ha. Treatments were applied three times at an average interval of 11 weeks. The magnitude of pH, exchangeable acidity and exchangeable Al changes as affected by the amount, rate and frequency of the applied treatments were recorded. All the treatments mentioned above seemed to increase the pH of soils and maintained the higher pH for the duration of the trial (33 weeks). The reduction of exchangeable Al in acid soils by the selected treatments was in accordance with the increase in soil pH by the treatments. The addition of nutrients from CMS and inorganic fertiliser was also shown to improve the fertility of the soil, in particular the N, P and K status of the soils.

Keywords: CMS, pH, acidity, aluminium, fertility, sugarcane

Introduction

In South Africa soil acidity is a serious problem that limits the crop production of both large and small-scale farmers. Acid soils predominate in the Western and Eastern Cape coastal belts, KwaZulu-Natal, Eastern Mpumalanga and the Northern Province (Beukes, 1997). CMS is an alternative source of K fertilizer and is also sometimes fortified with N and P to NPK formulations common for inorganic fertilisers. However, little is known about the effect of CMS on the environment. The primary concern is that CMS might have an acidifying effect on soil that is already acidic because of its low pH (pH of CMS is 4.5), and will therefore increase the solubility of aluminium (Al) in soils. The objective of this paper was therefore to determine the impact of CMS on the chemical properties (pH, and exchangeable Al) of acid soils in sugarcane producing areas.

Material and Methods

This work was conducted in 100 cm tall columns with a diameter of 20 cm in a rain shelter facility which opens when it is dry and closes during the onset of the rain so as not to interfere with the water balance in the columns. The initial pH ($CaCl_2$) of the soils used in this study were 3.84 for the sandy loam, 4.31 for the sandy clay loam and 3.93 for the sandy clay, and each was packed in the columns to bulk densities of 1.47, 1.38 and 1.34 g/cm^3 respectively. Clay contents for the respective soils were 15, 22 and 39%, and carbon contents 0.99, 0.87 and 1.51%.

The experiment was laid out in a 5 x 3 x (5) factorial design with five treatments and three soils in a complete randomised block design, with five replicates. Treatments were: Control (no nutrients), inorganic fertiliser (5:1:5 (46)), CMS applied at 5 t/ha, CMS applied at 3 t/ha and CMS applied at 3 t/ha but enriched with N (as urea) to the equivalent of 150 kg N/ha. The inorganic treatment were applied at 580 kg/ha to provide 120 kg N/ha (using urea as the N source) and 120 kg K/ha. An additional 30 kg K/ha was added as KCl to the inorganic fertiliser treatment in order to apply the equivalent amount of K than when CMS is applied at 3 tons/ha.

All treatments were evenly applied over the total soil surface of the columns using a porous deflector. The treatments were applied three times at intervals of two months. Simulated light rain was applied immediately after treatment application, and again after three and six weeks. The average amount of water evaporated from the surface (about 8 mm/week) was determined by weighing selected columns. Therefore, about 8 mm water was applied with each simulated light rain. A heavy storm equivalent to 23 mm rain (applied in a few seconds) was applied to every treatment seven weeks after treatment application and four weeks before re-application of the treatments. Soil samples were taken at the start of the trial and before each re-application of the treatments.

Results and Discussion

The magnitude of changes in pH (increased) and exchangeable Al (decreased) varied with treatment type, rate and frequency of application. The treatments impacted mostly on the top soil layer of all three soil types (sandy loam, sandy clay loam and sandy clay). The sandy clay loam was the exception with a significant ($p=0.05$) increase in pH and decrease in exchangeable Al for the lower depths (10, 20, 50 and 70 cm) over all sampling dates where inorganic fertiliser (5:1:5 (46)) was applied, except the last date (week 31). It is assumed that the N from the inorganic fertiliser was more mobile from this source and was carried more readily to the lower depths by water. Similar effects of urea-N on soil pH were reported by Ferguson *et al.* (1984). They explained that the hydrolysis of urea produces H_2CO_3, which consumes H^+, leading to a temporary increase in soil pH (reaction 1). However, with the help of Nitrosomonas and Nitrobacter, NH_4^+ will be converted to NO_3^- releasing H^+ which will eventually lower the pH (reaction 2).

$$CO(NH_2)_2 + H^+ + H_2O \rightarrow 2NH_4^+ + HCO_3^- \qquad [1]$$

$$NH_4^+ + O_2 \rightarrow NO_3^- + H_2O + 2H^+ \qquad [2]$$

Ferguson *et al.* (1984) found that soil pH increased quickly from an initial value of 5.5 following the application of urea to reach a maximum of about 8 in less than one week, and decreased gradually to a pH of about 6.5 by day 22 (still one pH unit higher than the starting pH after three weeks). What makes the results from the current work exceptional is that the higher soil pH was maintained until at least week 19, which is much longer than that reported in the literature (Ferguson *et al.*, 1984). The higher pH was probably also kept high by the frequent (every fourth month) application of treatments which would have resulted in renewed increases in the soil pH. The soil pHs was not measured at sufficiently short intervals to show the expected pH decrease (Malhi *et al*., 1995) following the application of urea based N (reaction 2).

Although significant (p=0.05) increases in soil pH were evident for most treatments, the effect was small. This means that soil pH increased by about 0.05 on average, which was substantially less than the 4 to 7 reported by Ferguson *et al.* (1984). The most likely explanation is that in the current study the peak pH might have been reached in the long period between treatment application and sampling (soil samples were taken on average seven weeks after treatments were applied). Clearly, in the current study, time between sampling was too long to allow for the characterisation of short term effects of N oxidation and reduction on pH. One of the sub-objectives of this work was to determine the effect of treatments over the medium (months) to long (years) term and short (days) term transitory effects are of less importance because farmers are concerned about the long term effect (cumulative effect of several years) of CMS on soil pH.

Ultimately all the CMS treatments increased the soil pH and decreased exchangeable Al. Initially this trend was noticed only for the surface soil layer (0-5 cm) but with repeated applications (three times with 11 week intervals) this effect eventually filtered through to the second layer (15-25 cm) of the most sandy soil (sandy loam). CMS applied at 5 tons/ha and CMS fortified with N were the first two CMS treatments to have an effect at depth. This was expected from the application of the larger CMS volume (5 tons/ha). The N in the N fortified CMS treatment might have been a factor contributing to the more rapid increase in pH at a greater depth. The large amounts of NH_4^+ measured in the soil indicates that the conversion to NO_3^- over the seven week period was incomplete and that the pH might eventually end up lower than the starting pH (Table 1). In follow up work samples are taken at longer interval (one year) to confirm this expectation. Nevertheless, the higher soil pH after seven weeks was significant and was confirmed by the significantly lower exchangeable Al in the topsoil layer (0-5 cm) of all three soils.

Conclusion

CMS applied repeatedly to all three soils in the absence of plants increased the pH and reduced exchangeable Al of the soil at the surface (0-5 cm). CMS fortified with N also increased the pH and reduced exchangeable Al, but it is assumed that, given sufficient time, this N will eventually acidify the soil. This will be confirmed in follow-up work. This study provides clear evidence that unfortified CMS does not acidify the soil relative to inorganic fertilisers. Indications are that where CMS is fortified with N, the effect on soil reaction will be largely similar to that of N supplied as N fertiliser.

Table 1. Values from soil samples collected at a depth of 5 cm four weeks after the second treatment application.

Soil	Treatment	pH ($CaCl_2$)	Al ($CuCl_2$) (mg/L)	Al (KCl) (mg/L)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)
Sandy loam	Control	3.79	62.29	10.31	13.01	58.39
	Fert 5:1:5 (46)	3.81	57.69	7.98	*52.72	43.69
	CMS 3 t/ha	*3.93	*48.66	*4.94	*46.55	*91.13
	CMS + N	3.84	*49.49	*4.39	*116.75	*168.86
	CMS 5 t/ha	*3.96	64.77	8.37	*57.35	*119.13
Sandy clay loam	Control	4.30	42.46	3.76	9.83	62.97
	Fert 5:1:5 (46)	*4.39	*37.70	2.34	*79.14	*121.01
	CMS 3 t/ha	*4.37	*28.38	*9.21	*30.29	*92.51
	CMS + N	*4.39	*36.77	4.10	*131.71	*157.94
	CMS 5 t/ha	*4.42	*37.84	3.18	*54.70	*164.96
Sandy clay	Control	4.04	64.13	6.11	8.52	49.61
	Fert 5:1:5 (46)	*4.09	*55.46	*2.64	*72.57	54.02
	CMS 3 t/ha	*4.10	60.31	*13.28	*32.14	*77.06
	CMS + N	*4.11	*53.72	6.49	*156.54	*184.06
	CMS 5 t/ha	*4.15	59.19	*18.32	*42.33	*73.61

*Significantly different from the control at p=0.05

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