THE EFFECT OF SILICA ON CANE GROWTH

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Abstract

A pot experiment was carried out to study the effect of calcium carbonate and various silica-containing materials on cane growth and to compare the relative efficiencies of calcium carbonate and metasilicate slag on three acid soils. All treatments caused a substantial reduction in exchangeable aluminium in the soil and in manganese uptake by the plant. With treatments containing silica an increase in yield was associated with an increase in the silica concentration in the plant. With the calcium carbonate treatments, however, increasing yields were accompanied by a decrease in silica concentration. Treatments containing silica proved superior to calcium carbonate treatments on all three soils.

Introduction

Even though silica is not regarded as an essential element for plant growth it occurs in sugarcane in high concentrations, varying from 0.14% in very young leaves to 6.7% in the stalks and older leaf sheaths according to Fox, Silva, Plucknett and Teranishi (1969). Recently it has been shown by Vlamis and Williams (1967) that silica plays an important role in the elimination of minor element toxicities in the *Gramineae*. It would therefore seem possible that silicon might also play a beneficial role in sugarcane nutrition.

One of the first instances of the use of silicate materials as a soil amendment was in Mauritius where D'Hotman de Villiers (1947) described improved yields due to application of finely ground basalt. However, the large quantities used (up to 210 metric tons per hectare) precluded its widespread use. In recent years a number of reports have appeared describing the beneficial effect of silica on cane growth. Clements (1965) reported the results of four experiments on an aluminous ferruginous latosol and hydrol humic latosols in Hawaii, and Ayres (1966) also described substantial yield increases in sugarcane due to a silicate slag applied to the same soil types.

These Hawaiian soils are very similar to the ferralitic soils occurring in the Natal Midlands. They have low base saturation and pH values with high concentrations of soluble aluminium and low concentrations of silica. A pot experiment was therefore designed to test the effect of silica on soils from this area and also to compare the relative efficiency of different silicate materials with that of calcium carbonate.

Experimental

The following amendments where applied, as replicated treatments, at levels equivalent to 4.5, 9 and 18 metric tons per hectare to a topsoil of the Balgowan soil series (Van der Eyk, Macvicar and De Villiers, 1969). This soil sample is referred to as Balgowan (A).

(a) Silene F (pure calcium metasilicate $CaSiO_3$).
(b) Amcor slag (a blast furnace slag).
(c) Sodium metasilicate (Na_2SiO_3).
(d) Hawaiian slag (a metasilicate slag from the same source as that used by Clements, Putman and Wilson, 1967).
(e) Portland cement.
(f) Calcium carbonate ($CaCO_3$).

Because Clements *et al.* (1967) reported that the particle size of the slag was important, all materials used were ground to pass a 100-mesh sieve. All pots received a basic dressing of N, P and K equivalent to 112 kg N, 167 kg P and 112 kg N per hectare as well as sufficient calcium chloride to raise the soil calcium level to between 150 and 170 ppm. The critical level for calcium in soil accepted by the Fertilizer Advisory Services laboratory of the Experiment Station is 150 ppm.

To another topsoil sample of the Balgowan soil series (sample B) collected in a different locality from the first, and a topsoil sample of the Trevanian soil series (Beater, 1957) only Hawaiian metasilicate slag and calcium carbonate were applied. The levels of application and the basic dressing were the same as above.

TABLE I
Analysis of Soil Samples

Sample	Soil series	Clay %	Silt %	Fine sand %	Medium sand %	Coarse sand %	Water-holding capacity %	pH	CEC meq %	Base saturation %	Exchangeable aluminum ppm
A	Balgowan	71	13	7	1	2	49	4.35	15.5	6.8	865
B	Balgowan	63	9	11	7	5	44	4.40	14.0	10.3	605
C	Trevanian	24	7	27	28	14	21	4.80	6.9	23.0	214

Table I shows that the three soils all have high exchangeable aluminium, low pH and low base saturation values.

A pre-germinated single-eyed sett was planted in each pot, which contained 1 200 g soil. The pots were watered daily with distilled water to 60% field capacity. All plants were harvested after 16 weeks and the tops and soils analysed separately.

Results and Discussion

Yield Data

All sources of silica except sodium silicate gave significant yield responses as indicated in Figures 1 and 2 and Table II. The sodium silicate caused an alkaline soil condition due to the large amounts of sodium added to the soil. This is probably the reason for the depression in yield observed.

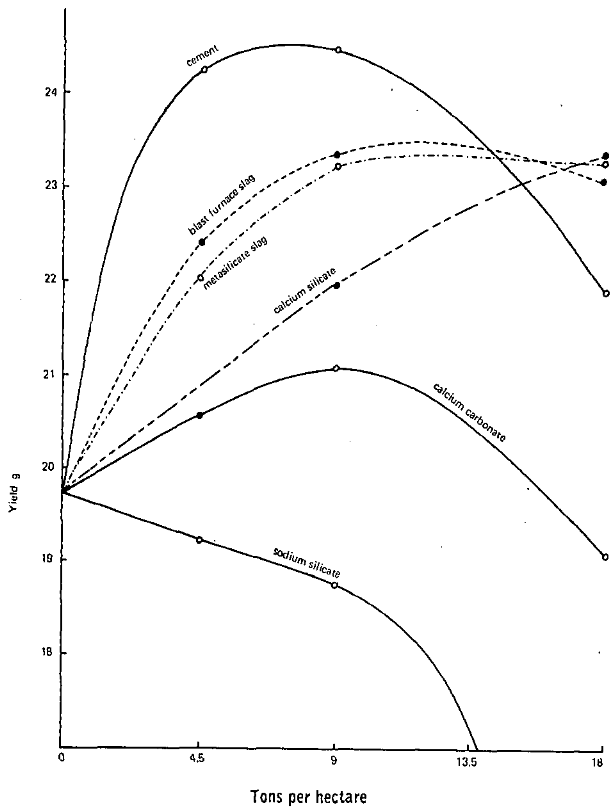

FIGURE 1: Yield in relation to levels of amendments on Balgowan (A).

The maximum yields from the metasilicate treatments were consistently better than those from the calcium carbonate treatments on all three soils, the differences being far greater on the Balgowan soils than on the Trevanian.

A depression in yield was observed at the highest level of calcium carbonate application on both the Trevanian and the Balgowan (A) soil. The highest level of cement on the Balgowan (A) sample also caused a depression in yield. This depression is unlikely to be a pH effect, because the metasilicate slag, calcium carbonate and cement brought about similar pH increases on each soil as shown in Figure 3 and Table II.

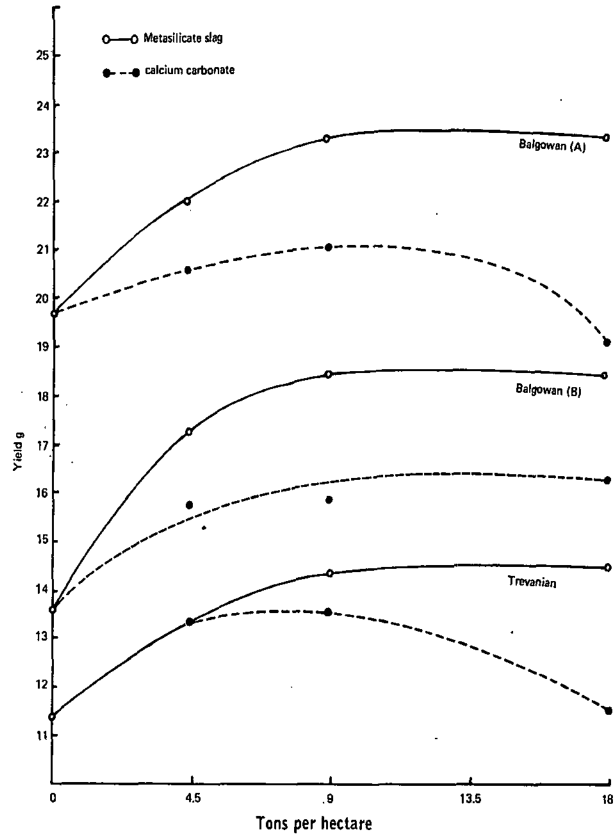

FIGURE 2: Yield in relation to levels of amendments.

The highest yields on the Balgowan soil were obtained with cement at 9 metric tons per hectare and Amcor slag at 18 metric tons per hectare. Both these yields were significantly better than the highest yield obtained from the addition of calcium carbonate.

Soil Reaction (pH)

Figure 3 and Table II show that the metasilicate slag, calcium carbonate, Amcor slag, cement and sodium silicate all had a similar effect on soil pH. The effect of calcium metasilicate on pH was smaller than that of the other amendments. The maximum or highest yield for each treatment on the Balgowan samples was obtained at soil pH levels between pH 5.0 and pH 5.4, and at pH 6.2 on the Trevanian sample. It is unlikely, however, that the increases in yield were due only to the change in pH, as large yield differences were obtained from treatments having a similar effect on pH.

Nutrient Uptake and Availability

The relationships between nutrient uptake and yield were examined in an attempt to determine the factor or factors responsible for the increases in yield, and for differences in yield between the various treatments.

There were no significant treatment differences in the concentrations of iron, copper, zinc and boron in the plants. A linear relation between uptake and yield was observed for all four of these elements, which indicates that none of them were deficient and that they were therefore not responsible for the yield differences.

A dilution of phosphorus due to increased growth is evident from Figure 4. A similar curve was obtained for potassium. Calcium metasilicate excepted, the 18 tons per hectare levels of all treatments on the one Balgowan sample (A) increased the uptake of phosphorus by the plant. On the Balgowan (B) and Trevanian soils the amount of phosphorus taken up by the plant was reduced by the addition of calcium carbonate, while metasilicate slag caused an increase in P uptake.

The amount of magnesium taken up by the plant was increased with the cement and Amcor slag on the one Balgowan sample and by the metasilicate slag on all three soils. The treatments with cement, Amcor slag and metasilicate slag are also the treatments from which the highest yields were obtained. Even though the levels of magnesium in these soils were at least twice the critical level of 25 ppm, it is possible that the increased yields were partly due to increased availability of magnesium.

The concentration of manganese in the plant and the amount of manganese taken up by the plant was reduced considerably by all treatments. Figure 5 shows that an increase in soil pH caused a marked reduction of manganese concentration in the plant. All treatments also caused a marked reduction in the manganese to silica ratio. This was greater in the silicate than in the calcium carbonate treatments, the silicate treatments reducing the manganese concentration while increasing the silica concentration. However, the calcium carbonate treatments reduced both the manganese and silica concentrations.

All treatments decreased the exchangeable aluminium in the soil considerably by raising pH values, the exchangeable aluminium being strongly pH-dependent as shown in Figure 6.

TABLE II

Yields, pH and nutrient uptake for the different soils and treatments.

Soil sample	Amendment	Level ton per ha	Dry matter g	Soil pH (H_2O)	P uptake mg	Mg uptake mg	Mn in tops ppm	Mn : Si ratio
Balgowan (A)	control	0	19.7	4.67	26	45	360	0.079
	$CaSiO_3$	4.5	20.6	4.73	26	41	278	0.047
		9	22.0	4.84	25	46	283	0.041
		18	23.4	5.03	26	50	223	0.025
	blast furnace slag	4.5	22.4	5.13	28	123	363	0.039
		9	23.3	5.33	32	130	283	0.027
		18	24.8	5.57	32	117	170	0.013
	cement	4.5	24.3	5.06	23	73	246	0.038
		9	24.5	5.37	26	82	163	0.020
		18	21.9	5.83	31	75	56	0.005
	meta-silicate slag	4.5	22.0	5.00	26	56	270	0.038
		9	23.2	5.27	26	62	166	0.019
		18	23.3	5.63	30	64	69	0.006
	$CaCO_3$	4.5	20.6	5.13	24	49	307	0.075
		9	21.1	5.43	21	49	197	0.059
		18	19.1	5.82	29	46	67	0.022
Balgowan (B)	control	0	13.6	4.49	22	38	338	0.061
	meta-silicate slag	4.5	17.3	5.00	25	48	230	0.024
		9	18.5	5.10	27	48	128	0.013
		18	18.4	5.45	29	47	57	0.004
	$CaCO_3$	4.5	15.8	4.87	25	37	183	0.037
		9	15.9	5.13	22	37	117	0.033
		18	16.3	5.62	20	36	67	0.019
Trevanian	control	0	11.4	4.63	20	58	428	0.116
	meta-silicate slag	4.5	13.4	5.58	24	59	93	0.012
		9	14.4	6.25	23	55	59	0.004
		18	14.5	7.17	23	41	46	0.003
	$CaCO_3$	4.5	13.4	5.85	24	60	90	0.028
		9	13.6	6.72	22	55	85	0.026
		18	11.5	7.27	19	34	67	0.023

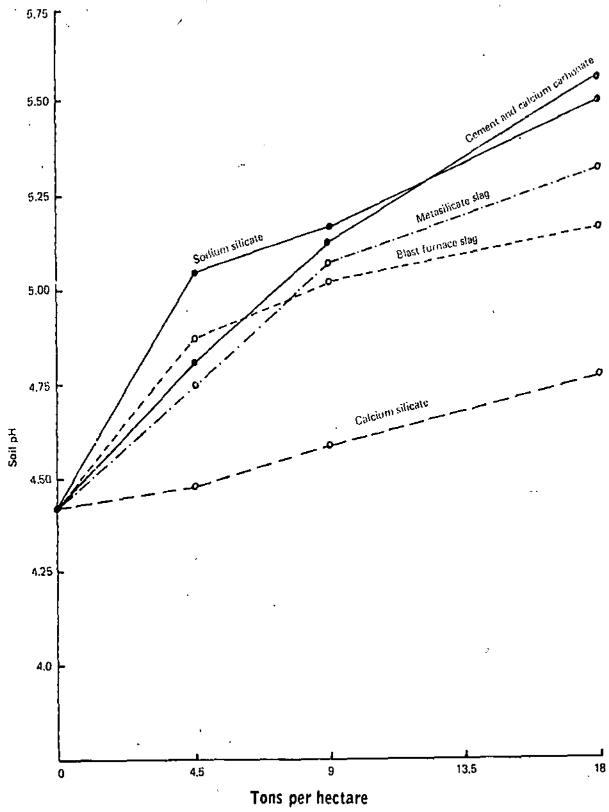

FIGURE 3: Soil pH in relation to levels of amendments.

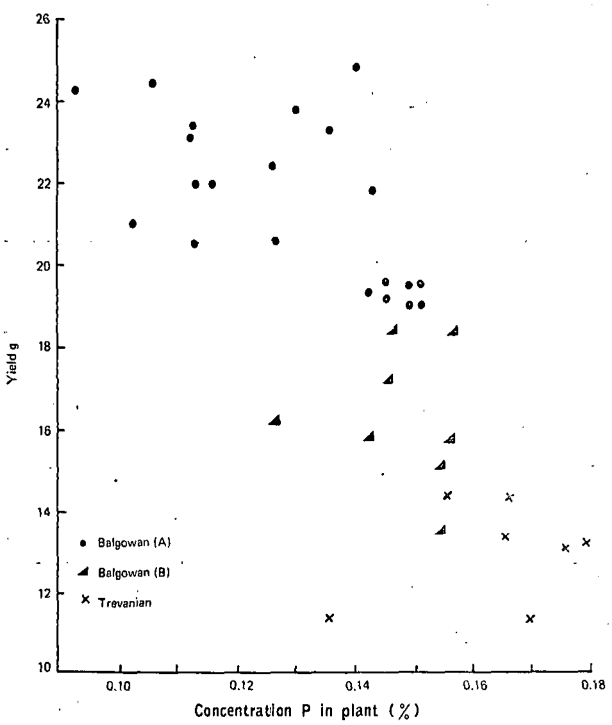

FIGURE 4: Relation between P concentration in the plant and yield.

A decrease in silica concentration in the plant by addition of calcium carbonate is indicated in Figure 7. All amendments containing silica caused a substantial increase in silicon concentration.

With the exception of the highest level of metasilicate slag application on the Balgowan (B) soil and the highest level of cement on the Balgowan (A), all the silicate treatments showed an increase in yield with increasing silica concentration in the plant, while the calcium carbonate treatments had the opposite effect.

It is interesting to note that the high yields observed with the 4.5 and 9 tons per hectare levels of cement can be explained by the addition of the curves for the calcium carbonate and silicate treatments as shown by the dotted line in Figure 7. This indicates that two unrelated factors could be responsible for the observed yield increases.

Conclusion

The results of this experiment agree very closely with the findings of Clements (1967) and Ayres (1966).

Ayres mentioned that slag is more beneficial than coral stone (calcium carbonate) even though both neutralize soil acidity and diminish the solubility of manganese and aluminium. He concluded that there is a level of soil silica below which optimum yields cannot be obtained.

Clements (1967) covered a larger number of amendments and he observed that yield improvements can be obtained by various other compounds. In descending order of yield improvement, some of these were: Hawaiian slag, sodium metasilicate, calcium carbonate, ammonium phosphomolybdate, sodium pyrophosphate, Rankinite (predominantly $Ca_3\ Si_2O_7$), sodium molybdate and ammonium phosphotungstate. Because all his pots received a heavy dressing of phosphate, the yield improvement observed with amendments containing phosphorus was ascribed to precipitation of toxic compounds and not to increased phosphorus fertilization. He also stated that calcium metasilicate was more effective than any of the other compounds in correcting the toxic soil conditions.

In the experiment described in this paper an adequate dressing of nitrogen, phosphorus and potassium was applied and the curves for nutrient uptake and concentration of nitrogen, phosphorus, potassium, calcium and magnesium against yield did not indicate any deficiency. It can therefore be assumed that the yield increases observed were not caused by increased availability of these nutrients.

The main factors probably responsible for the yield increases are decreased levels of aluminium and manganese, and increased levels of silica in the soil. The calcium carbonate and silicate treatments decreased exchangeable aluminium and manganese to the same extent, and both had the same effect on pH. It is considered therefore that the increased yields cannot be due only to elimination of toxic amounts of aluminium and manganese. Even though the function of silica in the plant is not clear, there still exists a possibility that it plays a beneficial role.

Silicate slag appears to be superior to lime because it gives higher yields and because the consequences of over-application are less harmful.

Acknowledgements

Thanks are due to Mr. R. A. Wood for advice on pot techniques and to Messrs. J. H. Meyer and K. E. F. Alexander for some of the leaf and soil analyses.

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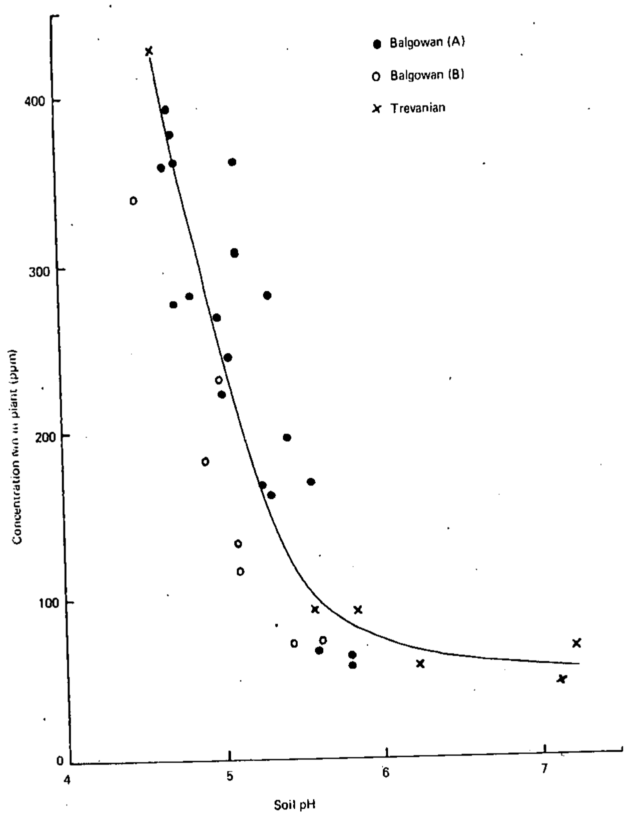

FIGURE 5: Relation between Mn concentration and soil pH.

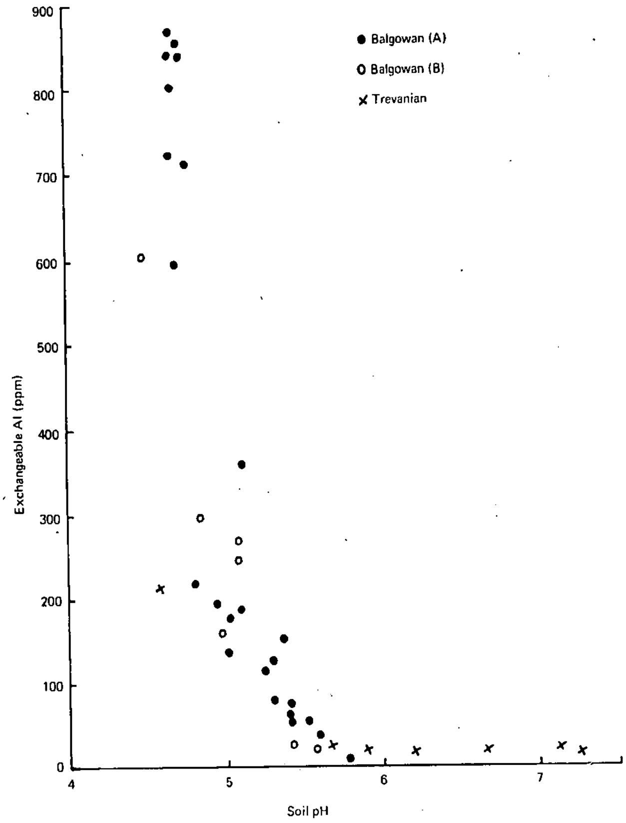

FIGURE 6: Relation between pH and exchangeable Al in the soil.

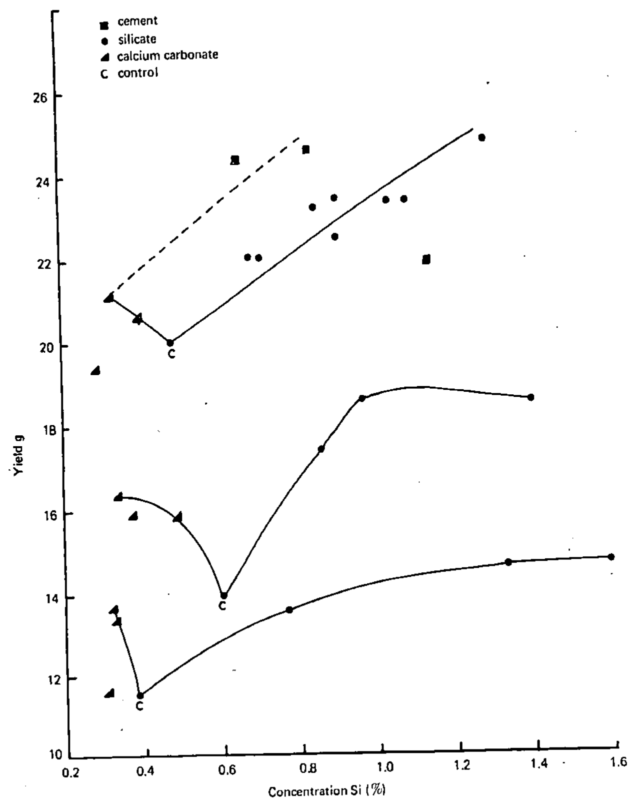

FIGURE 7: Relation between yield and Si concentration in the plant.

Discussion

Mr. du Toit (in the chair): Mr. du Preez refers to the work done by Mr. d'Hotman de Villiers many years ago in Mauritius. It took twenty-five years to recognise his point — that silica plays a role in the plant life of sugarcane.

Now Mr. du Preez says he cannot explain everything by the elimination of aluminium — silica, according to Mr. d'Hotman de Villiers, has an additional significance apart from its elimination of aluminium.

Professor Sumner: The relation between aluminium in the soil and the aluminium taken up by the plant depends on species.

Mr. du Preez does not say how long he equilibrated before he planted.

The time between liming and planting makes a big difference to results.

In table II, if you plot out the two columns — pH versus yield — you will probably get a clear idea of the effect of silica. It does seem that silica is a far more expensive treatment than liming.

Mr. d'Hotman de Villiers: There is unpublished data by me about thirty years ago, when I was working with Craig and Halais at the Sugar Experiment Station, Mauritius. I obtained significant increases in yield on plots that had received large doses of crushed basalt.

In these same plots cane leaves showed considerably higher silica content compared with control.

Mr. du Preez: The period for equilibration was not more than a week.

The level where we got a depression with calcium carbonate was high — about 18 tons per hectare. Do you feel if we had equilibrated for a longer period we may not have had that drop?

Professor Sumner: We get a drop from high levels of liming on soils like the Balmoral but we are not sure why.

Mr. du Toit: As regards the elimination of aluminium by either lime or silicates, Dr. Clements claims he can get a good response to lime due to the elimination of aluminium toxicity, but he gets a significantly better response to silicates and he feels that the silicates do play a role in plant nutrition.

The relationship between aluminium and pH as shown in this paper is most interesting. There seems to be a break in the area round about 5.4 — I refer to Figure 6.

It is reassuring that this same figure has been found by Professor Sumner in Pietermaritzburg.