

# SOME RESULTS OF FIELD EXPERIMENTS TO TEST LIME AND PHOSPHOGYPSUM FOR ALUMINIUM AMELIORATION

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## Abstract

Since 1985 two series of field trials have been conducted or established to assess the value of lime and phosphogypsum for the amelioration of aluminium toxicity. The first series considered their use on weak, coastal sandy soils and the second concerned their use on midlands' acid soils with high clay and organic matter contents and under the minimum tillage system. On weak sandy soils the overriding limiting factor to sugarcane growth was shown to be parasitic nematodes, and there was little if any response to the application of lime and/or phosphogypsum. In the second series on acid soils there has, to date, been little evidence of responses to lime or phosphogypsum applied as surface, shallow or deep incorporated treatments. Varietal differences may play a role in explaining the lack of response to lime.

## Introduction

Based on results of investigations (Meyer *et al.*, 1991), lime is recommended as an ameliorant for aluminium toxicity in acid soils of the Natal midlands by the Fertilizer Advisory Service (FAS) of the South African Sugar Association Experiment Station. Although aluminium occurs in some coastal sandy soils as well (Meyer, 1971, Sumner, 1970), little experimental work has been conducted on the toxicity hazard of aluminium to sugarcane growing on these soils. Claims, mainly by the trade, of responses to the application of lime and gypsum on weak sandy soils of the Zululand coast, led to the initiation of three trials in 1985 and 1986. At the same time, on steeply sloping acid soils under a minimum tillage system of establishment in the midlands, investigations were being initiated into suitable methods of lime incorporation. Further, the availability of phosphogypsum, a by-product of the manufacture of phosphoric acid at Richards Bay, led to it being considered as a possible alternative to lime where subsoil acidity was a problem and the deep incorporation of lime not practical (Meyer *et al.*, 1991). As a result of this a series of trials has been established to evaluate the efficacy of phosphogypsum to replace or supplement lime in the amelioration of aluminium toxicity. A 3<sup>3</sup> factorial lime x phosphogypsum x P trial has been conducted at Seven Oaks and results have been reported (Meyer *et al.*, 1991). There

was no response to lime but the phosphogypsum and phosphorus treatments improved cane and sucrose yields, and suggested that the P content of phosphogypsum was primarily responsible. Since there was no response to lime and the aluminium levels were not particularly high, it was considered that a site with higher levels of aluminium should be found. This paper reports the results of a series of trials on weak sands, and interim results of a series of trials on heavier acid soils in the midlands, one of which involved the use of the minimum tillage system of re-establishment.

## Experimental procedures

Details of sites and selected properties of the soils are presented in Table 1.

The first series of trials were all conducted on weak sandy soils of the Fernwood form at Emoyeni on the Zululand coast. The trial to test a range of lime treatments, using the minimum tillage technique of replanting, was conducted on an Inanda form soil at Entumeni in Zululand. The trials on the use of gypsum and phosphogypsum have been established on Inanda form soils at Eston.

Trial designs were factorial, randomised blocks or split plot, and plot sizes ranged from five rows of 15 metres to eight rows of 20 metres. The number of replications ranged from one to eight. A minimum of one metre of cane at each end and one row each side of each plot was disregarded for measurements of growth and yield. Cane in each plot was weighed at harvest and a sample of 12 to 16 stalks taken from each plot for sucrose determinations. Treatments in each experiment are indicated under the results.

## Results

### Series 1

#### Experiments I and II

These were conducted in the same field using cane variety NCo376. The old crop was eradicated with Roundup, the area disced or treated with a rotary hoe and treatments then applied. These consisted of lime at rates of zero, 1,5 and 6 t/ha broadcast on the surface and then either incorporated with a rotary hoe or with no incorporation besides that which

Table 1  
Sites and selected chemical and physical properties of the soils in the experiments (0-200 mm)

Expt. No.	Site	Soil form	Cane variety	pH	OM %	Clay %	PDI	P	K	Ca	ppm Mg	S	Zn	Al
I	Emoyeni	Fernwood	NCo376	5,49	1,40	5	>0,80	66	56	86	26	17		6
II	Emoyeni	Fernwood	NCo376	5,27	0,67	5	>0,80	59	32	66	15	15		10
III	Emoyeni	Fernwood	NCo376	5,93	0,43	5	>0,80	42	15	145	10	21		1
IV	Entumeni	Kranskop	N12	4,90	3,90	23	0,56	15	102	216	43	37	0,6	140
V	Eston	Inanda	N12	4,85	6,70	47	0,21	27	180	344	56	94	4,0	129
VI	Eston	Inanda	N12 ,N16	4,80	5,52	28	0,46	20	171	171	36	53	4,0	120
VII	Eston	Inanda	NCo376	4,70	4,20	27	0,50	19	110	161	31	40	4,0	124

occurred at ridging. A treatment of gypsum (2 t/ha) was applied on its own and in combination with shallow incorporated dolomitic lime (6 t/ha). An additional treatment consisting of the shallow dolomitic lime + gypsum (DL/G) combination with extra lime applied about 700 mm deep using a Waletz deep lime applicator, was included in both trials. A provision for a deep soil disturbance treatment, using the same applicator without lime, was made in the second trial. Because of the high nematode hazard of these soils, Temik nematicide was applied throughout as a split plot treatment. Sucrose yield results from experiments I and II are presented in Table 2.

sum. Lime treatments were either incorporated to about 150 mm or applied to depth on the interrow, using the same Waletz deep lime applicator. To eliminate possible confounding effects of deep disturbance, the deep lime applicator was passed through all plots. Gypsum and phosphogypsum treatments were broadcast on the surface after deep disturbance. Sucrose yield results are presented in Table 3.

As in experiments I and II the effects of nematicide were dramatic from an early stage. In the absence of phosphogypsum or gypsum there appeared to be a negative effect from additions of lime, sulphur and lime + sulphur. How-

**Table 2**  
The effects of lime and gypsum treatments on sucrose yields in the presence or absence of nematicides in experiments I and II (Emoyeni)

Treatment	Rate (t/ha)	Sucrose yields (t/ha)					
		Experiment I				Experiment II	
		Plant		Ratoon I		Plant	
		No nem.	Nem.	No nem.	Nem.	No nem.	Nem.
Control	0					6,6	11,9
DL incorporated (inc)	1,5	2,9	9,7	3,4	8,2	7,8	11,2
DL (inc)	6	3,4	8,7	3,7	8,5		
Gypsum (G) (inc)	2	5,5	9,4	4,5	6,8	8,8	11,7
DL + G (inc)	6 + 2	4,9	10,3	4,4	8,0	7,8	13,4
DL + G (inc) + DL deep	6 + 2 + 3,6	6,1	11,0	5,1	7,6	8,0	12,1
DL + G (inc) + deep	6 + 2					10,3	14,7
SE of the difference	±					1,05	
LSD (0,05)			1,16 2,68		0,92 2,13		2,34

It was obvious from an early stage that there was a dramatic response to nematicide, which was confirmed by crop measurements and the yield at harvest. Although there were indications of improvements in growth and yield due to treatment with gypsum or gypsum and lime, or due to deep disturbance, these effects were not consistent and were small compared with the effects of nematicide. In general, the combined gypsum and lime treatment combinations were marginally better than when either of these treatments was used separately. In the second trial, the deep soil disturbance treatment without nematicide yielded almost as well as the lowest yielding nematicide treatment, and produced a significant response of 2,5 t/ha compared with no deep disturbance.

**Experiment III**

This experiment was superimposed on a poor ratoon crop of NCo376 which was growing in the same Fernwood form soil. The objective was to test the effects of added gypsum, lime and sulphur. The experiment design was factorial and treatments included sulphur, lime, phosphogypsum and gyp-

ever in the presence of 6 t/ha PG there appeared to be some advantage to the addition of lime and sulphur treatments.

Leaf nutrient uptake was monitored in these experiments and relative treatment effects for experiments I and II are presented in Figure 1.

Sulphur was increased marginally by gypsum but lime appeared to have little effect. All leaves were above the threshold value (TV) of 0,12% S, suggesting that no yield response to gypsum treatment would have been expected. Calcium was markedly increased by gypsum treatments but not by lime treatment, and combinations of lime and gypsum had slightly lower calcium contents in the leaf than did gypsum alone. There was also no indication of a Ca deficiency in leaves from any treatment (TV=0,15%). Magnesium was increased by lime but decreased by gypsum. However, as with S and Ca, leaf levels were satisfactory and above the threshold value in all treatments (TV=0,08%).

Soil nutrient status was also monitored and the main treatment effects on Ca and Mg status of the topsoil are presented in Figure 2.

**Table 3**  
The effects of lime (L), phosphogypsum (PG), gypsum (G) and nematicide (N) treatments on sucrose yields in experiment III (Emoyeni)

Treatments	Rate (t/ha)	Sucrose yields (t/ha)					
		N	LN	SN	LSN	Mean	NO N
PG	0	6,0	5,3	4,6	5,6	5,4	1,2
PG	2	6,4	5,5	6,0	6,1	6,0	
PG	6	5,0	6,2	7,0	7,3	6,4	
G	6	6,9	4,9	5,8	6,6	6,0	2,3
Mean		6,1	5,5	5,9	6,4		
SE of the difference	±				0,92		
LSD (0,05)					1,3		

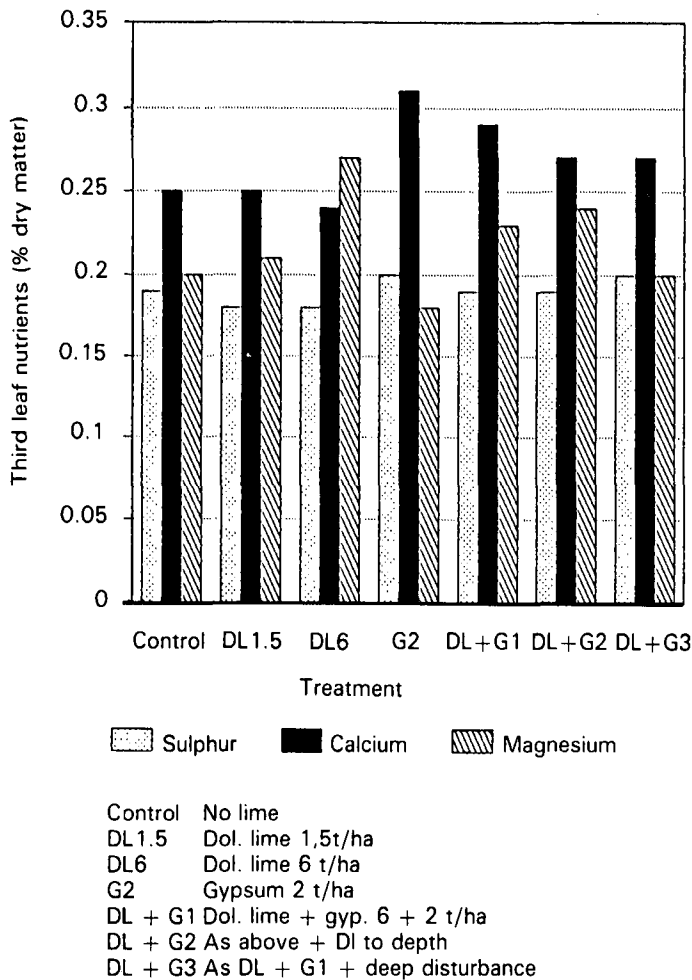


FIGURE 1 Mean third leaf nutrients after treatment with lime and phosphogypsum in experiments I and II (Emoyeni).

- **pH** – Gypsum did not increase soil pH whereas lime did, particularly at the higher rate.
- **Calcium** – Ca was diagnosed as deficient at both trial sites and lime at the rate of 1,5 t/ha would have been recommended by FAS. Ca levels were increased by lime treatment to above the threshold value of 150 ppm, but to a lesser extent by gypsum.
- **Magnesium** – Lime treatment appeared to increase the levels of magnesium which initially had been only marginally above the threshold value of 25 ppm. However, treatment with gypsum reduced magnesium in the topsoil to below the threshold value.

A similar assessment of subsoil analytical data showed that high rates of lime and application to depth appeared to have very little effect on subsoil calcium levels, and only a small effect on subsoil magnesium levels. Gypsum caused a decrease in magnesium throughout the sampled profile as observed by Meyer *et al.* (1991). Effects on aluminium at all depths were not easy to ascertain, but levels were not toxic in terms of current recommendations: toxic if above 27 ppm in soil with a clay content of less than 15%.

Series 2

Experiment IV

This experiment was established to evaluate the response to lime application under minimum tillage conditions. The experiment was conducted at Entumeni in Zululand and the following procedures were used. The old crop was sprayed with Roundup, dolomitic lime broadcast at a rate of 6 t/ha over the whole experiment site, and then furrows drawn. The variety N12 was planted.

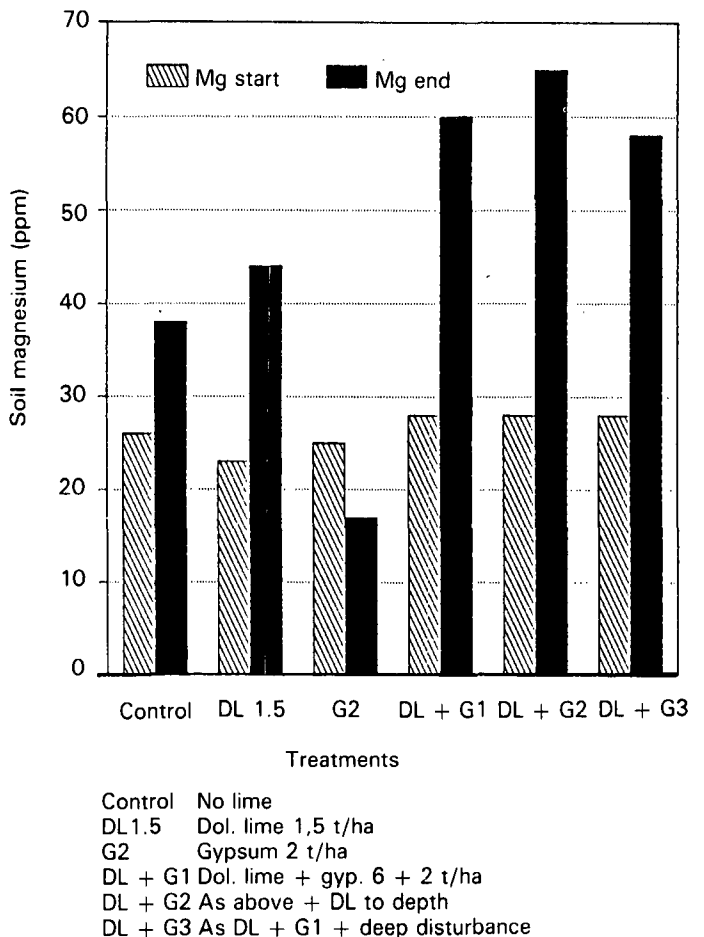
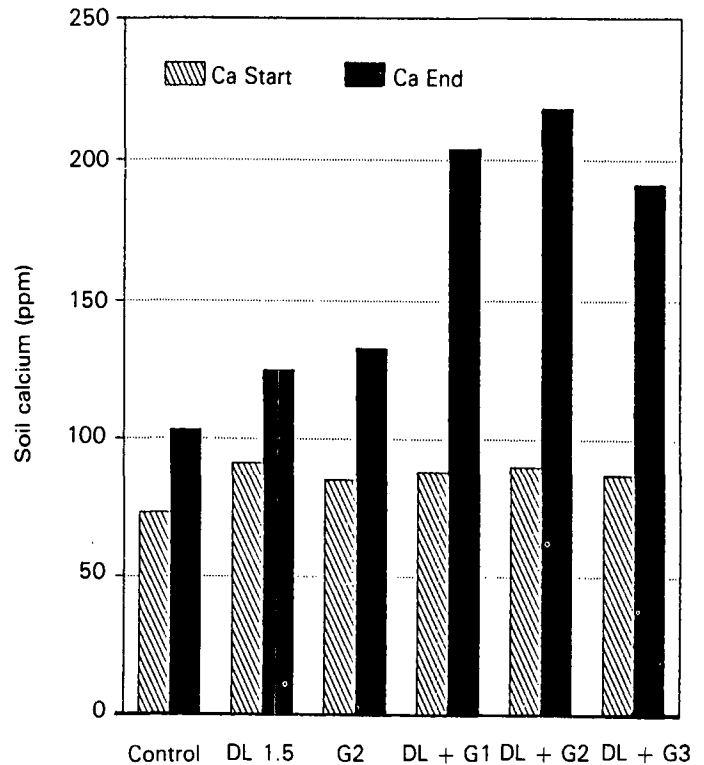


FIGURE 2 The effect of lime and gypsum treatments on calcium and magnesium in the topsoil in experiment II (Emoyeni).

Treatments consisted of:

1. No further incorporation besides that occurring at ridging
2. Incorporation in the new row using a rotary hoe (600 mm wide and 200 mm deep). This was followed by incorporation in the new interrow five weeks after planting with the rotary hoe
3. As for treatment 2 but in addition 4 t/ha dolomitic lime was applied to depth on the new interrow (old row) immediately after planting, using a Waletz deep lime applicator (depth about 700 mm).

Effects on sucrose yields, third leaf nutrients and soil nutrient status are summarised in Table 4.

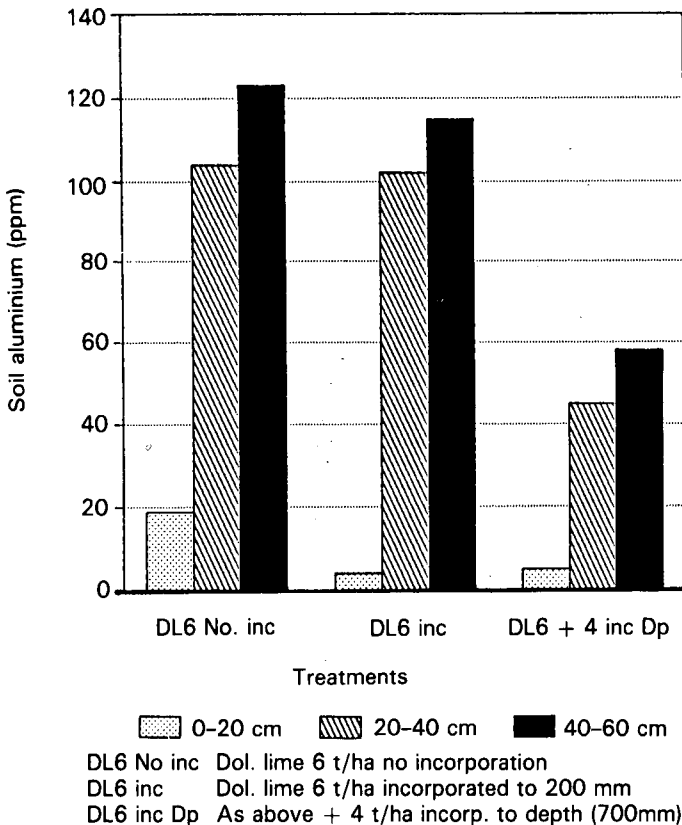


FIGURE 3 The effects of lime incorporated shallow and to depth on soil aluminium in experiment IV (Entumeni).

During incorporation of treatments on the new interrow it was obvious that the cane rows were too narrow (900 mm) to prevent some damage to the crop. This effect was marked in terms of yield in the plant crop. These effects were not present in the ratoon but there was still no evidence of the expected response to lime. The effects on pH and soil nutrients were that pH was raised by all treatments in the topsoil, as was the level of calcium. Aluminium was markedly reduced by all treatments to non toxic levels and this is illustrated in Figure 3.

Experiments V, VI and VII

These experiments were established to investigate the possibility of decreasing aluminium toxicity by surface applications of phosphogypsum in ratoons and by the use of combinations of lime and phosphogypsum in plant cane. Yield results and crop measurements from experiment V are shown in Table 5.

There was no evidence of any benefit from the application of phosphogypsum in this ratoon cane experiment (variety N12) in terms of crop measurements or yield at harvest. Phosphogypsum was broadcast on the surface at six months of age, and slight damage occurred to cane in treated plots. The experiment was harvested at 16,5 months, which is young for this area. It is possible that these factors contributed to the lack of response, but measurements in the next ratoon crop at 15 months tended to support the contention that a response was unlikely.

Experiment VI

In this experiment lime and phosphogypsum were broadcast after eradication of the old crop, and then incorporated with a rotary hoe to a depth of 200 mm. Deep incorporation was conducted with an Alubuster to a depth of 400 mm in the appropriate plots. Crop growth measurements of varieties N12 and N16 at 14 and 16 months of age are shown in Table 6.

It is apparent that at 14 months in variety N12, stalk length was reduced to some extent in plots treated with lime. Effects on N16, and in fact both varieties, in terms of stalk populations were less obvious. There is as yet no indication of the expected response to treatment of this aluminium toxic soil with these ameliorative treatments.

Experiment VII

Treatments of lime and phosphorus were applied to plots in a ratoon crop of variety NCo376 and incorporated on the interrow using a rotary hoe or applied to depth using an Alubuster. Some damage was caused to the cane rows at the time of incorporation but the cane appeared to recover remarkably quickly. Phosphogypsum was broadcast and not incorporated. Stalk length measurements at 20 months showed no benefits to treatment.

Leaf nutrients

In experiments V, VI, and VII trends were that calcium was increased in the leaf by lime and to a greater extent by phosphogypsum treatment. Magnesium was decreased by phosphogypsum but increased by lime. Sulphur was increased marginally by phosphogypsum and potassium tended to be decreased by these treatments. These trends follow those which occurred in the experiments on weak sands and which are illustrated in Figure 1.

Table 4  
Some effects of treatment with lime under minimum tillage conditions in experiment IV (Entumeni)

Treatments	Rate (t/ha)	Sucrose (t/ha)		3rd Leaf Ca (%dm)		Soil nutrients (ppm)								
		P	R1	P	R1	At start			End Plant			End R1		
						pH	Ca	Al	pH	Ca	Al	pH	Ca	Al
DL no incorp	6	12,0	14,9	0,25	0,23	4,9	216	140	5,15	635	12	5,53	771	2
DL incorp	6	9,6	14,2	0,24	0,25	4,9	216	140	5,24	582	10	5,85	866	3
DL incorp + deep	6 + 4	9,2	14,7	0,24	0,24	4,9	216	140	5,25	560	14	5,69	763	2

**Table 5 : Crop characteristics at harvest after treatment with phosphogypsum in experiment V (Eston)**

Treatments	Stalk				Yield		Quality
	Length (m)		Popln. (1000/ha)		Cane (t/ha)	Sucrose (t/ha)	Sucrose (% cane)
	R6	R7	R6	R7	R6	R6	R6
No phosphogypsum	1,23	1,58	127	145	51,6	6,4	12,52
Phosphogypsum	1,24	1,60	128	150	52,4	6,2	11,85
SE of diff. ±	0,011		2,66		2,51	0,27	0,38
LSD (0,05)	0,027		6,28		5,94	0,65	0,89

**Table 6**

**Effects of lime and phosphogypsum treatments on crop measurements in varieties N12 and N16 in experiment VI (Eston)**

Treatments	Rate (t/ha)	Stalk length (m)				Stalk population (1000/ha)			
		N12		N16		N12		N16	
		14m*	16m	14m	16m	14m	16m	14m	16m
DL (inc)	0	1,41	1,67	1,44	1,61	145	148	141	141
DL (inc) deep	0	1,43	1,72	1,48	1,64	151	157	138	140
DL (inc)	7	1,27	1,56	1,41	1,56	141	141	138	135
DL (inc) deep	7	1,27	1,56	1,40	1,61	131	135	145	144
DL (inc)	14	1,34	1,64	1,37	1,64	140	144	145	148
DL (inc) deep	14	1,31	1,61	1,41	1,62	144	130	151	137
DL + G (inc)	7 + 5	1,31	1,66	1,44	1,63	154	150	140	136

\* Age in months

**Soil nutrients**

As for leaf nutrients, the trends in soil nutrient changes after treatment with lime and phosphogypsum were similar to those that occurred in the experiments on weak sands, and could be summarised as:

**Effects of phosphogypsum:**

- Little change in pH
- Slight reduction in aluminium levels
- Marked improvement in calcium and sulphur status with depth
- A tendency for reduced magnesium levels
- A slight improvement in P availability

**Effects of lime:**

- Improvement in pH
- Reduction in aluminium in the topsoil and less so at depth
- Improvement in magnesium levels

**Conclusions**

**Weak sands**

A nematicide is essential and nematodes appear to be the overriding factor limiting cane growth in weak sandy soils of the Fernwood form, where calcium is deficient but aluminium is not present at a toxic level according to current FAS recommendations.

The supply of calcium to the plant was more efficient from the use of phosphogypsum than dolomitic lime whereas the reverse was true for the supply of magnesium. Thus a combination of the two ameliorants was most efficient in supplying both nutrients.

**Minimum tillage**

Damage to the plant crop from interrow incorporation of lime on slopes, where narrow row spacing was used, negated any yield benefits from lime on aluminium toxic soils.

The lack of residual response to liming in ratoon crops, despite markedly reduced aluminium levels and increased pH, was surprising but may possibly be attributed to the tolerance of variety N12 to aluminium.

**Phosphogypsum**

The use of gypsum or phosphogypsum in plant or ratoon cane does not increase soil pH and leads to increased calcium, but decreased magnesium levels in the soil and plant. They are thus unlikely to be able to substitute for lime where it is required for amelioration of aluminium toxicity, but they may be beneficial when used in combination with lime. The high moisture content of phosphogypsum (± 40%) is a serious disadvantage to its use, not only in ensuring uniform application but also on economic grounds.

**Aluminium toxicity**

The lack of response in crop growth and yield to lime and gypsum treatments, in spite of increased pH and decreased aluminium in the soil, may reflect tolerance of varieties N12 and N16 to aluminium. However there is also evidence of a negative effect of lime on crop growth in N12.

**General**

It is apparent that varietal sensitivity to aluminium and lime treatment should receive attention in future research programmes. Studies conducted in Australia have shown large differences in varietal tolerance to Al. In the maize industry Al tolerant cultivars have been developed by plant breeders for use on acid soils (Hetherington *et al.*, 1986).

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