THE INCORPORATION OF LIME UNDER MINIMUM TILLAGE CONDITIONS

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Abstract

Soil acidity and high levels of exchangeable aluminium in the soil have been identified as important growth limiting factors in the cultivation of sugarcane in many cane producing areas of the industry. Since the introduction of the minimum tillage concept to the industry some years ago, no effective method of incorporating lime under a minimum tillage system has been recognised. In view of the growing importance of minimum tillage to the industry, it was considered important at planting to find an effective method for ameliorating soil acidity and toxic levels of aluminium by liming.

A field trial was conducted to establish practical methods of incorporating dolomitic limestone on steep terrain using reduced or minimum tillage methods of cultivation. The performances of nine selected manual and mechanised implements were monitored, and chemical analyses of soil samples were conducted to establish the efficacy of lime distribution within the disturbed profile of soil when each method was practised. The effects of the various treatments compared with those of the accepted ploughing and discing method of incorporating ameliorants on highly acid soils are reported.

Introduction

The cultivation of sugarcane on the coastal hinterland and midland areas of Natal is frequently carried out on acid soils. Some of these soils also contain toxic levels of exchangeable aluminium which prevent optimum growth of sugarcane. Previous studies in the sugar industry have shown that aluminium may be ameliorated by liming (Moberly and Meyer[4]).

Sugarcane is cultivated in many of these areas on slopes in excess of 20 percent and to comply with the requirements of the Conservation of Agricultural Resources Act of 1983, reduced, or minimum tillage practices will be necessary under these circumstances. Soil and water losses from recently prepared or planted sugarcane fields can be a serious problem, especially where the topography is steep. It has been shown that soil loss and water runoff are greatly reduced when good minimum tillage is practised compared with losses when conventional tillage is used. (Haywood and Mitchell[2]). Other advantages, such as improved soil moisture retention and shorter intervals between crops, are possible (Iggo and Moberly[3]). However, the difficulty of incorporating dolomitic lime under minimum tillage conditions on acid soils poses a real problem, and to date very little information has been available on this subject.

A field observation trial was therefore conducted to establish the efficacy of selected manual and mechanical methods of incorporating lime under these conditions. The major objectives of this observation trial were to:

(i) measure the volume of soil disturbed in relation to the total volume of soil for each treatment
(ii) assess the efficacy of lime distribution within the disturbed volume of soil in each treatment
(iii) monitor power and traction requirements for each method of incorporating lime on steep slopes
(iv) where necessary, adapt existing equipment to improve its performance or effectiveness
(v) establish the most suitable methods for incorporating lime in future field trials when reduced or minimum tillage is indicated.

Method and Materials

The trial was established in the Upper Tongaat area on a site with an average slope of 21 percent. Row spacing was 1,2 m. The previous crop was burnt before harvesting. The details of the locality, soil form and some physical and chemical properties of the soil in the observation plot are presented in Table 1. Dolomitic lime was broadcast manually at 7 tons per hectare on alternate cane interrows except where a deep limer equipped with its own lime applicator was used. An unlimed, undisturbed interrow served as the control.

Table 1

Selected physical and chemical properties of the test site topsoil (0–300 mm)

Soil form	Soil series	Clay %	pH (H_2O)	P ppm	K ppm	Ca ppm	Mg ppm	Al ppm
Glenrosa	Trevanian	41	5,15	5	53	332	158	41

The implements used are listed in Table 2. A 58 kW front wheel assisted tractor was used for all implements except for the manual chipping method and for the deep limer, which was pulled by a 45 kW crawler tractor. Mechanical riding and manual closing of the furrows were done to simulate normal planting procedures as closely as possible.

Table 2

Summary of operations for applying lime

Treatment No.	Equipment and order of operation
Control	Not limed – undisturbed
1	Plough/disc/ridger
2	Alu-Buster/ridger
3	Disc min tiller/ridger
4	Rotary min tiller, ridger
5	Deep limer/ridger
6	Alu-Buster/ridger
7	Hand chipping
8	Rotary min tiller/Alu Buster
9	Ridger only

After allowing a six week period for the lime to neutralise part of the soil acidity, during which 59 mm of rain was recorded, a trench 0,60 m deep was dug across each plot. The purpose of the trench was, firstly to facilitate the measuring of the disturbed volume of soil, and secondly to ascertain the depth to which disturbance had taken place. The measuring of the disturbed part of the soil profile was simplified by the use of an adjustable profile template (Figure 1), which not only indicated the shape of the disturbed area, but also helped determine the cross sectional area of disturbance.

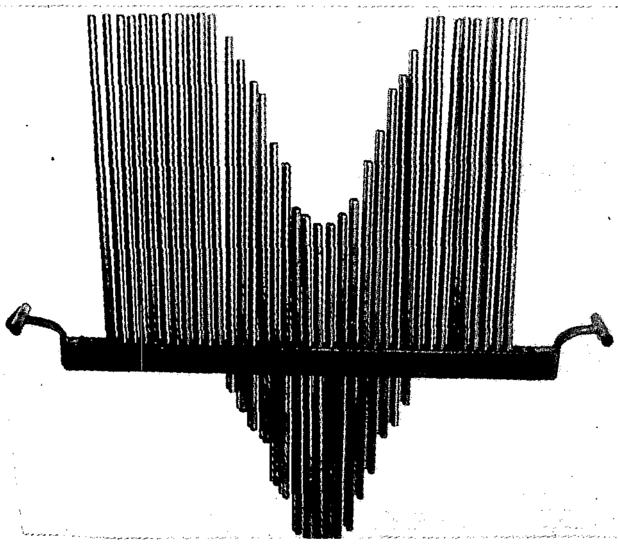

FIGURE 1 Profile template.

In each treatment five separate composite soil samples, 150 mm deep, were taken along the centre line of the disturbance and, where implements penetrated deeper than 150 mm a similar number of samples were taken at a depth between 150 and 300 mm. Samples to determine soil moisture content were taken horizontally, within and outside each disturbed area which was exposed on the side of the trench.

Results and Discussion

The 58kW front-wheel assisted tractor was adequate for all treatments under the trial conditions as far as lateral stability and traction were concerned. On slopes exceeding 20 percent it would be necessary to use a small crawler tractor depending on the type of implement used, and the width and depth of soil disturbance to be achieved. On steep slopes the use of powered implements would improve the performance and lateral stability of the tractor.

The disturbance generated by each treatment is shown in Figure 2. The depth and percentage disturbance for each treatment relative to a depth of 400 mm and a width of 1,2 m are presented in Table 3.

Percentage disturbance was calculated as the proportion of the total cross-sectional area of soil, from the centre of one cane row to the centre of an adjacent row, and to a standard depth of 400 mm, that was disturbed. Values varied from 8 for the manual chipping and ridger only methods, to 22 in the case of the deep limer. Generally, soil moisture conditions affect the degree of soil breakout, the tilth that can be achieved and the amount of soil/lime mixing that takes place. The width of disturbance in the top 100 mm of soil was sometimes increased by the ridger, which penetrated deeper where it had been preceded by other implements. This resulted in greater soil disturbance. The ridging operation and subsequent manual closing of the furrow also assisted in incorporating the lime.

The average chemical analyses of four sub-samples taken from the disturbed soil in each treatment are shown in Table 4. The percentage improvement due to each treatment in terms of soil acidity, and exchangeable calcium, magnesium and aluminium in the 0–150 mm stratum of soil, compared with the control, is illustrated by the bar chart in Figure 3. The amount of soil amelioration due to treatments that were effective to depths between 150 and 300 mm are presented in Figure 4. These results indicate that in all treatments lime was incorporated to some degree. In terms of overall improvement, taking into account changes in both the top and subsoil analyses, treatments 2, 4, 5 and 8 gave the greatest response to liming.

The effectiveness of incorporation of lime depends on the extent to which implements mix the soil and lime. If deep incorporation is necessary, the lime may first have to be placed at the desired depths. This is the way in which the commercially available deep limer distributes the lime (Treatment 5).

Experience with the various implements used in this trial has shown that there is potential for an improved implement that will meet the requirements for successful incorporation and distribution of lime under minimum tillage conditions. To achieve optimum incorporation and distribution throughout the disturbed profile, it may be necessary to apply the recommended amount of lime in a band that will be no wider than the furrow that will be drawn. Practical means of applying lime in bands of varying widths in the interrow will require further investigation.

The results obtained may be improved if the incorporation of lime and the ridging operation are carried out separately.

Treatments were also assessed by rating visually the amount of soil disturbance and the effectiveness of incorporation of lime at the two sampling depths. The treatment ratings are shown in Figure 5, confirming the trends identified in Figures 3 and 4. When treatments are compared it must be remembered that conventional tillage (treatment 1) would be unacceptable where minimum tillage is mandatory to meet the requirements of the conservation act.

The area occupied by the old cane row can be treated at a later date, preferably after the new plant crop has been harvested. In this way the total tilled area eventually becomes much greater than that indicated in Table 3.

Conclusions

The results of this study suggest that treatments 2, 4, 5 and 8 were promising. Where minimum tillage is practised, and with consideration to terrain, growers should choose one of these methods for applying lime. However, this was an observation trial and confirmation of the results requires a replicated trial in which the treatments can be assessed in terms of cane and sucrose yields.

The trial has shown that it is possible to incorporate lime under minimum tillage conditions; and although differences between the various implements and treatments have been demonstrated, it would be premature at this stage to express a definite preference for a particular treatment. Further investigations with implements specially designed to meet the criteria of cost, power consumption, maximum soil disturbance and soil/lime mixing are required.

Subjects which require further elucidation include the following:

- The incorporation of lime to depth. The need to distribute and incorporate the lime over the entire interrow area, thus reducing soil moisture and increasing the risk of soil erosion. The requirements of the crop and those of conservation may be in conflict here.

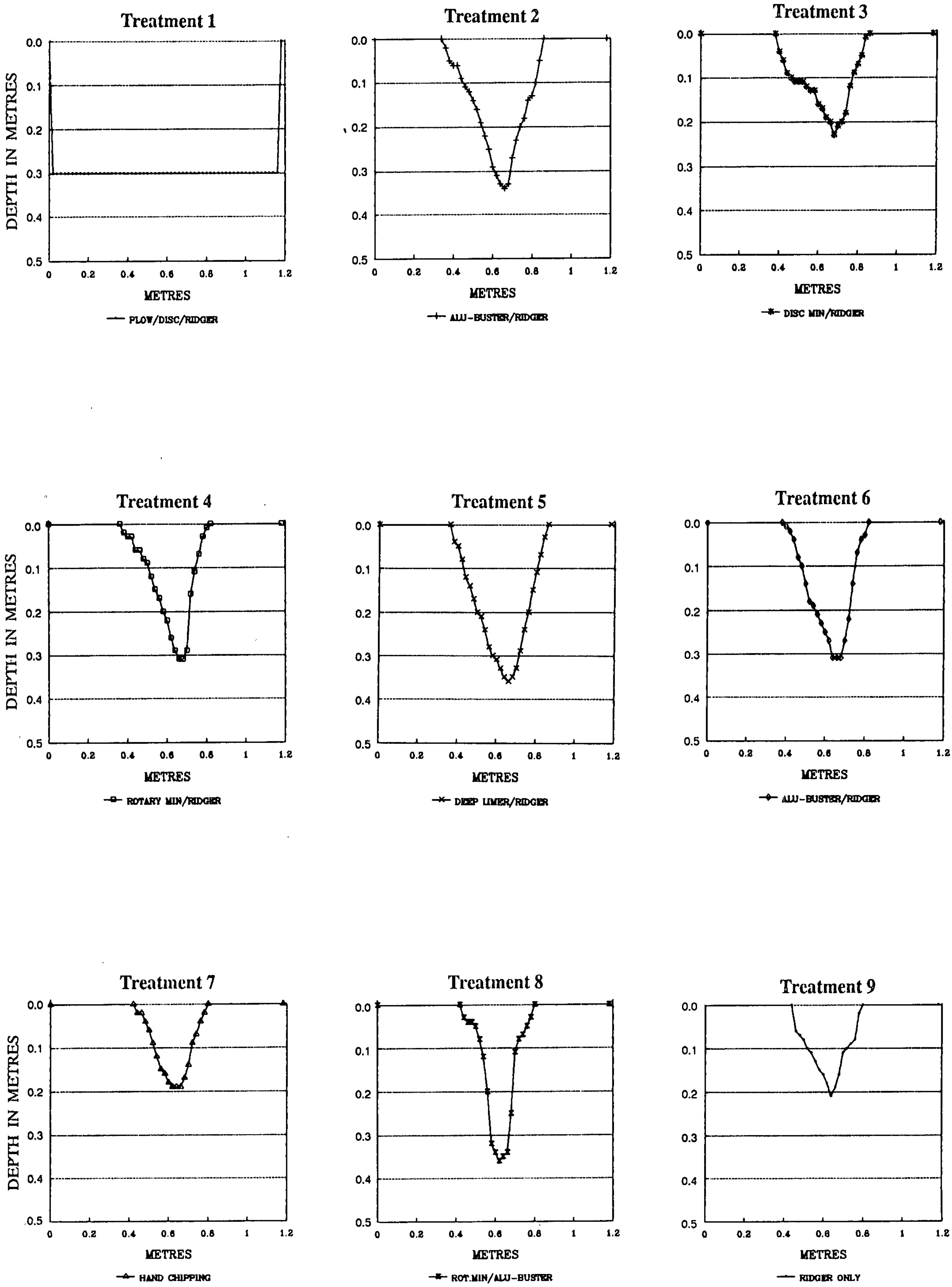

FIGURE 2 Comparison of soil disturbance for the nine treatments.

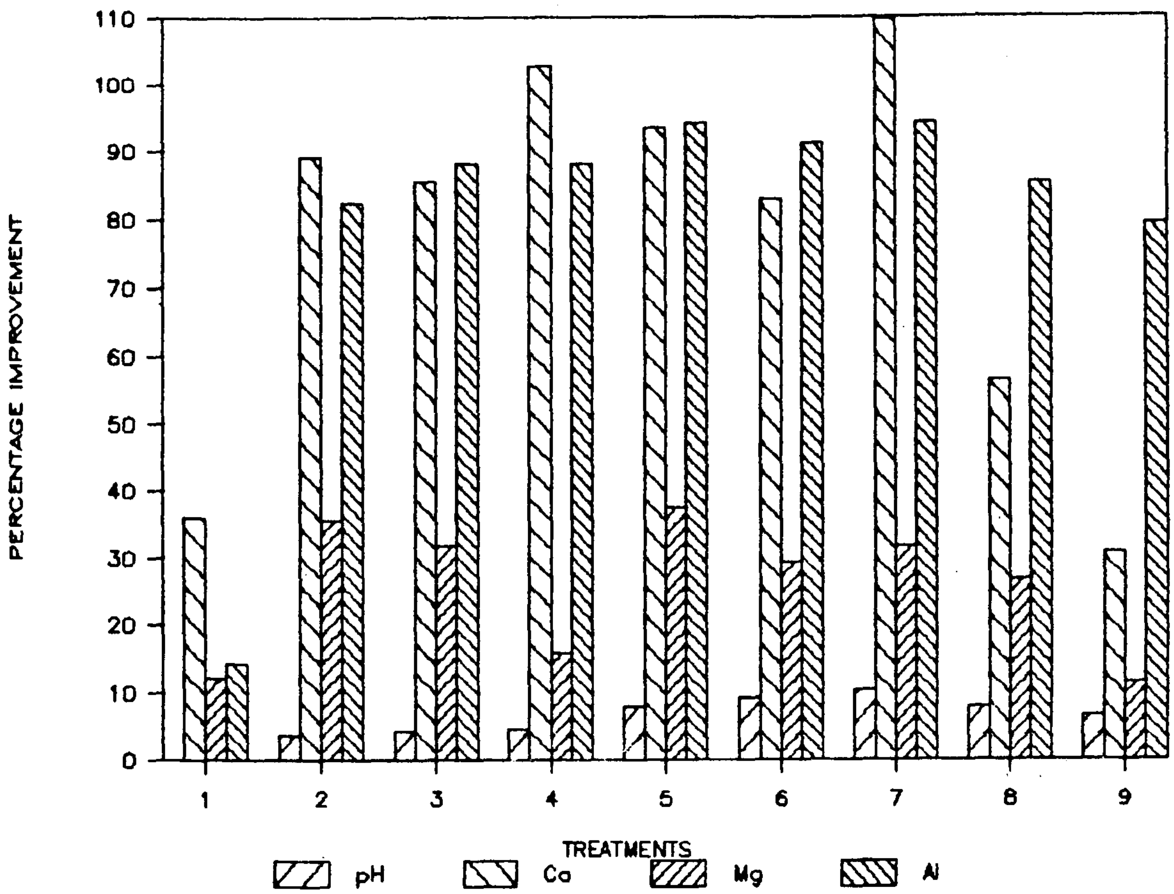

FIGURE 3 Relative change in chemical properties, 0–150 mm.

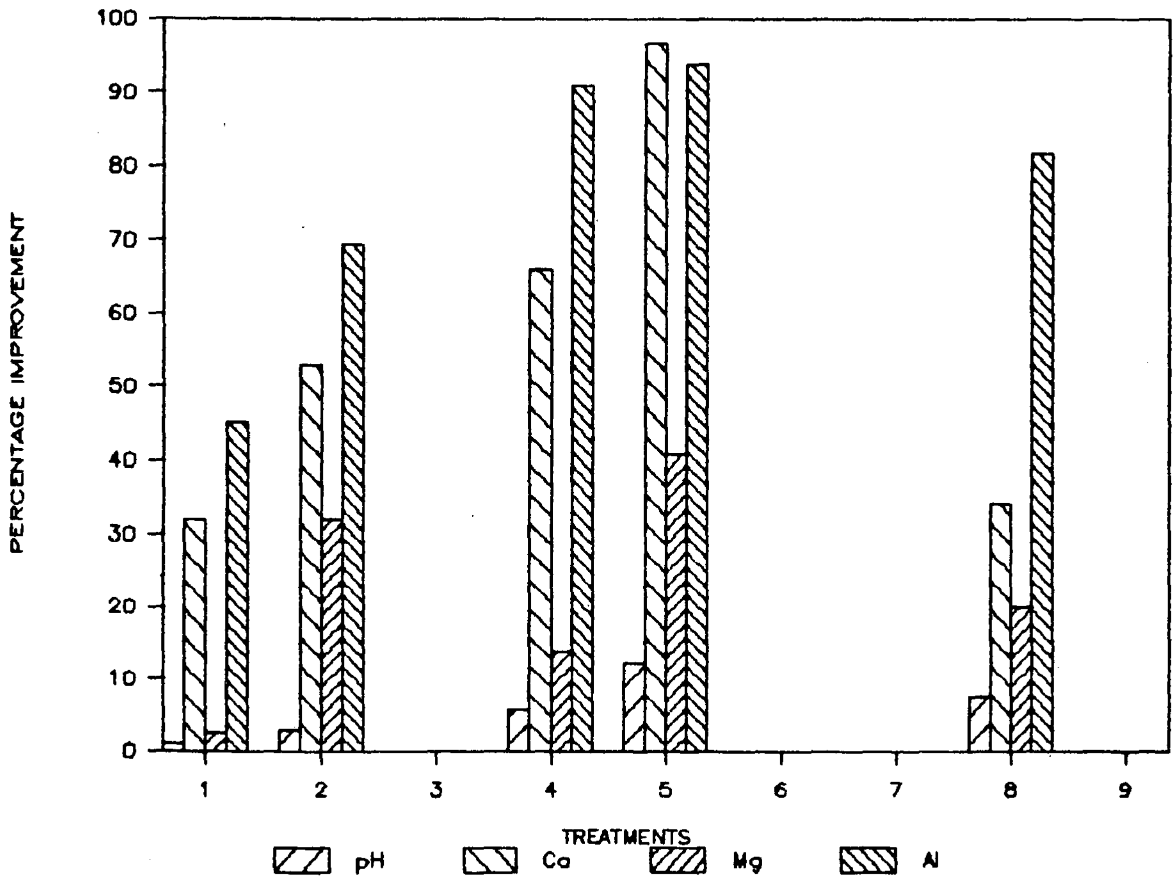

FIGURE 4 Relative change in chemical properties, 150–300 mm.

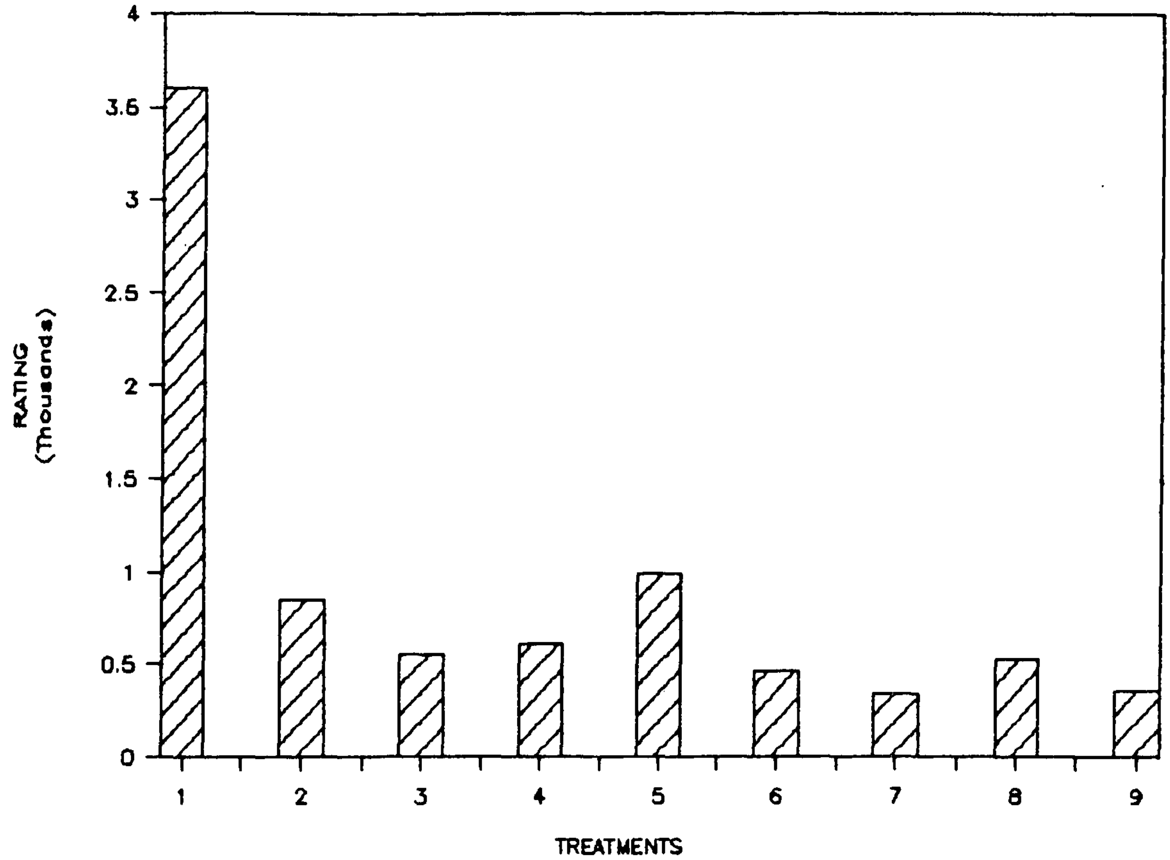

FIGURE 5 Relative treatment performance.

- The merits of banding versus broadcasting the lime before or during the incorporation operation, and an assessment of the rates applicable in each instance.
- The inclusion of phosphogypsum because it can move the displaced Al through the profile (Fey[1]). It may therefore not require deep incorporation. This would be of particular importance where sugarcane is cultivated on acidic soils on slopes in excess of 25 percent, where ameliorants can often be incorporated by means of manual chipping or with animal drawn implements.

Acknowledgments

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Table 3

Effect of treatment on depth and percentage disturbance

Treatment No.	Maximum depth mm	Disturbed area cm²	Percentage disturbance
1	300	3 600	75
2	335	863	18
3	225	554	12
4	310	609	13
5	350	1 045	22
6	300	682	14
7	235	373	8
8	360	562	12
9	210	378	8

Table 4

Chemical properties 6 weeks after treatment

Treatment No.	Water pH		Ca - ppm		Mg - ppm		Al - ppm	
	Depth - mm		Depth - mm		Depth - mm		Depth - mm	
	0-150	150-300	0-150	150-300	0-150	150-300	0-150	150-300
Control	5,17	5,13	318	348	157	160	34	33
1	5,17	5,18	433	459	176	164	29	18
2	5,36	5,28	602	532	213	211	6	10
3	5,39	—	590	—	209	—	4	—
4	5,40	5,43	645	578	182	182	4	3
5	5,57	5,75	615	684	216	225	2	2
6	5,65	—	582	—	203	—	3	—
7	5,71	—	667	—	206	—	2	—
8	5,57	5,52	497	466	199	192	5	6
9	5,51	—	416	—	175	—	7	—

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