RECLAMATION OF A SODIC SOIL AT PONGOLA

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Abstract

The results of a trial to test methods of reclaiming a sodic Bonheim form soil at Pongola, are presented. Subsurface drainage pipes were installed on the whole trial site to facilitate leaching. Various ameliorative treatments were applied amongst which gypsum (26 t ha^{-1}), sulphur (6 t ha^{-1}), filtercake (350 t ha^{-1}) and sulphuric acid (17 t ha^{-1}) were most important. There were no large yield responses to ameliorants but cane in plots treated with gypsum, sulphuric acid and filtercake produced consistently higher yields than cane in the plots which were only drained. The results emphasised the major role which effective drainage alone can play in reclaiming a sodic soil. However, the addition of ameliorants did accelerate the reclamation process.

Introduction

The problems of salinity and sodicity have long been recognised in the sugar industry (Maud[8] and van der Meden[11]) and laboratory studies on leaching have received much attention (Johnston[3,5]). The results of a field trial established on a saline sodic soil in the Nkwalini valley (Johnston[4,5]) emphasised the importance of adequate drainage in reclaiming soils. In conjunction with good drainage an ameliorant is necessary either to supply calcium ions to the soil or to dissolve precipitated calcium carbonate which will replace the excess sodium ions in the soil exchange complex. This not only improves the physical properties of the soil but also the permeability which enhances the leaching process. Although these techniques for reclaiming soils are well documented (Kovda *et al*[6], US Salinity Lab Staff[9]), additional local knowledge was necessary. Consequently in 1976, the salinity/sodicity research programme was expanded to cover a wider range of ameliorants than those tested at Nkwalini where only gypsum and sulphur had been used.

In selecting a site for the trial it was hoped that a sufficiently large area of moderately sodic soil could be found. Unfortunately, sodic conditions were found to vary from slight to extreme over very short distances. For the experiment, an area which had been abandoned for cane growing was selected on a farm near Pongola. The mean annual rainfall was approximately 650 mm and mean evaporation from a USDA Class A Pan was 1 887 mm, indicating that irrigation is necessary for satisfactory yields of sugarcane.

According to the binomial system of classification (Macvicar *et al*[7]), the soil was identified as the Bonheim form (Bonheim series) which typically comprises a thick dark melanic A horizon overlying a calcareous pedocutanic B horizon. Permeability at best is poor, but was made even worse by the high sodium concentrations which had increased over a number of years. Given these limitations, the purpose of the trial was to determine whether the installation of drains and the application of ameliorants could improve conductivity sufficiently to permit re-establishment of sugarcane in this highly sodic Bonheim soil. Sugarcane had previously been grown on the site but the level of sodicity had increased to such an extent that no crop, or even weeds, were able to survive. It was for this reason that an observational rather than a fully replicated trial, was established.

Experimental Procedure

Like many other salt affected soils in the South African sugar industry, the highly sodic state of the soil at the Pongola site had developed over many years (Table 1). The high concentration of salts in the soil was due to inadequate drainage. Most of the soil was highly dispersed.

TABLE 1

Average chemical status of the soil prior to applying ameliorative treatments

Sample depth (mm)	pH	EC (mSm^{-1})	Total cations (meq ℓ^{-1})			SAR
			Na	Ca	Mg	
0–150	9,0	130	11,3	1,1	0,6	13,0
150–300	9,0	145	12,6	1,0	0,7	14,1
300–600	9,0	199	17,3	1,0	0,8	20,2
600–900	9,0	195	17,0	1,2	0,9	23,8

Before the trial was established in the field, a leaching experiment was conducted with permeameters in the laboratory. Results showed that of the four treatments (molasses, sulphuric acid, gypsum and a control), gypsum and sulphuric acid were most successful in improving the hydraulic conductivity of the soil.

Drainage

In August 1977, two lateral drains 150 m long and 18,4 m apart were laid along the upper and lower boundaries of the trial using 50 mm smooth PVC drainage pipe. They were installed at a depth of 1,1 m and backfilled with a sand envelope about 800 mm thick, after which the trenches were filled with topsoil and compacted. Where the lateral drains joined a collector drain inspection boxes were installed. In September 1978, mole drains, 0,45 m below the soil surface, were drawn at 2 m intervals in the plots treated with sulphuric acid at 8,5 t ha^{-1} and with gypsum + filtercake, as well as in one of the plots treated with sulphuric acid at 17 t ha^{-1}.

Treatments

The experimental area was divided into 10 plots each 15 m × 17 m, which were allocated various treatments. All plots were drained. Treatments were as follows:

Control (C), drainage only : 2 plots
Gypsum (G) at 26 t ha^{-1} : 2 plots
Sulphuric acid (H_2SO_4) at 17 t ha^{-1} : 2 plots
Sulphuric acid ($\frac{1}{2}H_2SO_4$) at 8,5 t ha^{-1} : 1 plot
Sulphur (S) at 6 t ha^{-1} : 1 plot
Filtercake (FC) at 350 t ha^{-1} : 1 plot
Gypsum + filtercake (G+FC) at 26 t ha^{-1} + 350 t ha^{-1} : 1 plot

Gypsum and sulphur were applied by hand while a plastic watering can was used to spray concentrated H_2SO_4 onto the soil. Each plot was divided into 12 equal areas to facilitate even distribution. Filtercake was applied by shovelling it off the rear of a tractor-drawn trailer. The gypsum, sulphur and filtercake were incorporated into the soil to a depth of 180 mm by two passes of a disc harrow. The control plots and plots treated with sulphuric acid were not harrowed.

A single irrigation pipe line was installed down the centre of the plots in November 1977 and irrigation started in December 1977. The sprinklers were placed 18 m apart on the pipe line.

About 1 650 mm of irrigation water in addition to 1 350 mm rainfall were received on the site prior to planting in September 1979, by which time sodicity levels at most sampling points of the topsoil had decreased sufficiently to allow reasonable sugarcane growth. By this time, the growth of grasses and broadleaf weeds had also improved markedly. After planting the site to variety NCo 376, irrigation was applied in accordance with a profit and loss account using an estimated total available moisture (TAM) value of 90 mm. An amount of 40 mm effective irrigation water was applied on a minimum cycle time of 10 days but only when the deficit reached 54 mm. Fertilizer was applied to all four crops as recommended by the SA Sugar Association Experiment Station's Fertilizer Advisory Service.

Chemical measurements

To monitor changes in salt status, the soil was sampled at depths of 0 to 150 mm, 150 to 300 mm, 300 to 600 mm and 600 to 900 mm at four positions on a diagonal in each plot. Samples were taken before treatments were applied and generally at intervals of three months thereafter. Once the crop had been established, sampling was done annually after each harvest. The following parameters were measured on each sample:

electrical conductivity of the saturation extract (EC_{se})
sodium adsorption ratio of the saturation extract (SAR_{se})
soluble Ca, Mg and Na concentrations
total Ca, Mg and Na (1N NH_4 Ac extract)
soil pH (1:2,5, soil:water)

Physical measurements

Hydraulic conductivity was measured using the auger hole method (Black *et al*[2]). To monitor the level of the water-table, and to test whether the mole drains assisted in lowering the water-table and the leaching out of the salts the water-table heights were also recorded regularly from February 1978 to the end of January 1979.

Results

Sugarcane yield

Although seven different treatments were used in this observation trial, only the five most effective (control, gypsum, sulphuric acid, filtercake and sulphur) have been reported.

Sugarcane yields for each crop are summarised in Table 2. Although yield responses to the various ameliorants were not large, the plots treated with gypsum, filtercake and sulphuric acid produced yields that were consistently better than those of the control plots in all four crops. Filtercake and gypsum both resulted in the best cumulative responses of 3,4 tons sucrose ha^{-1}. The responses from the plots treated with gypsum were best during the first and second ratoon crops, while the response to filtercake was better during the second and third ratoons. Although it was positive in three out of four crops, the response to sulphur was small. This was probably because sulphur did not reduce sodicity levels as effectively as did the other treatments.

TABLE 2

Summary of yield data in tons per hectare

Treatment	Plant		1st ratoon		2nd ratoon		3rd ratoon		Cumulative response	
	Cane	Sucrose	Cane	Sucrose	Cane	Sucrose	Cane	Sucrose	Cane	Sucrose
Control	108	14,7	107	13,5	85	12,6	96	12,8	-	-
Filtercake	108	14,9	114	13,4	98	14,5	107	14,2	31	3,4
Sulphuric acid	110	14,8	107	13,7	96	14,5	99	13,2	16	2,6
Sulphur	105	14,4	106	14.3	85	12,8	97	13,6	−3	1,5
Gypsum	111	15,0	116	14,7	97	14,5	97	12,8	25	3,4
Mean	108	14,8	110	13,9	92	13,8	99	13,3	17	2,7

Chemical analyses

- SAR_{se}

During the first year after the application of ameliorants, there was a marked decline in sodicity levels (Figure 1) in the topsoil (0 to 300 mm) of all plots and was most pronounced in the plots treated with gypsum and sulphuric acid. Topsoil SAR_{se} values of the plot treated with sulphur fluctuated during the first three years, thereafter values remained fairly constant at about eight which was similar to the final average SAR_{se} value of the soil in the control plots. Final topsoil SAR_{se} values of the other ameliorated plots were all below six.

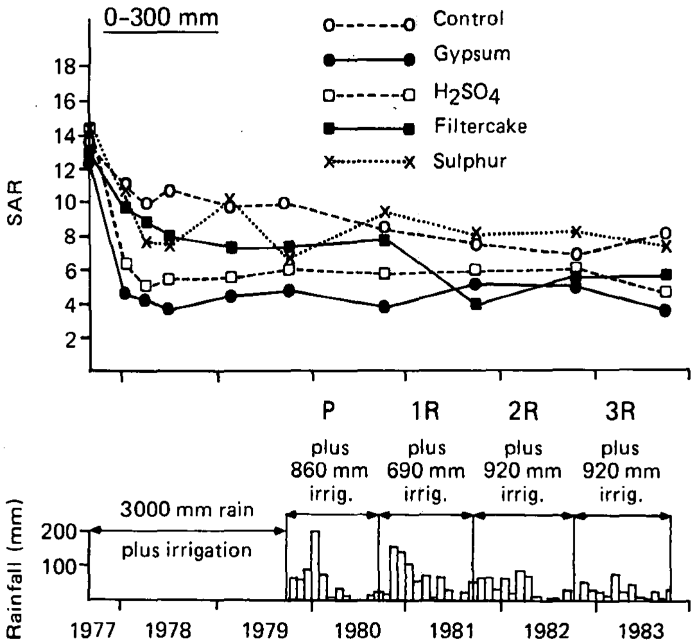

FIGURE 1 Changes in topsoil SAR values with time.

All subsoil (300 to 900 mm) SAR_{se} values declined gradually each year after an initial fluctuation and did not appear to have reached a minimum value when sampled for the last time (Figure 2). The subsoil SAR_{se} values were reduced most effectively by gypsum and filtercake while sulphur was least effective in reducing SAR_{se} levels. This lack of effectiveness of sulphur was not expected as it had proved to be as effective as treatment with gypsum in a previous experiment in a saline sodic soil (Johnston[4,5]).

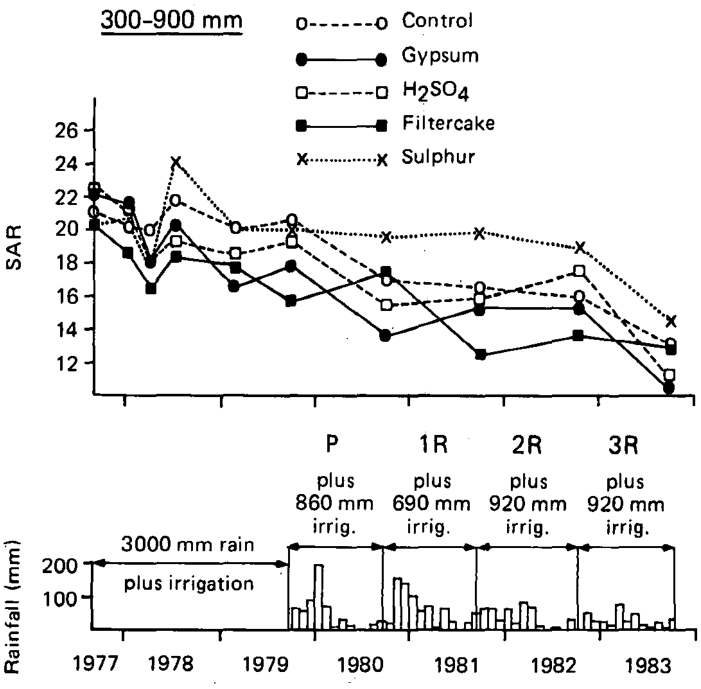

FIGURE 2 Changes in subsoil SAR values with time.

• EC_{se}

All topsoil EC_{se} values were between 100 and 160 mSm^{-1} before ameliorants were applied (Figure 3). By the next sampling, EC_{se} in control plots and those treated with filtercake had declined to less than 100 mSm^{-1}. EC_{se} of soil in other plots except where sulphur was applied, remained between 50 and 110 mSm^{-1} until the final sampling in 1983. EC_{se} values of soil in the plot treated with sulphur remained above 150 mSm^{-1} until the 1981 sampling, after which they gradually declined to about 90 mSm^{-1} at the final sampling.

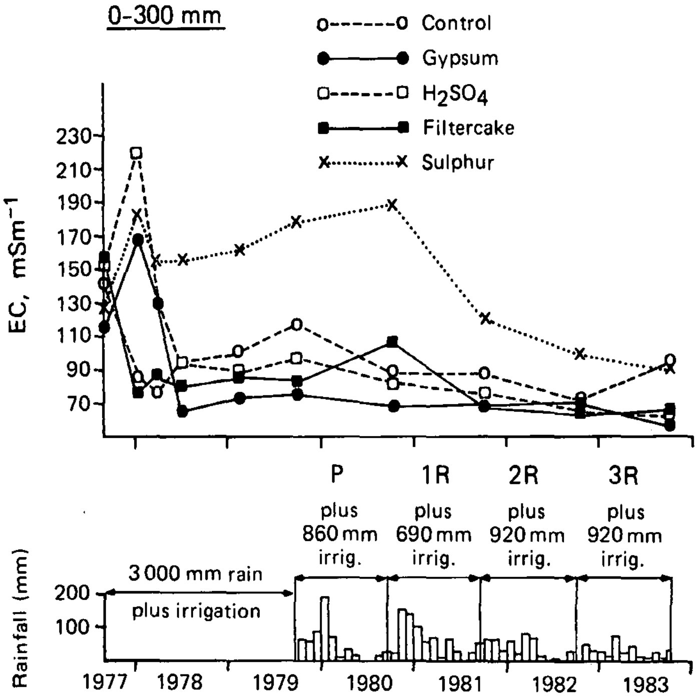

FIGURE 3 Changes in topsoil EC values with time.

All subsoil EC_{se} values were less than the critical value of 200 mSm^{-1} (von der Meden[10]) from the beginning of the trial (Figure 4) except in the plots treated with filtercake. The EC_{se} of the soil where filtercake had been applied declined sharply but the other treatments caused a gradual decline until the final sampling in 1983, when all subsoil EC_{se} values were below 120 mSm^{-1}.

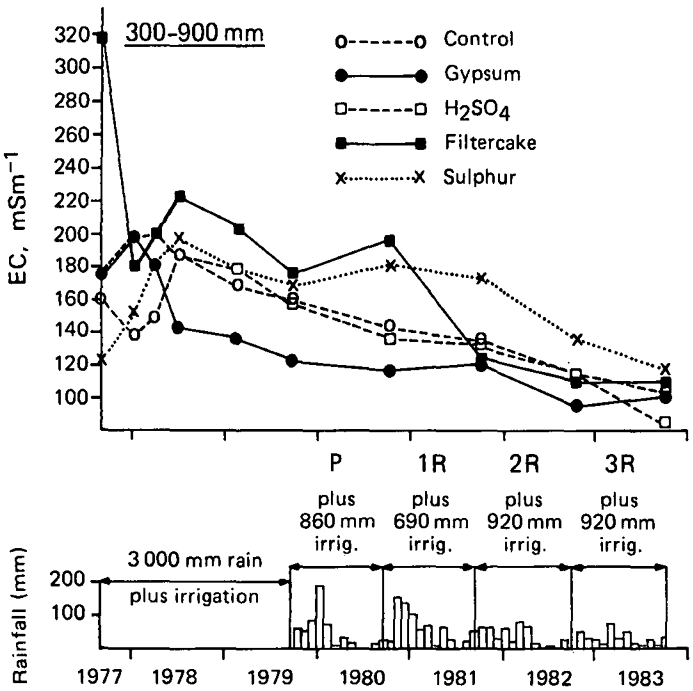

FIGURE 4 Changes in subsoil EC values with time.

• pH

Although gypsum and sulphuric acid caused initial decreases of about one pH unit in the topsoil, pH declined on average by only 0,5 of a unit from 9,0 to 8,5 during the trial (Figure 5). Although average pH values (water) of the soil in all plots were very similar (ranging from 8,4 to 8,6) when sampled finally in 1983, it took almost five years for the pH of the soil from control plots to fall significantly below 8,8. This implies that although drainage alone caused a drop in pH, the use of ameliorants accelerated the process considerably.

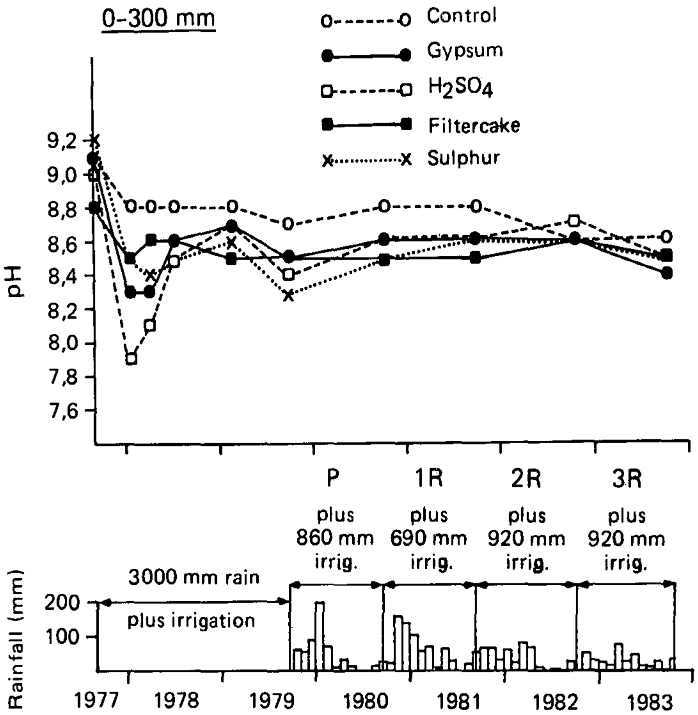

FIGURE 5 Changes in topsoil pH values with time.

Apart from the initial fluctuation in pH values of the subsoil between 9,4 and 8,7, all but the values for the plots treated with filtercake remained fairly constant at an average of 9,3 (Figure 6). The pH values of the soil in plots treated with filtercake tended to fluctuate more and were on average, lower than those in the other plots throughout the trial. However, this could have been due to the initial pH value of soil in the plots treated with filtercake being lower than that in the other treatments.

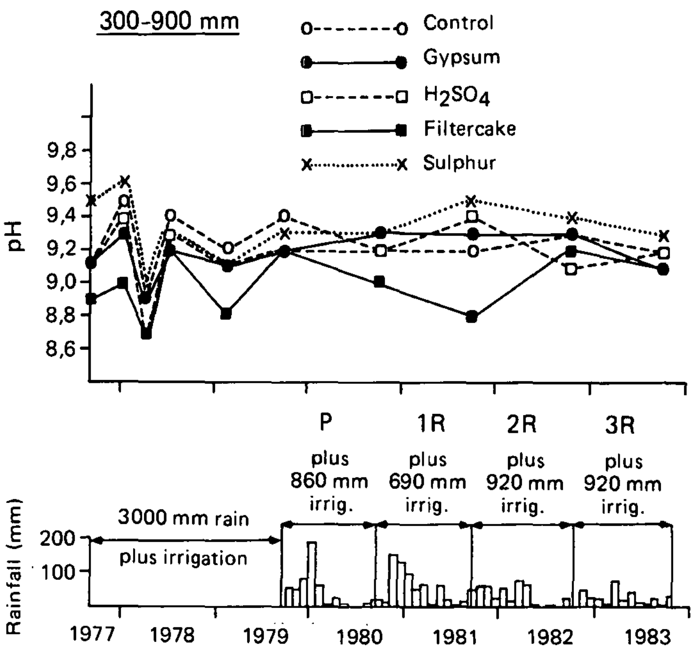

FIGURE 6 Changes in subsoil pH values with time.

Physical measurements

Hydraulic conductivity was found to be extremely low with values of 0,015 m d^{-1} being recorded. Such values would theoretically require subsurface drainage pipes to be only 2 to 3 m apart to drain the soil successfully.

Records of water-table heights considered in conjunction with soil chemical measurements did not indicate that added benefit was obtained where mole drains had been used in addition to subsurface drainage pipes.

Discussion and conclusions

Drainage alone reduced SAR_{se} and EC_{se} levels substantially. Although all ameliorative treatments except sulphur led to a more favourable chemical condition of the soil than that in the control plots, yield responses to these treatments were small. Because the physical condition of the soil was very poor, it was initially thought that leaching out the salts would be very slow and that successful reclamation was unlikely. Although the drains were spaced 18,4 m apart, which was inadequate theoretically, they were very effective and within two years of installation, sodium levels of the topsoil were sufficiently low to enable a crop of sugarcane to be established successfully. The marked efficiency of the drains is considered to be due to the sand having been backfilled to within 300 mm of the soil surface.

Results suggest that the poor physical condition of the soil was less detrimental to sugarcane yield than was the high sodium content. Chemical measurements and sugarcane yields suggest that gypsum and filtercake were similar in their ameliorative ability. However, the SAR_{se} levels in the plots treated with gypsum reached a minimum value within a year, while this took four years in the plots treated with filtercake. For this reason and because large quantities of filtercake are required, gypsum is favoured as an ameliorant for sodic soils. Where high pH values are encountered, sulphur or sulphuric acid may be more appropriate.

Since the critical SAR_{se} value for sugarcane in a Bonheim form soil is ten (Anon[1]; Johnston[5]) and because none of the subsoil (300 to 900 mm) SAR_{se} values were below ten, it is concluded that sugarcane can be grown on a soil which has excessive sodium in the subsoil provided the surface 300 mm is relatively free of sodium.

Although the soil on this site was successfully reclaimed with adequate drainage and ameliorants, the economics of the exercise are debatable. In this experiment ameliorants were applied in quantities far greater than those generally recommended. Gypsum for example was applied at 26 t ha^{-1} whereas 10 t ha^{-1} is the maximum that would normally be recommended. Before embarking on a reclamation project it would obviously be necessary to decide whether or not it was economic.

If mole drains could be made to operate effectively, the economics of reclaiming salt affected soils would be much more favourable. It is hoped that investigations into the use of mole drains will eventually lead to a method of draining clay soils that is more cost effective.

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