RESPONSE OF SOYBEANS TO AMELIORATION OF SODIC SOILS WITH POLYACRYLAMIDES

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Abstract
The effectiveness of polyacrylamides, gypsum, and their combination on improving the physical and chemical properties of a sodic soil was assessed in relation to the response of soybeans to such amelioration procedures. The results of a glasshouse study conducted in the 2002-03 summer season, clearly demonstrated that the polyacrylamides used either alone, or combined with gypsum, were effective in the amelioration of a sodic soil. It was also found that there was a significant beneficial effect on grain yield of soybeans when polyacrylamides and gypsum applications were combined. Soybean plants responded positively to such amelioration procedures. The application of polyacrylamides alone (10 kg/ha) increased the grain yield by 15%, but when combined with gypsum (25-100 kg/ha), polyacrylamides increased the grain yield by 22%. On the other hand, gypsum application alone (25-100 kg/ha) increased the grain yield by only 3%. These findings suggest that sodic soils could be ameliorated with the application of a low quantity of gypsum (25-100 kg/ha) combined with polyacrylamides (10 kg/ha). This may have great impact on large-scale reclamation of sodic soils in Australia, and consequently could significantly increase crop production in these soils.

Additional Keywords: polyacrylamides (PAM), sodicity, gypsum, reclamation, soybean

Introduction
Sodic soils have been defined as soils in which the adsorbed sodium ions occupy more than 6% of the exchange sites (Northcote and Skene 1972). About 12 million hectares out of 20.5 million hectares used for cropping in Australia are affected by sodicity (Rengasamy 2000). In most of these soils, the yield is restricted to less than 50% of the potential yield determined by the climate. As a result, there is a widespread net production loss which has been estimated to cost Australian society about $1.3 billion per year (Rengasamy 2000).

Amelioration of sodic soils with gypsum is the most widely used method for the reclamation of these soils in Australia (Loveday 1975). Generally, an initial application of 2-3 t/ha followed by regular maintenance applications at similar or lower rates are required (McKenzie *et al.* 1993). However, the poor water infiltration rate of these sodic soils often limits the rate of reclamation by gypsum application. Polyacrylamides (PAM) have been tested to improve various physical properties of sodic soils (Wallace and Wallace 1986; Wallace *et al.* 1986; Helalia and Letey 1988; El-Morsy *et al.* 1991; Zahow and Amrhein 1992; Gu and Doner 1993). The use of PAM for improving aggregate stability, maintaining high infiltration rate and reducing seal formation has been studied extensively (Shainberg and Levy 1994, and references cited therein). Zahow and Amrhein (1992) found that there was a significant beneficial effect on soil hydraulic conductivity when gypsum and PAM applications were combined. Similar results were reported by Shainberg *et al.* (1990). Wallace *et al.* (1986) found that an anionic PAM increased the water infiltration rate into a sodic soil by four-fold.

Sodic soils in rice growing areas create turbidity of water that seriously affects the successful establishment of rice seedlings. Cay *et al.* (2001) showed that an application of PAM at the rate of 5 kg/ha combined with gypsum at the rate of 0.6 t/ha, was effective in reducing the dispersion of a sodic soil and reducing the turbidity of water by more than 99.7% under laboratory conditions. Deery *et al.* (2002) demonstrated that a low molecular weight, high density PAM, at the rate of 5 kg/ha, applied with gypsum at the rate of 25 kg/ha, could be a possible treatment for reducing rice water turbidity without increasing water infiltration rates in the rice field.

The effectiveness of PAM, gypsum, and their combination on improving the physical and chemical properties of a sodic soil was assessed in relation to the response of soybeans to such amelioration procedures. The results from this study may have great impact on the reclamation of our sodic soils in general.

Materials and Methods
Three water soluble anionic polyacrylamides (samples supplied by SNF Australia Pty Ltd and Nalco Australia Pty Ltd) in powder form were used in this study (Table 1). Both low molecular weight (5-8 Mg/mole) and high molecular weight (15-20 Mg/mole) PAM were used in this study. Solutions of PAM in de-ionised water were

prepared to represent a PAM application rate of 10 kg/ha to treat a sodic soil in pots. Treatments included the application of PAM, gypsum and PAM plus gypsum combined. Rates of gypsum represented an application of 25, 50 and 100 kg/ha as dissolved in water. All 16 treatments had 6 replicates in each and arranged in a randomised complete block design. Three replicates were used for plant dry matter determinations. Soil in each pot was treated by pouring the prepared solutions on to the surface.

Table 1. The three PAM used in this study and their selected properties

PAM	Supplied by	Relative molecular weight	% anionic charge
AN910BPM	SNF Australia Pty Ltd	Low	10
X0211006	Nalco Australia Pty Ltd	Low	35
X0211005	Nalco Australia Pty Ltd	High	35

Soil sample collected from a farmer's field (sodicity in ESP > 12) in Wakool Irrigation District in NSW was used for this experiment. The treatments were applied on to the soil surface shortly prior to planting. Soybeans (*Glycine max*, cv Stephens) were used as the test crop for this glasshouse experiment during the summer season from January to April 2003. Two seeds were planted (6 January) in each pot and later thinned (20 January) to one plant per pot to achieve a plant density of 30-40 plants/square metre under irrigated conditions. Excess water was added to each pot during irrigation to promote the leaching process. Crop establishment by germination counts, growth rate by dry matter production at 25, 40 and 55 days after planting (DAP), and grain yield at final harvest (10 April) were determined for each treatment. At the end of the experiment, strength of the surface soil was measured using a Chatillon® pressure gauge.

Results and Discussion

The 3 PAM products (AN910BPM, X0211006 and X0211005), used either alone of combined with gypsum, failed to show significant difference between them for any of the measured parameters (germination, dry matter, grain yield and penetration resistance). This may be due to very small quantity of PAM (10 kg/ha) used in this experiment where this quantity was not sufficient to detect the difference in molecular weight or charge density of these PAM. Similar results were obtained for gypsum at 25, 50 and 100 kg/ha, where these application rates are very low compared with 1-3 t/ha commercial applications. Therefore, the results for the 3 PAM products and the 3 gypsum levels were pooled for further analyses.

PAM, gypsum and PAM+gypsum treatments significantly improved germination of soybean seeds compared with that of untreated soil (Figure 1). This can be attributed to better soil surface conditions prevailed in treated soils. Although PAM+gypsum treatment resulted in higher germination than that of PAM or gypsum treatments, this difference was found to be insignificant. Sodic soils disperse upon wetting and form a surface crust when they become dry. The surface crust will be hard to penetrate by the seedlings. Gypsum applied to a sodic soil can prevent dispersion and thereby avoid the formation of surface crust. PAM used alone or combined with gypsum seems to achieve similar results of gypsum application to a sodic soil.

In terms of dry matter production of soybean plants on 25 days after planting (25 DAP), a slight improvement in growth rate due to PAM, gypsum and PAM+gypsum treatments was hard to detect because of the small status of crop at that stage (Figure 2). However, the effect of these treatments on crop growth rate became prominent after 40 and 55 DAP. The highest amount of dry matter was produced by plants grown in PAM+gypsum treated soil. It should be noted that the effect of gypsum alone treatment on crop growth rate seems to disappear after 55 DAP. It may be due to the fact that only a small amount of gypsum (25-100 kg/ha) was applied and its effect did not last long indicating the necessity of repeated applications of gypsum to maintain its positive effect on plant growth.

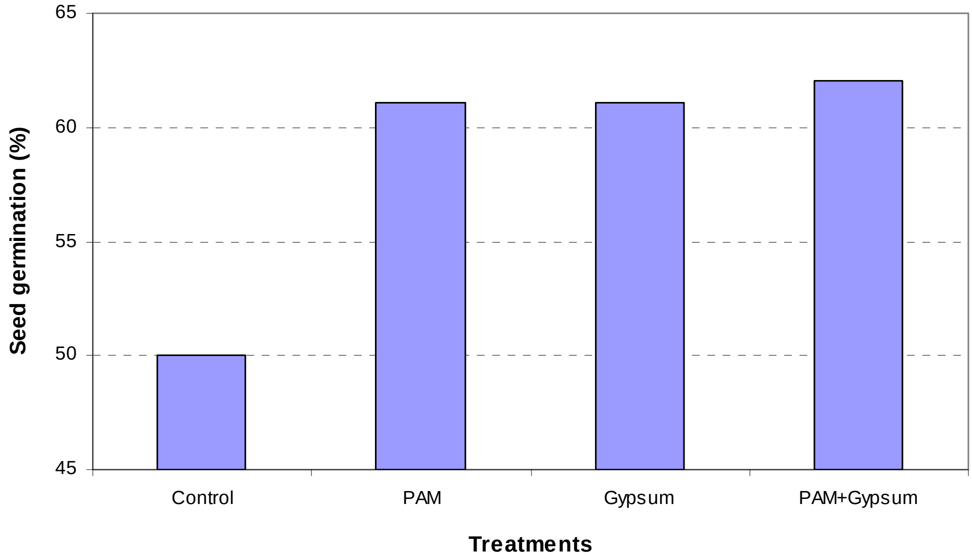

Figure 1. Effect of different treatments on seed germination.

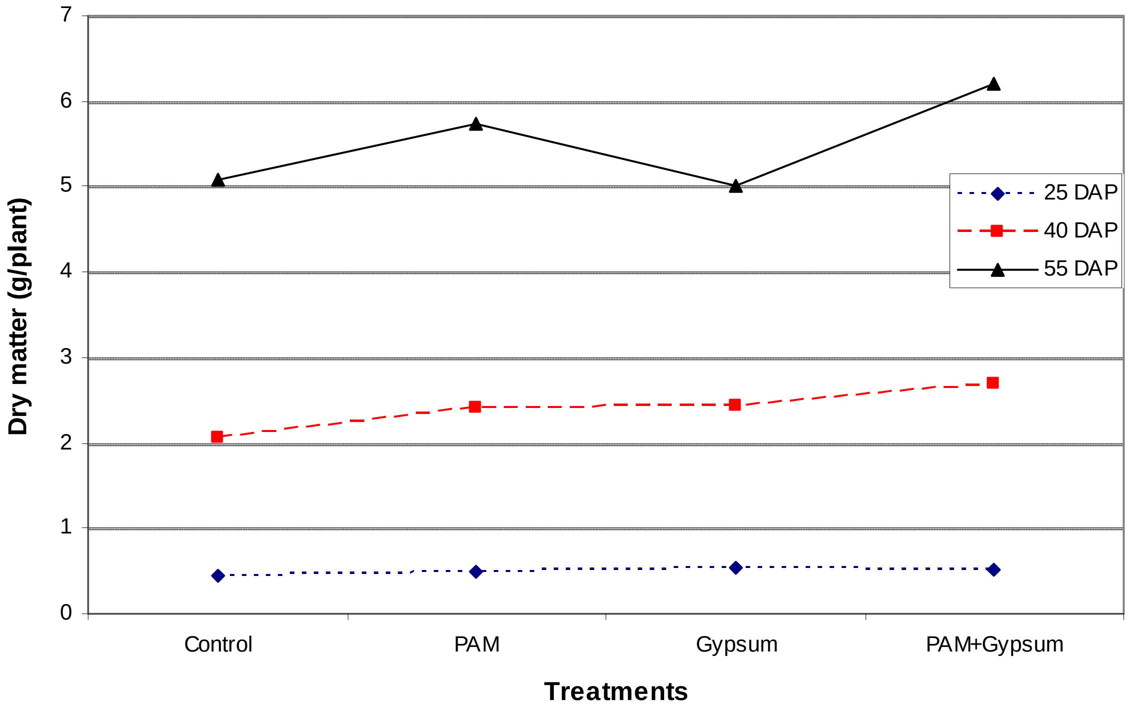

Figure 2. The effect of different treatments on dry matter production after 25, 40 and 55 DAP

Grain yields of soybean plants grown under different treatments are shown in Figure 3. Plants in gypsum treated soils yielded only 3% more than that of plants in the control soil. The treatment of soil with PAM increased the yield by 15%. However, when PAM was applied with gypsum, the yield increased by 22%. These results are supported by the higher dry matter produced by the plants in treated soils as described earlier. The beneficial effect when gypsum and PAM applications were combined was also reported by Shainberg *et al.* (1990), Zahow and Amrhein (1992), Cay *et al.* (2001) and Deery *et al.* (2002). It should be noted here that the above increase in yield was achieved with small quantity of PAM (10 kg/ha) and gypsum (25-100 kg/ha) to ameliorate a sodic soil. These results need to be verified under commercial field conditions.

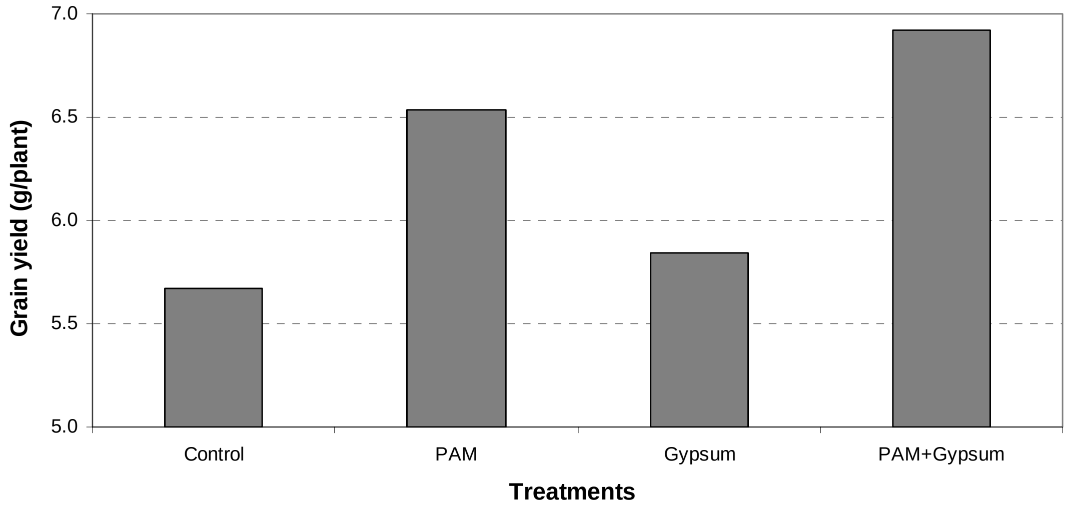

Figure 3. Grain yield of soybean plants under different treatments.

In an attempt to determine the extent of improvement in soil surface conditions, the penetration resistance of surface soil was measured and the results are shown in Figure 4. The penetration resistance of untreated soil was high and this was reduced by PAM and gypsum applications. The greatest reduction was achieved in soils treated with PAM and gypsum combined. It appears to be a cumulative effect of PAM and gypsum applications. However, the results of penetration resistance exhibit a high negative correlation (correlation coefficient of -0.98) with the grain yield reported above. In other words, higher yields were obtained when soil penetration resistances were lower. Further investigation is required to determine whether the effect of these treatments on crop growth was purely physical or chemical in nature, or indeed a combination of both.

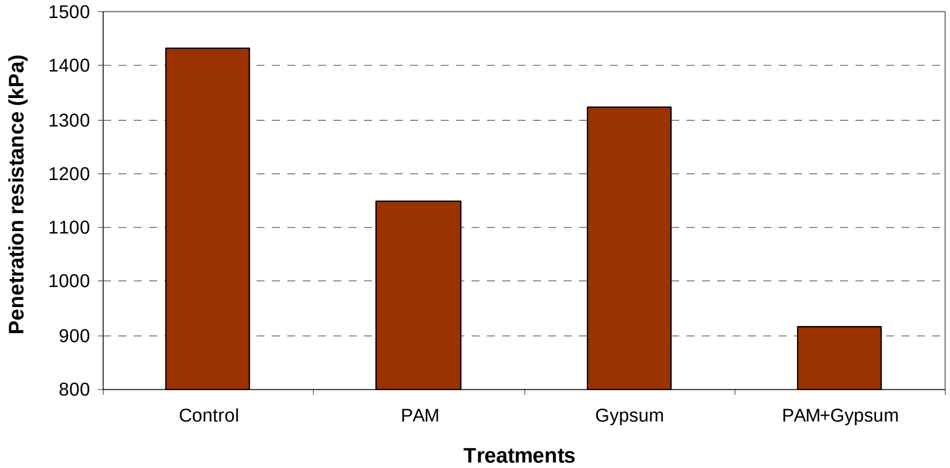

Figure 4. Penetration resistance of soil under different treatments.

Conclusions

Crop growth in sodic soils is highly limited unless significant quantities of gypsum are applied to ameliorate them. The results from this study have demonstrated that germination of seeds, dry matter production and grain yield of soybeans grown in sodic soils can be improved by treating the soil with PAM (10 kg/ha) and gypsum (25-100 kg/ha) applications. Application of PAM combined with small amounts of gypsum could be an alternative procedure to reclaim soils affected by sodicity. Significant increases in grain yields could be achieved by treating sodic soils with PAM.

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