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Improving crop production by the use of PAM: Potential benefits to Australian agriculture

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Abstract

An anionic polyacrylamide (PAM) at the rate of 7 kg ha^{-1} applied to the surface of a degraded hard-setting soil increased the germination of cotton seeds by 84%. Significant improvement in soil physical properties was also observed in treated soils. A cross-linked PAM at the rate of 0.03 and 0.07% increased the amount of water retained by a sandy soil by 23 and 95%, respectively. Consequently the water use efficiency of soybean plants grown in PAM treated soils was increased by 12 and 19 times, respectively. Increasing amounts of PAM in sandy soil enabled to extend the irrigation interval without any adverse effect on the grain yield of soybeans. An anionic PAM at the rate of 10 kg ha^{-1} reduced the turbidity of water in a sodic soil by 83%. However, PAM combined with small amounts of gypsum was highly effective in reducing the turbidity of water without significant effect on the percolation rate of water through the soil.

Key Words

Soil strength, water holding capacity, nephelometric turbidity units (NTU).

Introduction

PAM is used in agriculture in many countries mainly for the improvement of soil physical properties. In Australian cotton fields, PAM has been identified as a potentially useful tool in preventing soil erosion and reducing off-farm movement of chemicals during irrigation (1, 2). Improved irrigation efficiency of flood irrigated cropping under PAM treatment in northern Australia has been reported (3). Improved seedling emergence of irrigated perennial pasture was observed due to PAM treatment of the soil (4). New generation PAM have high molecular weights, low application rates, and important environment, soil conservation and irrigation efficiency benefits for general agriculture, making the use of these products economically feasible (5). Interest among researchers in using PAM in Australian agriculture is steadily increasing over the past few years. The potential use of PAM in Australian agriculture to improve off- and on-site environmental impacts and infiltration management has been identified (6). Soils with hard-setting properties are widespread in Australia and render difficulties for the germination of seeds of many crops. Crop production in coarse textured soils is limited due to low water holding capacity of these soils. Sodic soils in rice growing areas create turbidity of water that seriously affects the successful establishment of rice seedlings. This paper explores the possible applications of PAM to remedy these problems.

Methods

Ameliorating a degraded hard-setting soil

An anionic PAM (Cytec Superfloc A130) with a molecular weight of 10-15 millions and 35% charge was used to treat a hard-setting soil collected from 0-0.1 m layer of an Alfisol near Trangie in New South Wales (7). Four PAM application rates, namely 0, 0.001, 0.005 and 0.01% (dry weight basis), were used for a pot experiment with cotton seeds to treat surface 0.01 m soil layer. At the end of the experiment, strength of the surface soil was measured using a Chatillon® pressure gauge together with germination percentage of cotton seeds in each treatment.

Improving water retention capacity of sandy soils

An anionic acrylic copolymer (Alcosorb® 400) at three rates (0, 0.03 and 0.07 % by weight) was mixed with a Siliceous Sand containing 86% sand, 8% silt and 6% clay in the upper 27 cm layer with negligible amount of organic matter (8). The soil water holding capacity of treated soils was studied using a pressure plate apparatus at 0.01 and 1.5 MPa pressures. A pot experiment with soybean (*Glycine max*; cv Stephens) was conducted using the above treated soils. Water use efficiency was calculated from the weight of grain harvested and the amount of water used from planting to harvest. In another experiment, the grain production of soybean plants grown in PAM treated soils were compared under different irrigation intervals (9).

Reducing turbidity of water
Six high molecular weight PAM products representing anionic, cationic and non-ionic charges were tested with gypsum, to determine their ability to reduce turbidity of water (10). The soil (Grey and Brown Soil with ESP>11) was collected from Wakool in the Western Murray Valley and treated with two rates of PAM (5 and 10 kg ha^{-1}) and four rates of gypsum (0.6, 1.25, 2.5 and 5 t ha^{-1}) using split and single application methods. Turbidity was measured in nephelometric turbidity units (NTU) using a turbidimeter. Lower rates (25, 50, 75, 150, 300 and 600 kg ha^{-1}) of gypsum together with low (5-8 million) and high (15-20 million) molecular weight anionic PAM were also tested to study their effect on turbidity of water and percolation rate through the soil column (11).

Results

Ameliorating a degraded hard-setting soil
No germination of cotton was detected in the control soil (no PAM) where penetration resistance of the surface soil was the highest (Fig. 1). The soil penetration resistance decreased with increasing PAM application and this was accompanied by increasing percentage of germination. A maximum germination of 84% was reached when the PAM application rate was 0.005%. These results show that only a shallow layer of surface soil needs to be treated with PAM to improve seed germination. Therefore improvement can be achieved at fairly low rate of PAM (7 kg ha^{-1} at a rate of 0.005% to a depth of 0.01 m at a bulk density of 1.4 Mg m^{-3}).

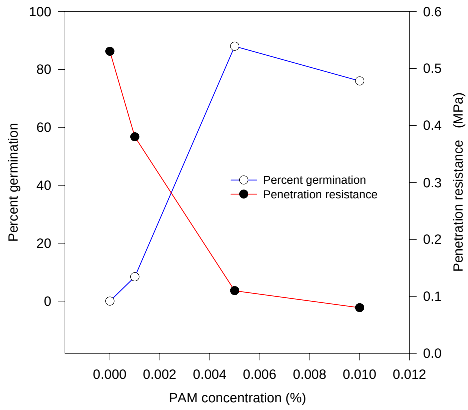

Figure 1. Variation in germination of cotton seeds and penetration resistance of soil at different PAM application rates.

Improving water retention capacity of sandy soils
The amount of water retained by the soil at 0.01 MPa pressure increased by 23 and 95% by adding very small amounts (0.03 and 0.07% by weight, respectively) of PAM to the soil (Fig. 2). This increase in water retention can reduce the amount of water otherwise lost by deep percolation. Similar increases in water retention at 1.5 MPa resulted in no significant difference in plant available water between treatments. However the pot experiment showed 12 and 18 times increase in water use efficiency of soybean plants grown in soils treated with 0.03 and 0.07% PAM, respectively (Table 1).

Soybeans grown under different irrigation intervals showed that the grain yield was highest (85 kg ha^{-1}) under 3-days of irrigation interval (Fig. 3). This yield was progressively increased by about 6, 9 and 14 times by incorporating 0.05, 0.1 and 0.2% PAM with the soil, respectively. The grain production of soybean plants grown in soil with no PAM under 3-days of irrigation interval was achieved with 0.05% PAM in soil under 4-days of irrigation interval or 0.1% PAM in soil under 5-days of irrigation interval. This demonstrated that soybeans grown in PAM treated soils require extended periods of irrigation interval without any adverse effect on their grain yield.

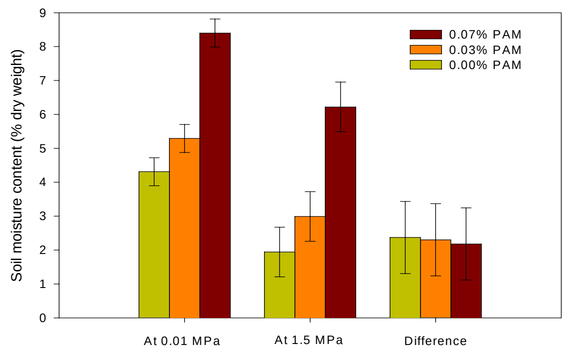

Figure 2. Soil moisture content at 0.01 and 1.5 MPa pressures and their difference for soils treated with 0, 0.03 and 0.07% PAM. Error bars are shown for l.s.d. (P=0.05).

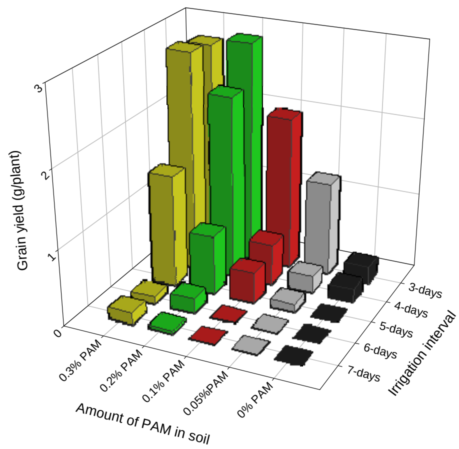

Figure 3. Grain yield of soybean plants at harvest under different soil and irrigation treatments.

Table 1: Amount of water used, weight of grain harvested and calculated water use efficiency of soybean plants grown in soils treated with PAM

PAM in soil (%)	Water used (L)	Grain harvested (g)	Water use efficiency (gL^{-1})
0.00	7.350*a*	0.14*a*	0.0194*a*
0.03	7.987*b*	1.91*b*	0.2385*b*
0.07	8.269*b*	3.04*c*	0.3678*c*
l.s.d. (P=0.05)	0.311	1.01	0.0013

Values in column followed by the same letter are not significantly different at P=0.05

Reducing turbidity of water

PAM with anionic charge was more effective than that with cationic or non-ionic charges. High density anionic charge PAM at the rate of 10 kg ha^{-1} reduced the turbidity of water by about 83% compared with the control. Split application strategy was significantly more effective than single application. The results indicated that the rate of 5 kg ha^{-1} PAM was not significantly different than the rate of 10 kg ha^{-1} to reduce turbidity. All PAM/gypsum combinations reduced the turbidity by more than 99% compared with the control. The results of this study indicated that a rate of 0.6 t ha^{-1} of gypsum coupled with 5 kg ha^{-1} of low or medium density anionic PAM could achieve turbidity levels lower than that of resulting by higher application rates of gypsum.

It was found that the low molecular weight PAM was more effective than high molecular weight PAM and PAM combined with gypsum was more effective than PAM alone. The advancement of water through the soil column after the application of PAM, gypsum and both combined treatments indicated that the rate of water movement through the soil was not significantly changed by the application of PAM and PAM with gypsum (Fig. 4). These results suggested that the use of PAM with lower rates of gypsum would reduce the turbidity of water without increasing the percolation rate through the soil.

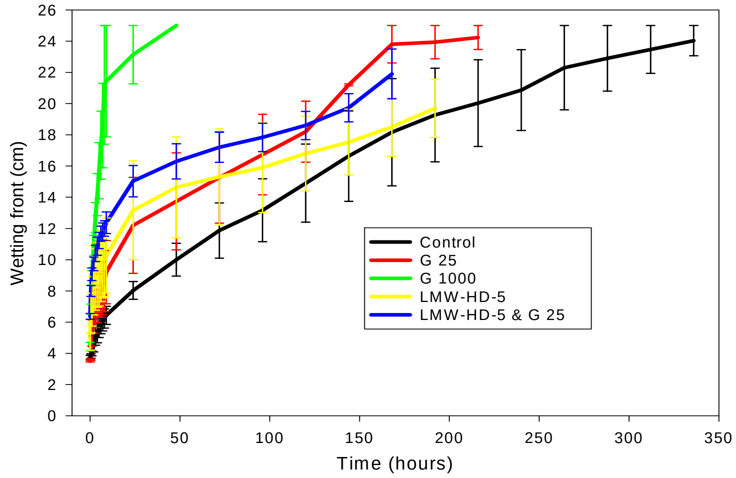

Figure 4. Depth of wetting front against time under different treatments. (G, gypsum; LMW, low molecular weight; HD, high density; numbers represent rate of application in kg ha^{-1}).

Conclusion

The results of these studies have demonstrated that crop production in a soil that exhibits some form of physical constraint to plant growth could be improved by treating the soil with PAM. The future of such PAM products in Australia looks very promising. Currently available PAM have higher molecular weights so that the quantity required to treat the soil is small. Since their price is becoming cheaper, their commercial application in large area agriculture seems economical.

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