EFFECT OF A POLYMER ON GROWTH AND YIELD OF SOYBEANS (*Glycine max*) GROWN IN A COARSE TEXTURED SOIL

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Sivapalan, S (2001) Effect Of A Polymer On Growth And Yield Of Soybeans (Glycine Max) Grown In A Coarse Textured Soil. In *Proceedings Irrigation 2001 Regional Conference*, pages pp. 93-99, Toowoomba, Queensland, Australia.

ABSTRACT

The water holding capacity of coarse textured soils is low. It can be increased by the addition of soil conditioners such as the cross-linked polymers (PAM). A synthetic anionic acrylic copolymer (ALCOSORB®400) was mixed with a sandy soil at 5 different rates (0, 0.05, 0.1, 0.2 and 0.3% PAM by weight) and subjected to 5 different irrigation regimes (3, 4, 5, 6 and 7 days interval between 2 irrigations). Soybean (*Glycine max*; CV Stephens) was grown during the period from January to March 2001 in pots containing 800 g of treated soil under glasshouse environment. Dry matter productions at 20, 40 and 60 days after planting (DAP), plant height at maturity and grain yield at harvest were determined. The results indicated that the amount of dry matter productions at 20, 40 and 60 DAP were found to be higher with increasing amounts of PAM in soil and decreasing intervals between 2 consecutive irrigations. Similar relationships were found for plant height at maturity. Soybeans grown in soils treated with 0.05, 0.1 and 0.2% PAM achieved grain productions which were about 6, 9 and 14 times greater, respectively, than that in control soil under 3 days of irrigation interval. It was also found that 0.05% PAM in soil with 4 days irrigation interval and 0.1% PAM in soil with 5 days irrigation interval enabled plants to achieve grain yields higher than that of control soil with 3 days irrigation interval. Therefore, crops in coarse textured soils treated with polymers can produce more grain or dry matter yield often under low frequent irrigations. It can also help to save water, time, money and energy which otherwise spent on high frequency irrigations. These findings also have potential beneficial implications to growing garden plants, pot plants, glasshouse plants and/or general horticulture.

INTRODUCTION

The productivity of coarse textured soils is mostly limited by their low water holding capacity and excessive deep percolation losses. Thus the management of these soils must aim at increasing their water holding capacity and reducing losses due to deep percolation. The water holding capacity of coarse textured soils can be improved with the addition of soil conditioners. Soil conditioners primarily the cross-linked polymers can absorb water and swell up to hundreds of times of their dry weight. The large quantity of water retained by the polymer provides extra available water to the plants. This facilitates better plant growth while reducing the losses due to deep percolation. More available water in soil also means less frequent watering or irrigation.

Use of polymers as soil conditioner increased after the introduction of Krilium® in 1951 (De Boodt, 1972). New generation polymers 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 (Sojka and Lentz, 1994). The use of gel-forming hydrophilic polymers have been tested to increase the water holding capacity of sandy soils (Stewart, 1975; Taylor and Halfacre, 1986; Silberbush et al., 1993). Sivapalan (2001) demonstrated that the amount of water retained by a sandy soil increased by 23 and 95% by adding very small amounts (0.03 and 0.07% by weight, respectively) of polymer to the soil. This increase in water retention can reduce the amount of water otherwise lost by deep percolation. His study also demonstrated a 12 and 18 times increase in water use efficiency of soybean plants grown in soils treated with 0.03 and 0.07% polymers, respectively. A significantly higher irrigation water use efficiency of wheat under polyacrylamide treatment was reported by Stern et al. (1992). Polymers in soil were also able to reduce the amount of water lost from the soil through evaporation (Al-Omran and

Al-Hardi, 1997; Sivapalan, 2001). Information on the effect of different rates of polymer and irrigation interval on the growth and yield of plants are lacking. This study was undertaken to assess the rate of growth and grain yield of soybeans as influenced by different amounts of polymer in soil and a range of irrigation intervals.

MATERIALS AND METHODS

A synthetic anionic acrylic copolymer (manufactured by the Allied Colloids Pty Ltd and marketed in Australia by the Ciba Specialty Chemicals Pty Ltd under the trade name of 'ALCOSORB® 400') at five different rates (0, 0.05, 0.1, 0.2 and 0.3% by weight) was mixed with a sandy soil (Great soil group - Siliceous sands containing 85-90% sand obtained from Currawarna in NSW). A pot experiment with soybean (*Glycine max*; CV Stephens) as the test crop was conducted in the glass-house at the Charles Sturt University, Wagga Wagga during the period from 8 January 2001 (planting) to 30 March 2001 (harvest). Two seeds were planted in each pot containing 800 g of treated soil and later thinned to one plant per pot to achieve a plant density of 30-40 plants/square metre under irrigated conditions. Irrigation intervals of 3, 4, 5, 6 and 7 days were imposed on each of the above soil treatments separately. At each irrigation, water filled in a saucer was allowed to soak into the pots through the bottom by capillary rise over a period of 7-8 hours. All the treatments had three replicates and additional 3 pots for dry matter determinations at 20, 40 and 60 days after planting (DAP), all arranged in a split plot design. Growth rate by dry matter production, height of plants at maturity and yield of grains at harvest were determined for each treatment.

RESULTS AND DISCUSSION

(a) Growth rate of plants

The oven-dry weight of dry matter produced by the aerial parts of each plant at 20, 40 and 60 (DAP) when grown under different soil and irrigation treatments are shown in Figures 1, 2 and 3, respectively. Harvesting of grain occurred after 82 DAP. The grand mean of dry matter productions at 20, 40 and 60 DAP were 0.356, 1.978 and 3.291 grams per plant, respectively. This indicated that the average growth rate of plants were higher during the period from 20 to 40 DAP compared with that in first or third quarter of growth period. Two-way analysis of variance for dry matter productions at 20, 40 and 60 DAP indicated a significant difference ($P<0.05$) between different soil and irrigation treatments. There is a general trend of increasing dry matter productions with increasing amounts of polymer in soil and decreasing interval between 2 consecutive irrigations (Figures 1-3). Mean dry matter productions at 20, 40 and 60 DAP for different soil and irrigation treatments are given in Table 1.

Table 1. Mean dry matter productions at 20, 40 and 60 DAP, height of plants at maturity and grain yield at harvest for different soil and irrigation treatments

Treatments	Mean dry matter production (g)*			Height of plants	Grain yield
	At 20 DAP	At 40 DAP	At 60 DAP	(cm)	(g/plant)
Amount of polymer in soil					
0% PAM	0.292[a]	1.078[a]	1.886[a]	30.400[a]	0.076[a]
0.05% PAM	0.288[a]	1.474[a,b]	2.294[a,b]	36.198[a]	0.310[a]
0.1% PAM	0.340[a]	1.810[b]	2.824[b]	41.734[a]	0.587[a,b]
0.2% PAM	0.474[b]	2.822[c]	4.362[c]	72.532[b]	1.257[b,c]
0.3% PAM	0.384[a,b]	2.706[c]	5.090[d]	78.200[b]	1.473[c]
Irrigation interval					
7-days	0.264[1]	1.336[1]	1.986[1]	32.932[1]	0.041[1]
6-days	0.290[1,2]	1.236[1]	1.678[1]	30.598[1]	0.061[1]
5-days	0.368[1,2,3]	1.860[2]	2.894[2]	54.602[2]	0.545[1,2]
4-days	0.452[3]	2.496[3]	4.218[3]	56.734[2]	1.232[2,3]
3-days	0.404[2,3]	2.962[4]	5.680[4]	84.198[3]	1.824[3]

* values with similar superscripts within a column are not significantly different at P=0.05

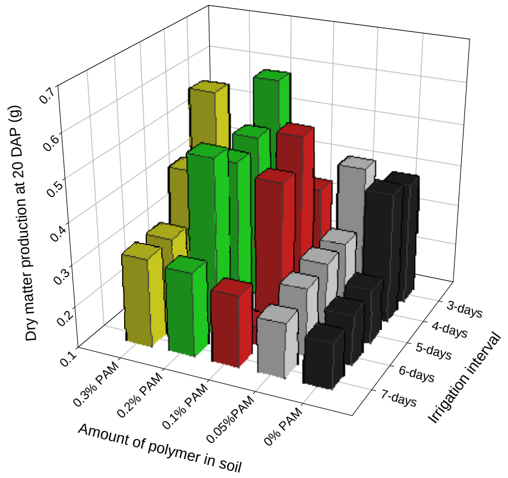

Figure 1. Dry matter production at 20 DAP under different soil and irrigation treatments

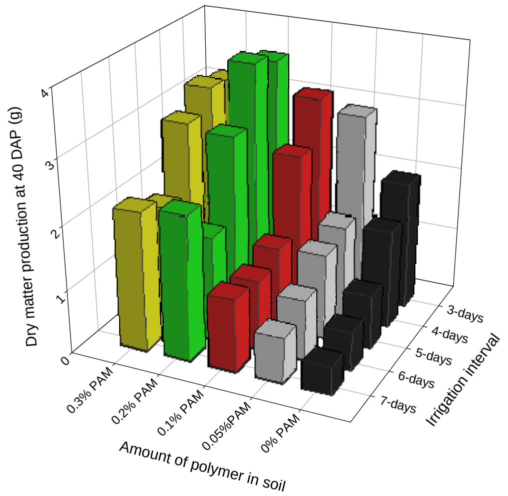

Figure 2. Dry matter production at 40 DAP under different soil and irrigation treatments

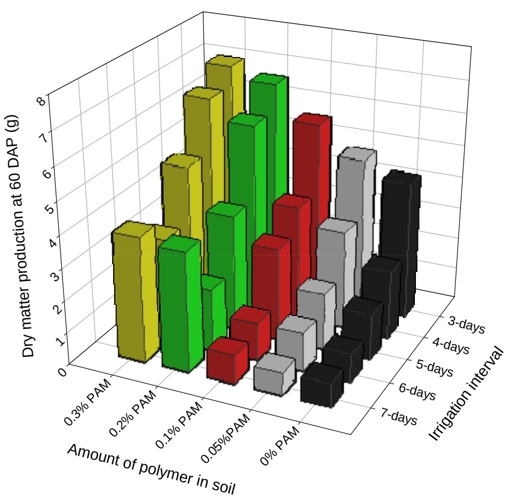

Figure 3. Dry matter production at 60 DAP under different soil and irrigation treatments

The variation in mean dry matter productions among different treatments of polymer was not large up until 20 DAP (Table 1). This indicated that the effect of different amounts of polymer in soil on growth of soybeans was not prominent until they reach 20 DAP. Evapotranspiration requirements of plants during early stages are low. These requirements could be adequately met by the amount of available water stored in the soil even without any polymer. When the plants reach their full canopy, they begin to use the extra water held in storage by the polymer. Increasing amounts of polymer enable greater amounts of water to be stored and used by the plants over a longer duration of time. The plants in soils with little or no polymer suffered severe moisture stress after 20 DAP specially with higher irrigation intervals. Limited volume of soil (800 g) in each pot restricted the amount of water storage that could be explored by the plant roots. This was evident from the fact that plants grown in pots containing 4.5 kg of soil survived an irrigation interval of 5 days under similar conditions (Sivapalan, 2001).

Correlation coefficients between dry matter productions at 20, 40 and 60 DAP are given in Table 2. Although the correlation coefficients were significant ($P<0.01$), the dry matter production at 60 DAP was highly correlated with dry matter production at 40 DAP than with that at 20 DAP. The correlation coefficient between dry matter productions at 20 DAP and that at 40 DAP was intermediate. This was due to the fact that the early plant growth up to 20 DAP was not much affected by the soil or irrigation treatments.

Table 2 Correlation matrix for dry matter production at 20, 40 and 60 DAP, plant height at maturity and grain yield at harvest

Parameter	Dry matter at 20 DAP	Dry matter at 40 DAP	Dry matter at 60 DAP	Height of plants	Grain yield
Dry matter at 20 DAP	1				
Dry matter at 40 DAP	0.711*	1			
Dry matter at 60 DAP	0.632*	0.946*	1		
Height of plants	0.585*	0.906*	0.933*	1	
Grain yield	0.596*	0.857*	0.894*	0.882*	1

* correlation is significant at P = 0.01 level

A comparison of growth of plants grown in the control soil (0% PAM) under different irrigation intervals indicated that an irrigation interval of 3-days enabled the plants to achieve the highest dry matter production at 60 DAP (Figure 3). If the same amount of dry matter production is to be achieved with a higher irrigation interval, it seems possible with 0.2% PAM in soil and 4-days of irrigation interval or with 0.3% PAM in soil and 5-days of irrigation interval (Figure 3). The dry matter production at 60 DAP for plants growing in soil without polymer and under 3-days of irrigation interval was progressively increased by about 12, 32, 56 and 65% by incorporating 0.05, 0.1, 0.2 and 0.3% PAM in soil, respectively (Figure 3). Many factors must have contributed to this increased growth of plants with increasing amounts of polymer in soil. Increased water storage, improved soil structure and better aeration of soil could be some of the possible factors. It was visually observed that the swelling of polymer granules upon wetting made the soil to remain lose. This must have created a better environment for root growth and microbial activity. It should be noted that the nitrogen fixing ability of rhizobium bacteria in the root nodules of soybean plants could also be enhanced by the improvement in soil structure. However, it is unknown whether this type of polymer could increase the nutrient retaining ability of the soil.

(b) Height of plants

The average height of plants measured at maturity is shown in Figure 4. Two-way analysis of variance for plant height indicated a significant difference between different soil treatments and irrigation interval. A grand mean height of 51.8 cm was achieved under the glass-house conditions for the cultivar Stephens used in this trial. The trend in height of plants at maturity for different soil and irrigation treatments was similar to that of dry matter production at 40 and 60 DAP (Figures 2-4). The correlation coefficients between height of plants at maturity and dry matter production at 20, 40 and 60 DAP are given in Table 2. These correlation coefficients indicated that plant height at maturity was mostly affected by the amount of dry matter accumulated at 40 and 60 DAP. The mean heights for different soil and irrigation treatments are given in

Table 1. According to mean heights of plants under different soil treatments, the effect of 0.2% and 0.3% PAM in soil on plant height was different from that of the rest of the soil treatments. Similarly, the mean height of plants under 3-days of irrigation interval was different from that under 4-days and 5-days of irrigation interval which in turn different from that under 6-days and 7-days of irrigation interval.

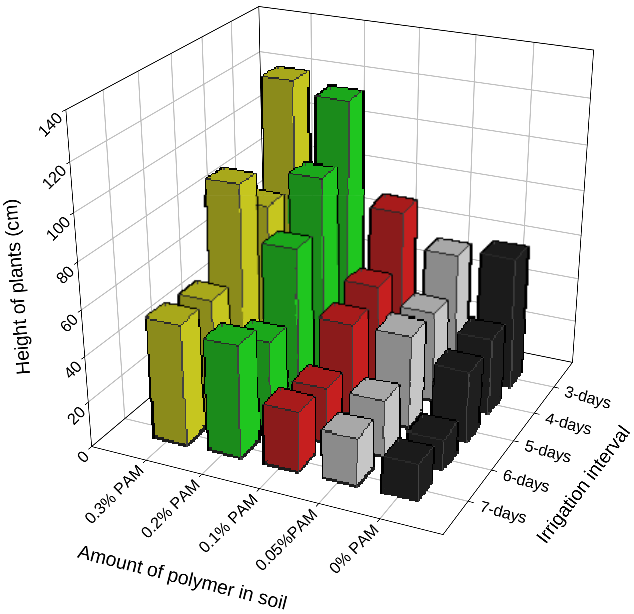

Figure 4. Height of plants at maturity under different soil and irrigation treatments

(c) Grain yield of plants

The average grain yield at harvest from each plant under different soil and irrigation treatments is shown in Figure 5. Some plants, especially those grown in soils with little or no polymer under higher irrigation intervals failed to produce any grain. Two-way analysis of variance indicated a significant difference ($P<0.01$) between different soil and irrigation treatments. The grand mean of grain yield was 0.741 g/plant which was equivalent to approximately 300 kg/ha assuming a plant population of 400,000 plants/ha under irrigated conditions. A highest grain yield of about 1150 kg/ha was achieved with 0.2% PAM in soil and 3-days of irrigation interval. The grain yields obtained from this trial were lower than that reported by Sivapalan (2001) due to restricted volume of soil in each pot used for this trial. The trend in grain yield was similar to that observed for dry matter productions at 40 and 60 DAP and height of plants at maturity (Figures 2-5). This was also shown by the correlation coefficients between these parameters (Table 2). Mean grain yields for different soil and irrigation treatments are given in Table 1. Grain yields were higher with increasing amounts of polymer in soil and decreasing intervals between 2 irrigations.

A comparison of grain production of plants grown in soil with no polymer under different irrigation intervals revealed that the grain yield was the highest (85 kg/ha) under the 3-days of irrigation interval (Figure 4). 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. Further increase in polymer (0.3% PAM) in soil failed to increase the grain yield achieved with 0.2% PAM in soil. The amount of water stored in soil treated with 0.2% PAM must be adequate to meet the evapotranspiration requirements of plants grown under 3-days of irrigation interval. Further increase in polymer in soil would retain more water than required by the plants and in fact, this could pose a threat to the ideal environment in the root zone. This trend was also shown by better grain production of plants grown in soil treated with 0.3% PAM under 4-days of irrigation interval than that under 3-days of irrigation interval. This meant that the water stored in this soil was adequate to meet the evapotranspiration requirements of plants during a 4-days irrigation interval.

A comparison of the interval between 2 consecutive irrigations showed that the grain production of plants grown in soil with no polymer under 3-days of irrigation interval could be achieved with 0.05% PAM in soil and 4-days of irrigation interval or 0.1% PAM in soil and 5-days of irrigation interval. However, if the maximum grain production is targeted, then plants grown in soils treated with 0.2% PAM under 3-days of irrigation interval or plants grown in soils treated with 0.3% PAM under 4-days of irrigation interval seems ideal for this purpose.

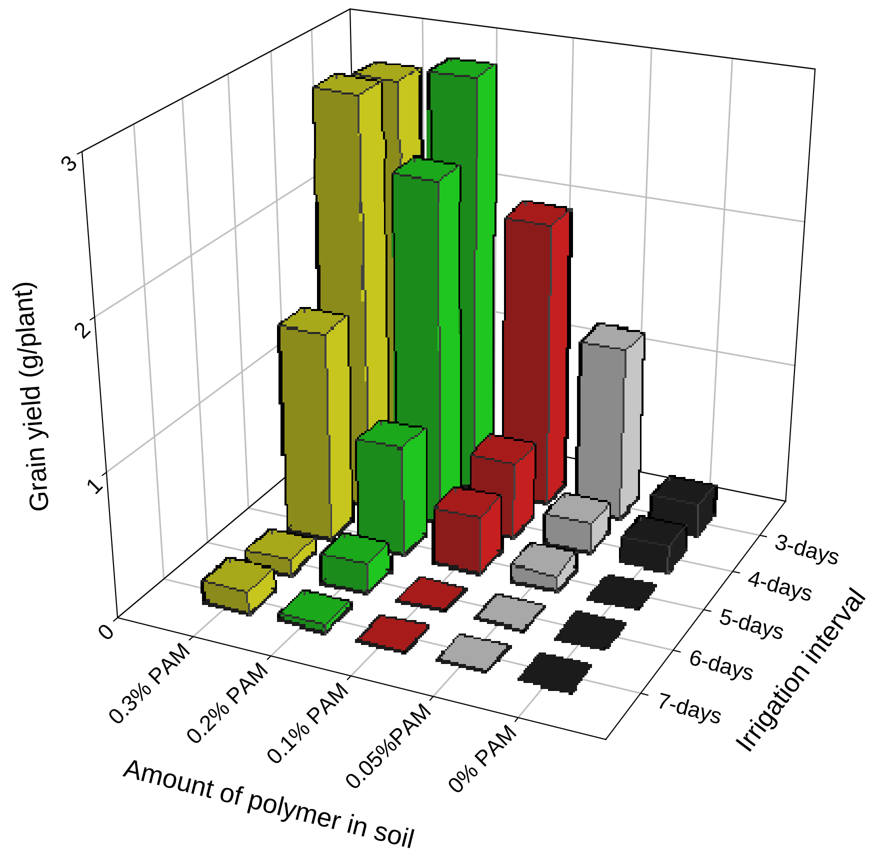

Figure 5. Grain yield of plants at harvest under different soil and irrigation treatments

CONCLUSIONS

Irrigation water is becoming increasingly limited in Australia. It is important to improve the water use efficiency of plants. The use of water retaining polymers has potential for horticultural and other crops. The results of this study have demonstrated that crop production in a soil could be improved by adding polymer to the soil. The polymer in soil can store extra water and enable plants to utilise that water over an extended period of time. The future of such polymers in Australia looks very promising. Currently available polymers have higher molecular weights so that the quantity required to treat the soil is small. Since their price is becoming cheaper, their commercial application seems economical.

ACKNOWLEDGEMENTS

Financial support from a Faculty Seed Grant provided by CSU is gratefully acknowledged. Thanks are due to Jeff West and Edward Cay for the assistance with irrigation of plants.

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