

The use of Polyacrylamides (Soilfix™) to improve the lateral spread of moisture in drip irrigation.

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April 1999

Abstract

The application of polyacrylamides (PAM) (Soilfix registered trade name) into drip irrigation water at 1 ppm of applied water can be seen to significantly alter distribution patterns of water in the soil profile. Soilfix treated soils showed less variance in wetting and drying patterns than non treated rows in 0.3 m spaced drippers. In 1 m spaced drippers higher soil moisture levels 40 cm away from the dripper were recorded. Yield responses in Thompson Seedless in excess of 10 kg / vine over the control were recorded in 4L/hr x 1 m dripper spacing. Yield responses in 0.3m x 1L/hr drippers was less, but still significant over the control, and water monitoring in 30 cm spacing less conclusive.

Introduction

Polymers are long chain molecules that contain identical chains of atoms held together by covalent bond; the bonds are strong and directional along the chain (Young 1981). Polyacrylamides consist of polymers of many sub units of acrylamide molecules (Sojka 1994). Polyacrylamides is a generic term given to long chains of acrylamide molecules which vary according to chain length, location and structure of the sub units.

Polyacrylamides (PAM) are water soluble, high molecular weight synthetic organic polymers (Seybold 1993). Because of their solubility, PAMs have many applications in modern society. They are used as flocculants in waste and potable water. The South Australian water treatment facilities at Morgan use polymers to flocculate colloidal material where aluminium sulphate is not used. Further uses are adhesion and flooding agents for petroleum recovery, soil stabilising agents, strengthening paper and paperboard and as a thickening agent.

PAMs were originally used during World War II to allow rapid construction of roads and runways under adverse conditions (Wilson 1975). The development of this technology found its way into the USA agricultural industries in the 1950's with a range of PAMs which were used to enhance the stability in the tilled surface section of agricultural fields (Azzam 1980). Polyacrylamides are widely used as coating agents in the formulation of microbial biopesticides (Burgess 1998).

Trials conducted across Northern Australia from 1995 - 97 (Schiller undated) investigated the role of PAMs in reducing soil runoff and improving infiltration. Results from this work revealed slowing in the advancement of water when treated with PAMs at rates varying from 1.2, 2 and 3.6 ppm. Measurement of water infiltration using a neutron probe indicated that infiltration was improved on lighter soils, whereas on the heavier Darling Downs soils very little infiltration increases

were recorded. Sediment runoff and turbidity were reduced in tailwater with the use of PAM's. Measured levels of sediment in tailwater decreased from 0.41 - 1.8 grams/litre in control areas to 0.1 - undetectable where 3.6 ppm PAM's were applied per volume of irrigation water. Further studies of tailing water indicated that with the use of PAM's pesticide / herbicide levels could be reduced. In the case of Oxyfluorfen reductions in tailwater of 100% were achieved.

Ross (1996) wrote on improvements in infiltration and reduced sediment runoff through the use of PAM's. High molecular weight PAM's were observed to reduce sediment runoff by 95.9% in furrow irrigated soils of Idaho. Net infiltration over the furrow length in a 12 hour period increased by an average of 10%. Studies in this trial revealed that the uptake of acrylamide by the plant was undetectable. The results of this trial indicated that there was no adverse environmental effects or potential health risks if recommended procedures were followed.

Studies by Levy (1991) showed that an inverse relationship between vegetative growth of cotton and level of runoff on a commercial field scale exists. The use of PAM (at 20 kg/ha) was seen to significantly reduce runoff from both vertisol and loess soils. A trend was observed where treatment with PAM increased yields compared to the control.

Vallant (1997) describes how the use of PAM's helped to reduce erosion and increase yields of furrow irrigated tomatoes and peppers. Soil loss was reduced by 63% and yield increases of 30% were recorded. Pryor (1988) also highlighted the role PAM's play in increasing the yield of processing tomatoes. Application of up to 15 kg/ha of a cross linked PAM resulted in yield increases of 30% when sidedressed into canning tomato beds. The paper further highlights the potential of PAM's in drought prone or sandy soils, or where water is high priced or in short supply. In South Australia which is regarded as the driest state in the driest continent, the use of PAM's must have great potential. Sousa (1998) used PAM's at a concentration of 10 ppm of irrigation water in processing tomatoes. In one section PAM's were used in the first 6 of 9 irrigations and in the other section a further PAM treatment was applied in the eighth irrigation. Yield increases at the 90% level of statistical significance were recorded. Results from this trial showed that treatment with PAM resulted in more water being available to the plant

Gardiner (1996) described how the use of PAM's at 10, 25 and 40 ppm improved hydraulic conductivity of soils significantly. The effects being most apparent in the first few weeks then tapering off. This paper reported that the use of PAM's had a greater impact on soil hydraulic conductivity than gypsum. PAM may also have a role in reducing wind drift. Chamberlain (1988) suggests that polymer treatment of the ground will stabilise soils against wind drift. In crops such as carrots and onions where wind damage at emergence can seriously reduce yields, polymers may play a role when applied after seeding.

It is worth noting that not all published research indicates that PAM's are beneficial in all situations. Vallant (undated) investigated various water absorbing polymers in bentgrass golf greens. Results from this work indicated some PAM's inhibited root development, and that starch polymers were more effective than PAM polymers. it is

worth noting that in this paper polymers were seen to enhance tissue concentrations of nitrogen. This effect can be explained by the use of PAM's increasing water holding ability of the root zone and it is therefore not unreasonable to suggest reductions in leaching losses. Inhibition of root development may be a consequence of excessive water being held in the root zone following an application of PAM's .

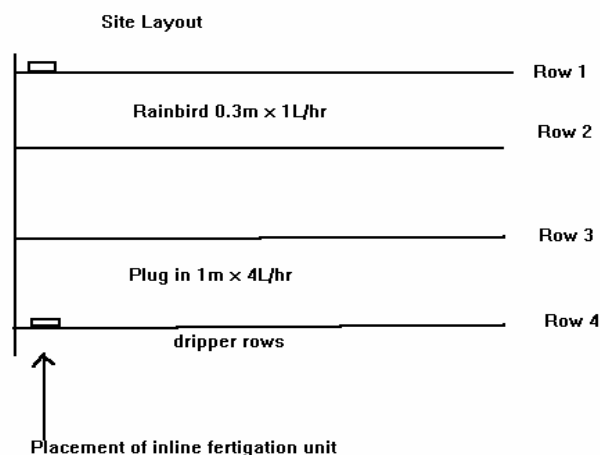
The aim of this trial is to investigate the role of PAM's in drip systems and the ability to have an impact on soil hydraulic conductivity. In Australia which suffers from variability of flows in its rivers and severe droughts, PAM's may have great potential in future irrigation scheduling practices.

Methods and Materials

The trial was conducted on the property of Brian Western, Berri South Australia. The property is devoted to the production of a variety of table grapes and citrus, all of which is under drip irrigation. The soil in the trial rows has been classified as a sandy loam over a free draining limestone base with a RAW (readily available water of 35 mm Yandilla Park Soil Survey).

Four adjacent rows of Thompson Seedless on K51/32 were used for this trial. Two rows were installed with Rainbird 0.3m x 1.1L / hour drippers with the other two rows being irrigated with 1.0m x 4.0 L / hour drippers. Two in line fertigation units (refer figure one) were installed in each line for the injection of polyacrylamide solution. The use of these injectors enabled rows to be treated in isolation yet receive the same irrigation scheduling.

Site Layout ----- N



Polyacrylamides (Soilfix as supplied by Ciba Specialty Products) was made into solution and placed into the fertigation units to supply a concentration of 1 ppm per irrigation water. The polyacrylamide solution was added to the fertigation unit at the commencement of the irrigation. The duration of each irrigation was 10 hours. The dose rate of polyacrylamides were calculated on a volumetric basis of irrigation water at a dose rate of 1 ppm. With an 11 mm irrigation, 1 ppm dose rate represented 110 grams of polyacrylamide per hectare. Each row was calculated on vines per row as a percentage of a hectare. For the treated rows this represented less than one gram of product per week.

Fertigation with Polyacrylamides was undertaken on the following dates :

November 1998 - 20

December 1998 - 4, 11, 18, 25

January 1999 - 1, 8, 15, 22, 29

February 1999 - 5, 12, 19

Soil moisture monitoring was undertaken by Yandilla Park Services, Renmark South Australia using the Neutron Probe. Readings were taken from December through to March. The Neutron Probe is widely used in Australia for soil moisture monitoring, using radioactive isotopes to measure soil moisture volumes. Two readings were obtained at each site, one at the dripper and the other 40 cm away from the dripper line. Readings were taken until the end of March. The period without application of PAM's was to determine the residual effect of PAM application via drip irrigation. Unfortunately in sites 1 and 2 (0.3m x 1.1 L/hr) there was an initial error in neutron probe installation which affected results obtained taken before the 20/11/98. The error in installation was quickly picked up and corrected the following week.

Results

Results were obtained from neutron probe moisture monitoring, berry measurement and yield data.

Berry Size

30 berries per bunch were measured with a gibberellic acid ruler to determine berry diameter. Berry measurement was conducted at the top, middle and basal part of the bunch. The average berry size was recorded as bunches with an average berry size in the listed diameter range.

Table 1 : Berry size by bunch,

Rainbird Tape + PAM	Rainbird Tape control	1 m x 4 L dripper + PAM	1 x 4 L dripper control	Berry diameter mm
1				> 20 mm
16	10	19	13	17 - 20 mm
12	17	16	25	15 - 17 mm
2	3	1	1	< 15 mm

Table 2 : Percentage of bunches in each berry size

Rainbird Tape + PAM	Rainbird Tape control	1 m x 4 L dripper + PAM	1 x 4 L dripper control	Berry diameter mm
3				> 20 mm
53	33	53	33	17 - 20 mm
38	57	34	64	15 - 17 mm
6	10	3	3	< 15 mm

The larger berry sizes were recorded in the treatments where irrigation water was being treated with polyacrylamides. Bunch thinning and fruit spacing was conducted to management practices of Western and Sons and total bunch numbers per vine appeared similar. In both PAM treatments berry size was similar recording 53 % of berries greater than 17 mm diameter, compared to 33 % in non PAM treated rows. Fruit buyers prefer larger sized berries and size can be directly linked to improved market prices.

Harvest Data

Fruit was picked on the 12/2/99, trimmed and field packed into 10 kg wooden crates according to field packing guidelines of Western and Sons. The first four vines in each row were picked and field packed. Due to earlier rains significant ringing of the berry neck and wastage was recorded. The yield data refers to pack out only and not to total yield. Estimates of crop loss due to rain were in the vicinity of 25 -35 %. There appeared to be little difference in wastage between the treatments and dripper tube.

Table 3 : Harvest data from each treatment, boxes of fruit per 4 vines harvested (each box is 10 kg in weight)

Rainbird Tape + PAM	Rainbird Tape control	1 m x 4 L dripper + PAM	1 x 4 L dripper control
10 cartons (100kg)	9 cartons (90 kg)	13.5 cartons (135 kg)	8.5 cartons (85 kg)

Table 4 : Kg's of marketable fruit per vine

Rainbird Tape + PAM	Rainbird Tape control	1 m x 4 L dripper + PAM	1 x 4 L dripper control
25	22.5	33.75	21.25

Table 5 : Yield as % of control system (1m x 4.0L/hr)

Rainbird Tape + PAM	Rainbird Tape control	1 m x 4 L dripper + PAM	1 x 4 L dripper control
118	106	159	100

Both PAM treatments yielded more than the control rows. There was no significant difference between dripper tape (ie: 0.3m x 1.1L / hr versus 1.0m x 4L / hr output) on yield and packout. There is some variance in water outtyputs per metre of dripper tubing. 1 m x 4 L /hr drippers emit 4 litres of water per hour. The use of the 1.1 L , 30 cm dripper from Rainbird gives an output per metre of 3.66 litres. It is interesting that this variance in water outputs has not had a significant variance in terms of yield in the control situation. It is worth considering here that it may have been possible that the higher outputs result in a better lateral spread of moisture Soil moisture levels in tube 2 of the PAM treated rows show higher moisture levels in the 1 m spacings over the 0.3 m spacing. Whether this is due to emiitter outputs or the effect of spacing can not be determined in this project.

However, yields when using PAM (irrespective of dripper tubing) were increased over controls. The yield response was significantly different between PAM in dripper tape. A possible reason for this observation is the reduced wetting and drying cycle which occurs under 0.3m drippers compared to 1.0 m spacings. This observation highlights the impact that different dripper tubing can have on the distribution of water in time and space. The use of different dripper tape within a shift could result in significant changes in the distribution of water in that area. As a result consideration issues on irrigation scheduling may need to consider dripper spacing as well as varietal and crop factors. Irrespective of this hypothesis, table grape yields were increased through the use of PAM. The increased berry size measured in PAM treatments would correspond to increased yield and packouts.

Neutron Probe Moisture Monitoring

Moisture monitoring was commenced on the 17/12/98. Two probes were inserted in each row, one in the dripper row and the other 40 cm from the dripper row. All probe sites were in line across the four rows being trialed. Readings were taken twice weekly with results given as summed graphs of moisture in the top 80 cm and as individual histograms documenting water status through the soil profile. Graphs were

given for both tubes and a summed mean both readings. Tube 1 is the sampling site under the drip tube, Tube 2 is located 40 cm away from the dripper and the Mean of the Two Tubes is the sum of Tubes 1 & 2.

For ease of interpretation each sensor has been plotted through the monitoring period to give soil moisture levels at 10 cm, 20 cm, 40 cm, 60 cm, 80 cm and 100 cm. The movement of water can be read at each depth over a time period comparing PAM and control rows.

1m x 4.0L/hr output dripper tape (Site 3 = Control, 4 = PAM)

Soil moisture levels were significantly increased in the top 60 cm in both probe sites. The attached graphs summarising neutron probe readings at each monitoring point show that the use of PAM significantly increase soil moisture levels in the top 60 cm.

Tube 1 shows higher moisture levels up to the 14/1/99 up to 80 cm, from when the graphs follow similar paths. It is surprising that there is such a difference in soil moisture levels considering the location of the probe within the drip row. Perhaps the issue of hydraulic conductance needs to be considered where water follows the wetted profile until sufficient sub soil wetting occurs allowing moisture to be retained in this area. As water moved through the soil profile the differences between sites became less, while at 100 cm, the graphs were almost identical.

Tube 2 highlights the effect that PAM has on increasing the lateral spread of moisture within the root zone. Soil moisture levels are higher in this region until PAM was no longer applied via fertigation (19/2/99). Moisture levels were significantly higher down to 60 cm, after which probe readings showed no obvious differences.

The mean of the two probes show higher soil moisture levels from 10 cm through to 60 cm. Levels at 80 and 100 cm show no noticeable differences.

Rainbird Tape (Site 2 = Control, 1 = + PAM)

This tape represents low cost partial pressure compensated in line dripper tube. The control row initially had the neutron probes placed in the wrong location adjacent to the dripper which was corrected in the week commencing the 18/12/98. Readings from the treated row did not exceed the non treated until the 14/1/99. Comparing the sites, the control row had significantly higher soil moisture levels in the top 60 cm at tube 1 (drip row) and in tube 2 at 40 and 60 cm. There was no significant difference at 80 cm. However at 100 cm the control row had higher readings than the PAM treated row indicating that more water has gone through to drainage. These figures are not noticeable in the 1m dripper spacing rows.

The higher yields achieved with the use of PAM (12% of non treated) and observation of the 100 cm probe may indicate that the water lost to drainage, (or past the root zone) and the increased soil moisture levels in the dripper row (reduced root zone activity caused by continually high soil moisture levels). It appears that this dripper tubing maintains high soil moisture levels in the top soil but also encourages

downward movement of water through the soil profile. The continual close spaced drippers maintaining head pressure on the top soil and resultant increased drainage. Water flow tends to follow a wetted pathway and until the soil began to dry out it is possible that the closely spaced drippers create a soil that is close or above field capacity for prolonged periods.

Comparing moisture levels at 100 cm between dripper tubing shows marginally higher soil moisture levels with 30 m drippers compared to 1.0 m spacing drippers. This indicates that different dripper spacings under the same irrigation scheduling regime can result in varying volumes of water going to drainage.

Monitoring data as such indicated that control rows had higher soil moisture levels than untreated rows in the period up to late December. After this period PAM treated rows held higher soil levels than the control but with less discrepancy as was seen in the 1.0m spacing situation. The use of low flow high output dripper would be expected to create an even soil wetting profile. A possible explanation for the increased yield from the use of PAM is the greater movement of moisture away from the dripper, resulting in less saturation of the soil in the root zone

The use of the 0.3 m x 1.1L/hr dripper system was useful in determining that PAM (as Soilfix) in solution would go through these drip systems. However the data indicates that different irrigation scheduling should be used when different dripper tape is being used. The lateral spread of moisture can be seen to vary according to the dripper outputs in time and space. In deciding crop water usage the use of different tubing may warrant changes to scheduling and subsequent crop water use figures. Likewise it would appear that PAM has the potential to increase soil wetted areas in the root zone with similar amounts of water. It is likely that factor could have a major impact in increasing yields of perennial crops under drip irrigation.

Results

The attached sheets are summaries of yield and neutron probe data. The first two pages highlight yields between PAM and controls. The following pages contain Neutron Probe data for Sites 1, 2, 3 and 4. Graphs are for tube 1, 2 and the mean with readings through the soil profile from 10 cm to 100 cm

Conclusion

South Australia is often referred to as the driest state on the driest continent on earth. Water restrictions and declining water quality are real issues facing irrigators not only in South Australia but in irrigation districts across the world. The use of polyacrylamides represents a low cost option for irrigators faced not only with poor or unsatisfactory lateral distribution of moisture through the root zone, but with limited access to irrigation water. Reductions in losses to drainage and increased soil moisture levels in the root zone would make for greater efficiencies in crop water use.

The trial indicates that the use of Soilfix (Polyacrylamide used in the trial) offers irrigators an opportunity to significantly increase yields and vary soil moisture wetting patterns. Data recorded in this trial corresponds favourably with research data presented earlier indicating that yield responses can be achieved through the use of polyacrylamides. Responses under drip irrigation are likely to be greatest when dripper spacings are further apart. However further work integrating irrigation scheduling, crop water use and varying dripper systems is worth considering. The hydraulic effect of water in time and space and crop production can not be disregarded. Research evidence indicates that the use of PAM has a significant impact wetting profiles in the top soil

The use of closely spaced drippers (0.3 m) created an environment where moisture levels at 100 cm were higher and indicates that such dripper tubing may not be appropriate where high crop water use requirements are needed and / or drainage water recharge issues are a concern.

The increased wetting patterns in the top 60 cm associated with the use of PAM in widely spaced drippers may play an important role in the leaching of salts. The increased wetting pattern would result in accumulated salts being pushed further away from the root zone. This would create the potential for better use of saline water reserves

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