

1.9 Using PAM in irrigated cotton

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Key points

- Polyacrylamide (PAM) is used in irrigation fields to minimise soil erosion. Increases in infiltration and decreases in runoff concentrations of sediment and contaminant also typically occur.
 - Rigorous scientific trials conducted on PAM use in the USA have been undertaken using drastically different furrow irrigation systems to those employed in the Australian Cotton Industry. The performance of PAM under these Australian conditions may be significantly different.
 - Understanding current furrow irrigation performance is essential when considering PAM for in-field use, as slower advance rates are likely to increase total water use and decrease water use efficiency in all but low infiltration soils.
- When used in the right circumstances (eg. soils with low infiltration rates), PAM has the potential to dramatically decrease sediments, nutrients and various contaminants in runoff and improve irrigation infiltration.
 - When used incorrectly, PAM has the potential to dramatically decrease irrigation performance and increase water use.
 - PAM also has potential application for evaporation and seepage control although the effectiveness under typical Australian cotton industry conditions is not well known.

Introduction

Polyacrylamide (PAM) is a long chain hydrocarbon of high molecular weight that has been used extensively across numerous industries for many decades. Some of the current uses of PAM include:

- treating potable water,
- dewatering sewage sludge,
- food processing practices,
- paper and adhesive manufacture (including food grade paper products),
- cosmetic manufacture; and
- mining and drilling operations.

PAM is generally used as a settling agent. When added to a solution it flocculates (clusters together) fine particles which can then settle out of the solution. Hence when added to irrigation water, PAM binds the fine clay and silt particles together. The resulting action is twofold; soil structure is stabilised, reducing the detachment and transport of sediment from the soil surface, whilst any detached particles are flocculated and can settle out of the irrigation stream.

There are actually hundreds of different formulations of PAM including cationic, neutral and anionic varieties with molecular weights ranging from 1 to 20 million. PAM rarely contains hazardous elements (e.g. heavy

metals or radionuclides) and due to its low toxicity to the environment and organisms, it is believed to have low environmental and public health impacts (Misra and Hood, 2007).

PAM used for irrigation is mostly anionic and may be provided in either fine granular, liquid or emulsion forms. Some cationic and neutral varieties are not suitable as they are not only less effective but may have environmental toxicity issues which are not present with anionic PAM when used at recommended rates. Appropriate PAM formulations are typically referred to as 'linear' or 'non-cross linked'. 'Cross linked' or 'super water absorbent' PAM's have a different function and should not be used for erosion control purposes.

Typical application rates of PAM in irrigation application systems are in the order of only a few kilograms per hectare. Often subsequent irrigations require lower application rates and so the typical seasonal application may only be five or ten kilograms per hectare. For applications in evaporation or seepage control the applications may be an order of magnitude higher.

Sufficient turbulence or agitation must be provided at the application point to dissolve granular PAM to the required concentration.

PAM use in Irrigation

The properties of PAM provide for a number of irrigation applications. As a flocculating agent, introducing PAM into irrigation water allows water borne soil colloids to fall out of suspension and remain in the field rather than being transported from the field in runoff. PAM can also act to stabilise soil structure, inhibiting soil breakdown and dispersion, and therefore is useful to maintain or improve infiltration in soils that are prone to sealing.

In higher concentrations, PAM also increases the viscosity of the water solution which has been proposed to have benefits in reducing evaporation and, in combination with the deposition of sediment, seepage in channels and storages.

Erosion Control

When PAM is applied to irrigation water, erosion from irrigated fields is reduced as the PAM enables clusters of soil particles to form which can then settle out of the irrigation water, reducing their transport from the field.

Trials in the USA have indicated reductions in runoff sediment of up to 94% through the use of PAM. The method of application involved dissolving 10 kg/ML of PAM in the irrigation water during the initial advance only. After runoff begins, PAM dosing is ceased. The resulting dose was generally 1-2 kg/ha. Where furrows were not disturbed, the erosion control during subsequent irrigations, without PAM application, was typically reduced by half.

The effectiveness of the PAM application for freshly formed furrows was found to vary according to inflow

rate, PAM concentration, duration of furrow exposure and total amount of PAM applied. These variations may have dramatic impacts on the adoption of these results in Australia as the test conditions involved short fields (175 - 264 metres) and flow rates in the order of 13 - 38 L/min compared to the much longer field lengths (~400 - 1600 metres) and higher flow rates (> 60 L/min) typically employed in the Australian Cotton Industry. Flow rates in excess of 200 L/min are not uncommon. The performance of PAM under these conditions may be considerably different.

Australian trials have indicated reductions in erosion from furrow irrigation events at flow rates of up to 120 L/min using either wheat stubble or PAM. Accordingly, levels of some contaminants, particularly endosulfan, were also effectively reduced using these erosion control methods. However other contaminants such as metolachlor, which are not as strongly associated with soil particles, were not effectively controlled.

Trials in irrigated cotton fields in Emerald showed a reduction in tailwater sediment concentration of 80% with PAM concentrations of 0.5 to 1 kg per hectare (Waters, 2001). Misra and Hood (2007) report that Hugo (1999) obtained similar results in trials at Warren and Kingsthorpe, although this outcome in the Warren trial required a PAM application rate exceeding 3 kg per hectare. However all of these trials also found that erosion due to rainfall was not significantly influenced by the use of PAM during irrigation events. [Misra and Hood](#) (2007) also report on some further results from Australian studies.



Modifying Soil Infiltration Characteristics

PAM is also commonly used in irrigation to increase soil infiltration, which is thought to be achieved by both increasing soil surface stability and by decreasing the amount of suspended solids, which results in fewer soil pores being blocked by fine sediments.

In some hard setting or sodic soils, where obtaining sufficient infiltration is problematic, such an increase in infiltration may be desirable. In these cases, PAM can help to improve infiltration and reduce runoff losses. Similarly, where gypsum is used to reduce surface sealing, PAM may be useful to help improve infiltration without the amount of salt loading inherent in the continual use of gypsum.

However, most soils within the cotton and grains region are not of this type and in fact generally exhibit excellent infiltration properties. In such soils, which includes most heavy clay soils in this region, additional infiltration may encourage waterlogging, deep drainage losses and may also decrease irrigation performance.

When PAM use increases infiltration, this is reflected in the slowing of the advance of furrow irrigation water. However for most cotton growing soils, surface irrigation performance evaluations have typically indicated adequate soil infiltration rates and, in fact, water use efficiency will often increase through speeding up the irrigation advance (achieved with higher flow rates and shorter irrigation durations). Hence the use of PAM in such situations is likely to act against the commonly employed performance improvement tactics and may decrease water use efficiency if the system is not adequately analysed beforehand.

Successful application of PAM to modify soil infiltration characteristics is further complicated by the mix of results that can be obtained. For example, instead of increasing infiltration, Misra and Hood (2007) reported instances of soil infiltration being reduced through timing of application, incorrect PAM dosing or application to soils which already exhibit soil structural damage.

For these reasons, it is strongly recommended that where PAM is being considered for the purposes of modifying soil infiltration properties, current irrigation performance is first measured and independent advice is sought regarding the appropriateness of PAM application for the desired purpose.

Seepage and Evaporation Control

There has also been interest in the use of PAM for control of evaporation and seepage from storages and channels.

For evaporation control, it is thought that PAM may be able to reduce evaporation by increasing water viscosity. Trials at the National Centre for Engineering in Agriculture in small scale tanks of clean water showed evaporation savings of between 31 and 43% when applied at a concentration of 100 parts per million. However the level of potential savings under on-farm conditions is not clear.

Surprisingly, considering PAM may be used in fields in an attempt to increase infiltration, high application rates in channels and storages is believed to offer the potential to reduce seepage. The level of seepage reduction will most likely depend on the type, size and amount of suspended soil particles and the concentration of the PAM solution. Whilst there has been some investigation of the success of PAM for such applications in the US and to some extent in southern Australia, there has been limited investigation in cotton growing regions and the small amount of work that has been conducted has shown mixed results. Further information on PAM application for seepage reduction is included in WATERpak Chapter 1.6.

Environmental Considerations

As well as decreasing sediment runoff from irrigated fields, studies have shown that using PAM in irrigation water also decreases certain nutrient and pesticide loads in drainage waters. This is because many nutrients and pesticides are attached to the soil particles which are retained within the field. In addition, numerous microorganisms and weed seeds, typically removed in tailwater, remain in the field following PAM application. Minimising this movement results in significantly lower concentrations of pollutants in distribution systems and storages as well as off farm waterways.

When used at recommended rates, no significant negative impacts have been documented for crop species, soil microorganisms or aquatic macrofauna.

The movement of PAM from fields is minimal due to its attraction to sediment particles; as they settle out of the water stream, the PAM settles also. Trial results indicate that only 3-5% of the PAM applied to a field leaves in the tailwater and this volume travels no further than 100-500 metres along the tail drain. PAM in soil gradually breaks down at about 10-20% per year due to physical, chemical and biological activities.

Important Considerations

1. The biggest consideration facing the use of PAM on fields within the Australian Cotton Industry is its effect on furrow irrigation water use efficiency. Recent furrow irrigation trials have indicated that in many situations, water use efficiency is currently compromised through advance rates that are too slow, leading to poor uniformity, over application and extended periods of water logging. PAM used in these situations would likely exacerbate the problem by slowing advance rates even further. However there is quite probably potential for PAM use in some circumstances such as high slopes prone to erosion or soils with poor infiltration. The key is to gain an understanding of your situation before proceeding with PAM application. Surface irrigation performance evaluation (see WATERpak Chapter 5.3) is strongly recommended when considering PAM for in-field use as the potential for PAM to decrease water use efficiency if used in the wrong situations is significant.
2. In circumstances where furrow optimisation suggests that optimum flow rates are high enough that erosion is a significant issue, there may be potential to combine improved furrow irrigation practices and PAM application.
3. When using PAM, it is important to ensure that the first water to proceed down the furrow during the irrigation advance is of the correct PAM concentration. Any non-treated water that comes into contact with dry soil will start to degrade soil structure almost immediately, reducing the ability of PAM to stabilise soil structure and reduce erosion.

Case study: application of polyacrylamides in rural water use efficiency initiative demonstration sites

Irrigators in Queensland undertook several on-farm demonstrations of PAM use during the 2000 to 2003 summer irrigation seasons. The purpose of these demonstrations was to allow irrigators in the St George/Dirranbandi and Emerald regions to investigate the effect PAM had on improving infiltration and reducing erosion during cotton furrow irrigation events.

Due to lack of Australian research into the use of PAM in irrigated agriculture, irrigators and Rural Water Use Efficiency officers designed crude demonstrations (not rigorous trials) to monitor the effect of PAM treatments on fields with similar soil, design and management characteristics. The trials compared PAM treated and untreated fields or portions of fields. **The following results are simply recorded observations from the demonstration sites, and should not be taken out of the context of these demonstrations.**

In these demonstration sites, PAM was applied to irrigation water in the head ditch prior to siphons being started. The need for more investigation into application methods was highlighted due to some practicality issues



Case study: continued

St George

During the 2000/2001 season, a crude comparison of irrigation advance times for PAM treated and untreated furrow irrigation events demonstrated that it took approximately two hours longer for PAM treated water to reach the end of the furrow. It is therefore inferred that infiltration can be increased on these hard setting soils through the application of PAM. The effect on total water use, distribution uniformity and water use efficiency was not measured.

Emerald

In the Emerald irrigation subregion, trials investigated likely improvements in water retention in the root zone (due to PAM) and the effect on waterlogging and potential yield reductions. Advance rates and the amount of tailwater were measured in treated and untreated sites. Continuous soil moisture monitoring was undertaken at several soil depths at both sites.

Observed outcomes included an average advance time increase of one and a half hours over the furrow distance of 375 m at the treated site. This implies an increase in infiltration due to PAM application. Less tailwater was measured at the treated site, potentially indicating that less sediment and nutrients left the field. Soil moisture monitoring at the treated site indicated prolonged waterlogging, which may have contributed to yield loss.

Other investigations have demonstrated that PAM application may have been useful in ensuring even bed-wetting, thus assisting uniform germination and improved seedling establishment. In a demonstration of PAM on wheat an irrigator remarked on improved germination and seedling establishment, heavier seed heads, increased yield (0.25 tons/acre) and decreased water use (one whole irrigation) between a crop that was split into a treated section and a non-treated section.

Irrigators in the Emerald region are increasingly using PAM in their early irrigation particularly to save nutrients from being washed or leached away when the soil is still loose and fertiliser has just been applied.

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