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Grape and Wine Research and Development Corporation

Role of Polyacrylamides (PAM) in Drip Irrigated Vineyards in the Riverland of South Australia.



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GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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2. Executive Summary

A field test of polyacrylamide (PAM) amendment to commercial fertigation systems at two Riverland vineyard sites (Angove's, Renmark and Centenary Orchards, Loxton), during 2008/09 aimed to:

- investigate the impact of PAM and its effects on vine performance in at least two commercial sized field trials (soil types);
- manage vineyard irrigation using PAM at critical water-use periods and make comparisons with standard management practices; and
- improve the technical aptitude of regional stakeholders with respect PAM and enable them to make informed decisions about its potential role in integrated irrigation and soil management systems

The treatments were applied PAM either as AG30, a more costly but easy to use formulation, or as AG60, a lower cost form lacking surfactants and emulsifiers. At each site, vines and vineyards were monitored via weekly sap analysis, and assessment of yield and quality parameters, soil moisture, berry quality and canopy growth.

This extension project at both sites confirmed earlier published research and showed that PAM could play an important role in improving irrigation efficiency at a field level. The perceived impact of PAM on bunch elongation and increased fruit colour raises issues with regards to vineyard management and fruit composition that lay outside the scope of this study but which offer potential for further research at some future stage.

The outcomes from this trial indicated that the use of PAM (in either liquid or solid formulations) has potential to increase crop water use efficiency and decrease overall water requirements. The effect appears to be mostly through slower infiltration, greater lateral spread and lower percolation losses of irrigation water.

PAM treatment has the ability to reduce infiltration rates of irrigation water in light textured soils. The treatment has potential to assist retention of soil water within root zones and reduce losses to drainage below the root zone.

PAM treatment, especially formulations like AG30 that include a surfactant, through its effect on soil aggregate stability, has potential to improve water infiltration rates into heavier clay based soils.

The observations in this demonstration trial were consistent with earlier work conducted by Phillips (2007) indicating that PAM treatment of irrigation water had capacity to reduce water requirements in the field, improve the capacity of soil to re-wet and retain moisture and hence offer greater flexibility between irrigation cycles on coarse sandy soils.

PAM has potential for further evaluation in Riverland vineyards. Rates, application methods and costs need to be refined. For example, investigation into optimum rates for various soil types where higher concentrations of PAM are required to reduce infiltration rates. Also, the potential for changes in soil biology as a result of greater water retention near the soil surface needs assessment.

The PAM formulation AG 30 at the label rate of 10L/ha, was applied to make an easy-to-use form for growers with very small fertigation systems, or where isolation of irrigation sections and/or valves was difficult. While this formulation was easier for grape growers to apply than AG 60, it was more expensive.

PAM, being a powerful flocculent, removed colloidal material within the drip irrigation systems used in the trial. This action required care in flushing irrigation lines and illustrated the potential for PAM to better clean drip irrigation lines not scoured by increased flushing velocities. As such, the initial PAM application will need to be carefully managed.

The field trial at both Century Orchards and Angove's revealed that PAM could play an important role in improving irrigation efficiency at a field level. Further evaluation of best PAM formulations is needed to determine optimum rates and applications for vineyards of the Riverland and beyond.

3. General Report

3.1. Introduction

Several years of market volatility followed by drought had left the Riverland region precariously poised. The extent of the market depression and the drought caught many within the grape industry ill prepared and winegrape growers were left wanting for decision support tools and practical applications of science to assist their profitability under pressure.

The drought may have reflected a cyclical circumstance or something far greater but predictions by the CSIRO indicated that the region would probably need to adapt to higher temperatures and lower (winter and spring) rainfall. Regardless of individual persuasions in the debate on climate change or weather variability, all agreed that water supply was and remained severely constrained and a change in current practice was needed if community, environment and industry were to be sustained.

Polyacrylamides (PAM) had long been used by the construction industry for erosion control. Applications to disturbed soils had shown improved aggregate stability and infiltration, thus reducing surface run-off and erosion. As far back as the 1950's, Monsanto saw an opportunity for the use of PAM for agricultural applications, albeit in furrow irrigated management systems. The expense of the product however meant that it did not see gain in market acceptance. (see - http://www.cropinfo.net/bestpractices/bmppamreport.html)

It appeared that the application of PAM improved the level of absorbance of water into soils and the retention of soil moisture. For instance, Ajwa and Trout (2006) noted that PAM's effect on water viscosity harboured opportunity to improve water distribution in coarse textured soils. This effect, in combination with a change in soil water conductivity, warranted exploration for commercial practicality. Information regarding product selection (molecular weight etc); the timing of its use; environmental integrity; and the influence of water quality (salinity) on its performance needed to find its way to market place.

The local media advertised claims that several PAM products saved up to 30% water use. If only half this saving (*viz.* 15% economy) were achieved in the Riverland, an average water use of approximately 6.5ML/ha/annum would be reduced by close to 1ML/ha annually. Application costs of the products averaged $20-30/ha. If three applications were made in a season (@ total $90/ha), only a small increase in yield, quality and/or water economy would deliver an economic benefit to the modified management activity.

In consequence, Riverland winegrape growers, desperate to maintain a crop and eke out a living, had shown strong interest in these products and the industry needed to provide leadership in the search for a sustainable future. As a result, the following project was undertaken in the Riverland, South Australia during 2008/09.

3.2. Aims

The aims of the project were:

- To investigate the impact of PAM and its effects on vine performance in at least two commercial-sized field trials (soil types).

- To manage vineyard irrigation using PAM at critical water-use periods (bunch hook, fruit set, pre-veraison and post- harvest) and make comparisons (soil moisture and plant monitoring) with a standard practice management system; and

- To improve the technical aptitude of regional stakeholders with respect to PAM and enable them to make informed decisions about its potential role in integrated irrigation and soil management systems.

Matters of particular interest were:

- To evaluate the field use of PAM in improving irrigation efficiency in Riverland vineyards; and
- To explore practical methods of applying PAM through drip irrigation systems

3.3. Methods – for more details, see Section 4

In a field demonstration trial in the Riverland of South Australia during 2008/09, two field sites were chosen: one in Renmark, with clay loam soils, and the other in Loxton, on an old dunal sand system.

Two formulations of PAM were used, one at each site*:*

- PAM as AG 30 at Site 1, and as
- PAM as AG 60 at Site 2.

Site 1: Cabernet Sauvignon at Angove Family Winemakers, Anchorage Vineyard, Renmark, SA

Treatment 1 (Block 1): **PAM as AG 30.**

- An expensive formulation but is easily applied. Its main ingredient is PAM as AG 60 (see Treatment 2, below) with an added range of surfactants that aid dissolution and stabilisation of the PAM molecule.
- Applied at 10L/ha which is the label rate where flow rates are uncertain – it is a form of PAM for easy application by growers with either very small fertigation systems or where isolation of sections and valves was going to be difficult.
- Fertigation solution at concentration 50 ppm or 50L/ML irrigation water applied through the drip system. This was a rate significantly higher than used in Treatment 2.
- Application was made to a block of Cabernet Sauvignon with propagation material ACA S2, at the following timings:
  - First irrigation (Late September)
  - Bunch hook (Late October)
  - Veraison (Late December)

Treatment 2 (Block 2): **Untreated Control** – with standard commercial vineyard management

Treatment 3 (Block 3): where **Aquapen®** - an inverse emulsion formulation of PAM was applied to Cabernet Sauvignon ACA S9.

Site 2: Chardonnay on Ramsay at Century Orchards, Loxton, SA

Treatment 1 (Block 19): **PAM as AG 60.**

- A less expensive formulation comprised of PAM as a water soluble, high molecular weight, anionic powder.
- Applied at between 1-2ppm (1-2 kg/ML applied water) via fertigation solution at the following timings:
  - First irrigation (Late September)
  - Bunch hook (Late October)
  - Veraison (Late December)

Treatment 2 (Block 18): **Untreated Control** – with standard commercial vineyard management.

Measurements (for more detail, refer to Section 4)
Soil Moisture Monitoring was undertaken at both sites. The amount and frequency of irrigation water applied was varied according to the need for vine growth as determined by soil water monitoring.

Vine sap analyses were conducted using Horiba Cardy Meters giving readings of levels for nitrate nitrogen, potassium and sodium. Petiole samples were taken from leaves opposite the flowering bunch for information on trends within treatments over the growing season.

3.4. Results and Discussion – for more details, see Section 4

PAM applied as either of its two formulations in this demonstration project, was useful in reducing water usage and/or in increasing infiltration rates of irrigation water and enhancing the water retention capacity of soils. For instance, at Site 1 on clay loamy soils, the PAM treated site used 17% less water compared to the untreated control.

At Site 1, the third treatment comprising a second formulation of PAM (Aquapen®) produced a high yield (30t/ha) with only 6.1ML/ha applied irrigation water.

AG 30, at Site 1, Renmark, SA:

- The treated section appeared to have better initial canopy growth and greater bunch elongation than in untreated vines. This effect has potential for advantageous secondary effects in reducing disease and pest incidence and/or severity where bunch and berry density influences their occurrence, *eg* light brown apple moth and bunch rots.
- Overall the AG 30 treated vines had larger bunches than the untreated section. However this was not seen in overall yield at harvest.
- The berry colour score was significantly higher in the AG 30 treated section compared with the untreated control with scores of 1.25 to 1.01 respectively while yields were unchanged.
- PAM treatment showed higher soil water readings in comparison to the untreated control in the summed histograph.
- Higher levels of soil water were retained at depths associated with the root zone; but
- Water levels at greater depth (100cm) were significantly lower in the PAM treated area than the untreated. This indicates that even on clay soil types that deep percolation losses of water under drip irrigation need to be considered and that PAM (as AG30) helps facilitate better lateral spread of water even in clay soils.
- In many cases, water at these depths could be regarded as an inefficient placement of water because there are few active roots within this zone and they contribute to only a small portion of the vine's demand for soil water.
- This suggests that applied irrigation water moved to depth more slowly in the treated soils, a significant observation with potential for improvement in irrigation efficiency. This outcome supported earlier investigations by the senior author (Phillips, 2007).

- A post-flowering spike in nitrogen levels observed in both PAM treated and untreated vines, was significantly higher in PAM treated than in control plot vines. Visual assessment of plant growth at this time showed greater growth in the treated over the untreated samples. Initial indications from both sites suggested the use of PAM leads to an increased effectiveness of applied nitrogenous fertilizers. This effect needs further evaluation.
- Petioles in PAM treated vines showed lower levels of potassium compared to untreated vines
- Early in the growing season, the untreated section had considerably higher levels of iron deficiency than in the PAM treated plots.

The reduced downward flow (drainage) of water beneath PAM treated drip irrigated vines was of interest. This finding suggests that even under normally managed drip irrigated vines, deep percolation losses of water are occurring and that these were reduced through application of PAM. This approach has potential for further investigation since many irrigators are unaware of this water use inefficiency and this treatment may assist in maximising water use efficiency in vineyards of the Riverland and elsewhere.

AG 60, at Site 2, Century Orchards, Loxton, SA, showed similar trends in water retention as was evident in the PAM AG 30 treated vines. Canopy development was greater in the PAM treated area than the control for the same volume of applied water. In contrast, generally, the leaf petiole analyses showed little difference between both treated and untreated control vines in either nitrogen, potassium or sodium.

From an economic perspective, even AG 30, the most expensive PAM formulation designed for ease of handling, cost less than one third the value of the water saved as a result of the reduced irrigation demand (assuming water costs $300/ML). Pre-made PAM solutions such as AG30, are cost effective when compared to the current price of water. The site management considerations and existing infrastructure in handling emulsions, solutions or PAM powders becomes the issue in determining which product is most suitable at an individual site.

PAM powders (anionic linear polyacrylamides) require good agitation in large water volumes (at <1kg/1000L) for dissolving in tanks. Flushing and line cleaning as well as an understanding of managing colloidal clay content in drip lines need to be considered before the use of PAM in commercial viticulture is recommended.

Site and Field Visits Conducted during the project

- Riverland Viticultural Technical Group - November 2008
- Loxton Ag Bureau - November 2008
- Fosters Riverland Grower Liaison Officers - November 2008
- Grow Smart Science Group - December 2008
- Doug Samuels, Clean Water, California USA - February 2009
- Queensland PAM network - March 2009
- Grow Smart Science Group - May 2009

3.5. Conclusion

A simple test in two Riverland vineyard sites over one season showed that applications of two formulations of PAM at very low concentrations through fertigation systems via drip irrigation had positive significant effects on aspects of soil quality likely to enhance irrigation efficiency.

The use of PAM (in either liquid or solid formulations) has potential to increase crop water use efficiency and decrease overall water requirements. The effect appears to be mostly through slower infiltration, greater lateral spread and lower percolation losses of irrigation water.

PAM treatment reduced infiltration rates of irrigation water in light textured soils. The treatment has potential to assist retention of soil water within root zones and reduce losses to drainage below the root zone.

PAM treatment, especially formulations that include a surfactant, through its effect on soil aggregate stability, has potential to improve water infiltration rates into heavier clay based soils.

The findings in this demonstration trial were consistent with earlier work conducted by Phillips (2007) indicating that treatment of irrigation water had the capacity to reduce water requirements in the field, improve the soil's capacity to re-wet and retain moisture and hence offer greater flexibility between irrigation cycles on coarse sandy soils.

PAM has potential for further evaluation in Riverland vineyards. Rates, application methods and costs need to be refined. For example, investigation into optimum rates for various soil types where higher concentrations of PAM are required to reduce infiltration rates in coarser soils. Also, the potential for changes in soil biology as a result of greater water retention near the soil surface needs assessment.

The PAM formulation AG 30 at the label rate of 10L/ha, was applied to make an easy-to-use form for growers with very small fertigation systems, or where isolation of irrigation sections and/or valves was difficult. While this formulation was easier for grape growers to apply than AG 60, it was more expensive.

PAM, being a powerful flocculent, removed colloidal material within the drip irrigation systems used in the trial. This action required care in cleaning and flushing irrigation lines and illustrated the potential for PAM to better clean drip irrigation lines not cleaned by increased flushing velocities. As such, the initial PAM application will need to be managed with care such as coinciding with a flushing of the system.

The field trial at both Century Orchards and Angove's revealed that PAM could play an important role in improving irrigation efficiency at a field level. Further evaluation of best PAM formulations is needed to determine optimum rates and applications for vineyards of the Riverland and beyond.

The ability of PAM to remove colloidal material in the drip line even in systems with high levels of hygiene maintenance was an indication that current management practices may not be overly effective in removing this material from within the irrigation system. The impact of PAM on bunch elongation and increased fruit colour also raises other issues with regards to vineyard management and fruit composition that was outside the scope of this study. This may offer further research opportunities for PAM in viticulture at some stage in the future.

3.6. References

1. H. A. Ajwa and T. J. Trout (2006) Polyacrylamide and Water Quality Effects on Infiltration in Sandy Loam Soils: http://soil.scijournals.org/cgi/reprint/70/2/643

4. Scientific Report

4. Scientific Report:
The Role of Polyacrylamides (PAM) in Drip Irrigated Vineyards in the Riverland of South Australia.



Century Orchards, Loxton, South Australia. October 2008

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4. Scientific Report

4.1. Introduction

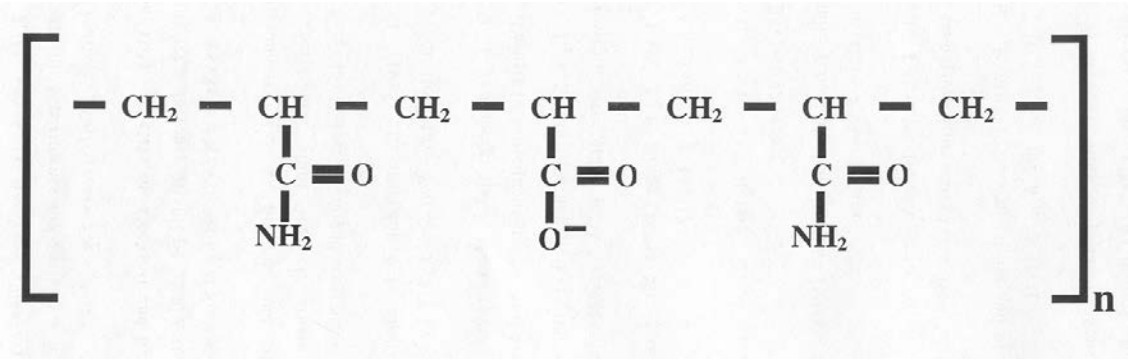
The Riverland region of South Australia is the largest producer of wine grapes in Australia. The Global success of the Australian wine brand would not have been possible without the secure supply of quality wine grapes from the warm, inland, irrigated districts of the Nation.

Innovation has never been far from the practice of irrigation within the Riverland. The region is regarded as one the most efficient irrigation areas in the world. The district when faced with drought, turned to the process of innovation again; the commercialisation of polyacrylamide products (PAM) provided the opportunity.

Research into PAM had shown a capacity to alter the movement and retention of water when applied under drip irrigation. The early adopters and market leaders of the region had experimented with the integration of PAM into their irrigation regimes. There was a positive air about the products, although the benefits remained difficult to quantify. A regional approach was required to assess the opportunity for seamless integration at a scale deemed practical for industry.

The project was funded by GWRDC through the RITA program and initiated by the Riverland Wine Industry Development Council (RWIDC). Biocentral Laboratories Ltd, Thebarton, SA, provided the product and technical support.

Polyacrylamide (PAM)



Varying the length of the chain and the attached functional groups will alter the behaviour of the molecule in water and soil.

4. Scientific Report

Influence of PAM on soil physical properties

4.1.1.1. Infiltration

PAM has been shown to effect movement of water into soils in different ways. Coarse textured soils benefit from the increased viscosity that PAM brings to a water solution. Phillips (2007) and Husein and Trout (2006) noted that applications of PAM at very low concentrations had significant effects on reducing infiltration rates of water in light textured soils. For vineyards with sandy soils, the ability to reduce deep percolation losses of water brings significant opportunity to increase water use efficiency in drip irrigation systems.

Heavier soils benefit from the improved structural integrity PAM applications deliver. Sojka *et al.* (1994) showed that applications of PAM significantly improved soil aggregate stability. Trout *et al.* (1995) reported that small quantities of a high molecular weight PAM reduced furrow induced erosion by 85-99%. The ability of PAM to assist with soil stabilisation has long been recognized by the mining and construction industries.

In short PAM:

- through its effect on viscosity reduces the infiltration rate in coarse texture soils; and
- through its effect on soil aggregate stability can improve infiltration into heavier clay based soils (formulations that include a surfactant can further improve infiltration in these soils)

How can this be applied?

Phillips (2007) documented how PAM applied in irrigation water reduced the infiltration rate of that water in some light textured Mallee soils.

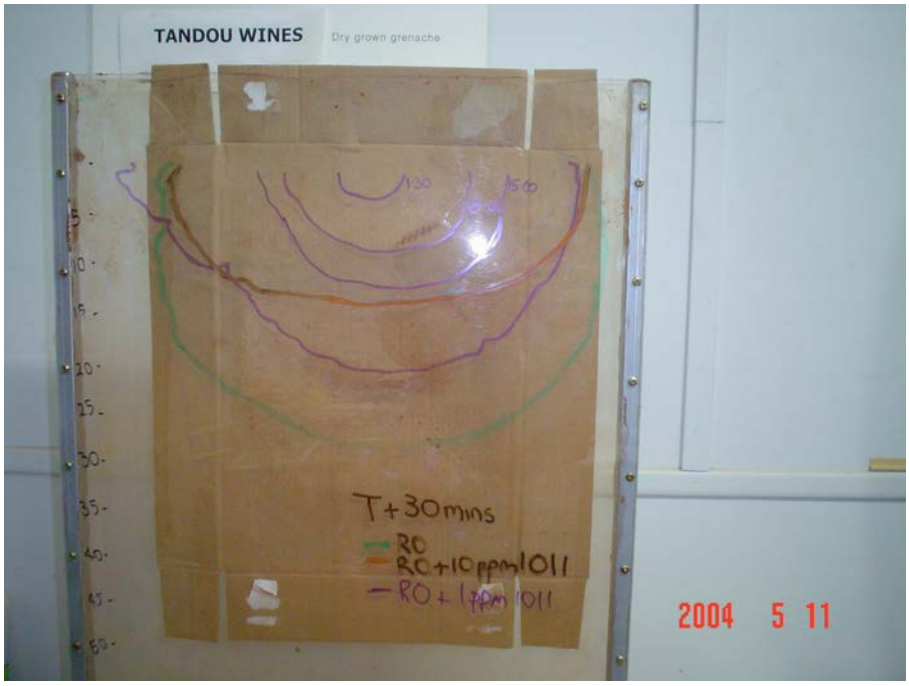


Figure 1: The Gardner Model was used to show that PAM could be seen to slow down water movement through the soil profile in similar amounts of time.

4. Scientific Report

The work conducted by Phillips (2007) suggested that a number of applications were available:

- Improved soil hydrology (slower infiltration, greater lateral spread and lower percolation losses) had the capacity to reduce water requirements in the field, improving the soil's capacity to re-wet and retain moisture and hence offer greater flexibility between irrigation cycles on coarse sandy soils.
- Sodium and calcium in irrigation water clearly reduced the viscosity of PAM solutions, but sodium and calcium are not the only cations in irrigation water (iron is seen to have a major influence on the behaviour of many commercially available PAM products).
- In coarse sands, water tends to finger its way down the soil profile, so the water content is rather variable in the root zone.
- The utility of PAM (and equivalent negatively charged products) covers a wide range of sands, but higher concentrations are required to reduce infiltration rates as the soil become coarser.
- The potential for changes in soil biology as a result of greater water retention near the soil surface needs to be at least considered.

4.1.1.2. Soil sodicity, structure and mechanical strength

The use of PAM offers an interesting opportunity in the battle against salinisation. Gardiner and Shainberg (1996) investigated the use of PAM and/or gypsum to overcome the effects of sodium (sodic soil). The experiment showed PAM performed better than gypsum in increasing infiltration rates. Aly and Letey (1989) also showed that PAM ameliorated soil hardness in water with EC 0.05 and 0.7 dS /m.

Levy *et al.* (1995) added small amounts of anionic PAM to highly salty clay soils and also, studied the impact that PAM had on runoff and erosion from sodic soils. PAM was seen to control runoff at low ESP (<4) but was inefficient at high ESP levels. However, PAM applications to the irrigation water reduced soil erosion in moderate and high ESP soils.

In short:

- PAM through its ability to flocculate clay improved infiltration in sodic soils
- PAM applied to salty water (moderate to high ESP) reduced soil erosion

4.1.2. Influence of PAM on plant growth and development

The application of PAM to soil has been shown to have an impact on plant and soil nutrient levels. The addition of PAM to irrigation water was seen to markedly reduce furrow runoff losses of sediment and phosphorus, whilst also reducing chemical oxygen demand in the runoff water. The use of PAM did not appear to influence nitrate runoff (Lentz *et al* 1998a) but significantly reduced phosphate runoff (Lentz *et al* 1998b).

Willams *et al*. (1966), Bres and Weston, 1993, Wallace *et al*. (1986) and Abraham et al. 1995 all undertook a range of experiments looking at the influence of PAM on plant nutrition. In all cases, the use of PAM led to increased nitrogen retention within the soil. Levy and Rapp (1999) added synthetic polymers to crusting soils and found that seedling emergence was improved.

4. Scientific Report

4.2. Project Aims

Knowing that PAM influences soil hydrology, chemistry and that potential existed to improve viticultural practice is one thing. Investigating how PAM might be integrated into existing irrigation strategies on a commercial scale and assessing the net benefits is another; particularly when the scope of the project is limited to a single season. To this end two field sites were chosen, one in Renmark SA with clay loam soils and another in Loxton on an old dunal system.

The aims of the project were set out as follows:

- To investigate the impact of PAM and its effects on vine performance via application in at least two commercial-sized field trials (soil types).
- To manage vineyard irrigation using PAM at critical water use periods (bunch development, fruit set, pre-veraison and post- harvest) and make comparisons (soil moisture and plant monitoring) with a standard practice management system; and
- To improve the technical aptitude of regional stakeholders with respect PAM and enable them to make informed decisions about its potential role in integrated irrigation and soil management systems.

4.3. Methods

4.3.1. The Field Sites

Two field sites were chosen, one in Renmark SA with clay loam soils and another in Loxton on an old dunal system.

1. The Renmark (Angove Family Winemakers) vineyard was devoted to the production of Cabernet Sauvignon on own roots on a shallow clay loam soil.
2. The Loxton vineyard was devoted to growing Chardonnay on Ramsey on sandy soils of various depths (dunal system) overlying limestone.

4.3.2. The Treatments (PAM products)

AG 30 (used at the Renmark site)**:** A PAM solution comprising AG 60 (see below) and a range of surfactants that aid dissolution and stabilisation of the PAM molecule.

The applied rate is significantly higher (50ppm of actual flow or 50L/ML of irrigation water) than that of AG60.

The trade off with products such as AG30 is that there are no issues with dissolution of the product or filter blockages. Choice of this product was dictated by the capability of fertigation systems. Where the capacity is low (less than 1000L), AG 30 should be used.

The additions of surfactants make this product useful for heavier soils or soils that are water repellent.

AG 30 was used at the Angove's Renmark vineyard with application rates at 10L/ha which is the label rate where flow rates are uncertain. The reason for looking at the label rate of 10L/ha was to make an easy form of PAM application for growers with either very small fertigation systems or where isolation of sections and valves was going to be difficult.

4. Scientific Report

AG 60 was used at Loxton site: A water soluble, high molecular weight, anionic PAM powder.

It requires agitation to dissolve the powder and for ease of handling and mixing within the irrigation stream should be dissolved at no more than 600g/1000L.
The product should be applied at 1-2ppm of actual flow rate (1-2kg/ML irrigation water).

Once the product is dissolved in the fertigation tank the solution is quite viscous. Under normal conditions it is worth allowing 30-45 minutes of mixing to ensure that the PAM powder (AG60) is totally dissolved to avoid any blockages in the back up filters.

PAM fertigation should commence at the start of the irrigation shift as it is the flow of water through the soil profile that is being addressed. Even at rates as low as 1ppm through the dripper, the increased viscosity of the water can be seen in how the water droplet comes out of the dripper emitter (Picture 5).

Important note:

PAM, being quite powerful flocculent, will also remove colloidal material from within the drip diaphragm and along the drip line wall that are not necessarily moved by increased flushing velocities. As such, the initial PAM application should also coincide with a flushing of the system.



Figure 2: Adding AG 60 to fertigation tank at Century Orchards, Loxton, SA. The product needs to be added slowly *while agitating (!!!)* to avoid product forming one large gluey lump.

4. Scientific Report



Figure 3: Water droplet as influenced by addition of PAM AG 60 (increased length of water droplet)

4. Scientific Report

Key Operational Considerations with PAM AG 30 and 60

AG 60

- Requires excellent agitation and large mixing tank, dissolving product takes time
- Should not be dissolved at rates greater than 600g/1000L (higher rates are possible but difficult to manage, especially in cold weather)
- Rates should be very low – applied between 1-2ppm (1-2 kg/ ML applied water)
- Needs to be added slowly to the tank to avoid lumps forming in fertigation tank
- Product is incompatible with calcium, iron and potassium products
- Ideally applied post filtration as the viscosity of the solution can cause significant blockages when injected directly into a filtration system
- Very cheap

AG 30

- Premixed PAM solution - easy to use
- Does not require specialised mixing and dissolving facilities
- Compatible with a wide range of chemicals
- High applied rates will not cause problems other than to your wallet
- Very effective at rates of 10L/ha where flow rates are unknown

NOTE

- With all PAM products it is recommended that flushing is undertaken with the first PAM injection. This is to ensure that all loosened colloidal material can be flushed out of the lines

4.3.3. Plant Sap Analysis

Sap analysis data were collated through use of the Horiba Cardy Meters. These meters are used for taking readings of nitrate nitrogen, potassium and sodium. Petiole samples were taken from leaves opposite the flowering bunch for information on trends within treatments over the growing season.

Samples were taken from the same rows over the season to minimize potential site variances. Samples were also taken at the same time to reduce the potential for differences associated with dehydration of plant tissue.

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4.3.4. Case Studies: Practical Use of PAM in the Drip Irrigated Vineyards

4.3.4.1. Angove Family Winemakers, Anchorage Vineyard, Renmark, SA

Both ACA S1 & S2 are of the same clone of *cv.* Cabernet Sauvignon and were on similar soils.

The property was irrigated with 2.3L x 0.6m drippers. Extensive soil moisture monitoring via the Sentek Enviroscan Irrigation system was used to determine the irrigation schedule.

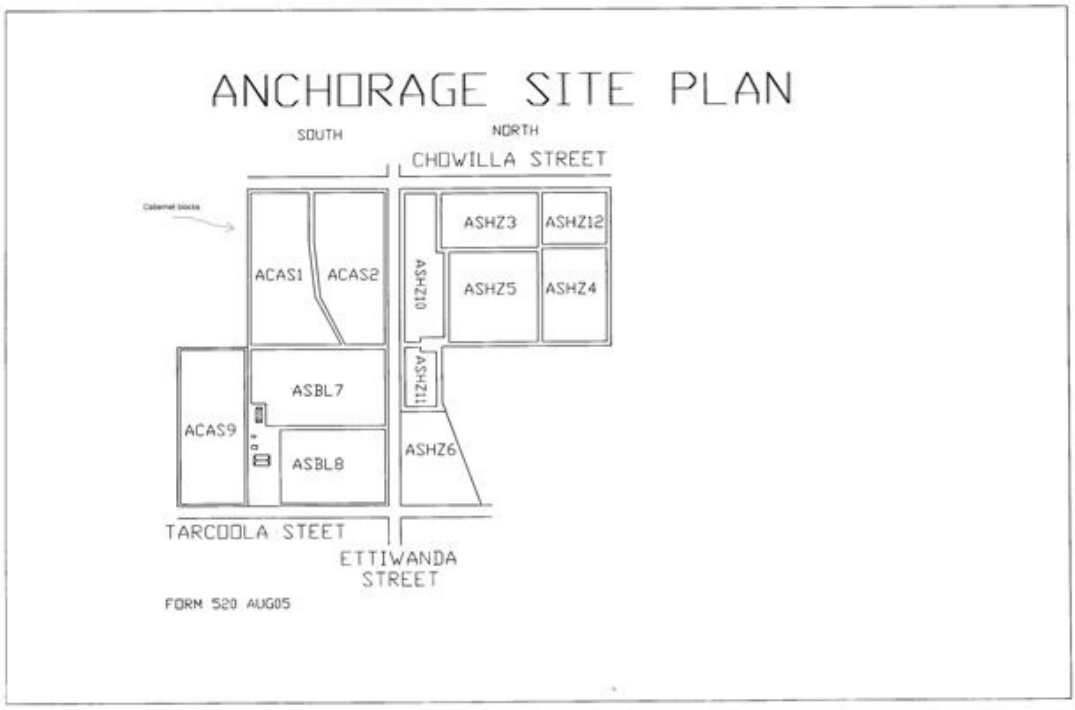


Figure 4:: **Site Map of Angove's Anchorage Vineyard, Renmark, South Australia.**

Block 1: ACA S1 = Untreated Control
Block 2: ACA S2 = Treatment applying AG 30
Block 3: ACA S9 = Treatment applying Aquapen™
- a PAM emulsion, for comparative purposes only

4.3.4.2. Century Orchards, Loxton, SA

Century Orchards is located in Loxton, South Australia and though devoted to the production of almonds, has some plantings of wine grapes (Chardonnay and some red varieties). For the trial, AG 60 (linear anionic PAM powder) was used.

In previous seasons, Century Orchards had difficulty in obtaining sufficient canopy to ensure fruit were adequately protected from sunburn and potential downgrading issues. As a result, the program implemented at Century Orchards was to grow as much canopy as possible to protect the fruit from over exposure in the January-February period. Part of the objectives from Century Orchards perspective was to see what impact that PAM (AG 60) would have on the vine for the same quantity of applied water in adjacent blocks on similar soil types.

The trial was undertaken on Chardonnay/Ramsey with 2.3L x 0.6m drippers.

4. Scientific Report

4.4. Results and Discussion

4.4.1. Angove's Anchorage Vineyard, Renmark, SA, 2008/09

4.4.1.1. Overview Comments

Angove's Anchorage Vineyard Cabernet Polymer trial season detailed data

block	ha	Tons	Tons/ha
Block 1 control	3.65	82.48	22.6
Block 2 trial	3.53	80.80	22.9
Block 9 competitor aquapen	3.60	106.16	30.04

CabSav Color scores 2009

GROWER NAME	B/P	PICK DATE	VARIETY	COLOUR SCORE	BAUME	DIFF. FROM AVE.
ANCHORAGE	ACAS9	25-Mar	CAB SAUV	1.01	13.3	-0.28
ANCHORAGE	ACAS2	25-Mar	CAB SAUV	1.25	14.0	-0.03
ANCHORAGE	ACAS1	25-Mar	CAB SAUV	1.08	13.3	-0.21

Winery received CabSav color score range 2009

AVERAGE	**1.29**
MAX	**2.00**
MIN	0.51

Water usage block specific 2008/2009

South	Month / KL														Vintage 2009				
Block	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	Total KL	Ha	ML / Ha	Total T	T/Ha	ML / T
ACAS 1			446.85	1638.90	2143.35	3126.60	7258.50	5341.50	2205.00	1305.00			23465.70	3.65	6.429	82.48	22.60	0.28
ACAS 2			548.94	1174.74	1621.20	2748.06	5754.00	4559.94	1638.00	1344.00			19388.88	3.53	5.493	80.80	22.89	0.24
ACAS 9			513.71	1351.25	1837.70	3102.00	6674.00	5170.00	1833.00	1504.00			21985.66	3.60	6.107	108.16	30.04	0.20

Nick Bakkum 7th May 2009 1
Angove Family Winemakers

Table 1: 2008/09 Yield and Water Use Data for Anchorage Vineyard

From the details in Table 1 and past records, the site has consistently yielded between 20-25t/ha. The difference in water use from the AG 30 and control treated blocks was approximately 1.0ML of water. This equated to 17% less water applied in the AG 30 treated section than the control. From the initial soil pits dug on site, the soil profile for both sections was very similar and little can be attributed to soil variance in this field study. ACAS9 was treated with an inverse emulsion PAM (Aquapen) for comparative purposes and while not included in the study, revealed that a very high yield (30t/ha) was obtained with only 6.1ML/ha applied irrigation water.

The colour score was significantly higher in the AG 30 treated section than the control with 1.25 to 1.01 colour score. With similar yields in terms of t/ha it raises some interesting questions about how the application and distribution of water in time and space influences the vines physiology, chemistry and structure. What was visually noticeable early during the growing season was that the untreated section had considerably more iron deficiency than the treated area. While iron deficiency is commonly associated with overly wet soils, it can also be found in soils that are excessively dry, where the availability of iron does not occur as a function of soil dryness. From water applications in the early part of the growing season (no significant difference), the variance in plant growth could reasonably be given to the movement of water within the soil profile.

It is widely regarded that increased fruit colour is attributed to lower crop yields and reduced irrigation practices. In this instance, the yields from both treated and untreated sections were similar but the AG 30 treated section was able to obtain similar yields with 17% less water over the control.

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4.4.1.2. Soil Moisture Monitoring

Sentek Environscans™ were installed in both sections to record soil moisture levels over the growing season. Irrigation was undertaken according to Enviroscan™ data.

The graphs shown below highlight the soil moisture monitoring for the 2008/09 irrigation season.

What is noticeable is that the AG 30 treated section has considerably higher soil water content readings in comparison to the untreated control in the summed histograph.

Soil Water Levels - Untreated Control, Cabernet Sauvignon ACA S1:

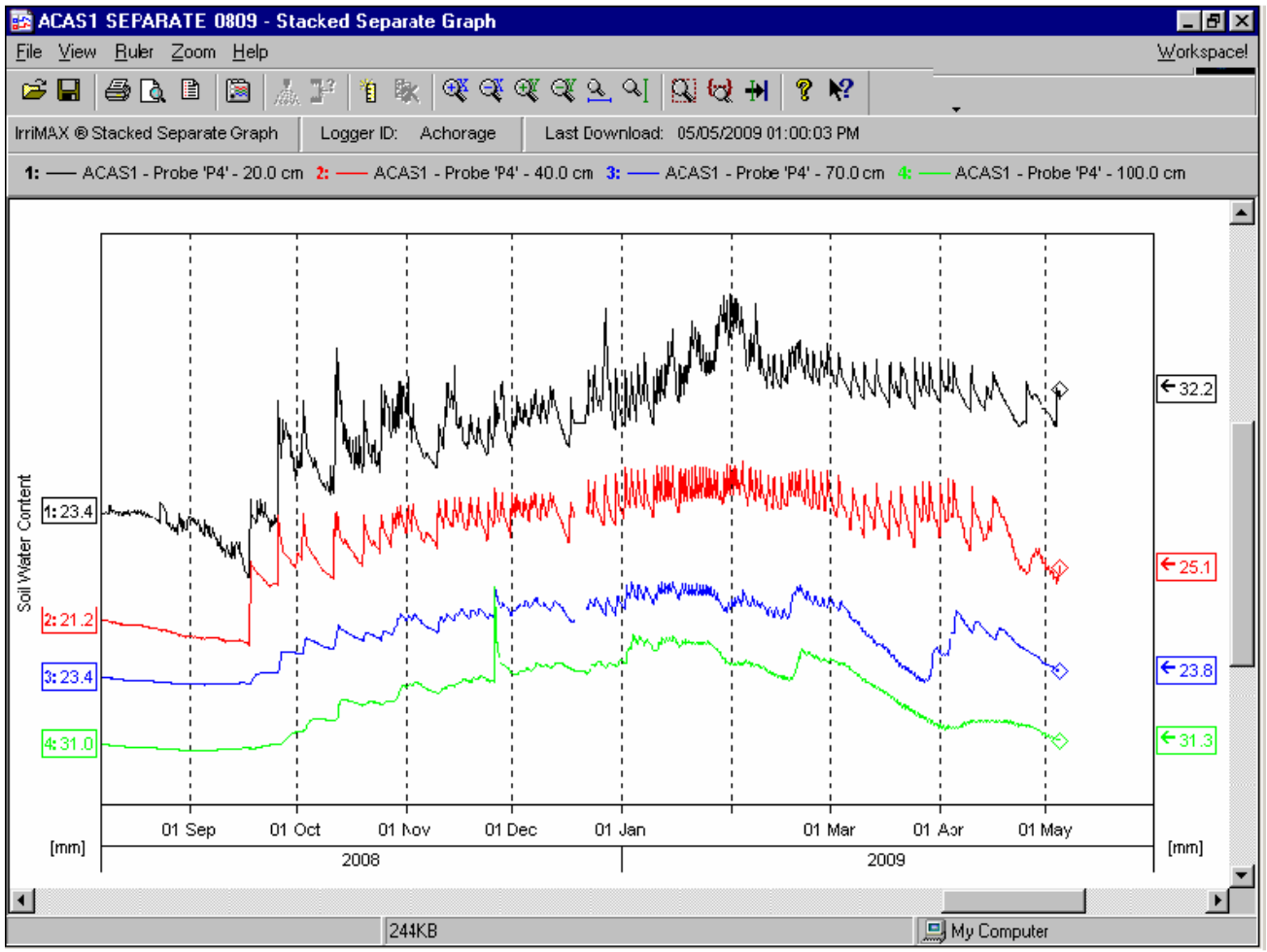


Figure 5: Separated soil moisture graph for Site 1, Untreated Control plot on Cabernet Sauvignon ACA S1 at Renmark, SA. 2008/09.

When looking at the separate graphs what becomes quickly apparent is that soil water content levels at depth (100cm) are significantly lower in the treated area than the untreated. This recorded observation supports the work done by Phillips (2007) in Gardner models that showed that PAM treated water moved more slowly to depth than water without PAM. More importantly, soil water content readings were higher in the rootzone where PAM was applied in comparison to where PAM was not applied. This would tend to suggest that even under drip irrigation, deep percolation losses of water are a concern when aiming to maximise water use efficiency.

Soil moisture monitoring also shows considerable more movement in soil moisture levels at both the 70 and 100cm sensors in the untreated area. This again confirms deep percolation movement of water even under drippers in the Renmark clay soils.

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What the data shows is that the summed histograph may give a misleading picture of soil moisture monitoring as in many cases soil water levels recorded at the 70 and 100cm depths contain few active roots and contribute to only a small portion of total plant water use. In many cases, water at these depths could be regarded as an inefficient placement of water.

Soil Water Levels - Treatment with AG 30, Cabernet Sauvignon ACA S2:

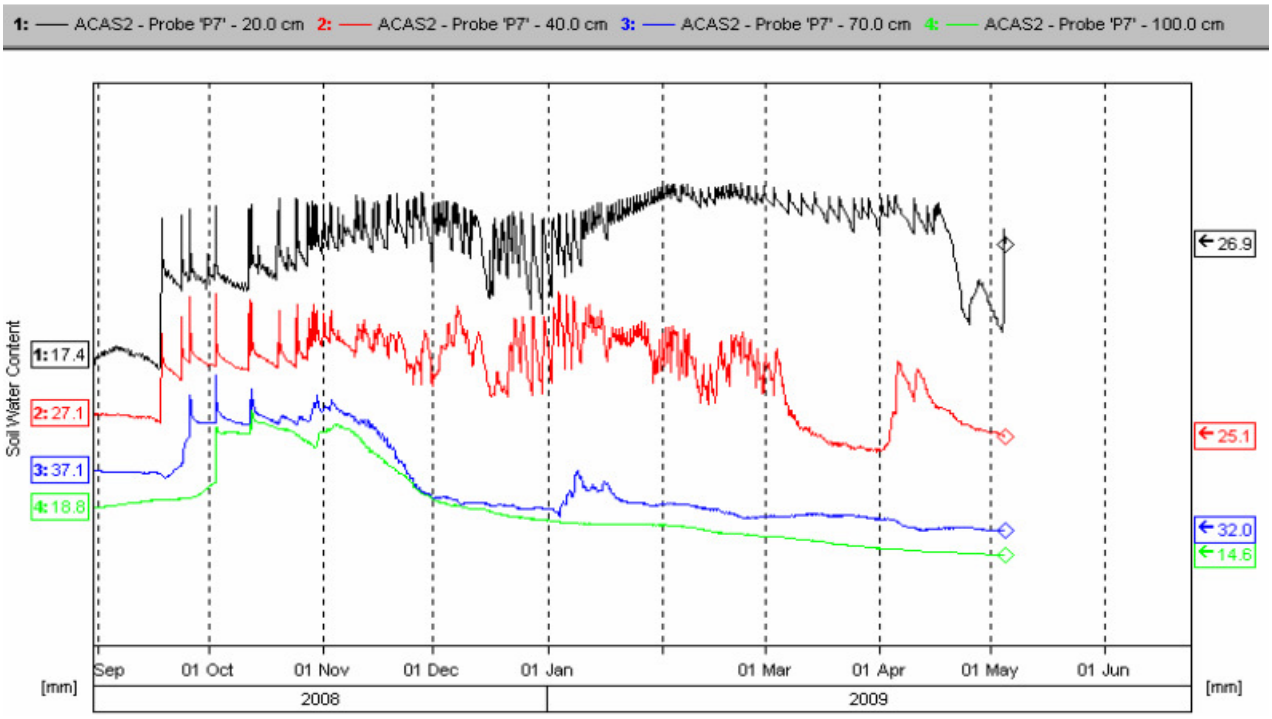


Figure 6: Separated soil moisture graph for Site 1, PAM AG 30 Treated plot on Cabernet Sauvignon ACA S2 at Renmark, SA. 2008/09.

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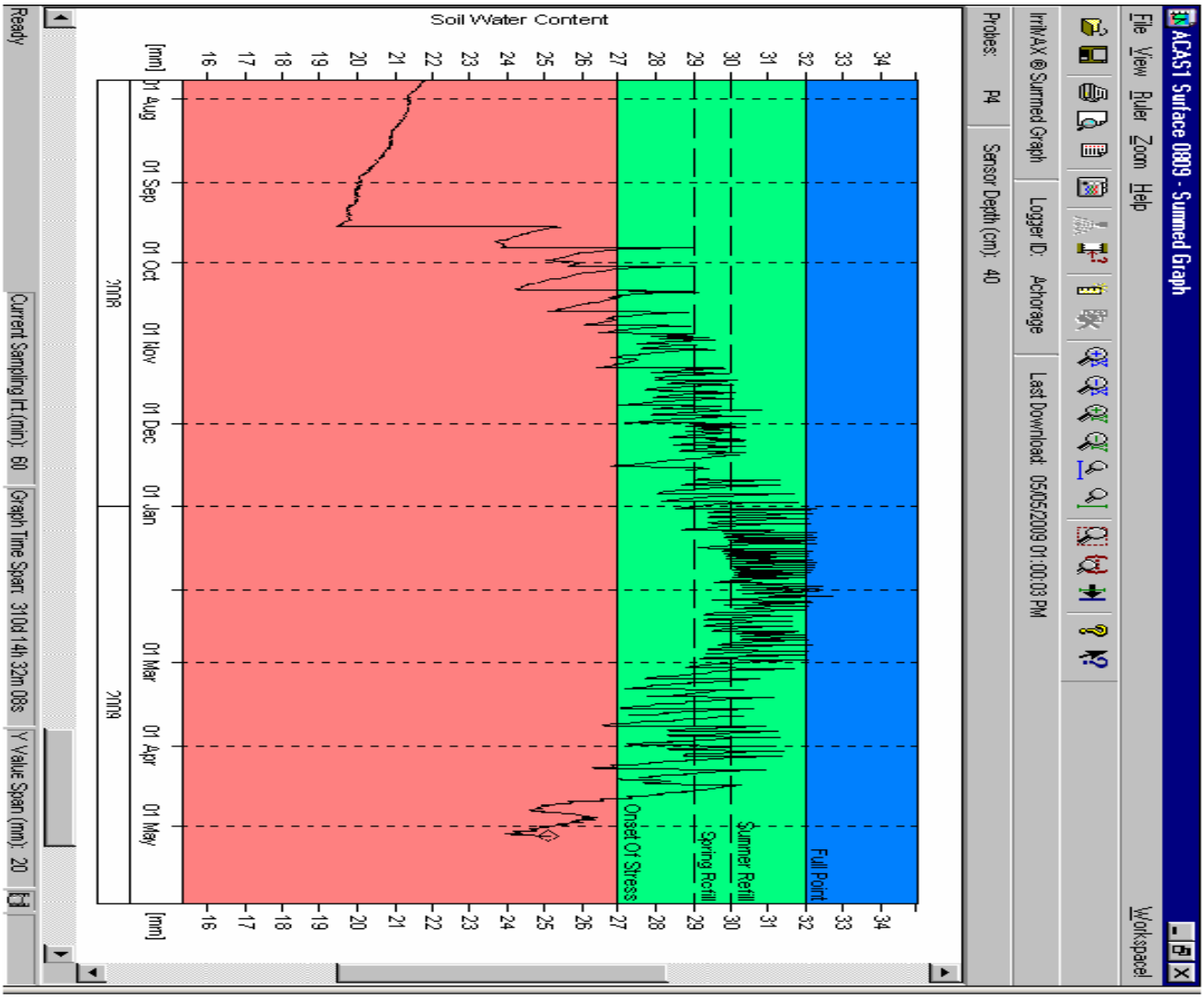


Figure 7: Summed soil moisture graph for Site 1, Untreated Control plot on Cabernet Sauvignon ACA S1, Renmark, SA. 2008/09.

4. Scientific Report

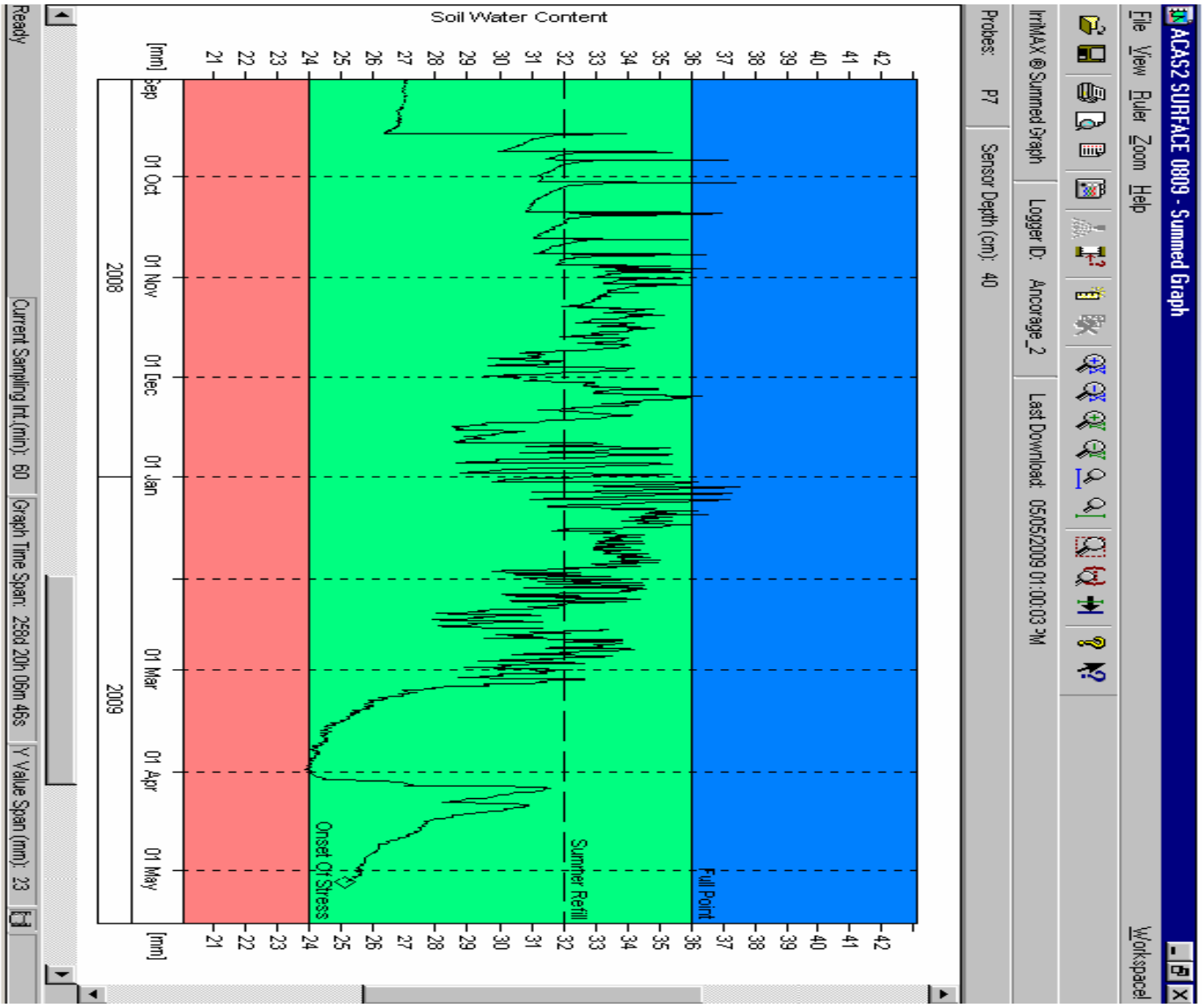


Figure 8: Summed soil moisture graph for Site 1, PAM AG 30 Treated plot on Cabernet Sauvignon ACA S2 at Renmark, SA. 2008/09.

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4.4.1.3. Plant physiology over the growing season

The influence of different spatial positioning of water within the root-zone showed a possible effect on early shoot development and bunch elongation.



Figure 9: AG 30 treated vines of Cabernet Sauvignon at flowering, Site 1, Renmark, SA, 2008/09.



Figure 10: Untreated control vines of Cabernet Sauvignon at flowering, Site 1, Renmark, SA, 2008/09.

The influence of the AG 30 PAM formulation could be seen in initial shoot and bunch development at this site. The AG 30 treated section had better initial canopy growth and greater bunch elongation.

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Figure 11: Untreated Control Plot, Site 1, Angove's Vineyards, Renmark, SA, November 2008/09.



Figure 12: PAM AG 30 Treated Plot, Site 1, Angove's Vineyards, Renmark, SA, November 2008/09.

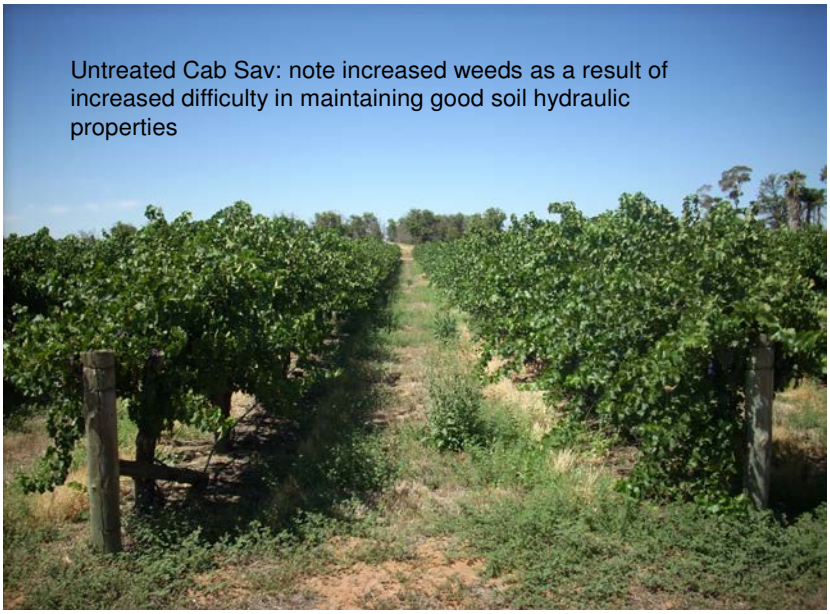
4. Scientific Report



Figure 13: Comparison of Cabernet Sauvignon bunches between PAM AG 30 treated (left) and Untreated Control plots (right), Site 1, Angove's Vineyards, Renmark, SA, January 2009.

Overall the AG 30 treated vines had larger bunches than the untreated section. The influence of this was not, however, seen in yield at harvest.

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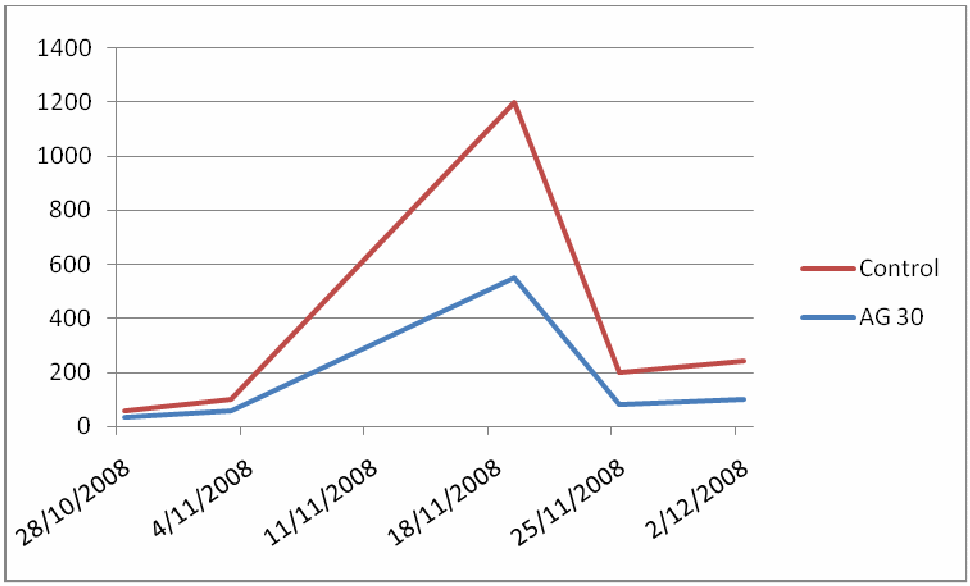


Figures 14 and 15: Weed composition in PAM treated and Untreated Control plots at Site 1, Angove's Vineyard, Renmark, SA. 2008/09. Note the difference in growth of summer weeds in the untreated area.

4. Scientific Report

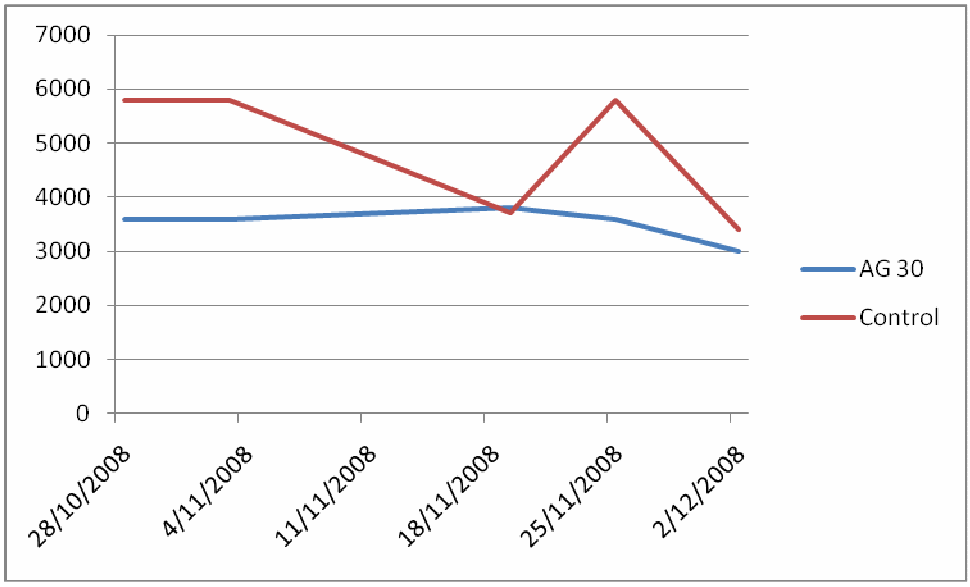
4.4.1.4. Sap Analysis - Angove's Anchorage Vineyard

4.4.1.4.1. Sap Nitrate Levels ppm



Similar trends in sap nitrate levels can be seen between the treated and untreated areas. The post flowering spike in nitrogen levels was significantly lower in the PAM treatment than in the control section. Visual assessment of plant growth at this time, however, showed greater growth and bunch elongation in the treated over the untreated samples.

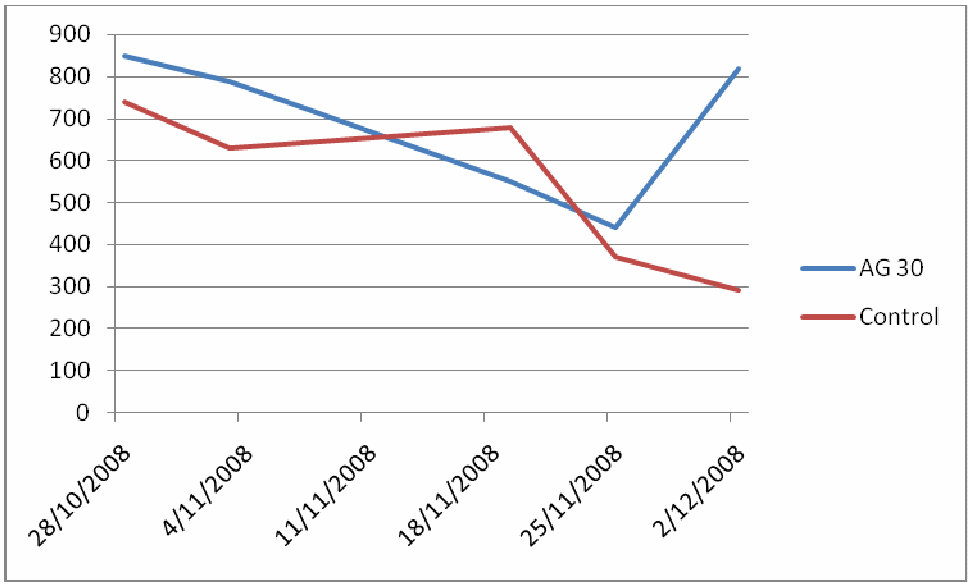
4.4.1.4.2. Sap Potassium Levels ppm



Sap potassium levels were significantly higher than those at Century Orchards. While some varietal considerations can be drawn, the soil type variance is the major reason for the high potassium levels seen in these samples. The Renmark clay flats are very high potassium soils (>450mg/kg Colwel K) whereas the sand dunes at Century Orchards are quite low (<200mg/kg). The varietal significance is that Chardonnay has significantly earlier shoot growth than Cabernet Sauvignon and in cooler soils, the availability of soil potassium is less, due to cooler weather and in many cases lower applied water volumes (to aid the solubility of potassium). In some of the cooler growing regions early season potassium deficiencies are often seen as a result of the plant out growing the roots ability to supply these nutrients due to short term unavailability of soil

potassium. In most years once the weather warms up and solubility of potassium in the soil increases the deficiency symptom dissapears.

4.4.1.4.3. Sap Sodium Levels



Higher salinity levels are seen in this sample in comparison to that at Century Orchards. This is a reflection of the reduced irrigation practices and the use of RDI practices to increase fruit colour in this variety. One of the consequences of reduced irrigation and some drying out of the vine is that the sap sodium levels tend to increase.

The management of plant nutrition is closely linked to irrigation practices, soil type, varieties and winery requirements. As such sap analysis results can be looked as trends for each site and not necessary valid for comparisons between soil types and varieties. With differing irrigation practices, wide variances between sites are expected and the performance of rootstocks has a major influence on the recorded levels of nitrate nitrogen, potassium and sodium.

The results here highlight how the different treatments were managed from an irrigation perspective. The control received more water late in the season, in an effort to maintain the vines. The increase in applied water at this time appears to have an affect in diluting the salts and increasing leaching efficiency.

The message from this is clear: vineyards were there is a reduced amount of applied water, in combination with low rainfalls, will need to have the impacts of salinity managed very carefully.

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4.4.2. Century Orchards, Loxton, SA

4.4.2.1 Overview Comments

2009 Harvest Information

Treatment	Be	pH	Ta	Yield t/ha
PAM AG 60	12.21	3.47	7.43	26.17
Untreated Control	12.18	3.55	7.56	24.59

Monthly Water Use Figures, Century Orchards, Loxton, SA, 2008/09

Season 2008/09	Water Use (mm/ha)
September	21.1
October	39.7
November	75.5
December	96.0
January	141.4
February	108.6
March	36.5
April	5.1

Total Irrigation Applied = 5.24ML/ha

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Figure 15: Untreated Control (top) and PAM AG 60 treated Chardonnay vines (below) at Century Orchards, Loxton, SA, December 2008.

Note the greater canopy growth in the vines treated with AG 60. The treated section had greater cane growth at the end of the cordons. Heavy topping removed most of this growth. It would have been preferable to control this vegetative growth through irrigation management rather than heavy topping late in the season.

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Figure 16: Untreated Control Chardonnay vines, Century Orchards, January 2009. Note lack of canopy at the end of the cordons.

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4.4.2.2. Soil Moisture Monitoring – Century Orchards, Loxton

The results of the soil moisture monitoring are seen in the figures below.

Block 18 Chardonnay on shallow soil type – Untreated Control

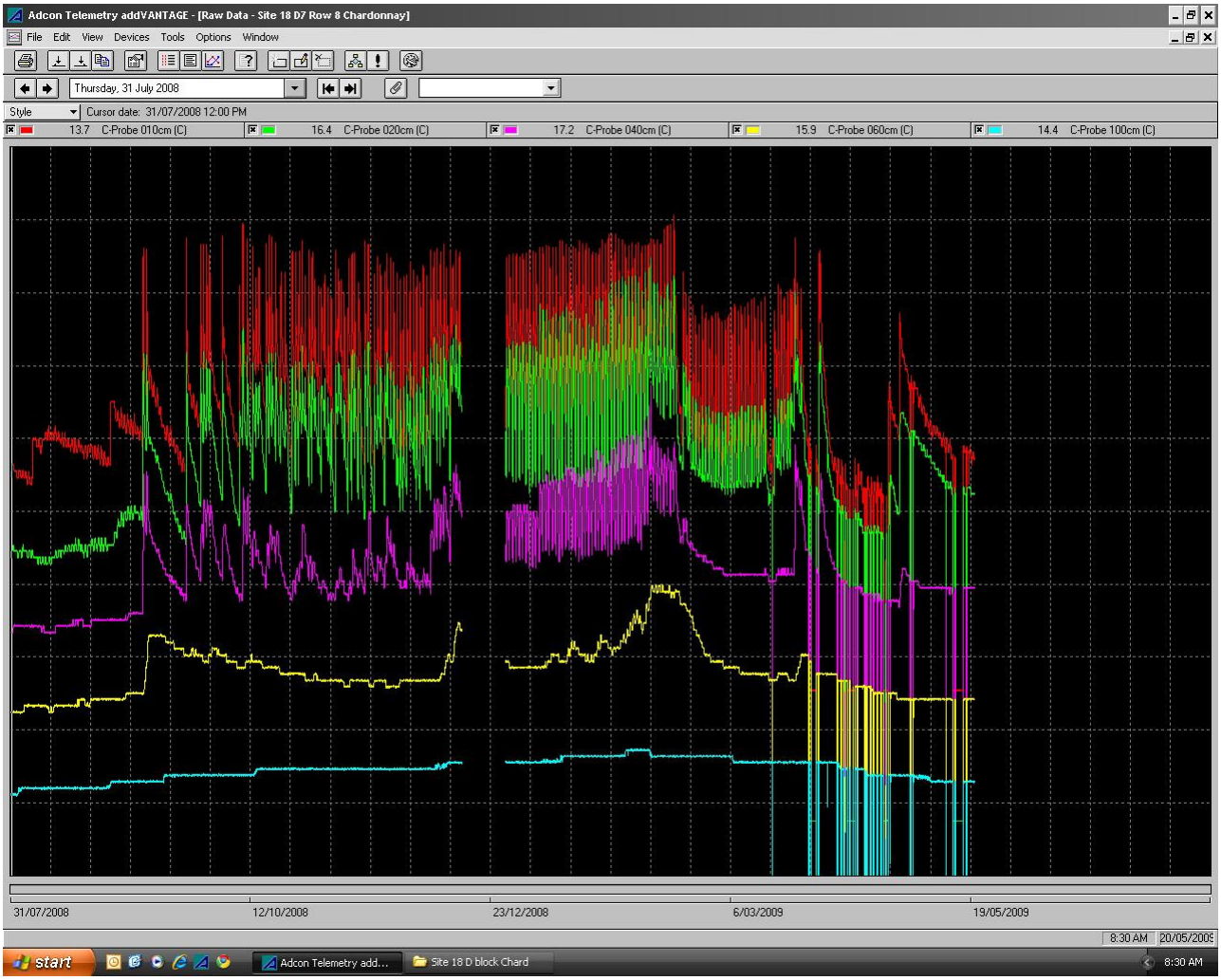


Figure 17: Season soil water analysis in the Untreated Control plot, Century Orchards, Loxton, SA. 2008/09.

The 100cm sensor is located in limestone rubble, and that, being so porous did not easily register spikes in soil water content as it is naturally even under irrigation and water retention is low.

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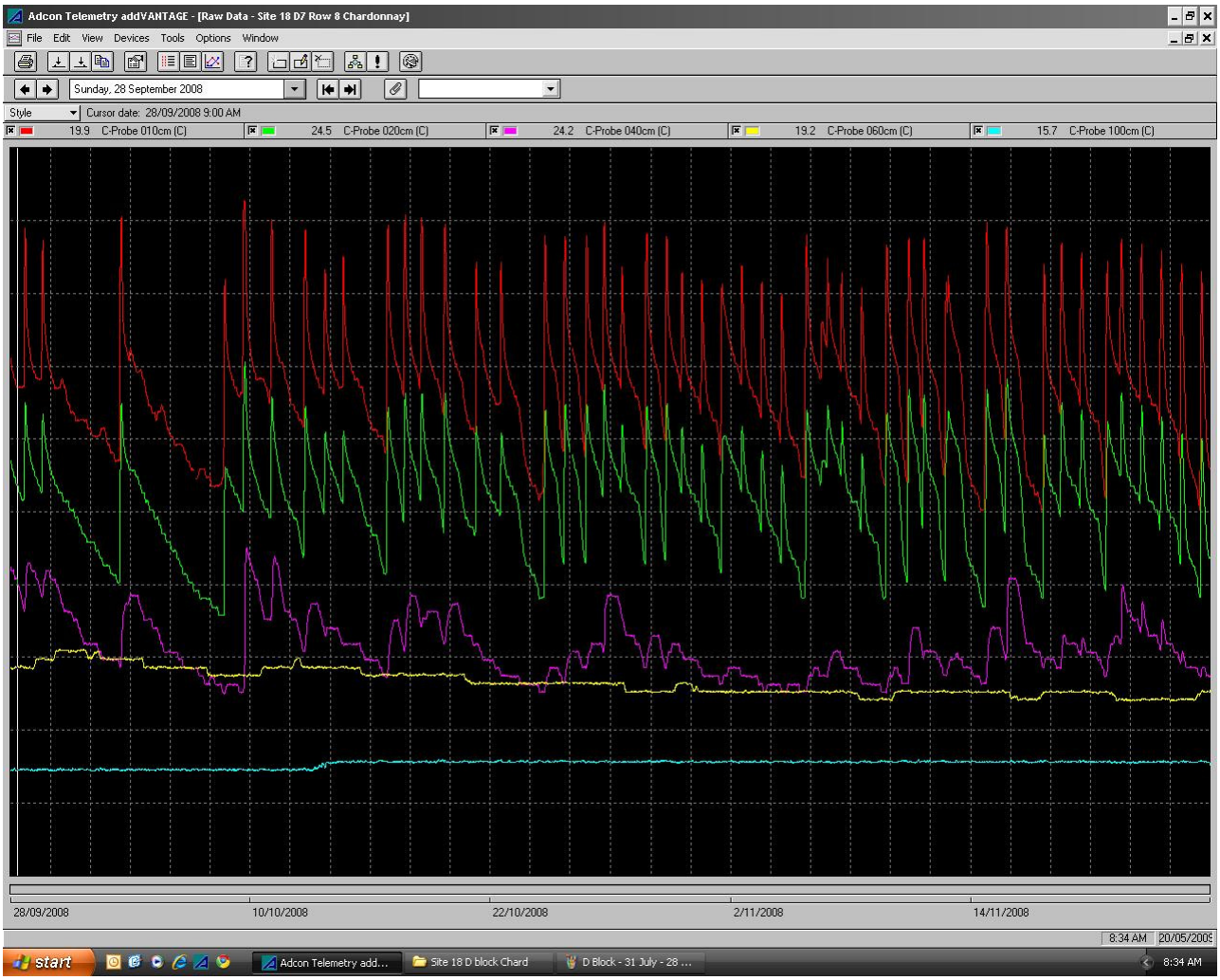


Figure 18: 90 days (separate graph from 28/9/08) Soil water analysis in the Untreated Control plot, Century Orchards, Loxton, SA. 2008/09.

The 90 day graph showed the typical spikes associated with drip irrigations systems. During the early part of the season, the irrigation events and frequency were lower and the loss of water to deep percolation was generally lessened as applied water was appropriately match to crop water demands.

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Block 19 Chardonnay: Treated Plot PAM AG 60

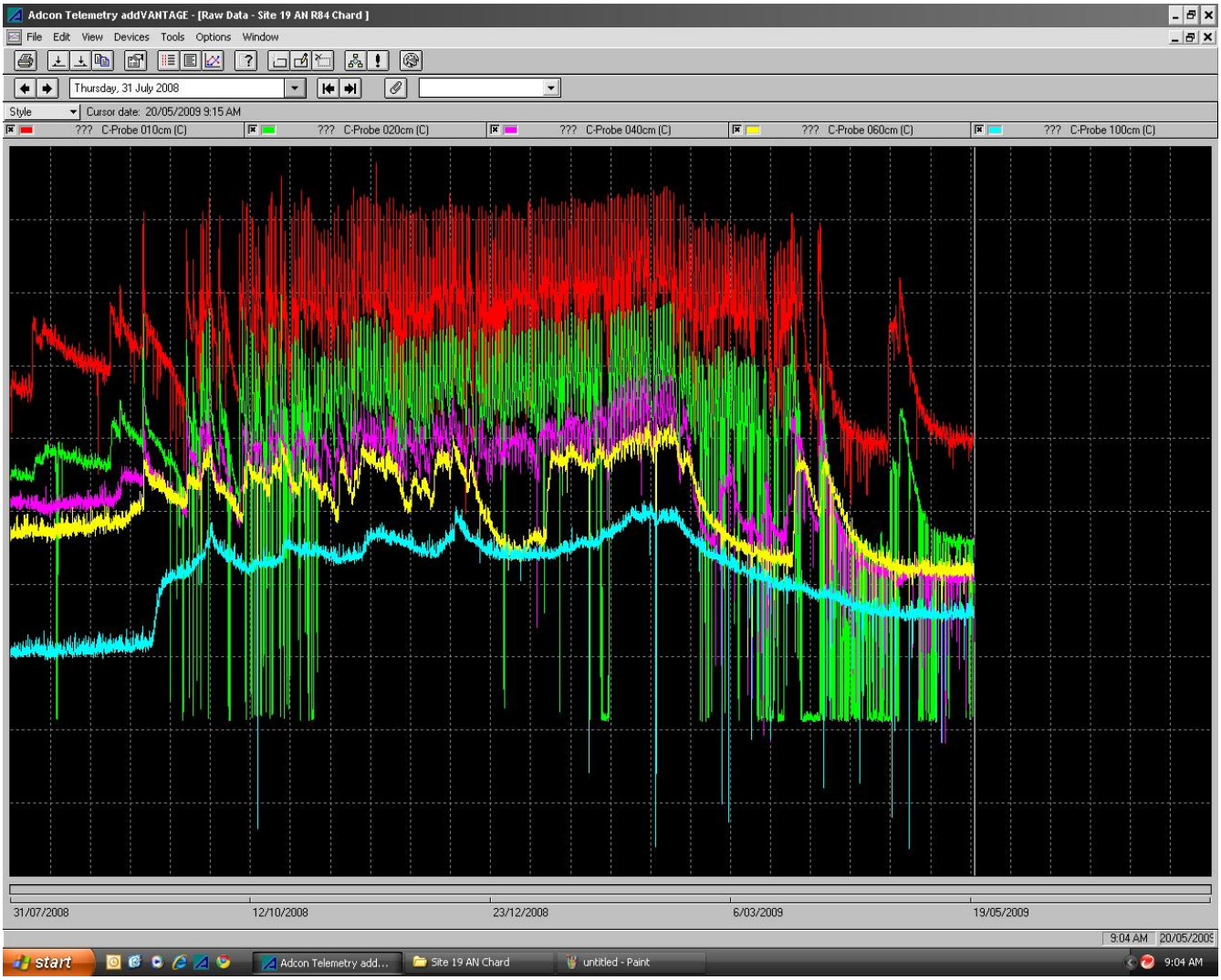


Figure 19: Separate histograph water analysis in the PAM AG 60 Treated plot, Century Orchards, Loxton, SA. 2008/09.

The decline is soil water content at the end of the season was in line with the irrigation regime and water restrictions that resulted in reduced irrigation once the crop was harvested. Being on Ramsey root stock resulted in the vines being able to extract water over a larger volume of soil in these light sandy conditions.

Soil water content over the season showed the trends for the deep light textured sands where soil deep percolation losses, even under drip (and the creation of preferential flow pathways), occur. The nature of the soils in this site was that the RAW content exceeded 90mm and in many parts of the system it was in excess of 150mm. One of the issues with drip irrigation was that the clay content of the soils was so low that the lateral spread of moisture was very low and deep percolation losses were quite high. A consequence of irrigating in these soil types is that leaching losses of nutrients can be quite high.

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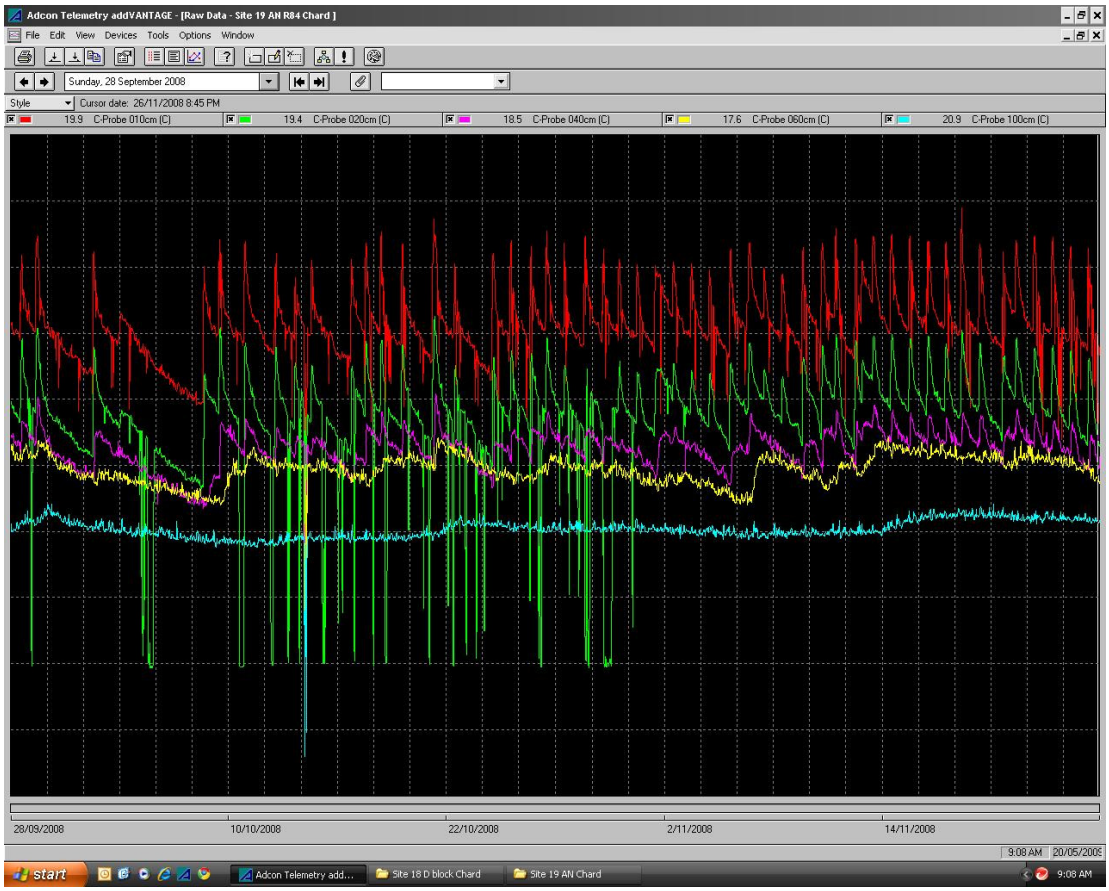
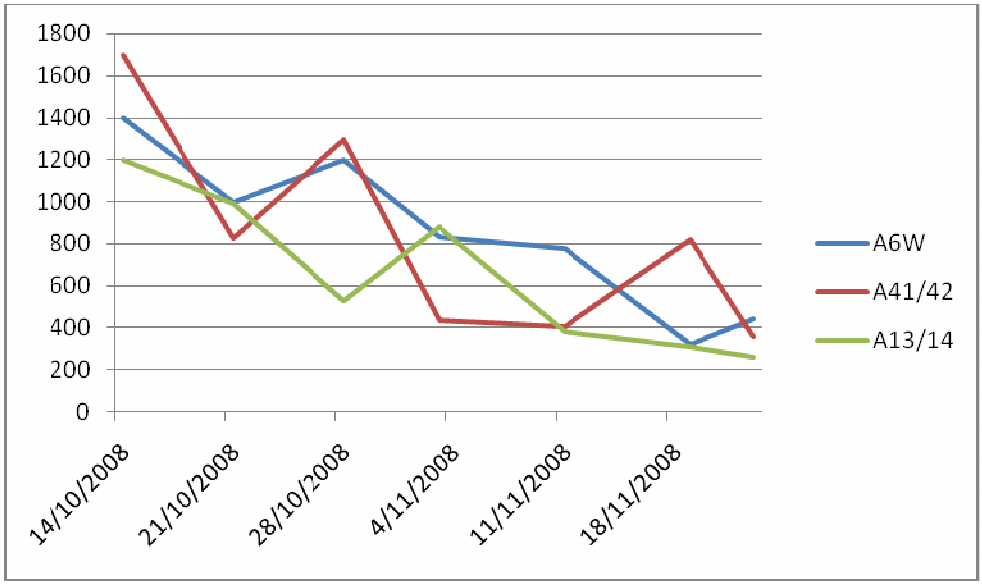


Figure 20: 90 day Separate histograph water analysis in the PAM AG 60 Treated plot, Century Orchards, Loxton, SA. 2008/09.

4.4.2.3. Plant Sap Analysis

4.4.2.3.1. Sap Nitrate Levels



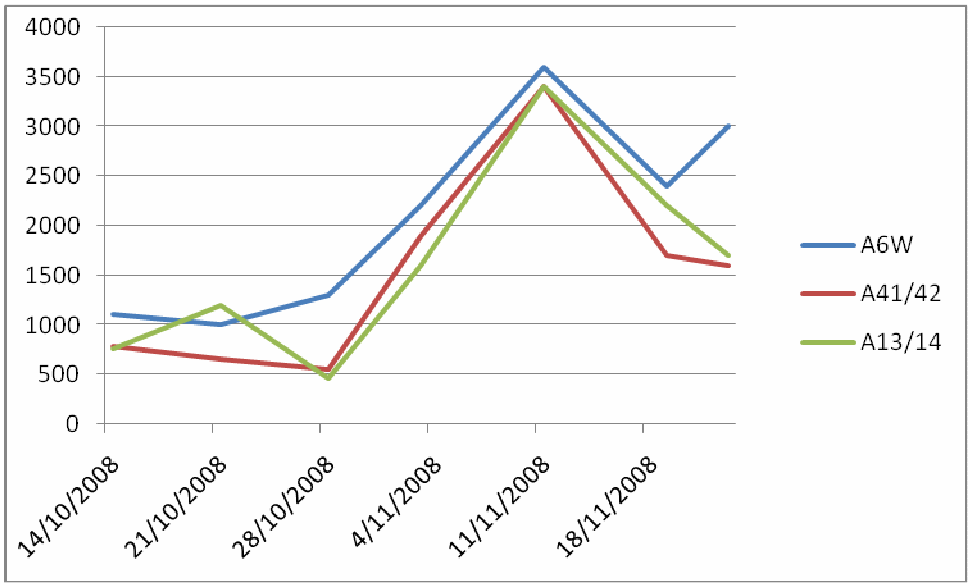
Samples were taken from two PAM treated sites (top of the sand dune and flat). This accounted for two soil types within the valve. The control sample (13/14) was directly opposite PAM (43/42)

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on similar light textured sandy soils. A6W was also in the treated area but on a heavier soil type that A41/42 and A13/14.

Nitrate Nitrogen levels declined over the season. This was in line with normal nitrate nitrogen levels within the plant. Significant declines in sap nitrate levels were seen during the bunch hook and flowering stage with some recovery post fruit set but under normal management conditions a general decline is seen over the rest of the season from the initial peaks during early shoot development. Overall similar trends in petiole nitrate nitrogen levels were seen over the growing season. In general, the PAM treated section of the property had greater vigour and slightly higher sap nitrate levels indicating a greater efficiency of use in line with altered soil hydraulic water movement (less deep percolation water movement and subsequent different placement of applied nutrients within the soil profile).

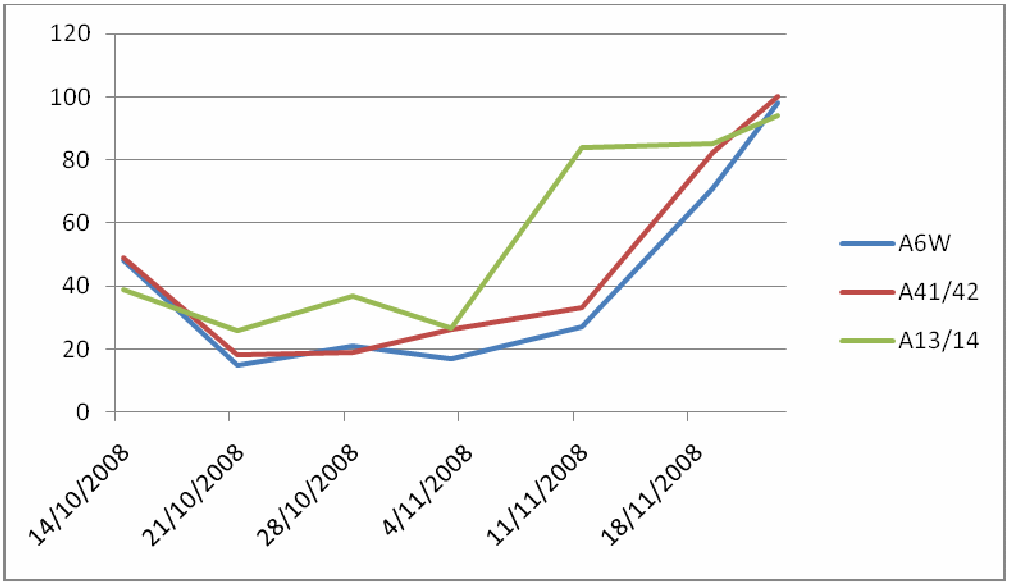
4.4.2.3.2. Sap Potassium Levels



Slightly higher potassium levels occurred in the A6W sample. This was not surprising as this location is on soils with higher clay content and available soil potassium levels than the other sampling sites. However, the trends between samples were not significantly different and the end of sampling levels were more indicative of the impact that potassium demands have on the vine as bunch development occurs. The trial site in the past had been seen to have drying of the bunch on the lighter soil types consistent with low potassium levels at the bunch developing stages. In soils with fluctuating soil moisture levels and poor wetting patterns, soil potassium levels can become unavailable and deficiencies as a function of soil hydraulic conditions can occur. Under very saline conditions and poor irrigation practices, sap sodium levels have been seen to be as high as 700ppm sodium. At these levels salinity in juice can be tasted. The levels in these samples were well below levels where salinity damage can be noticed

4.4.2.3.3. Sap Sodium Levels

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Sap sodium levels tended to rise over the season and data seen in this sampling was consistent with trends seen in many other crops around the district. The salinity spikes in the control areas were sharper than the treated vines. From historical monitoring using this equipment, salinity spikes are often associated with drying soils and plant dehydration. As the plant is rehydrated, sap sodium levels decline.

4.5. Summary

This extension project has been able to confirm some of the conclusions from published research.

The outcomes from this trial indicate that:

- The use of PAM (in either liquid or solid formulations) can help increase crop water use efficiency and decrease overall water requirements. In the case of the Angove case study water reductions of 17% were achieved without any loss of yield,
- At Century Orchards, canopy development was greater in the PAM treated area than the control per same ML of applied water,
- Fruit colour in the Angove Cabernet sample was greater in the PAM treated area than the adjacent control section. This was achieved without any yield loss
- The use of PAM at bunch elongation could be seen to result in an increase in bunch length. This may have implications on improved control of pest and diseases where greater bunch elongation exists.
- The use of PAM could be seen to result in lower soil water content readings at depth at the Angove's site. This indicates that even on clay soil types that deep percolation losses of water under drip irrigation need to be considered and that PAM (as AG30) helps facilitate better lateral spread of water even in clay soils.
- Initial indications from both sites are that the use of PAM leads to an increased effectiveness of applied nitrogenous fertilizers.
- From an economic perspective even the most expensive PAM formulation (designed for ease of handling – AG 30) is no more than 33% of the cost of water saved (at $300/ML).

From a PAM management viewpoint the following comments are worth considering:

- Pre-made PAM solutions such as AG30 are cost effective when compared to the current price of water. The site management considerations and existing infrastructure in handling emulsions, solutions or PAM powders becomes the issue in determining which product is most suitable at an individual site.

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- PAM powders (anionic linear polyacrylamides) require large water volumes for dissolving in tanks (<1kg/1000L) and good agitation. Flushing and line cleaning as well as an understanding of managing colloidal clay content in drip lines need to be considered
- PAM will flocculate clays out of drip lines and as such some attention to clean and flush lines to remove this material must be considered when using PAM.
- PAM offers a low cost alternative to cleaning drip lines of build-up of colloidal material.

The field trial at both Century Orchards and Angove's revealed that PAM could play an important role in improving irrigation efficiency at a field level. The ability of PAM to remove colloidal material in the drip line even in systems with high levels of hygiene maintenance was an indication that current management practices may not be overly effective in removing this material from within the irrigation system. The impact of PAM on bunch elongation and increased fruit colour also raises other issues with regards to vineyard management and fruit composition that was outside the scope of this study. This may offer further research opportunities for PAM in viticulture at some stage in the future.

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Site and Field Visits

- Riverland Viticultural Technical Group - November 2008
- Loxton Ag Bureau - November 2008
- Fosters Grower Liaison Officers - November 2008
- Grow Smart Science Group - December 2008
- Doug Samuels, Clean Water, California USA - February 2009
- Queensland PAM network - March 2009
- Grow Smart Science Group - May 2009

4.6. Acknowledgement

The continual help from both Century Orchards and Angove's Pty Ltd in terms of data collection and liaison with site visits was greatly appreciated. Without the support from GWRDC the opportunity to undertake these field studies into the practical use of PAM in drip irrigated wine grape properties would have been unable to occur.

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