Rootzone Salinity Management of Premium Wine Grapes Irrigated With Poor Quality Water

TK Biswas[1*], M Cutting[2], T Pitt[1], P Zurcher[3], T Hoare[4] and G Schrale[1]

[1]Water Resources & Irrigated Crops, SARDI Sustainable Systems, GPO Box 397, Adelaide, SA 5001
biswas.tapas@saugov.sa.gov.au Ph: 08-83039400 Fax: 08-83039424 ([*]corresponding author)
[2]SA Murray-Darling Basin NRM Board, Mannum Road, P.O Box 2343, Murray Bridge S.A 5253
[3]School of Natural & Built Environments, University of South Australia, Mawson Lakes SA 5095
[4]Tony Hoare Viticulturists, PO Box 1106, McLaren Flat SA 5171

Abstract

Increasing salinity of irrigation water is one of the biggest threats facing wine grape production in the Lower Murray region of South Australia. The Currency Creek/Finniss wine region relies heavily on sourcing irrigation water from the predominantly winter rainfall charged streams of the Eastern Mt Lofty Ranges. During the peak growing season flow from the Finniss river effectively ceases resulting in very high water salinities (average 3.4-6.0 dS/m from Nov'06 to Mar'07). The problem has been exacerbated by successive drought seasons of reduced water availability and continued drive for improved irrigation efficiency resulting in negligible to no water being applied for leaching salt from the root zone. A by-product of high irrigation efficiency is the excessive salt accumulation in the root zone, via evaporation and plant transpiration.Many vignerons have reported an increase of sodium and chloride in their plant tissue analyses. Consequently, managing root zone salinity is becoming critical for sustaining wine grape production in this part of SA.

To assess the method of leaching accumulated root zone salts post vintage with particular emphasis on using natural rainfall events, a field experiment was set up on a 5 year old Cabernet Sauvignon vineyard (*Vitis vinfera*) irrigated with Finniss water. This paper reports the use of a real-time rootzone salinity monitoring tool 'SoluSAMPLER™', for checking the salt build up and its movement within the root zone. Management option for minimizing root zone salinity by using winter rainfall and its relationship to critical salinity tolerance levels for wine grapes has been discussed.

Introduction

Irrigation water usually contains dissolved salts, whether from surface supplies or groundwater. Improvements in water use efficiency (WUE), through the adoption of precision irrigation practices, have led to significant water savings in the semi-arid region of the Lower Murray River. Many irrigators apply water to meet crop needs only, and achieve high levels of water efficiency. In taking up this water plants exclude much of the salt, which then slowly builds up in the root-zone if leaching is inadequate. Current drought conditions have augmented the accumulation of salt in the soil due to low rainfall (natural leaching), low allocation and high crop demand. For sustainability of irrigation, leaching rates must be high enough to prevent crop losses due to a build up of salt within the plant's active root zone. Thus, for irrigation sustainability to be achieved we need to strike a balance between high WUE and preventing salt building up to deleterious levels in the crop root-zone.

At high levels, root-zone salinity can be toxic to plants and visual plant symptoms occur, such as burning at the edge of leaf margins (Shani and Ben Gal 2005). Grape-vine root-zone salinity has the potential to affect productivity and juice quality. The critical productivity threshold salinity for own rooted vines, as measured by the electrical conductivity (EC) of soil saturated paste extract (ECe) is 1.8 dS/m (Zhang *et al.* 2002). A recent economic analysis by (Biswas *et al.* 2007c) estimated rootzone salinity damage for lower Murray horticulture at $117 million annually when and if river salinity rises to 1000 EC units (=1dS/m) at Morgan.

Stirzaker (2006) reported that most irrigation communities are ill-equipped to cope with issues such as water scarcity and declining water quality. He stressed that irrigators may have mastered agronomy, marketing, disease and pest management, yet few grasp the essentials of soil-water interactions. Hence, there is an urgent need for precision irrigators to monitor the real time accumulation of salts in the rootzone in order to develop strategy to minimise its risk. Recognising this need, SARDI (Biswas 2006; Biswas and Schrale 2008) has developed a soil-water extractor called the 'SoluSAMPLER™'. When permanently installed, the SoluSAMPLER extracts soil-water samples from the root-zone which can then be analysed for salt content and expressed as soil water EC (ECsw). (Biswas *et al.* 2007b; Biswas *et al.* 2007a) found out that ECsw is twice the ECe in a range of sandy loam to silty clay loam field soils of the Riverland, SA.

While monitoring root zone salt build up is the key, leaching is the only means to get rid of salt from the rootzone. Although there is much information on leaching and drainage there is little information available on using winter rainfall under precision irrigation to leach salts from the soil. This paper discusses the dynamics of salt accumulation and its leaching with winter rainfall rather than post vintage leaching irrigation in order to achieve maximum salt leaching with minimum water.

Materials & Methods

A field experiment was conducted at a vineyard in Currency Creek, South Australia (35°26′S, 138°46′E) from November 06 through to January 08. This vineyard had 5 year old own rooted vines (*Vitis vinfera* cv. Cabernet Sauvignon), planted at 3m (row) x 1.5m (plant) spacing, producing approximately 4t/ha berry yield during 2006/07 vintage. The soil was a sandy clay loam over yellowish friable clay with occasional carbonate deposits. Irrigation system was a conventional drip system [Netafim 'Dripmaster 17'] with 0.5 m emitter spacing and 1.6 L/hr flow rate. During 2006/07 vintage, the property received 345 mm rainfall and 184 mm irrigation water sourced from the Finniss River. Irrigation water samples were collected from flowing river water next to the pump inlet and tested for EC. Using a SAMDBNRM Board automatic weather station the potential evapotranspiration (ETo) of 1286 mm, a measure for crop water demand, was calculated by using FAO 56 method (Allen 2000).

The movement and accumulation of salt through the soil profile were measured using a series of SoluSAMPLER™ soil pore water sampling devices. Three replicates of SoluSAMPLER™ were installed in the rootzone at multiple depths, 30, 60 and 90 cm, within 15cm of a dripper. Soil water samples were collected weekly to fortnightly and measured for salinity by using a Eutech®510 conductivity meter.

The transfer of salt from the soil to the plant was monitored by analysing sodium and chloride levels in leaf petiole and berry samples. Petiole was sampled at flowering [Nov] and harvest [March], whereas berry was sampled at harvest.

Results & Discussion

Changes of irrigation water salinities

The average monthly Finnis river water salinities during the experiment (Table 1) varied from 1.1 to 6.0 dS/m. River water EC was at its lowest during the winter months compared to the peak irrigation summer season. Low EC during winter months was due to high flows attributed by rainfall events. During summer months low river flow combined with groundwater inflows and high evaporation contributed to high salinity readings. Between Nov 06 and March 07 about 150 mm irrigation water was applied, which if on an average reads 4.6 dS/m EC will bring with it about 4.5 tonnes of salt to a hectare. Given that the water is applied via a drip system, most of these salts will accumulate in and around the partially wetted rootzone.

Table 1: Average monthly salinity levels of Finniss River (Oct 2006 - Dec 2007)

Year	2006			2007											
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Irrigation EC (dS/m)	3.3	3.4	3.8	4.8	5.2	6.0	5.8	5.5	1.5	1.1	2.1	3.9	4.9	5.2	4.3

Effects of irrigation, rainfall and evapotranspiration on root-zone salt accumulation and distribution

A comprehensive account of irrigation volumes (mm) applied, daily potential evapotranspiration (ETo), rainfall (mm) and corresponding temporal changes of soil water salinities at 3 different soil depths (30, 60 and 90 cm) within the rootzone are presented in Fig. 8. The theoretical production threshold soil water EC for own rooted vines was taken as 3.6 dS/m (Biswas et al., 2007b) and is presented by a red dashed line. It is imperative to say that the success of collecting soil water samples using the SoluSAMPLER depends on adequate moisture in the soil profile.

During the peak summer months (Nov-Mar) daily ETo varied between 1.6 to 8.6 mm while the average daily irrigation was only 1.1 mm (5.5 mm every five days). It is likely that most of the irrigation applied during this period would have been used by the plant or lost in meeting soil evaporative demands. Under this negligible to no leaching situation, salts imported with the irrigation water (as high as 6 dS/m through summer) were expected to accumulate in the soil profile. Movement of salts out of the root zone did not occur until the profile was saturated with winter rainfall and water started to move down carrying salts with it.

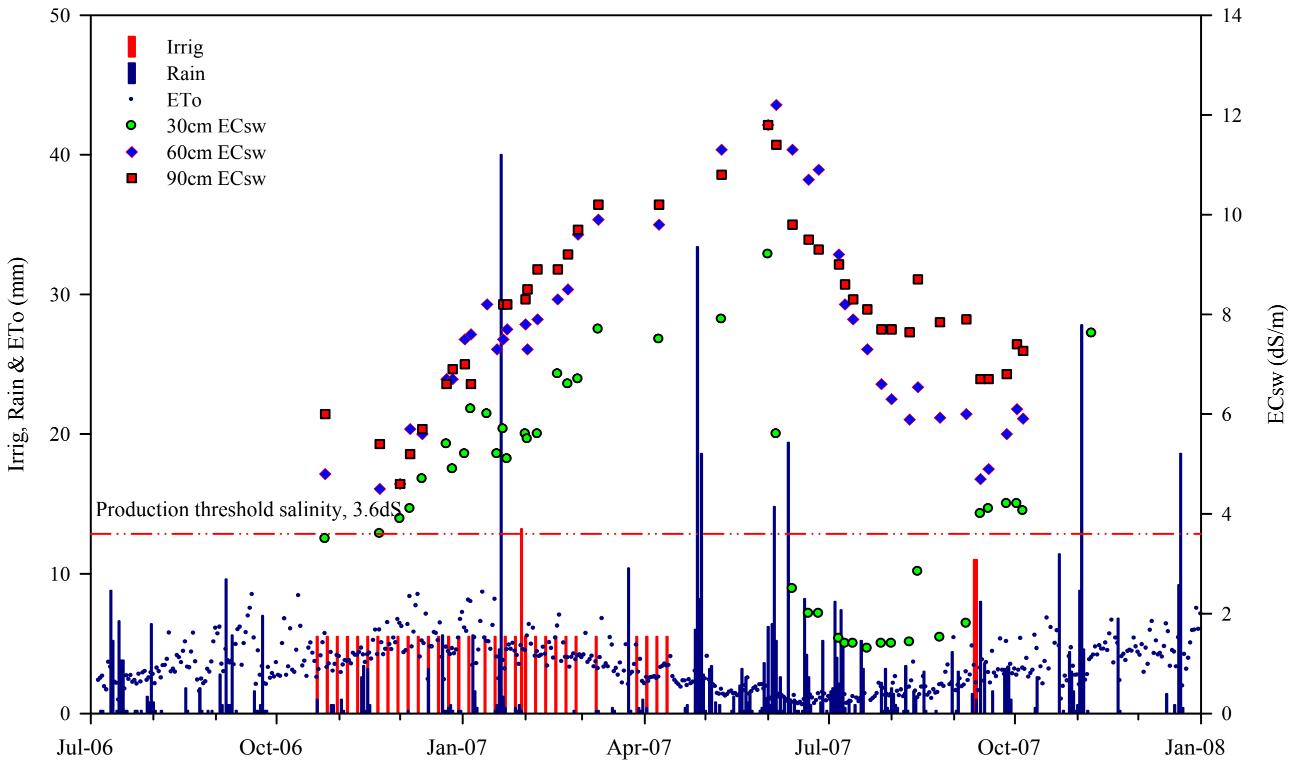

Figure 8: Changes in root-zone salinities within the 90 cm soil profile during 2006-08 at a Currency Creek vineyard as influenced by irrigation, rainfall and ETo.

At the beginning of the irrigation season in Nov’06, rootzone salinity (ECsw) at 30 cm was below the threshold EC (3.6 dS/m) for sensitive to moderately sensitive wine grape varieties for production decline. Salinity at this shallow depth, contributed mainly by irrigation salinity, quickly rose above 3.6

dS/m sometime in early December and remained high until autumn and then sharply fell below the threshold in mid June with winter rains, to a minimum of about 1.2 dS/m. Changes in ECsw at the 60 cm depth followed a similar trend but values were always above the 30 cm readings and recorded a maximum ECsw value of 12.2 dS/m in early June 2007. For 90 cm depth, due to negligible water movement/replenishment, the salinity levels started at around 5 dS/m in Nov'06 and peaked at 11.8 dS/m in early Jun'07.

Irrespective of depths of monitoring, it was obvious that salt had been accumulating within the profile during the irrigation period. Two large rainfall events on the 27 and 29 Apr'07 started to wet the rootzone which resulted in salt mobilisation. In mid to late Jun'07, several rainfall events reduced ECsw to below threshold EC for 30 cm soil layer. Subsequent rainfall events pushed the salt front further down which saw ECsw continue to drop to as low as 1.4 dS/m, 6.6 dS/m and 7.7 dS/m at 30, 60 and 90 cm respectively at the end of Jul'07. As salt gradually moved out of the 30 cm region of the rootzone, it started to add into the immediate next layers 60 cm and then to 90 cm depths. It took another week for 60 cm to respond and for 90 cm it was about 15 days before it started to flush out. Rainfall events through winter 2007 increased soil moisture suuficiently. Soil moisture data (not shown here) from these depths suggest that water fronts were moving deeper but the salts were yet to be flushed out of the 90 cm depth.

The average root-zone salinities for the entire 90 cm profile, calculated as a weighted arithmetic mean, for the entire growing season was above the salt tolerance threshold of wine grape, and so we would expect yield reductions from sensitive or moderately sensitive varieties.

Effects of winter leaching irrigation on salt mobilisation in the root zone

Residual salts from irrigation stays within the soil, mainly within micropores, until sufficient water first dissolves them and then brings them out by mass flow (Hoffman and van Genuchten 1983). Traditionally in Southern Australia, a post harvest summer leaching irrigation is practiced by grape growers to fill the soil profile and to leach salt. In this study, participating grower applied a summer leaching irrigation of 13.2 mm in late Jan'07 represented by a long red bar in Fig. 8. Ten days after a 40 mm rainfall event, this leaching irrigation was applied with water of 5 dS/m. It contributed to a 0.5 dS/m increase in ECsw at 30 cm and a negligible drop in ECsw at 60 cm. It had no effect at 90 cm. Hence, the summer leaching irrigation in this case, had little effect on reducing salinity values as moisture was quickly used by the plant.

From Fig. 8, it can be concluded that during winter, when the soil is wet and ECsw are at their lowest values, is the most suitable time for additional irrigations to push the salt front beyond 90 cm. This timing takes advantage of low EC river water, normally available through winter, as well as winter rainfall events which wet the soil profile before leaching. Due to unforeseen reasons, the irrigation pump controlling water supply to the valves broke down between July and August 2007. This meant the window of opportunity for timing leaching irrigation was missed. As soon as the pump was repaired the first leaching irrigation of 11 mm was applied with water of 3.8 dS/m on 11 Sep'07. This was repeated on the next day to push the previous days 11 mm down through the soil. As expected, the leaching irrigation increased 30 cm root zone salinity levels due to the presence of high amounts of salt in the irrigation water compared to soil water EC. However, leaching irrigation was successful in reducing ECsw levels from 6.0 to 4.7dS/m at 60cm and 7.9 to 6.7dS/m at 90cm. These results reinforce the importance of water quality and timing in maximising both leaching and water use efficiency.

Hence, an additional winter leaching in the July to August window, when the salinity of irrigation water is much lower than during the irrigation season, can reduce soil salinity significantly. Average seasonal rootzone salinity may then be reduced to the threshold or even below.

Effects of saline irrigation on sodium and chloride content of petiole and berry

Grapevine petiole and berry analyses are given in Table 2. In 2007 vine petioles, collected at flowering, recorded 0.77% chloride on dry matter basis. According to Robinson *et al.* (1997) toxic or excessive chloride levels in vine petioles starts at 1% chloride content when measured at flowering. Petiole samples collected at harvest suggested additional absorption of salts through the growing season, however toxicity standards are not available for this sampling time. High levels of chloride were expected in the vine petiole sample given that the average root zone soil water salinities (ECsw) were much higher than the theoretical production threshold of 3.6 dS/m during the entire growing period. Vines displayed symptoms typically associated with exposure to saline conditions. Lack of salt leaching will add excessive amount of salt within the root zone which ultimately ends up in plants.

Table 2: Grape petiole analysis from flowering 2007 and berry analysis from harvest 2007 and 2008.

Sample & Analysis	Harvest 2007	Flowering 2007	Harvest 2008
Berry – Na (mg/L)	71	-	82
Berry – Cl (mg/L)	97	-	310
Petiole – Na (%)	0.45	0.11 (>0.5 % toxic)	0.45
Petiole – Cl (%)	2.3	0.77 (>1.0-1.5% toxic)	2.5

The European Union and Australian bilateral agreement on wine quality requires wine to contain less than 394 mg/L of sodium and 606 mg/L of chloride. Berry samples from both 2007 and 08 harvest showed lower than the wine guideline’s Na or Cl content. However, there is an increased concentration of both the Na and Cl in 2008 harvest compared to the previous year. Due to extreme low flow in Finniss and its high salinity reading no irrigation was applied during 2008. As a results Cl content in berry juice increased by over 3 times compared to 2007, which is a clear signal of increased Cl entry to plants from the soil solution.

Conclusions

By irrigating with high salinity water, the risk of accumulating salts in the rootzone is real. During the peak grape growing season (Nov – Mar) the Finniss river flow effectively ceases resulting in very high irrigation water salinities (3.4 - 6.0 dS/m). This problem has been exacerbated by successive drought seasons of reduced water availability.

Soil-water salinity levels in excess of wine grape salt tolerance (3.6 dS/m) were recorded throughout the entire rootzone as a result of applying Finnis river water during the peak irrigation season. A steady increase in root-zone salinity levels was evident as irrigation water quality reduced. With soil pore water salinity levels being toxic to plants, the factor most likely to mitigate the salinity risks and guaranteeing the long-term sustainability of this region is managing the root zone salinity. Effective management of rootzone salinity risk depends on a good monitoring program. Growers should be encouraged to implement some form of root-zone salinity monitoring program, like installing SoluSAMPLER to check the salt build up and its movement in the rootzone. This will remove the guess work from decision making and at the same time allow the effectiveness of introduced management strategies to be accurately quantified & reassessed where required.

If root-zone salinity is not managed, not only will there be higher levels of salt in the grape juice, potentially lower yields and short-term reductions in economic returns, but longer-term natural resource impacts, such as salinisation, decline in soil structure and water quality impacts.

A key recommendation arising from this project is that grower’s should avoid applying post harvest leaching irrigations if irrigation water quality is poor. Instead, salts can be efficiently leached below the root-zone with little extra irrigation water at the end of winter rains and when irrigation salinity level is at its lowest, the soil profile is wet and evapotranspiration are minimal.

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