MODULE 03

Sustainable salinity management in your vineyard

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Background

These notes are to be read in conjunction with the train-the trainer power-point presentation “Sustainable salinity management in your vineyard”, prepared by the South Australian Research and Development Institute (SARDI) for the Grape and Wine Research and Development Corporation **(Slide 1)**. These notes reinforce the key messages and provide additional background information to the above presentation.

What is salinity?

All irrigation waters contain salts. A definition of salinity is necessary to show that many different salts may contribute to an overall salinity level, and that it is dissolved salts that cause the problem. **(Slide 2)**. Salinity is commonly measured as electrical conductivity of water or soil water.

A clear distinction should be made between irrigation and dry-land salinity, because they involve different processes and so require different management options **(Slide 3)**.

There are several major impacts of salinity **(Slides 4 and 5)**. At low salt concentrations toxic ions play a dominant role, and at high salt concentrations, it is the osmotic effect that plays a major role. In Australia many soils are naturally saline with a prevalence of sodium salts. Hence, there is a close relationship between salinity and sodicity.

Poor quality irrigation water adds extra salt. If sodium is present in high amounts, it may replace calcium, which is normally attached to clay particles. Soil then becomes sodic well as saline. Leaching or flushing the soil by rainfall or extra irrigation removes salinity, but may result in poor soil structure due to the development of sodicity. As poorly structured soils will reduce the effectiveness of leaching and hence increase salinity build-up, sodicity must be corrected.

Salinity affects overall crop yield when it exceeds a certain threshold value of average root-zone salinity over the growing period **(Slide 6)**. A good reference for salt tolerance of grapevine is Zhang et al. (2001) . Our understanding of thresholds is not comprehensive; so we can only suggest indicative values. Thresholds vary with salt root-stocks, growth stages and perhaps with climate and agronomic practices. In addition grape growers using less than maximum target yields for better quality will be able to manage with higher than the threshold root-zone salinity level shown in the graph.

How is salinity measured?

Salinity is measured as electrical conductivity(EC) of water or soil water. In practice many different units of EC are used, which can cause considerable confusion. It is important to understand how the most commonly used units relate to each other, and to the accepted international standard unit, decisiemens/meter or dS/m **(Slide 7)**.

There are a number of ways of measuring soil EC **(Slide 8)**. The EC of the saturated soil-paste extract (ECe) and soil suspension EC1:5 (1:5 soil:water) are widely used as industry standards in Australia. These are laboratory based methods which require destructive soil sampling. Theoretically, EC of the soil solution or soil water (referred hereafter as ECsw) is a better index of soil salinity than ECe or EC1:5. This is so because the plant roots actually experience the soil solution; they extract their nutrients from it, absorb other solutes from it and they consume this water through the process of transpiration. Most importantly, ECsw has not been widely adopted for routine appraisals of soil salinity because methods for obtaining soil water samples were not practical at typical field water contents. Recent developments by SARDI have made it possible to collect and measure ECsw, which was found to be about twice EC of the saturated paste extract (ECe). The advantage of these measurements is that they can easily be set up to make on-going readings throughout the year.

Other more expensive techniques are based on measuring changes in electrical capacitance or electromagnetic field **(Slide 9)**. Electromagnetic survey is commonly used to survey field-scale soil salinity, which is then followed up by ground-truthing and more accurate measurements of individual problem areas.

Salinity can also be measured in plants, for example by testing petioles at flowering or juice at harvest. These can be related to levels that can cause toxic effects, or to maximum international standards that are permitted in wine **(Slide 10)**.

Correlations have been made between plant and soil measurements to see if plant measurements could be an alternative. SARDI data from the Riverland of SA for example shows a general trend of increasing petiole chloride with increasing soil water salinity (ECsw). Unfortunately, the scatter of points means that the correlation is not good enough for one value to reliably predict the other **(Slide 11)**. In addition toxic plant levels did not occur until very high soil water ECsw was measured.

The data for juice chloride shows even more scatter than that for the petiole measurements **(Slide 12)**. Similar results occurred for sodium (data not shown).

Plant measurements are useful tools when soil salinity is already high. This may ensure wine quality meets export standards. However these slides suggest that soil water ECsw is a better indicator. This provides an early warning of potential salinity problems compared to plant measurement. For example, by the time petiole measurement is taken, it is probably too late for correction.

[1]Zhang, X., Walker, R. R., Stevens, R. M., and Prior, L. D. (2002). Yield-salinity relationships of different grapevine (Vitis vinifera L.) scion-rootstock combinations. Australian Journal of Grape and Wine Research 8, 150-156.

Why salinity is becoming an increasing problem in vineyards?

Irrigation management across the Murray Darling Basin has changed significantly over the past 60 years **(Slides 13, 14, 15 and 16)**. In most horticultural irrigation areas furrow irrigation systems have been replaced firstly by overhead sprinklers, and later by micro-jet and drip systems to save labour and improve water use efficiency. New designs and layouts now match soil infiltration rates, and overall irrigation is based on crop needs. Application rates of 10-15 Ml/ha have now been reduced to 6-7 Ml/ha and less.

Several factors have contributed to salt build-up in recent years **(Slide 17)**. Water management in highly efficient vineyards in the Riverland and Murray Valley has resulted in lower irrigation amounts being applied, resulting in close to 100% water use efficiency. The question is now being asked if this is a sustainable system in the longer term.

Since the 1950's total water applied during the year has decreased significantly. In recent years the salinity of irrigation water has been high, and extra salt has been added to the root-zone. Current drought conditions across the Basin have reduced the total even further. The impact of this has been a considerable reduction in the amount of water flushing through the root-zone, and so salt levels have risen on many properties. The amount of deep drainage or flushing has decreased from about 50% of total applied under flood irrigation down to around 20% with sprinklers and 5- 10 % under modern drip systems **(Slide 18)**. Field measurements with good quality water in a Sunraysia vineyard have recorded almost no deep drainage at all **(Slide 19)**.

Modelling of salt accumulation by SARDI suggests that under low rainfall or drought conditions, and with river salinity levels increasing, considerable amounts of salt can be deposited in the root-zone over only one irrigation season **(Slide 20)**. There is a temptation under drought conditions, and low allocations, for irrigators to think less about water for flushing the root-zone. However the reality is that deep drainage for salt removal is still just as important, and even more if water quality is declining. The modelling also suggests considerable build up of salt occurred during the veraison to harvest period (200 -250 days) and salinity at this time may exceed the threshold EC of grapes.

Field sampling of soil under a drip irrigated vineyard in McLaren Vale showed considerable spatial variation of salinity build-up in the root-zone **(Slide 21)**. The left hand contour map in the slide shows salinity profile directly under a dripper, moving away along the drip line and vine row as you move to the left. The right hand contour map shows salinity under the dripper, moving away across the midrow as you move right. This field investigation was done after winter rainfall, and shows that under current practices even good winter rain may only leach salt from the inter-row, and not adjacent to the vines.

Leaching in-efficiency

The process of salt build-up in the root-zone needs closer examination. If 5-10% deep drainage occurs under a drip system for example, then this is often called the leaching fraction (LF), or the percentage of water applied that is not used up by the crop. Most of this will drain below the root-zone and help remove salts that have built up. If drainage occurs in a uniform manner it would be expected that all of the salt in the profile would be removed. This is known as piston flow. Earlier simple modelling of the drainage process assumes piston flow and predicts that for most soils in the Basin, 5-10% leaching should be enough to at least maintain salt at a constant level.

However recent understanding suggests that uniform piston flow is not occurring. Some of the drainage is through larger macro-pores or cracks in the soil, which is known as by-pass flow. By-pass flow is less likely to contact salt in the profile and remove it, so overall the efficiency of the leaching process is not 100%, as was conventionally assumed with piston flow **(Slide 22)**. This means that to remove the same amount of salt a higher LF will be needed if not manipulated with winter rainfall.

Recent field survey data from Riverland and Sunraysia irrigation districts shows that salt is building up much more than earlier predictions and supports the idea that leaching efficiency is less than 100%. **(Slide 23)**.

A number of measurements of leaching efficiency (LE) have been made in the field, and it now appears that this value depends on several factors **(Slide 24)**. For example it is usually lower in the top 30 cm of soil, probably because this is where most soil cracking and biological activities occur. By comparison, measurements between 60 and 90 cm have suggested LE is closer to 100%. LE has also been shown to vary at different times during the year, and is highest in winter, when soil cracking and biological activities are minimal. Together with dormant vines, evapo-transpiration is also lowest during winter. These conditions enhance the mixing of drainage water with salt and prevents any up-ward movement of water in the soil, which potentially could off-set the effectiveness of leaching.

Annual variation of root-zone soil salinity in a vineyard

SARDI has recently developed an improved suction cup to extract field samples of soil water. The equipment has been validated against ECe values from soil samples, and is now marketed commercially as the SoluSAMLER by Sentek Sensor Technologies in Adelaide. This equipment has been used on trial sites and by commercial growers in SA, NSW and Victoria to show the change in soil water EC throughout the year.

The annual variation of soil water EC generally follows a trend of higher values during summer, when irrigation is applied, and lower values following leaching by winter rainfall if it is sufficient. This trend can change due to many local factors, for example in the slide of Cab-Sav vines at Langhorne Creek in the Lower Lakes district close to the Murray mouth **(Slide 25)**.

The variation during the year is best tracked at several depths to properly represent the root-zone, eg 30, 60 and 90 cms. Any sudden changes can be related back to particular conditions at the time. For example in January 2008 in this slide, readings increased rapidly because river salinity rose to about 4 dS/m.

In some situations spikes in soil water EC are due to other management operations, such as the application of fertiliser **(Slide 26)**. In this case in an almond orchard at Willunga in SA, the short term spike can be ignored as it is the overall trend during the year that is important.

This is also an example where salinity appears to have slightly dropped during the summer season of 2006/07, instead of increasing above the previous winter levels. Data like this reinforces the need for continual monitoring in more saline areas, to ensure that correct management decisions are made.

The impact of irrigation system on root-zone salinity

Most vineyards across the Murray Darling Basin are now drip irrigated, or in the process of being converted to drip systems. In some areas sub-surface drip systems are now being trialled, and showing some interesting results in relation to root-zone salinity. Data from the Lower Lakes **(Slide 27)**, show soil water EC is lower at each depth under sub-surface, compared to conventional drip.

The super-script numbers against each value in the slide are the number of samples that could be extracted from the suction cups. Considerably more samples were extracted from the top 30 cm, compared to 60 cm, and even less at 90 cm.

As saline irrigation water is being applied to the surface under conventional drip, and slightly below 30 cm below the surface for sub-surface drip, it would be expected that a higher soil water EC would be recorded at 30 cm under the conventional system.

In addition, more samples were extracted at 60 and 90 cm, under the sub-surface system, indicating that these depths were wetter. This would be expected given the location of the sub-surface dripper. Because they are wetter more water is likely to be available for leaching, and this probably explains the lower soil water EC values at 60 and 90 cm compared to conventional drip.

Further trial work needs to be done with sub-surface drip to better understand the mechanisms operating, but there are already signs that this may be a valuable approach in controlling root-zone salinity as well as reducing irrigation amounts.

Best management practice for salinity

Recent research into root-zone salinity is now pointing to new strategies that grape-growers should implement, to complement existing water management. Much of the research has been carried out in the middle and lower parts of the Murray Darling Basin, where increasing salinity problems occur. Research sites have been located within the Murray Valley, Riverland and Lower Lakes districts, on a range of soil types and across a range of climatic environments. While salinity is less of a problem in upper parts of the Basin, the same principles apply and should be considered by grape-growers in these regions.

Two basic principles behind best management practice for salinity are; measure to manage, and manage against critical levels or thresholds. Two practical best management techniques are; the use of winter leaching to ensure maximum leaching efficiency, and the use of salt tolerant root-stocks **(Slide 28)**.

Root-zone salinity measurement can be based on annual soil sampling **(Slide 29)**, or on-going measurements during the year using equipment such as a suction cup **(Slide 30)**.

More comprehensive information on the installation and operation of suction cups can be downloaded from www.sentek.com.au site.

On-going monitoring may indicate that no leaching is required. If needed, winter leaching is likely to be the best way to manage root-zone salinity, but the appropriate threshold will change if salt tolerant root-stocks are used **(Slide 31)**. These are only indicative thresholds at this stage, and require further research to refine them. It has already been mentioned that grape growers using less than maximum target yields for better quality will be able to withstand higher root-zone salinity levels.

A practical way to implement winter leaching is to put a protocol in place **(Slide 32)**. This is an example only. July is the ideal month for winter leaching based on long term climate records, but this may vary from year to year depending on rainfall and temperature patterns.

This can be best determined with actual monitoring data collected **(Slide 33)**. This data set is from Currency Creek in the Lower Lakes district and represents a highly saline situation following high salt levels in the Murray River. Soil water EC values are averages of the root-zone, ie averages of 30,60 and 90 cm. If grape growers do not have the resources to install multiple suction cups at each location, then a single cup in the middle of the root-zone will give a good indication of trends, as in this example. The data shows that the average soil water EC over the whole year is approximately at the tolerance level for tolerant root-stocks, but well above that for more sensitive varieties.

It should be noted that a large rainfall event in the summer of 2007, followed by a summer leaching irrigation, had little impact on average root-zone salinity. However a large rainfall event at the beginning of the following winter significantly reduced salinity values. This is further confirmation that winter leaching is more effective. In this case if the grape-grower wished to further reduce salinity in preparation for the following irrigation season, if he had sensitive varieties, then a winter leaching during July 2007 could have been used. The data shows an irrigation in the spring of 2007. It is common practice to irrigate at this time to ensure the soil profile is full at the beginning of the growing season. If salinity levels were considered too high an alternative strategy may have been to bring this irrigation forward to July and achieve both objectives.

To allow this sort of flexibility there may be a need for Water Regulators to consider these strategies when planning future water allocation policy.

Having made the decision to leach during the winter, the next decision is how much leaching is required? **(Slide 34)**. The amount of leaching is influenced by soil, plant and climatic factors. Modelling of the leaching process done by SARDI has resulted in the development of a leaching calculator and a new grower-friendly version is currently being prepared. The basis of the calculations is not complex but requires several steps **(Slide 35)**.

EC iw is usually known, and ECsw is measured directly in the field. The amount of leaching or the Leaching Requirement (LR) as a percentage of the total annual water use by the crop is equal to ECiw/ECsw. To calculate this in actual mm of water we need to also know the amount of water used by the crop, or ETc in mm. Total water needed for the crop and the LR equals ETc/(1-LF) in mm. Deducting ETc from this value gives the amount of the LF in mm. Some additional adjustments to LF can be made depending upon soil type.

Impact of salinity on soil structure

Impermeable sodic layers can occur at the surface but are more common deeper in the root-zone, or below the root-zone. Impermeable layers are not always caused by sodicity, and it is important to be able to distinguish the different processes occurring to correct the structural problem **(Slide 36)**.

The usual process for structural loss due to excess sodium is that a soil first becomes saline. Subsequent leaching with irrigation or rainfall removes salt leaving behind sodium saturated clays. A sodic layer develops when sodium replaces calcium that is attached to clay particles. If the soil is still saline at this time, then the concentration of salt in soil water holds the clay particles together. As soon as the salt is leached, the presence of excessive sodium adsorbed on clays causes the particles to "explode or disperse into tiny pieces" when the soil gets wet. This phenomenon blocks soil pores and results in little or no water penetrating through the sodic layer **(Slide 37)**.

If the sodic layer is lower in the profile, it can not be seen without digging an observation hole, but the effect is the same. Water collects above the sodic layer and then runs sideways along the top of this layer, rather than down through the soil.

A common field method of demonstrating the impact of salinity on soil structure is to place small peds of sodic soil into a flat dish. In rainwater the peds quicky disperse and break down. If placed in saline water, the same peds remain flocculated (intact) or not dispersed **(Slide 38)**. For a particular level of sodicity, we will notice soil structure breakdown under low salinity but not when the salinity is high. When structure breaks down it restricts water movement within the soil as well as into plants. However, at higher salinity levels, plants are affected both by osmotic stress and specific ion toxicity.

Soil sodicity is traditionally measured as exchangeable sodium percentage (ESP) of soil. ESP is calculated as the proportion of the cation exchange capacity occupied by the sodium ions and is expressed as a percentage. For practical purposes soil or water sodicity is measured as sodium adsorption ratio (SAR) which is defined as the ratio of sodium ions to calcium plus magnesium ions **(Slide 39)**. This requires the measurement of concentrations of sodium, calcium and magnesium in soil water. Measuring SAR in soil water collected by suction cup (SARsw) is less laborious than ESP.

A simple relationship between SAR measured in saturated paste extract (SARe) and in soil water (SARsw) has been worked out, where one unit of SARsw =1.414*SARe **(Slide 40)**. Critical SARsw levels indicating the degree of sodicity have been established where <9 indicates non sodic soil.

Measurements of SARsw within the rootzone of Riverland vineyards on sandy loam soils showed they are all well below the critical values. In some cases SARsw has decreased over time due to leaching of sodium salt by good quality irrigation water and rainfall. These soils are not sodic **(Slide 41)**. On the other hand, the higher clay content soils in the Lower Lakes district at Langhorne Creek, which received high saline water (~1.2 dS/m) , showed that the soils were moderately sodic **(Slide 42)**. In this case the soils were probably sodic well before irrigation water was applied.

How to manage soil structure?

If it has been determined that the soil is sodic, gypsum is commonly added to the soil. Gypsum is a cheap source of calcium. Very high concentrations of calcium in the soil reverse the sodicity or structure breakdown process by replacing sodium with calcium. **(Slides 43 and 44)**.

However, if breakdown has already occurred due to factors other than sodicity, such as simple mechanical pulverisation of soil by tillage, then just adding gypsum is not going to be the complete answer. In this case soil pores need to be rebuilt. This can be done through strategic tillage of the problem layers in the soil, and complemented with the establishment of cover crops or grasses with deep fibrous root systems. These crops not only provide organic matter to assist soil structure build-up, but the fibrous root systems provide a "natural" soil tillage effect. If perennial grasses are used, they can be managed so that they are not growing in winter when leaching may be required to remove salinity **(Slides 45 and 46)**.

Recommendations for the major wine-growing areas of the Murray Darling Basin.

Understanding the processes of salinity and sodicity in the root-zone, and the various management options to address these problems, is a good basis to make local recommendations for the major wine-growing areas of the Basin.

The intensity of management options will increase with the severity of salinity and sodicity. For salinity in particular, more management options will be required down-stream, or if alternative water sources such as bores indicate poor quality water **(Slide 47)**.

A first decision point for grape-growers should be the salinity of the water source. It is suggested that a water EC value of 0.5 dS/m or 500 EC units is a useful indicator, which can separate less intensive management from more intensive management **(Slide 48)**. Many wine-growing areas in the upper parts of the Basin are yet to experience high levels of salinity and so it is appropriate that less intensive management be put in place. However other trends in irrigation practice in these areas, eg conveting to drip irrigation in the Riverina for water savings, may require a frequent monitoring of salinity..

It is less likely that sodicity will be a problem for sandy/sandy loam soils of the Murray Valley and the Riverland, however clay soils are present in the sub-soil of much of these areas, and strategic monitoring to identify sodic problems should be carried out.

River Murray water is piped off to some wine growing areas such as the Clare and Barossa Valleys, where soils are known to be higher in clay with some known soil structure problems. In addition, these regions use poor quality local bore water together with river water and management of soil structural problems is likely to be a priority.

The highest water salinities in the Basin are experienced in the Lower Lakes, near the Murray mouth. Monitoring/management of both salinity and sodicity should be an integral part of irrigation operations in this area.

In summary:

- Low salinity conditions today may not be the case in the future.
- A number of factors are working against the need to continually remove salt from the root-zone, such as;
  - water scarcity and access to poor quality water
  - lower irrigation volumes for higher grape quality,
  - more water efficient drip systems, especially in low rainfall areas
- There is a need to tailor monitoring and management for individual situations depending upon factors such as;
  - Climate
  - Soils
  - Irrigation system, and irrigation volumes used
  - Soil and irrigation water salinity
  - Agronomic practice
  - Grape variety or root-stock

Recommendations for the major wine-growing areas **(Slides 49 to 56)**, are general guidelines, which should be further modified at the vineyard level.