Factsheet

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Sustainable salinity management in Australian vineyards

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What is salinity?

The term salinity refers to the concentration of dissolved salts present in soil or water. When salts dissolve, they separate into constituent parts known as ions, which carry electrical charges and may be either positive or negative. The main salt in saline water and soils is sodium chloride, the same salt as table salt.

Other ions may also be found in water and soil, including calcium, magnesium, potassium, carbonate, bicarbonate, sulphate, borate and nitrate ions. While some salts, such as fertilisers, can be beneficial, excess salt of any kind is detrimental to soil and plants.

What is the impact of too much salt?

The accumulation of salt in the rootzone of grapevines can have drastic effects on their growth and yield (Figure 1). At very high concentrations, salt will eventually kill plants. The salt concentration of wine is also very important. Wine produced in Australia must not contain more than 607 ppm of chloride, equivalent to 1 g/L of sodium chloride (ANZ Food Standards Code, Standard 4.5.1). Even at much lower concentrations, salt can result in undesirable taste in wine.

Where does salt come from?

All water sources used for vineyard irrigation contain some salt. The quantity of salt (the salt load) added to soil with each irrigation depends on the volume of irrigation and the concentration of salt. Every irrigation adds additional salt to the vine rootzone, which if not adequately managed will increase the salt content of the soil and reduce vineyard productivity.

Where does the salt in the soil go?

Leaching is the process in which dissolved salt in the soil is pushed below the rootzone of vines as a result of rain or irrigation. Over-irrigation can leach salt applied through irrigation; however, it can have other undesirable consequences, such as rising water tables or off-site impacts. Under-irrigation, such as may be practised in deficit irrigation, will not leach applied salt and may result in increased rootzone salinity.

In higher-rainfall regions, salt is generally leached through the soil profile. During periods of low rainfall, however, salt can accumulate in the rootzone.

The challenge in managing salinity with irrigation is to apply enough water to meet crop needs and to produce sufficient drainage to leach salts, but not so much as to produce excessive drainage, which causes unacceptably high water use.

This factsheet examines the causes and effects of soil salinity, and how it can be monitored and managed. Measuring rootzone salinity assists the efficient management of irrigation and should be considered as best practice.

Figure 1: Grapevine leaf exhibiting chloride damage (Photo: Rob Walker, CSIRO).

What causes soil salinity?

Salts are naturally present in all Australian soils. However, additional salts can concentrate in the rootzone due to:

- high concentrations of salts in irrigation water
- insufficient irrigation to leach salt out of the rootzone
- poor soil structure that limits drainage or leaching of salts out of the rootzone
- non-uniform water application across the irrigated area resulting in localised patches of inadequate leaching
- increased soil salinity in the rootzone due to high water tables, which may bring salt from other areas or from the soil below.

What are the impacts of soil salinity?

- A high concentration of salts in soil water can prevent the vine from extracting enough water from the soil, resulting in water stress. Grapevine roots exclude more than 95% of the salt in water they extract from soils and, as a result, salts accumulate in the soil near roots. Salt concentrated outside the roots creates a difference in salt concentration between the water in the soil and the water in the root vascular system (an osmotic gradient). The higher the salt concentration, the harder the plant must work against this gradient to extract water from the soil; leading to reduced production, quality downgrades and possibly vine death. Excess quantities of salts containing sodium, chloride and boron cause cell death in green tissue.
- High salt concentrations can predispose soils to physical structure problems, including the development of hard crusts that reduce water infiltration. This occurs when sodium ions at high concentration become bound to clay particles, resulting in soil 'slaking' or 'dispersion' when the soil is subjected to rainfall (see section - What are sodic soils and how can I manage them?).

Figure 2: **In-field assessment of soil salinity using a 1:5 soil-to-water extract (Source: Lanyon 2011).**

How can I measure soil salinity?

Salt water conducts electricity more readily than pure water. Electrical conductivity (EC) is commonly used to measure salt levels in soil or water. Soil water samples for salinity measurement can be collected in a number of ways. The 1:5 soil-to-water extract method is commonly used and described in Figure 2.

'Saturated soil paste' is also used where drainage water is collected from saturated soil to measure EC. Soil water can also be 'extracted' from soil in the field using a soil water sampling device (e.g. the Sentek SoluSAMPLER™). The electrical conductivity of soil water (EC_{sw}) is a better index of soil salinity than that of a saturated paste extract (EC_e) or 1:5 soil-to-water extract (EC1:5), as vine roots extract water, nutrients and other solutes from soil water. EC_e or EC1:5 are more often used, however, as EC_{sw} is difficult to measure without appropriate pre-installed devices.

The most commonly used unit of soil salinity is decisiemens per metre (dS/m), where 1 dS/m is equivalent to 1000 EC units. The relationships between various electrical conductivity units and approximate salt concentrations are given in Table 1.

How and when should I collect soil samples to measure soil salinity?

Standard soil sampling procedures should be followed to obtain a representative sample from different soil types or from specific problem areas in the vineyard. Soil sampling in drip-irrigated vineyards is more complex due to the multiple point sources of water, hence samples should be taken at the same depth and distance from a dripper.

Samples should be taken at the beginning and end of the growing season. In late spring, following winter rains, salinity levels should be at their lowest. In autumn, following additions of salt from irrigation and before

decisiemens per metre (ds/m)	millisiemens per centimetre (mS/cm)	microsiemens per centimetre (µS/cm)	EC unit (EC)	parts per million (ppm)	milligrams per litre (mg/L)
1	1	1000	1000	640	640

Table 1: Conversion table for electrical conductivity measurements.

any significant rainfall begins, salinity should be highest. Repeated measurements should be taken over several seasons to show that the soil salinity is changing and leaching practices or rainfall are effective.

Soil water can be extracted directly from the rootzone using several types of equipment, such as a suction cup sampler, a wetting front detector and some types of capacitance probe; these are discussed below. Note that soil water samples collected for salinity testing with suction cup samplers or wetting front detectors can also be used to measure soil nutrient levels to determine whether fertiliser needs to be applied.

Suction cup sampler

Suction cup samplers remove soil water by applying suction to a buried ceramic cup. Typically, suction cups are placed at depths of 30, 60 and 90 cm in a rootzone of 1 m, and located about 15 cm from a dripper along the line of a drip irrigation system.

Advantages:
- Easy to install, with minimal expense and disturbance of soil
- The salt content of the extracted soil water sample can be measured using an inexpensive handheld EC meter.

Disadvantages:
- The sample can only be obtained when the soil is sufficiently wet
- Sample collection requires two separate visits to the vineyard. First, suction is applied to the suction cup sampler by creating a vacuum on the sampling tube using a syringe. After 2–6 hours, soil water will be drawn into the syringe and the soil water sample can then be retrieved.

The SoluSAMPLER™ (Figure 3a) is an example of a suction cup sampler available in Australia.

Wetting front detector

A wetting front detector is funnel-shaped instrument that is completely buried in the soil. It allows observation of how far water has travelled through the soil profile. As water percolates through the soil, it enters via the wide funnel opening and continues downward. As water reaches the narrow section of the funnel, the soil water content increases and eventually exceeds saturation. A small receptacle captures about 5 mL of soil water, which can be used for salinity testing.

Advantages:
- The wetting front detector automatically captures a sample each time there is a strong wetting front
- The salt content of the soil water sample can be measured using an inexpensive handheld EC meter.

Disadvantage:
- A sample is only captured when sufficient water has been applied.

The Fullstop™ instrument (Figure 3b) is an example of a wetting front detector available in Australia.

Capacitance probes

Capitance probes measure the water content and electrical conductivity of soil via one or more sensors that continuously log soil data.

Advantages:
- Data can be continuously logged and remotely retrieved
- Allows calculation and observation of bulk soil electrical conductivity (bulk soil EC)
- Continuous data improves monitoring and allows interpretation of factors contributing to changes in soil salinity.

Disadvantages:
- Converting bulk soil EC to soil water EC is often difficult due to soil variability
- Bulk soil EC values can be influenced by numerous factors other than salinity
- Without knowing what level of salinity is being experienced by the plant, it is difficult to identify threshold EC values at which yield decline sets in (Table 2)
- Figure 3c shows an example of a capacitance probe that measures bulk soil EC .

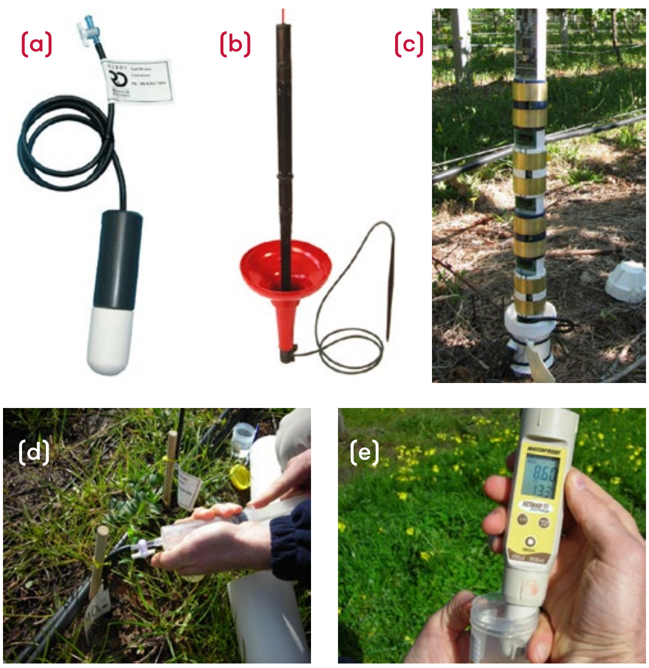

Figure 3: Examples of (a) a suction cup sampler, (b) a wetting front detector, and (c) a capacitance sensor. (d) Extracting soil water samples with a syringe, (e) testing a water sample with a handheld salinity meter. (Photos: SARDI, CSIRO & Sentek Technologies)

Crop sensitivity	Varieties	Rootzone EC_e threshold at which yield decline starts (dS/m)
Sensitive	Own roots: major wine grape (*Vitis vinifera*) varieties Rootstocks: 3309, 1202×, K51-40	1.8
Moderately sensitive	Own roots: Colombard & Rootstocks: 1202C, Kober 5BB, Teleki 5C, S04	2.5
Moderately sensitive	Rootstocks: Ramsey, Ruggeri 140, Schwarzmann, Rupestris St George	3.3
Tolerant	Rootstock: 1103 Paulsen	5.6

Table 2: Rootzone salinty threshold values for grapevines, based on EC_e (Adapted from Walker 2010).

How tolerant are grapes to soil salinity?

Season-to-season trends in soil salinity provide information that can aid management decisions and may help minimise potential salinity problems. If monitored blocks continue to perform well and fruit quality is satisfactory, observations of seasonal trends in soil salinity are as important as the absolute salinity values.

Own-rooted grape varieties and rootstocks vary in their tolerance to soil salinity. Table 2 contains data (Walker 2010) on the salt tolerance of a range of own-rooted varieties and rootstocks. Sensitivity levels will be influenced by management, irrigation and vineyard site characteristics.

How can I manage rootzone salinity in the vineyard?

Soil leaching occurs when soluble salts are washed through or out of the rootzone by water (rain or irrigation) percolating through the soil profile. Soil leaching is one of the best ways to manage rootzone salinity. Usually, leaching is not necessary unless the average rootzone salinity over the irrigation season increases above threshold levels (Table 2). Regular monitoring of changes in rootzone salinity will indicate whether values are reaching these critical levels and a leaching irrigation is required.

The best opportunity for leaching salts is between late winter and early spring in regions with winter-dominant rainfall. Research suggests that around 250 mm or more of winter/spring rainfall is necessary to leach applied salts from the rootzone; however, this varies depending on soil type, rainfall duration and intensity.

Supplementing winter/spring rainfall with a leaching irrigation may reduce soil salinity if the rainfall was not sufficient. A leaching irrigation is best applied when the soil is wet to saturation (or as close to it as possible) throughout the rootzone. This is to avoid having the water travel preferentially through soil cracks (paths of least resistance) where it will not interact with salts in the soil; this will significantly reduce the effectiveness of the leaching irrigation. Experience has demonstrated that summer rainfall, or the application of leaching irrigation (especially with drip irrigation) when the soil is not saturated, is much less effective than winter rainfall in reducing soil salinity.

Applying leaching irrigation to soil following sufficient winter/spring rainfall can also yield benefits, including:
- vines are dormant and so are not drawing water from the soil
- soil water evaporation is low, which maximises the volume of water infiltrating into the profile (night-time leaching may further reduce soil water evaporation), and
- leaching irrigation efficiency is vastly improved when applied to a wet soil.

Note that the water used must be of low salt content, otherwise a larger leaching irrigation will need to be applied. As the salt distribution in the rootzone is not uniform in a drip-irrigated vineyard, it is difficult to predict how much irrigation is needed and the final outcome following the leaching irrigation. It is very important for growers to monitor changes in rootzone salinity following the leaching irrigation and during the season to guide their management decisions.

How can I maximise irrigation leaching effectiveness?

Field and laboratory studies by the South Australian Research & Development Institute (SARDI, unpublished) indicate that several smaller irrigations on wet soil, rather than a single larger irrigation, can increase leaching efficiency by up to 10%. An effective leaching protocol might be:

1. Monitor changes in rootzone salinity throughout winter, but especially after any significant rainfall event that may have filled the rootzone

2. Check the soil water salinity measurement against crop thresholds (Table 2), or against measurements taken at about the same time in previous seasons
3. Check whether any further significant rainfall is predicted in the coming 1–2 weeks; if so, wait (provided budburst is not imminent)
4. If no significant rainfall is predicted, apply one or several small leaching irrigations and recheck rootzone salinity against thresholds a day after the last leaching irrigation.

What are sodic soils and how can I manage them?

Sodic soils have disproportionately high concentrations of sodium, which makes them inherently unstable. When sodic soils are wet with low-salinity water (e.g. rain), they may slake or disperse. Slaking is a process in which soil aggregates crumble and disintegrate; dispersion occurs when clay particles are forced apart. Both processes significantly reduce the infiltration and percolation of water into soil (Figure 4). In extreme circumstances, a sodic soil that has been mechanically dispersed by tillage can have rainfall pond on the surface for several days, or may lead to severe erosion on a sloping site.

The chemistry of sodic soil is governed by the concentrations of the positively charged salts (cations) that are bound to clay particles in soils. In well structured soil, the concentrations of calcium and magnesium bound to clay particles are much higher than that of sodium. Irrigation with water that has sodium levels much higher than its calcium and magnesium concentrations results in the soil having more bound sodium and less bound calcium and magnesium. This increase in the level of sodium cations predisposes clay particles to separate from one another

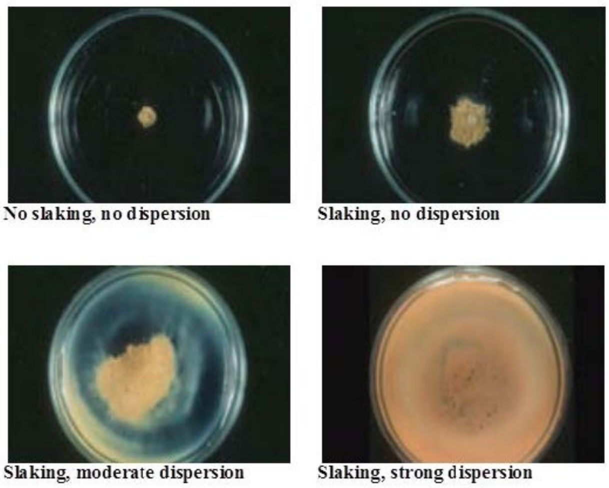

Figure 4: Assessment of an undisturbed soil aggregate after it has been placed in distilled water for a period of two hours. The higher the dispersion, the higher the sodicity. (Photo: Alf Cass).

(disperse). The resulting tiny clay particles then block soil pores, leading to water ponding, and limit water, air and root movement in the soil, resulting in reduced vine performance. The Victorian Resources Online website provides additional information on the chemistry of soil dispersion at http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_soil_structure_dispersion.

The propensity for irrigation water to increase the concentration of sodium bound onto clays can be estimated by calculating the sodium adsorption ratio (SAR) from measurements of the concentrations of sodium, calcium and magnesium in the water.

The critical SAR values at which soil dispersion will occur are also influenced by the salinity of the irrigation water. As can been seen in Table 3, there is a greater risk of soil dispersion when low-EC water (irrigation or rainfall) is applied.

If soil tests done before the vineyard is established suggest the presence of sodic layers, then gypsum addition is recommended. As gypsum has low solubility, deep ripping will help gypsum to reach the sodic layer.

If sodicity develops after vineyard establishment, surface banding of gypsum on the undervine area is recommended; this should be done annually if possible (or at least every 2–3 years), and before autumn/winter rains. Soluble forms of calcium complexes are available that can be injected into the irrigation water. These are marketed as 'liquid gypsum' and although they are more expensive than normal gypsum, they may be easier to handle and apply. Some (limited) experimental work (SARDI, unpublished) indicates that soluble forms of calcium complexes should be injected at every irrigation during the growing season to ensure sufficient calcium ions are moved with irrigation into dispersive soil layers. Soil dispersion can also be reduced by

SAR	EC_i	Soil sodicity hazard
0–3	>0.7	None
	0.7–0.2	Slight to moderate
	<0.2	Severe
3–6	>1.2	None
	1.2–0.3	Slight to moderate
	<0.3	Severe
6–12	>1.9	None
	1.9–0.5	Slight to moderate
	<0.5	Severe
12–20	>2.9	None
	2.9–1.3	Slight to moderate
	<1.3	Severe

Table 3: Suggested critical ranges of soil sodicity hazard, based on SAR and EC of irrigation water (SAR and EC_i).

minimising cultivation and adding organic matter (e.g. mulch) under the vines. As the organic matter breaks down, it improves soil aggregate stability by binding soil particles together. The organic matter on the soil surface also protects soil from raindrops, which may otherwise break up soil aggregates.

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Figure 7, kindly supplied by T Pitt (SARDI) and incorporating rainfall data from the Australian Government Bureau of Meteorology, was reviewed by R Stevens (SARDI).

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