SUSTAINABLE
IRRIGATION MANAGEMENT UPDATE

Guidelines for Managing Soil Salinity in Groundwater Irrigated Vineyards

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NATIONAL PROGRAM FOR
Sustainable Irrigation

Key Findings for NPSI Project CIF5121

- Ensuring rainfall flushes salt is the key to sustaining supplementary irrigation with saline groundwater
- At 24 years of age, salt excluding rootstocks have equal or better yield than own rooted vines and half the fruit chloride
- Soil water extractors give fast and cheap guidance on vineyard salinity status

How does soil salinity affect the grapevine?

The poor conditions for vine growth which arise with excess soil salinity are caused by an osmotic effect, a toxic effect and changes to the physical structure of the soil.

Osmotic effect - excessive concentrations of dissolved salts in the soil causes salinity stress in grapevines. While roots can exclude more than 95% of the salt in soil water, the process leads to a gradual concentration of salt in soil near the roots. A high concentration of salt outside the roots creates an osmotic gradient between the soil water and the water in the root vascular system. The vine must work against this gradient to extract water from the soil. In highly saline soils this gradient is high enough to prevent vine roots from extracting sufficient water. This effect of salinity is known as the osmotic effect. All types of dissolved salts exert this effect and salt does not need to enter the plant to exert this effect. The osmotic effect has been linked to vine yield using measurements of soil EC_e.

Toxic effect - the most common salt under saline conditions is sodium chloride. Whilst sodium is a beneficial element and chloride an essential micronutrient, their concentrations under saline conditions reach levels where their rates of entry into the grapevine exceed those necessary to meet its nutritional requirements. Excessive tissue concentrations of these ions poison the plant metabolism which causes a decline in metabolic processes such as leaf photosynthesis and often presents as burning of the leaf margins. This effect is known as the toxic effect of salinity. Salts must enter the plant to exert this effect. The toxic effect has been linked to yield loss through measurements of chloride and sodium concentrations in the leaf.

Excessive/toxic concentrations of salt in grapevine leaves

	Leaf petiole at flowering	*Leaf lamina at harvest*
Sodium (%)	*> 0.5*	*> 0.5*
Chloride (%)	*> 1.5*	*> 1.3*

Measures of soil salinity

Soil salinity is quantified by measuring the electrical conductivity (EC) in dS/m of water extracted from soil

EC_e	*(lab test)*	*EC of extract from saturated soil paste*
$EC_{1:5}$	*(shed test)*	*EC of extract from 1:5 soil:water dilution*
EC_{sw}	*(field test)*	*EC of soil water*

Soil texture	*Sand*	*Loam*	*Clay loam*	*Light clay*	*Heavy clay*
Factor to convert $EC_{1:5}$ *to* EC_e	*x 13*	*x 11*	*x 9*	*x 7*	*x 5*

See Figure 7 for conversion from EC_{SW} *to* EC_e

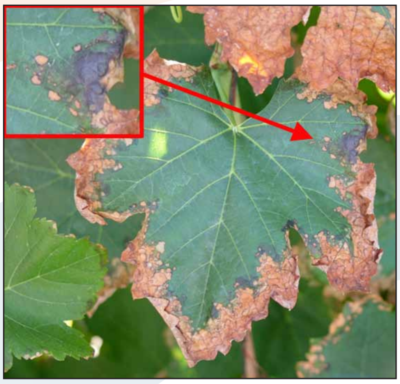


Figure 1. Sodium toxicity showing dark edges and scorching (left). Chloride toxicity showing burnt leaf margin (right).

Sodicity effect - salinisation of soil can predispose it to the development of sodicity and a potential loss of structure. Irrigation water with high sodium adsorption ratio (SAR), water in which the sodium concentration is greater than that of calcium and magnesium, can cause the surfaces of clay particles to be enriched with sodium and depleted of calcium and magnesium. In sodic soils, the sodium enriched clay particles can separate from each other when the salinity of soil water drops following rains. This separation of clays (dispersal) causes a loss of aggregation and a reduction in soil permeability to water. It is difficult to flush salts from soils with low permeability. The likelihood that a soil will exhibit sodic behaviour is quantified by measuring the soil's exchangeable sodium percentage (ESP)

ESP (exchangeable sodium percentage) is the percentage of cation exchange sites in soil that are occupied by sodium.

Sodic behaviour emerges at ESP > 6%

If your soil test does not provide ESP, it can be estimated from SAR using one of the formulas below:

$ESP = 1.95 \times SAR_{1:5} + 1.8$

when SAR measured on an extract of a 1:5 soil:water dilution

$ESP = 1.475 \times \frac{SAR_e}{(1 + 0.0147 \times SAR_e)}$

when SAR measured on an extract of a saturated soil paste

Salt and fruit quality

Excessive soil salinity has been shown to cause yield loss in vines. Soil salinity at levels below those that affect yield can still affect fruit quality.

Quality, in terms of sodium and chloride concentration, can be defined as product acceptability in a target market or as a component of the flavour profile.

Market access - Both Australian and overseas wine markets have maximum permissible levels for chloride and/or sodium in wine. In Australia, the maximum allowable chloride concentration in wine is 607 mg/L (equates to 1000 mg/L sodium chloride). Some international markets have lower limits, eg- Turkey with a limit of 303 mg/L chloride (equates to 500 mg/L sodium chloride). Australia and many other markets don't currently impose limits for sodium in wine. But in those that do, the limit can be as low as 60 mg/L, eg – Switzerland.

Conversion of salt in juice to salt in wine

	Sodium Juice : Wine	Chloride Juice : Wine
Chardonnay	1 : 1.1	1 : 1.7
Shiraz	1 : 1.2	1 : 2.3

Adapted from Walker et al. 2010

Flavour - even at concentrations below those set for market access, sodium and chloride can result in undesirable salty flavour characteristics. There is still uncertainty about the salt levels associated with the emergence of these salty characteristics in wine, however wineries are placing increasing emphasis on the allowable concentrations of both sodium and chloride in parcels of fruit purchased by them.

The relationship between concentrations of sodium and chloride in fruit and the level of soil salinity is not unique. It can be modified by rootstocks, timing of high salinity in soil, history of vine exposure to salinity, irrigation method and soil aeration.

Other factors affecting the concentrations of sodium and chloride in vines

Timing – the rate of uptake of chloride into fruit when soil salinity is high between flowering and veraison is double that when salinity is high before or after this growth stage.

Legacy effect – salt can be stored in the permanent structure of the vine and continue to influence fruit quality even after salts have been flushed from soil. If high chloride persists in fruit for one season after soil flushing, then high sodium is likely to persist for two.

Uptake through the leaf – salt enters through leaves more readily than through roots. In an overhead irrigated vineyard, salt concentration in fruit can be 10 times greater than in a drip irrigated vineyard. Similarly, in coastal vineyards, saline aerosols can deposit on leaves leading to increased salt uptake.

Waterlogged soil – can increase vine uptake of sodium and chloride.

Manage – leach, monitor, plant material

The three key elements of managing saline irrigation are: ensuring adequate leaching of salts; knowing soil salinity status; choosing appropriate planting material. These key elements were addressed by a recently completed NPSI project with the code CIF5121. A summary follows and the full report is available from www.npsi.gov.au .

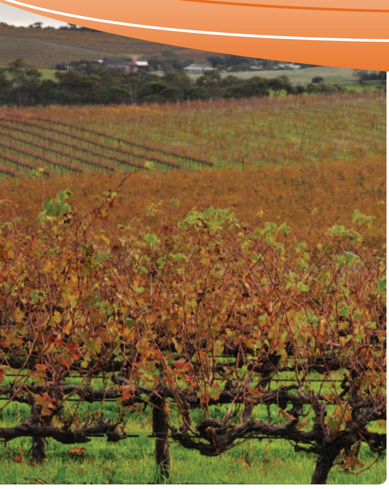
Adequate leaching with saline supplementary drip irrigation

In many of Australia's wine producing regions, rainfall meets vine water requirements in all but the hottest months, when rainfall is supplemented with irrigation. In these regions, irrigation is drawn from groundwater and it is often saline.

Use of saline water is sustainable provided salt does not accumulate in the soil. Under saline supplementary drip irrigation, the salts are added with the irrigation and the water to flush salt through the soil is provided by rain. The salinity of a soil is indicative of the balance between these two processes. Insufficient rain leads to salt build up and sufficient prevents it.

To assess whether rain was sufficient we measured the across row distribution of soil salinity in three salt affected vineyards in south east Australia. Soil measurements were made just after harvest. The soil immediately under the vines after harvest was saline, ECe above 7 dS/m, whereas the soil in the mid-row was non-saline, ECe below 1.5 dS/m (Figure 2).

The low salinity of soil in the mid-row indicates that the amount of rain falling there was more than sufficient to flush any salt which may have migrated there from soils under the drippers. In contrast the high salinity under the vine indicates that the amount of rain falling there was insufficient to flush salts.



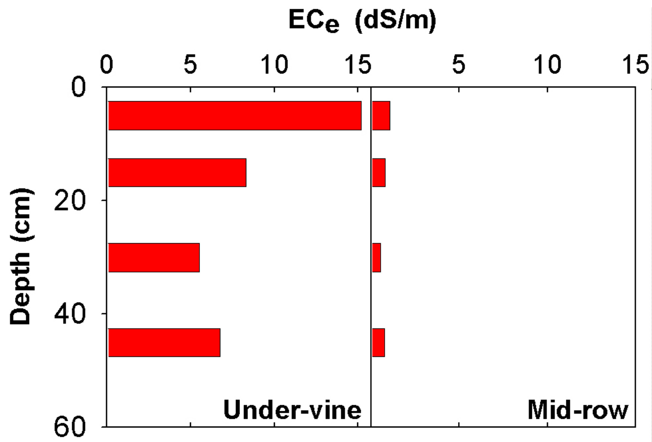


Figure 2. Soil salinity under the vine and in the mid-row in a salt affected vineyard.

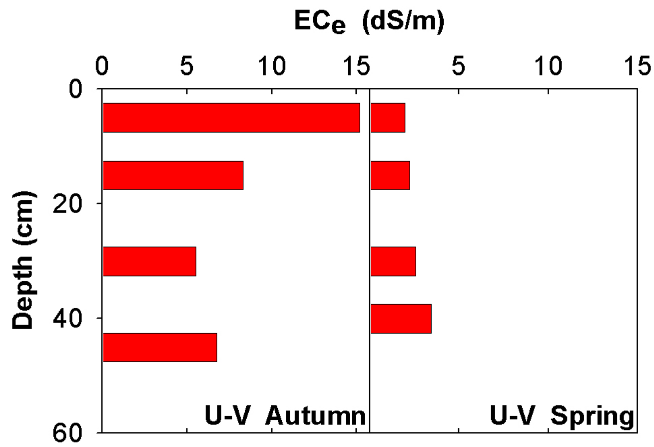


Figure 3. The effect of winter rain on flushing of salt from under-vine soils in a salt affected vineyard.

Soils under the vine were also sodic with average ESP of 16%.

Soil sodicity can reduce soil permeability to low salinity water such as rain. If this effect was present, then rain would be less effective at flushing soil salts. Figure 3 shows that winter rains flushed most of the salt from the under vine soils. Even though the soils were sodic, when rain was sufficient, the salts were flushed from the soil.

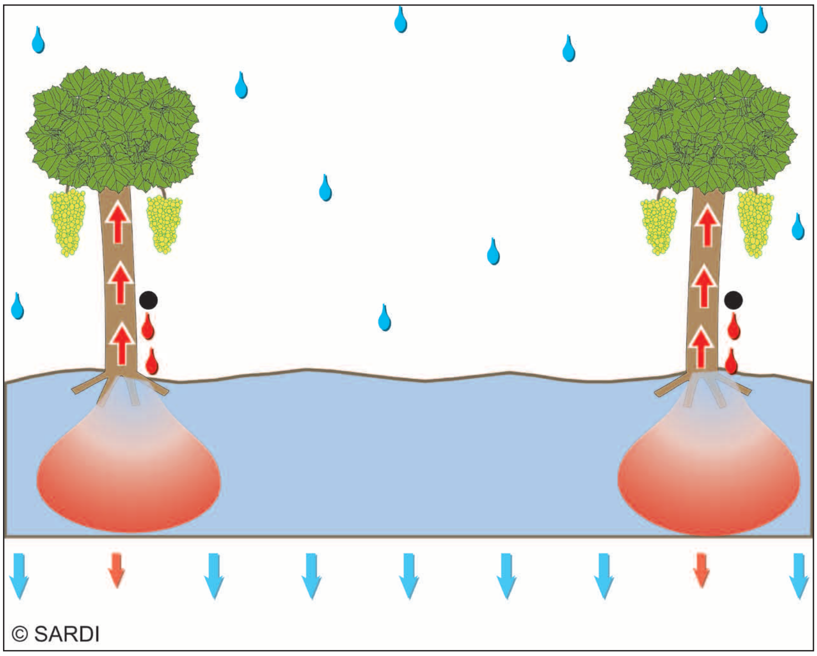


Figure 4. Looking down the row of a vineyard irrigated with saline water. Saline soil below dripper leads to high salt uptake by vine. Uniform distribution of rain across the row results in mid-row drainage without adequate flushing of under-vine soils.

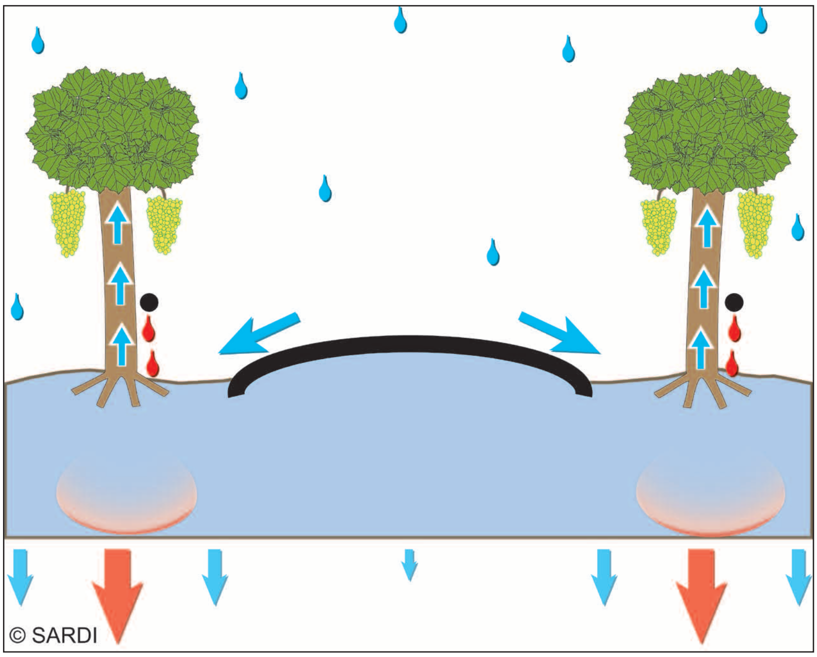
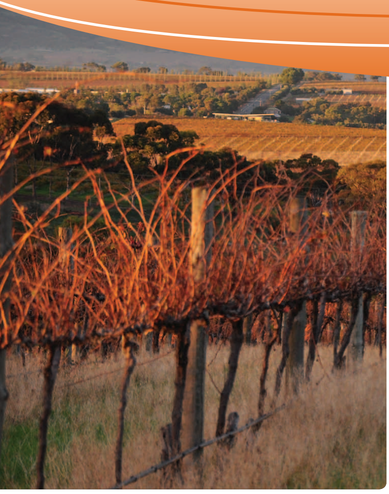


Figure 5. Experimental rainfall redirection treatment applied. Drainage and salt removal from under-vine is increased. Mid-row drainage reduced. Lower salt uptake by vine.



We hypothesised that redirecting rainfall from the mid-row to under the drip line would reduce soil salinity during the growth season.

In vineyards where vines were suffering salinity damage, we envisaged that the across row distribution of salt in soil, and in water draining from these soils, is as shown in Figure 4. Drip irrigation with saline water leads to a build up of the soil in the soil under-vine. Rain falls uniformly across the vineyard. Mid-row soils are non-saline and drainage from this area of soils does not carry salt out of the rootzone. Drainage from the soil under-vine is not sufficient and the concentration of salt in this area of soil is high enough to cause salts to enter the vine.

Figure 5 shows the same processes in a vineyard where the soils are mounded in the mid-row and covered with plastic. These modifications re-direct rainfall from the mid row to soils under the vine. This increases the amount of water draining through the under-vine soils and reduces that draining through the mid-row soils. The extra flushing under-vine removes more salt and, as a result, the concentration of salt in this area is low and salt entry into the vine is reduced.

We tested this proposal in a "proof of concept" trial. The amount of work required to maintain the plastic was in excess of that available in a commercially setting and hence the label, "proof of concept".

Re-direction of rainfall reduced soil salinity by 38% and reduced the concentrations of sodium and chloride in petioles by 23% and in juice by 35% on average. Rainfall re-direction shows promise as a technique which may improve the sustainability of supplementary irrigation with saline water.

Monitor

Improvements in the management of saline irrigation require a tool with which managers can readily assess a vineyard's salinity status. Currently, the techniques used to assess the salinity status of vineyards are the same as those used by researchers. These techniques have been widely used and have a set of well established numbers that indicate the level of salinity stress. This advantage, however, is offset by other characteristics. The techniques are labour intensive and require laboratory analysis which increases the cost and extends the time elapsing between sampling and when a value can be had.

Soil water extractors, Figure 6, provide a measure of soil salinity that is readily obtainable in the vineyard. However, the relationship that the values of salinity obtained with this technique have with those obtained using established techniques is unclear.

Figure 6. Soil water extractor

The relationship between measures of salinity made with the soil water extractor, EC_{SW}, and the conventional measure undertaken on the extract from a saturated soil paste, (EC_e), was determined across a salinity monitoring network in south east of Australia, Figure 7. While the relationship is significant, the scatter is too great for it to be used as a basis for calibration. However, the relationship shows potential for EC_{SW} measures to be used as guides.

For own rooted grapevines, yield decline begins at soil salinity EC_e above 2.1 dS/m. At EC_{sw} of less than 3.5 dS/m, no value of EC_e was above the threshold for salinity damage of 2.1 dS/m. Thus any measure below 3.5 dS/m indicates acceptable soil salinity. For extracts with salinity between 3.5 and 7 dS/m, the soil salinity could be either excessive or below the level of concern, and, for values in this range, a definitive assessment of vineyard salinity status could only be obtained by application of other methods. Values of EC_{sw} above 7 dS/m indicate an EC_e greater than 2.1 dS/m, and an unacceptably high level of soil salinity.

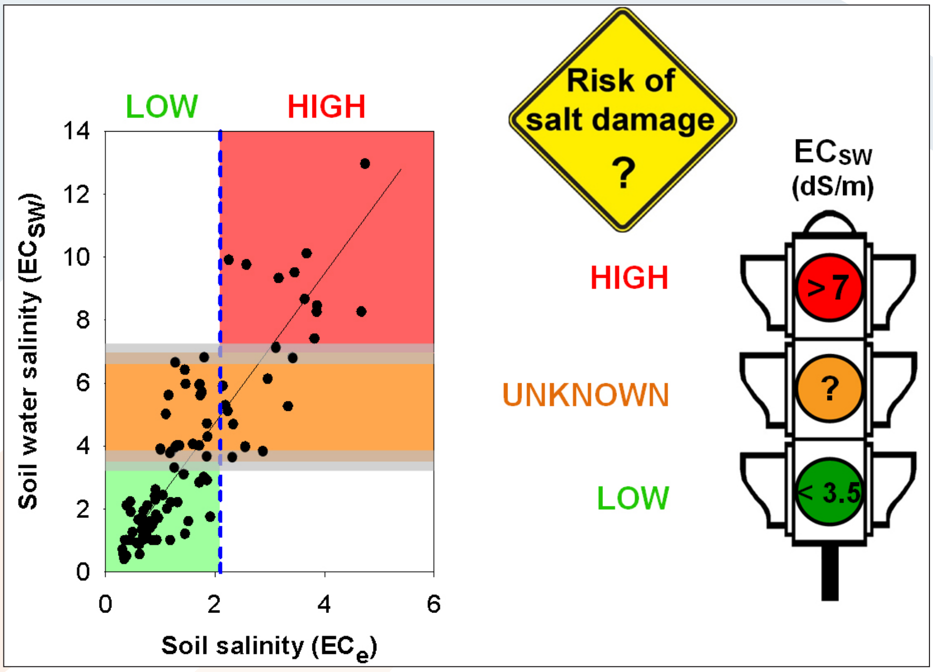


Figure 7. Relationship between soil water salinity EC_{sw} and soil salinity EC_e in South Australian vineyards in Spring. Soil salinity yield decline threshold (2.1 dS/m EC_e). EC_{sw} below ~3.5 dS/m equates to EC_e below 2.1 dS/m. EC_{sw} above ~7 dS/m equates to EC_e above 2.1 dS/m.

Salt excluding rootstocks

While salt tolerant rootstocks can reduce the effect of salt on yield decline, salt tolerance does not equate to salt exclusion and fruit quality remains susceptible at salt levels below those that affect yield.

Salt excluding rootstocks can be used to reduce the effect of excessive soil salinity on fruit, and, hence wine, sodium and chloride concentrations in vines growing on soils with elevated salinity. Exclusion is a relative property and rootstocks are most commonly benchmarked against the concentrations of sodium and chloride in fruit from own rooted vines. Most of the information on the exclusion properties of rootstocks has been generated in settings where the salinity pressure was below that expected to affect yield, that is the concentrations of sodium and chloride in leaf petioles sampled at flowering were below values indicative of salinity stress.

For 24 year old grafted Chardonnay vines growing on deep sands in the south east Australia, Table 1 shows the rootstocks that had yields matching or in excess of those on own rooted vines and that could reduce juice concentrations of either sodium or chloride to at least half that in fruit from own rooted vines. The use of Ramey, K51-32, SO4, 5C Teleki, and Fercal, stocks halved juice chloride levels with out loss of yield. The stocks K51-32, SO4, 5C Teleki and Fercal halved juice sodium levels with out loss of yield. Rootstock effects on sodium and chloride exclusion can also depend on scion variety.

Table 1. the effect of rootstock on yield and juice salt concentrations of grafted Chardonnay relative to Chardonnay on own roots. Yield - ✔ if yield from the grafted vines were greater than or equal to that from own rooted vines. Juice sodium and chloride - ✔ if the respective concentration was less than half that in fruit own rooted vines. (Stevens et al. 2011)

Rootstock	Yield	Sodium	Chloride
Ramsey	✔		✔
K51-32	✔	✔	✔
K51-40	✔		
Schwarzmann		✔	✔
SO4 8341	✔	✔	✔
5C Teleki	✔	✔	✔
Fercal	✔	✔	✔
Freedom			✔

Further reading

Stevens, R.M., Pitt, T.R., and Dyson, C. (2012) Managing soil salinity in groundwater irrigated vineyards. Final Report to the National Program for Sustainable Irrigation. Project Number CIF5121.

References

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