Overhead irrigation management for improved grapevine yield and quality under saline conditions.

FINAL REPORT to
GRAPE & WINE RESEARCH & DEVELOPMENT CORPORATION
PROJECT NO. DAS 16GW

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Organisation : Primary Industries South Australia
Date : 1998

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Final Report

Overhead irrigation management for improved grapevine yield and quality under saline conditions.

MDBC-NRMS NLP COMMUNITY GROUP APPLICATION CCW Co-operative Ltd
Project nos. S3137
GWRDC Project nos. DAS 16GW

Primary Industries South Australia

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Summary

Over three consecutive seasons, Colombard vines on Ramsey rootstock were irrigated with saline water (EC 3.5 dS/m) by overhead sprinklers during three of four physiologically distinct stages in the vine's seasonal growth cycle. From harvest to leaf-fall and at other times they were irrigated with river water (average EC 0.5 dS/m) as was a control treatment which received river water throughout the season.

Saline irrigation between bud-burst and full-bloom (BB-FB), between full-bloom and veraison (FB-V), and between veraison and harvest (V-H) reduced the cumulative yield by 3%, 10% and 17%, respectively.

Comparison with a trial identical in all respects, excepting that irrigations were applied by dripper, showed:
i) that the maximum yield loss was six fold greater with overcanopy irrigation
ii) that the concentrations of Cl and Na in the leaf and those in the juice were respectively two and between five and fifteen fold greater with (saline or non-saline) overcanopy irrigation.

In the second and third seasons, vines irrigated by overhead sprinkler (both saline and non-saline treatments) had a sodium excess (concentration of Na greater than that of Cl) in the juice of greater than 2.5 mM. Sodium is not lost during vinification and an excess of more than 2.5 mM is undesirable in wine destined for European markets.

In the field trial, the concentrations of Cl and Na in the leaves of Colombard vines were highly correlated with the concentrations of the respective ion in the juice.

The effect of foliar salt uptake on the leaf concentrations of Chardonnay, Shiraz, Ruby Cabernet and Sultana, on either their own-roots or Ramsey rootstock was investigated using potted immature vines. With saline overhead irrigation (26 mM NaCl), the Cl concentration in the leaves of Shiraz was 31% greater than the that in the other three varieties where the concentrations were equivalent and the Na concentration in Shiraz was 129% and in Sultana 28% greater than in the two other varieties where the concentrations were equivalent.

Recommendations

1) Where saline conditions are expected during the irrigation season and an opportunity exists to time the application of saline water, then to minimise yield loss saline irrigations should be applied in order of preference between harvest and leaf fall or before full bloom, between full bloom and veraison and if no other option exists then between veraison and harvest.

2) Where saline irrigation water is a regular feature of viticulture then avoidance of irrigation application by overhead is likely to reduce yield losses to salinity by at least 50%

3) Where saline conditions exist and fruit is destined for markets which have requirements of low NaCl or/and low Na in excess of Cl the fruit be preferentially sourced form vineyard which are irrigated by undercanopy methods.

4) That the varietal effects on uptake of Na and Cl under overhead irrigation be investigated in the field to identify varieties with low and high uptake characteristics. In the development or redevelopment of vineyards, that the choice between under and over canopy irrigation systems be made after considering the uptake characteristics of relevant varieties.

Aims and findings pertinent to them

To identify irrigation management strategies which reduce the yield loss and lower juice sodium due to overhead irrigation with saline water.

- Yield losses depend on the timing of saline irrigation and the later in the seasonal growth cycle that the saline irrigation is applied the greater the loss - for saline irrigation between bud burst and full bloom, full bloom and veraison, and veraison and harvest the yield losses were 3%, 10% and 17%. Juice sodium concentrations with saline irrigation between either full bloom and veraison or veraison and harvest were more than double those with saline irrigation between bud burst and full bloom. Relative to other growth stages before harvest, the application of saline irrigation before full bloom will give the least yield loss and the lowest juice sodium.

To quantify an avoidable source of sodium and chloride contamination of grape juice.

- The juice Na and Cl concentrations in grapevines irrigated with either saline (EC 3.5 dS/m) or non-saline (EC 0.5 dS/m) water applied by overhead sprinkler irrigation were between five and fifteen fold greater than the concentrations when the same irrigations were applied by undercanopy methods. Substituting overcanopy irrigation with an undercanopy system will reduce juice Na and Cl concentrations.

To separately quantify growth reductions due to the uptake of salt by the foliage from that due to the uptake of salt by the roots for glasshouse grown vines.

- Saline (26 mM NaCl) foliar irrigation over 27 weeks reduced total vine growth by 14% while saline root irrigation had no effect.

- Comparing results from the present field trial with those from a trial identical in all respects, excepting that irrigations were applied by dripper, showed that the maximum of 17% yield loss with irrigation which wets the foliage was much greater than the maximum of 3% loss with drip irrigation.

To provide an irrigation management strategy which supports an economically viable method of saline water disposal, quantify the agricultural costs associated with this strategy, and assess the response of important grapevine varieties to saline water disposal with overhead and undercanopy irrigation.

- With overhead irrigation of Colombard vines on Ramsey rootstock up to 16% of the annual water requirement may be met by water with an EC of 3.5 dS/m without a significant yield loss provided it is applied before full bloom. If the water is applied by dripper then up to 40% of the annual water requirement may be met by water with an EC of 3.5 dS/m provided it is applied between veraison and harvest.

Personnel

Research - R.M. Stevens
Extension - S.W. Norton
Technical - G. Harvey and W. Frahn
Statisticians - D. Partington and A. Frensham
Farm staff - J. Draper
Managers - G. Davies and A. Meissner

Communications

A seminar `Effects of saline irrigation on grapevine yield and wine quality' presented to the board of CCW Co-operative Ltd in March 1993.

A field day `Overhead irrigation management for improved yield and quality under saline conditions' as held in October 1994 for members of CCW.

Publications

Stevens, R.M., G. Harvey and G. Davies. Separating the Effects of Foliar and Root Salt Uptake on Growth and Mineral Composition of Four Grapevine Cultivars on their Own-roots and on Ramsey Rootstock. Submitted to the Journal of the American Society for Horticultural Science 6/1995.

Stevens, R.M., S. Norton and G. Harvey. Response of grapevines to saline over canopy irrigation during different growth stages. In preparation for submission to Agricultural Water Management.

EXPERIMENT 1

Objectives

To determine the yield response of overhead irrigated field vines to transient salinization of the irrigation water.

To quantify the contribution that foliar uptake of salt makes to juice chloride and sodium content.

Materials and Methods

Over three consecutive seasons, Colombard vines on Ramsey rootstock were irrigated with saline water (E.C. 3.5 dS/m) by overhead sprinklers during three of four physiologically distinct stages in the vine's seasonal growth cycle. Saline irrigation was applied to treatment BB-FB from bud-burst to full-bloom, treatment FB-V from full-bloom to veraison, to treatment V-H from veraison to harvest. From harvest to leaf-fall and at other times they were irrigated with river water (E.C. 0.5 dS/m) as was treatment CONT, a control, which received river water throughout the season. Irrigation water was salinised by the addition of a NaCl brine.

Irrigation scheduling was based on measurements of soil water content which were made with a neutron moisture meter. Irrigations were applied whenever the soil water deficit reached 60 mm. At this deficit the average matric potential in the 1.6 m deep rootzone was -25 kPa.

Water and soil salinity were regularly measured. The response of grapevines was quantified by regular measurements of tissue Na and Cl concentrations, vegetative and fruit growth. These results were compared with those obtained in the same vineyard with an experiment where the vine underwent identical treatments except that irrigation was applied by dripper (Stevens, 1995/96).

Results and Discussion

The irrigation schedule produced a variation in the volume of water applied in each growth stage. Over the three seasons, the percentages of the seasonal application applied in the growth stages BB-FB, FB-V, V-H and harvest to leaf fall (H-LF) were 16%, 39% , 37% and 12% respectively. This variation in turn produced a variation in the amount of salt applied per season in each treatments. The seasonal salt loads can be characterised by assuming that the salt load, which was applied in a two month period, was evenly spread across the season which gives annual average ECw in treatments V-H, FB-V and BB-FB of 1.4, 1.5, and 0.8 dS/m. The ECw of the CONT was 0.4 dS/m.

Soil salinities rose following saline irrigation and sometimes remained elevated after the end of saline irrigation. Over the entire trial the maximum values of the root weighted ECe (RWECe) for treatments BB-FB, FB-V and V-H were 2.3, 3.5 and 3.1 dS/m. At bud-burst in the second season the RWECe's of treatments FB-V and V-H were greater ($P<0.10$) than that in the CONT indicating that elevated soil salinity in this and the subsequent season was due both to salt applied within the season and that applied in the preceding season(s).

The Na and Cl concentrations in leaf petiole samples taken one month after budburst in the second season were elevated in all saline treatments. Increases in the levels in treatments FB-V and V-H preceded the annual application of saline irrigation. They were due to a carryover of salt in either the soil or the grapevine or both from the previous season. Such a carryover was also present in the third season. The carryover of salt within the soil and within the vine indicates that the vine experienced salinity stress beyond the duration of the saline irrigation.

Saline irrigation increased the leaf lamina concentrations of Na and Cl (Table 1). The differences between saline treatments were due to differences in both the timing of saline irrigation and the seasonal salt load. The confounding effect of differences in the seasonal salt loads was reduced by normalising the data. This consisted of dividing the amount that the value of a parameter in a saline treatments deviated from that in the control treatment by the difference between the seasonal salt loads in the two treatments. The resultant value indicated the rate of change in the parameter per unit increase in the seasonal salt load. Using the concentrations in the blade at harvest in the third season, the normalised data for BB-FB, FB-V and V-H were, for Cl, 234, 74 and 262 mmol/kg.dS/m and for Na, 234, 78 and 538 mmol/kg.dS/m. The uptake of Na and Cl per unit salt load was lower with saline irrigation between full bloom and veraison. This contrasts with the pattern under drip irrigation where the uptake rate for both Na and Cl was lower with saline irrigation between either full bloom and veraison or veraison and harvest (Stevens, 1995/96).

Saline irrigation did not affect either pruning weight or the annual change in butt circumference.

In the second season, saline irrigation in any growth stage before harvest reduced yield (Figure 1). In the third season, saline irrigation applied between full-bloom and harvest, i.e. treatments FB-V and V-H, reduced yield.

Saline irrigation only affected one of the three harvest components. It reduced the weight of 100 berries in all three seasons with the greatest reduction occurring in treatment FB-V (Figure 1). It did not affect either the number of bunches per vine or the number of berries per bunch.

Table 2 shows that the yield loss in the first three seasons of saline irrigation can be up to nearly six fold greater when irrigation is applied by overcanopy rather than undercanopy methods. Further, the sensitivity of yield to the growth stage at which saline irrigation is applied was dependent of the type of irrigation. With drip irrigation the most sensitive period

was between full bloom and veraison, whereas with overhead irrigation the most sensitive period was between veraison and harvest.

Table 1. Effects of applying saline irrigation by overcanopy sprinkler and by dripper at different growth stages on the Na and Cl concentrations in leaf lamina and berry juice of grapevines. Data from leaf lamina and berries samples taken at harvest in the third consecutive season of saline irrigation. Data for drip irrigated vines drawn from Stevens (1995/96).

	CONT	BB-FB	FB-V	V-H
		Leaf lamina (mmol/kg d.w.)		
		Sodium		
Dripper	32.6	91.3	140.3	184.9
Overcanopy	61.7	167.9	145.3	508.9
		Chloride		
Dripper	63.1	115.0	124.1	150.2
Overcanopy	132.0	237.5	210.4	349.8
		Berry juice (mM)		
		Sodium		
Dripper	0.5	2.2	3.6	2.9
Overcanopy	7.3	11.1	28.0	29.8
		Chloride		
Dripper	0.3	0.9	1.3	0.8
Overcanopy	3.8	7.1	20.8	14.2

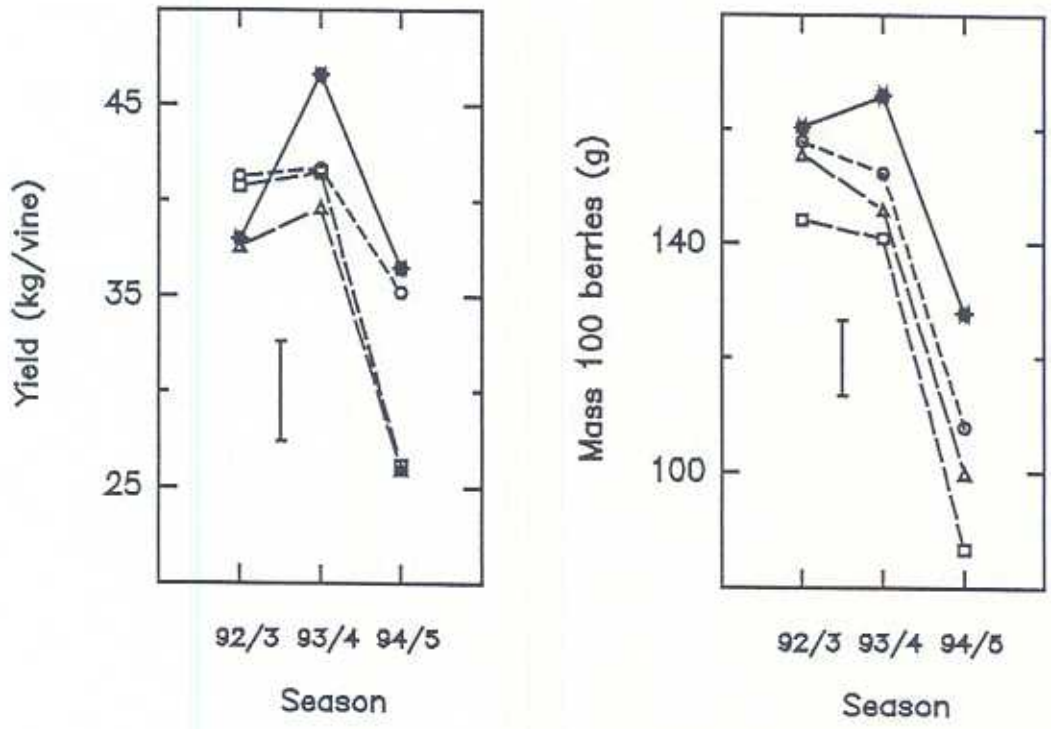


Figure 1 The effects of treatments on yield and berry weight. Bar indicates l.s.d. at $P = 0.05$. BB-FB(○), FB-V(□), V-H(_) and CONT(●).

Table 2. Effects of applying saline irrigation by overcanopy sprinkler and by dripper at different growth stages on the yield relative to that in the CONT treatments. Data from cumulative yield in the first three consecutive season of saline irrigation. Data for drip irrigated vines drawn from Stevens (1995/96). (CONT - control; BB-FB bud burst to full bloom; FB-V full bloom to veraison; V-H veraison to harvest)

Treatment	CONT	BB-FB	FB-V	V-H
Period of salinisation	-	BB-FB	FB-V	V-H
		Overcanopy sprinkler		
Annual salt load (dS/m)	0.44	0.78	1.47	1.41
Yield as %CONT	100%	97%	90%	83%
		Dripper		
Annual salt load (dS/m)	0.44	0.79	1.46	1.60
Yield as %CONT	100%	101%	97%	100

Saline irrigation increased the concentrations of Na and Cl in the grape juice (Table 1). The concentrations of Na and Cl in the berry were positively correlated with that of the respective ion in the leaf lamina for ($P < 0.001$ for both). Normalising the data from the third season gave for treatments BB-FB, FB-V and V-H rates of 7, 16 and 13 mM.dS/m for Cl, and 8, 19 and 27 mM.dS/m for Na. The uptake of Na and Cl per unit salt load was higher with saline irrigation applied after full bloom i.e. between full bloom and veraison, and between veraison and harvest. This contrasts with the pattern under drip irrigation where the uptake rate for both Na and Cl was lower with saline irrigation between veraison and harvest (Stevens, 1995/96)

Table 1 shows that with overhead irrigation the leaf Na and Cl concentrations in both the saline and non-saline treatments were at least double that when the same treatments were applied with drip irrigation. The effect of varying the type of irrigation is more marked when the concentrations of Na and Cl in grape juice are considered. With overhead irrigation the juice Na and Cl concentrations in both the saline and non-saline treatments were on average ten and thirteen fold greater than those with drip irrigation.

In the second and third season, the mM of Na in excess of that of Cl in grape juice from vines in the saline and non-saline treatments was greater than 2.6 mM Na is not lost during vinification and therefore it is likely that the Na excess in wines would also be greater than 2.6 mM. The Na excess should remain below this level in wines destined for the EEC (Lee, 1990). In all treatments, except FB-V in the third season, the NaCl concentration in the juice remained below the acceptable upper limit for wine, 17.5 mM (Lee, 1993).

EXPERIMENT 2

Objective

To separate the loss in growth due to uptake of salt by the foliage from that due to uptake of salt by the roots in glasshouse vines.

Materials and Method

The effect of foliar salt uptake on potted grapevine growth and ionic composition was investigated in a split plot trial. The main plot was a two by two factorial of irrigation treatments [combinations of plus (+S) or minus (-S) salt in the foliar (F) and root (R) irrigation solutions] and the sub-plot was a four by two factorial (combinations of four cultivars, Chardonnay, Shiraz, Ruby Cabernet and Sultana, either on their own-roots or Ramsey rootstock). The NaCl concentrations in saline and non-saline solutions were 26 and 3 mM.

Results and Discussion

Saline foliar irrigation over 27 weeks reduced total vine growth by 14% while saline root irrigation had no effect. Neither rootstock nor cultivar modified this response. These results probably do not translate to the field where irrigation with 26 mM NaCl would produce a higher concentration of salts in the soil water. In the interval between irrigations, the processes of evaporation and transpiration concentrate salts in the soil water. Where the irrigation frequency is reduced to once every 14 days, as in the field, the effect of these processes would be significant, whereas in the present study, which was irrigated five times per day, the effect was negligible.

Leaf Na and Cl concentrations were elevated by both saline foliar and saline root irrigation. The increases above the concentrations in the non-saline control with saline foliar irrigation were four times those with saline root irrigation. Both rootstock and cultivar modified the effects of the irrigation treatment. Averaged over the four varieties, the ratio of the lamina Cl concentration in scions on Ramsey rootstock to those own-rooted vines was 0.5, 0.8 and 0.9 for treatments F-SR-S, F-SR+S and F+SR+S, respectively (Table 3). With saline irrigation of both roots and foliage the Cl and Na levels were highest in the leaves of Shiraz, but with saline irrigation of only the roots Sultana had the higher levels of leaf Cl and Shiraz the highest leaf Na (Table 4).

Given the finding that the concentrations of Na and Cl in the juice are highly correlated with the concentrations of the respective ions in the leaf, it is likely that under overhead irrigation the concentration of Na and Cl in juice from Shiraz will be higher than that in juice from Chardonnay, Sultana and Ruby Cabernet.

Table 3. The effects of saline(+S) foliar(F) and root(R) irrigation on the concentrations of Cl and Na in the leaves of grapevines on their own-roots and Ramsey rootstock. Data were log transformed for analysis and the untransformed values of concentration (mmol/kg dry weight) are enclosed in parenthesis.

	Irrigation treatment		
	F-S,R-S	F-S,R+S	F+S,R+S
	Chloride		
Own-rooted	2.29 (198)	2.40 (260)	2.70 (502)
Ramsey	2.01 (103)	2.31 (212)	2.66 (468)

l.s.d. 0.03 ($\underline{P}$ = 0.05)for comparison between rootstock species receiving the same irrigation treatments and for comparison between different irrigation treatments with the same or different rootstock species.

	Sodium		
Own-rooted	1.63 (48)	1.81 (77)	2.48 (336)
Ramsey	1.55 (37)	1.97 (102)	2.52 (355)

l.s.d. 0.05 ($\underline{P}$ =0.05) for comparison between rootstock species receiving the same irrigation treatments: 0.07 ($\underline{P}$ = 0.05) for comparison between different irrigation treatments with the same or different rootstock species.

Table 4. The effects of saline(+S) foliar(F) and root(R) irrigation on the concentrations of Cl and Na in the leaves of four grapevine cultivars. Data was log transformed for analysis and the untransformed values of concentration (mmol/kg dry weight) are enclosed in parenthesis.

	Irrigation treatment		
	F-S, R-S	F-S, R+S	F+S, R+S
	Chloride		
Chardonnay	2.14 (144)	2.30 (205)	2.63 (432)
Sultana	2.17 (166)	2.46 (294)	2.66 (463)
Ruby Cabernet	2.18 (153)	2.36 (238)	2.66 (457)
Shiraz	2.11 (139)	2.31 (206)	2.77 (590)

l.s.d. 0.10 ($\underline{P} = 0.05$) for comparison between cultivars in the same irrigation treatment: 0.05 ($\underline{P} = 0.05$) for comparison between irrigation treatments with the same or different cultivar.

	Sodium		
Chardonnay	1.43 (28)	1.73 (56)	2.39 (256)
Sultana	1.63 (44)	1.92 (86)	2.50 (317)
Ruby Cabernet	1.57 (44)	1.75 (60)	2.37 (239)
Shiraz	1.73 (54)	2.17 (156)	2.74 (569)

l.s.d. 0.12 ($\underline{P} = 0.05$) for comparison between irrigation treatments with the same or different cultivar: 0.10 ($\underline{P} = 0.05$) for comparison between cultivars receiving the same irrigation treatment.

References

Lee, T.H. (1990). Chloride and sodium ions in Australian wines. Aust. Wine Research Inst., Technical Review 68:2-7.

Lee, T.H. (1993). Australian/EC wine agreement. Aust. Wine Research Inst., Technical Review 82:10-12, 33-36.

Stevens, R.M. The response of grapevines to transient soil salinisation. M Sc. Thesis submitted to the University of Adelaide for examination 10/95.

Facsimile Message

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Number of Pages including cover sheet 3	

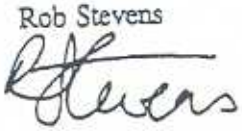
COMMENTS

Peter

The attached fax is two page proposal seeking funding to analyse data collected from vines previously in GWRDC Project # DAS 16GW entitled `Overhead irrigation management for improved grapevine yield and quality under saline conditions'. The data has been collected in the three seasons which have elapsed since completion of this project in 1995.
I have also sent an electronic copy of the proposal to you via e-mail.

Regards

Rob Stevens



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Extension of the GWRDC Project # DAS 16GW entitled `Overhead irrigation management for improved grapevine yield and quality under saline conditions'

Background

The effect of three seasons (1992-93 to 1994-95) of saline irrigation on yield was detailed in the final report for the project entitled `Overhead irrigation management for improved grapevine yield and quality under saline conditions' . This study quantified the losses which occurred whilst saline irrigation was in progress.

In brief, the study investigated the effect of applying saline irrigation (EC 3.5 dS/m) during any one of the first three of the four 4 physiologically distinct stages in the seasonal growth of mature vines. At other times, plots were irrigated with river water (EC 0.4 dS/m), as was the control throughout the season. The vines were irrigated by overhead sprinkler. Based on raw data averaged over three seasons, saline irrigation pre-anthesis caused a 2% yield loss, saline irrigation during berry development caused a 10% yield loss and that during berry ripening a 13% yield loss. These losses were associated with elevated levels of sodium and chloride in grapevine leaves and juice.

In 1995 the irrigation system at the study site was converted to drip and over the next three seasons (1995-96 to 1997-98) all the vines were irrigated with non-saline river water throughout the entire season. In every season, vine yield was measured and in some seasons the sodium and chloride levels in the leaves and juice were measured.

Based on raw data averaged over three seasons, the yield loss (relative to that of vines previously in the non-saline control) in vines which had previously received saline irrigation pre-anthesis was 3%, that in vines which had previously received saline irrigation during berry development was 10% yield loss and that during berry ripening was 24% yield loss. At harvest in 1998, the levels of sodium and chloride in the leaf and juice of all treatments were below those in the non-saline control at harvest in 1995 i.e. at the end of the first three seasons period.

During the three seasons, 1995-96 to 1997-98, the yield of the treatment which was previously irrigated with saline water during berry ripening has continued to decline. The average loss during the three-season recovery period was double that during the three seasons of saline irrigation. Likewise, during the latter three seasons of this study the yield of the treatment which was previously irrigated with saline water during berry development had failed to recover. The average losses during the recovery period were equal to those during the period of saline irrigation. Both the continued yield decline and the failure to achieve recovery have occurred whilst vine sodium and chloride levels have fallen to pre-saline irrigation levels.

Implications

Preliminary analyses of the data in this study suggests that the losses during recovery from a period of saline irrigation are equal to or greater than those during application of saline irrigation. This suggests that development of strategies to minimise losses during recovery will be as important as development of strategies to minimise losses during periods of saline irrigation. Before giving consideration as to

whether to invest in such development, these observations will need to be rigorously analysed and documented in a form subject to peer review.

Current research into managing salinity in viticulture relies heavily on developing rootstocks which exclude sodium and chloride. This research is based on observations that during saline irrigation the growth of vines is proportional to the amount of chloride and sodium within the vine. Preliminary analyses of the data in this study suggests that the losses during recovery from a period of saline irrigation are not associated with high concentrations of chloride and sodium in the vine. Before this observation can be useful in guiding future research, it needs to be braced with details of the soil ECe and vine tissue sodium and chloride concentrations. These samples have been collected, but have not yet been analysed.

Work to be done

Funds are sought to undertake
(i) a statistical analyses of the data collected since 1995.
(ii) analyses of some soil and tissue samples

Costs

- For a full statistical analyses of the data sets will involve identification of the most appropriate model for analysing repeated measures with the addition of co-variate adjustment to remove pre-trial variation and treatment of missing data (in some data sets) – Biostatistics SA has quoted 7 days at $75/hr giving a total cost of $3938.
- For measurement of ECe in soil samples collected since 1995; for measurement of sodium and chloride concentrations in tissue samples collected since 1995 – Analytical Crop Management Service has quoted $1404
- For travel by RM Stevens to and from Adelaide to consult with statistician – 2 trips at 520 km per trip and @ $0.5/km - $520 plus one overnight stay in Adelaide - $110
- Total costs = $5972

Timing

Project extension begin date 1/7/98, end date 30/6/99

Output

Submission of final report describing the recovery of vines from saline irrigation – by 9/99
Submission of paper describing the recovery of vines from saline irrigation to a refereed journal - by 12/99