SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Irrigation strategies for improving Water Use Efficiency



TRAVEL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **SAR 03/10**

Principal Investigator: **Shannon Pudney**

Research Organisation: **SARDI**

Date: **16th January 2004**

ABSTRACT 3
EXECUTIVE SUMMARY 4
BACKGROUND 5
PROJECT OUTPUTS 5
1. IRRIGATION SYMPOSIUM 6
1.1 PARTIAL ROOTZONE DRYING/ DEFICIT IRRIGATION 6
Grapevines 6
Other Crops 7
Summary 9
Miscellaneous 9
1.2 PLANT BASED MEASUREMENTS 10
Stem and Leaf Water Potential 10
Deficit irrigation strategies using stem water potential in winegrapes 11
1.3 SUSTAINABLE PRODUCTION 12
Gravel Vertical Mulching 12
1.4 WATER QUALITY 13
Effects of recycled water on soil salinity levels of cool season vegetables 13
2. CALIFORNIA STATE UNIVERSITY – FRESNO 14
2.1 GENERAL INFORMATION – SAN JOAQUIN VALLEY 14
2.2 DR ROBERT WAMPLE (PROFESSOR AND CHAIR) 15
2.3 DR SANLIANG GU (RICCHIUTI CHAIR OF VITICULTURE RESEARCH) 16
3. GOLDEN STATE VINTNERS TAILGATE MEETING 17
4. UNIVERSITY OF CALIFORNIA KEARNEY AGRICULTURAL CENTRE 19
4.1 DR DAVID GOLDHAMER (IRRIGATION MANAGEMENT SPECIALIST) 19
4.2 PROFESSOR LARRY WILLIAMS 19
APPENDIX 1 21
PAPER SUBMITTED FOR PUBLICATION IN ACTA HORTICULTURAE 21
APPENDIX 2 30
ARTICLE PUBLISHED IN THE JANUARY 2004 ISSUE OF THE AUSTRALIAN AND NEW ZEALAND GRAPEGROWER AND WINEMAKER 30
APPENDIX 3 34
CONTACTS 34

ABSTRACT

The objective of this project was to attend and present research at the 4th International Symposium on Irrigation of Horticultural Crops (International Society of Horticultural Science). A presentation entitled "Water Use Efficiency of Field Grown Chardonnay Grapevines Subjected to Partial Rootzone Drying and Deficit Irrigation" was presented at the conference. A paper (with the same title) has been submitted to Acta Horticulturae for publication in the conference proceedings. The major finding of the study tour is that deficit irrigation can achieve the same improvements in water use efficiency as partial rootzone drying. Results from recent field trials (Israel, America, Australia) suggest that it is the volume of water applied that determines the vine response. It does not matter if the water is applied to alternate portions of the rootzone or repeatedly to the same area.

EXECUTIVE SUMMARY

Results from recent field trials in Israel, America and Australia suggest that partial rootzone drying does not confer any advantage over conventional irrigation when the same volume of irrigation water is applied. Many researchers are now looking for alternative ways of improving vineyard water use efficiency. At the present time, imposing a sustained deficit (placing vines under water stress for majority of growing season) is the favoured approach. Researchers are also investigating the possibility of using plant based measurements to improve irrigation scheduling in vineyards. Midday stem water potential and trunk diameter measurements are emerging as possible scheduling tools.

Portable pressure bombs are being used to measure midday stem water potential in Californian vineyards. It is generally accepted that if midday stem water potential is less (more negative) than –10 bar irrigation is required. Threshold values for imposing specific levels of stress are yet to be defined. Although the measure is becoming popular, there are several limitations associated with the method. The measurement of stem water potential is labour intensive and it cannot be automated. Measurements may also only be taken during a relatively short time interval. For these reasons other researchers are focussing on the use of LVDTs (Linear Variable Displacement Transducers) to schedule irrigations. LVDTs measure variations in trunk diameter. Work in peaches suggests that 'trunk' parameters are more sensitive indicators of water stress than soil moisture status and midday stem water potential. It is recommended that the Australian viticultural industry invest in research to determine whether LVDTs or other similar devices can be successfully used as scheduling tools.

Other areas requiring further investigation include:

- The relationship between vine nutrition and berry colour
- The relationship between wetted soil volume and plant nutrient status
- The use of vertical gravel mulching

The major findings of project 2.3.1 were presented at the symposium. A manuscript entitled "Water Use Efficiency of Field Grown Chardonnay Grapevines Subjected to Partial Rootzone Drying and Deficit Irrigation" has been submitted for publication in Acta Horticulturae. An article of general interest, "Are plant sensors the key to irrigation scheduling? An American perspective", was published in the January 2004 issue of the Australian and New Zealand Grapegrower and Winemaker. A seminar to which CRCV and industry personnel are to be invited will be delivered in early 2004. Australia is to host the next ISHS Symposium on Irrigation of Horticultural Crops in 2006.

During the study tour links were established with the following overseas researchers: Dr Horst Caspari, Professor Alan Lakso, Dr Larry Williams, Dr David Goldhamer, Dr Samuel Ortega, Dr Robert Wample, Dr Sanliang Gu, Dr Amos Naor. Collaborative links have also been strengthened with representatives of the Victorian Department of Primary Industries (Ian Goodwin, Yasmin Chalmers and Mark O'Connell), and Sigfredo Fuentes (University of Western Sydney) and Dr Gordon Rogers (Applied Horticultural Research - NSW). A PhD student from Spain (Diego Intrigliolo) has expressed interest in visiting Australia to broaden his research experience.

This project was supported by the Commonwealth Cooperative Research Centres Program and conducted by the CRC for Viticulture (CRCV). Australian grapegrowers

and winemakers are key stakeholders in the CRCV, contributing levies matched by the Commonwealth Government and invested by the Grape and Wine Research and Development Corporation in the Centre. Additional support was received from the South Australian Research and Development Institute and the Grape and Wine Research and Development Corporation.

BACKGROUND

The primary aim of this study tour was to attend and present research at the International Symposium on Irrigation of Horticultural Crops. Meetings were also held with key personnel from the Californian State University (Department of Viticulture and Oenology) and the University of California (Kearney Agricultural Centre). The objective of these meetings was to obtain information on vineyard irrigation practices and to develop contacts with overseas scientists for future collaboration.

PROJECT OUTPUTS

Output	Performance Target	Achieved
1. Travel Report	Complete report submitted to GWRDC	Yes
2. Scientific Manuscript	Submitted to ISHS	Yes

1. IRRIGATION SYMPOSIUM

The 4th International Symposium on Irrigation of Horticultural Crops was held at the University of California, Davis from 1st September to 5th September. The conference attracted approximately 150 delegates representing 20 countries. Formal presentations and posters were presented throughout the course of the symposium. The major topics covered included: crop water requirements, plant water relationships, irrigation scheduling, water quality and he economics of irrigation.

1.1 Partial Rootzone Drying/ Deficit irrigation

Partial Rootzone Drying (PRD) is an irrigation technique that has been reported to double vineyard Water Use Efficiency. Deficit irrigation occurs when the vine is supplied with less water than it requires for optimal growth. Partial rootzone drying and deficit irrigation were the subject of discussion in Session 2 A of the symposium. Summaries of recent trials conducted on grapevines, apples and pears are presented below.

GRAPEVINES

The effect of Partial Rootzone Drying on wine quality, yield and water consumption of red wine grapes - Amos Naor (Golan Research Institute, Israel)

Trial Location: Galilee, Israel

Experimental Set Up:

- 3 year trial on Merlot
- Deep terra rossa soil
- 3 Irrigation levels:
  - 1mm/ day = 0.15 Class A Pan Evaporation (50%)
  - 2mm/ day = 0.28 Class A Pan Evaporation (100%)
  - 4mm/ day = 0.55 Class A Pan Evaporation (200%)
- PRD was implemented at each irrigation level
- Each treatment was watered daily, PRD treatments were switched every 14 days
- Soil moisture monitored with a Neutron Probe
- Measured: yield, pruning weight, bunch no., berries per bunch, gas exchange, brix, pH and TA and conducted a wine sensory analysis

Results

- Differences were found between irrigation levels but not between PRD and Non- PRD.
- PRD had no effect on midday stem water potential, yield, bunch number, and bunch weight
- There was no treatment effect on Brix, pH and TA. The only exception being that Brix was slightly lower in the 200% treatment.
- No treatment effect was detected in the sensory evaluation

Conclusion

- The authors concluded that drip irrigation is a form of "natural' PRD. Under drip irrigation only a small portion of the soil profile is wetted during an irrigation event, hence there are always some roots in contact with drying soil. These roots are believed to trigger the PRD response.

Irrigation of Shiraz wine grapes using partial rootzone drying - Yasmin Chalmers (Department of Primary Industries Victoria, Australia)

Trial Location: Sunraysia, Australia

Experimental Set up:

- 2 year trial on Shiraz
- ?Deep sandy loam
- 4 Irrigation Treatments
  - 100% Control Etc -100% of estimated crop water requirement
  - 50% Deficit - 50% of estimated crop water requirement
  - 50% 14 Day PRD - 50% of estimated crop water requirement, wet and dry sides alternated every 14 days
  - 50% 2 Irrigation PRD - 50% of estimated crop water requirement, wet and dry sides alternated after 2 irrigations

Results:

- Yield was not affected by irrigation treatment
- 14 Day PRD had the lowest berry weights and highest anthocyanin levels (per berry).
- 2 Irrigation PRD and 100% Control had the highest berry weights
- All berries matured at the same time, there was no difference between pH, TA and Brix.
- 3.07 ML/Ha applied to 100% in 2002, 2.61 ML/Ha in 2003
- 1.54 ML/Ha applied to 50% in 2002, 1.3 ML/Ha in 2003
- 50% Deficit and 50% 2 Irrigation PRD behaved very similarly

OTHER CROPS

Progress in the development of partial rootzone drying of apple trees – Dr Horst Caspari (Colorado State University, USA)

Trial Location: Colorado and Washington State

Experimental Setup:

- Several varieties of apple trees (Gala and Fuji on M26) for past 2 years
- All trial sites include Control (well watered trees), PRD and Deficit trees. PRD and deficit trees receive 50% of the water applied to control trees.
- In PRD treatments only half of the rootzone was watered, control and deficit treatments were irrigated over the full rootzone.

Results:

- Gala – no significant treatment effects were observed (yield, fruit size at harvest and post storage quality)
- Fuji – no significant effects on yield and fruit quality in year 1, however mean fruit size was reduced at 1 of the 4 sites in the PRD treatment. In second season Deficit irrigation tended to reduce fruit size and yield.
- At one site PRD and Deficit fruit had firmer fruit with higher total soluble solids (at harvest and after storage)
- Fruit disorders (sunburn, russet, watercore) were not affected by the irrigation treatments.
- Summarised PRD effects as being:
  - Small reduction in yield and fruit size
  - Advances fruit ripening
  - Has no effect on fruit disorders, including sunburn
  - Is associated with slightly more negative leaf water potentials
  - Has no effect on vegetative growth

- Crop coefficients may be reduced as low as 0.3
- Dr Caspari believes that under certain conditions PRD trees respond to water stress differently to deficit trees. His data suggests that PRD treated trees use water more efficiently as there is more water available in the soil profile at the end of the season in PRD treatments.
- PRD vines also seem to retain their leaves longer than deficit trees. Preliminary analysis suggests that early leaf fall may be a result of N depletion in the wetted zone. Relationship between wetted soil volume and nutrition needs investigation.

Partial rootzone drying and deficit irrigation of 'Gala' apples in a semi-arid climate - Todd Einhorn (Western Colorado Research Centre, USA)

Trial Location: Colorado, United States

Experimental Setup:

- Gala apples, semi-arid climate
- 5 treatments
  - Control
  - 25% PRD
  - 50% PRD
  - 75% PRD
  - 50% DI

Results:

- No significant difference in yield or fruit size between any treatments

Conclusion

- All trees may have been over-watered?

Pear water relations under partial rootzone drying - Mark O'Connell (Department of Primary Industries Victoria, Australia)

Trial Location

- Goulbourn Valley, Australia

Experimental Setup

- 3 Treatments
  - 0.5 PRD (50% Etc)
  - 1.0 PRD (100% Etc)
  - Control (100% Etc)
- Crop evapotranspiration (Etc) was estimated using FAO Reference Crop Evapotranspiration (Eto) adjusted for Effective Canopy Cover
- In PRD treatments water was applied to alternate halves of the rootzone on a 14 day cycle
- In control treatments the water was applied to both sides of the rootzone

Results

- 1.0 PRD and Control responded similarly
- 0.5 PRD had reduced fruit growth, decreased (more negative) stem water potentials and increased leaf temperature
- 50% water application results in significant water stress. In this study there was no evidence of a 'PRD stomatal control mechanism.

SUMMARY

Field trials conducted on winegrapes in Israel (Merlot) and Australia (Shiraz) have found that vines elicit the same physiological responses to PRD and deficit irrigation. It appears that it is the volume of water applied, not the method of application that determines the vine response. These results are consistent with the findings of project 2.3.1 (CRCV 99/13).

Work conducted on pears (Goulbourn Valley, Australia) failed to find evidence for the 'PRD stomatal control mechanism'. Dr Caspari (United States) found that there is little, if any difference between 'PRD' and 'deficit' apples. The only difference he noted between the two treatments is that PRD vines tend to retain their leaves longer and have higher end of season soil profile moisture contents compared to deficit trees.

The results presented at the irrigation symposium suggest that deficit irrigation improves WUE by the same amount as partial rootzone drying, with little effect on fruit quality. Past studies have shown that PRD doubles vineyard WUE. The disparity between early and more recent results is most likely an artefact of trial design. Early trials failed to include a 'control' for the PRD treatment. In early studies, the performance of fully watered vines was compared to the performance of vines receiving half the amount of water applied to alternate portions of the rootzone. In these studies it is not possible to distinguish between the effects of deficit irrigation and partial rootzone drying.

Many studies have scheduled irrigations by replacing a fraction of estimated evapotranspiration. How closely this relates to the actual water requirement of the plant is unknown. In project 2.3.1 (CRCV 99/13), irrigations were scheduled according to soil moisture readings. Interestingly the same conclusion has been reached in all studies; deficit irrigation can improve WUE by the same amount as partial rootzone drying.

Industry Relevance

The commercial implementation of Partial Rootzone Drying should not be encouraged until PRD is proven advantageous over deficit irrigation in the field. All future trials should include a deficit strategy that receives the same amount of water as PRD treated vines. Further work needs to be undertaken to clarify the absence of a PRD response at some sites. The relationship between wetted soil volume and plant nutrient status is another area that requires investigation.

MISCELLANEOUS

Soil wetting pattern monitoring and irrigation scheduling as key factors for water use efficiency under RDI and PRD - Sigfredo Fuentes (University of Western Sydney, Australia)

Sigfredo Fuentes (University of Western Sydney) presented software that is capable of generating progressive 3D images of 'real' time soil moisture data from continuously logging soil moisture sensors. Proprietary software packages represent the data as simple line graphs; the graphing tool that Sigfredo Fuentes has developed allows users to view irrigation events as wetting onions (2 or 3D images). The software is a graphing package rather than a model; hence it is only possible to generate 3D images if soil moisture monitoring devices are installed in each of the three planes. For this reason the graphing tool will be of limited use to industry, in most industry applications sensors are installed at given distance from the vine at

several depths. The package will be able to display the irrigation depth, but not the lateral movement of water. It is likely that the software will be most beneficial in research applications where soil moisture sensors have been installed at multiple depths and distances from the point water source. Researchers will be able to 'visualise' the wetting onion in various soil types.

1.2 Plant Based Measurements

Soil moisture sensor technology has lead to improvements in vineyard water use efficiency. Plant based measures may enable growers to further refine irrigation schedules and thus become even more efficient water users. Plant based sensors are believed to detect water stress sooner than soil moisture sensors. Limited research has been conducted in Australia, however other countries (United States, Chile, Spain) are exploring the feasibility of various techniques (see below and meeting with Dr David Goldhamer). The most commonly measured plant parameters are leaf water potential, stem water potential, and trunk diameter.

STEM AND LEAF WATER POTENTIAL

Dr Ken Shackel (University of California, Davis)

Midday stem water potential has been used as a tool for irrigation management for a number of years in tree crops (prune, almond and walnut) and in some vineyards in parts of California. Most work has been conducted in tree crops and the current recommendations for measurement are:

- Midday stem water potential should be measured on shaded leaves near the centre of the tree
- It is only necessary to measure 1 leaf per tree
- Each leaf should be bagged for 10 minutes prior to measurement (after 10 mins readings will be within 0.1 bar of what they would be after 1 hour)

Stem water potential is measured in preference to leaf water potential. Dr Shackel has shown that stem water potential can detect changes in leaf water status earlier than leaf water potential and that the measure is less variable. Another advantage of measuring stem water potential is that under well watered conditions there is a linear relationship between stem water potential and vapour pressure deficit (as stem water potential becomes more negative, vapour pressure deficit increases). Dr Shackel has used this relationship to develop tables that predict stem water potential under different environmental conditions (for tree crops) -see Figure 1. Growers are using these tables to manage irrigations accordingly. Stem water potential is measured by a portable pressure bomb (Figure 2). It appears that stem water potential is being measured in preference to soil moisture status.

Table 2. Values of midday stem water potential (SWP in Bars tension) to expect for fully irrigated almond and dried plum trees under different conditions of air temperature and relative humidity.

(Table courtesy of Ken Shackel, Department of Pomology, University of California Davis)

Air	Air Relative Humidity															
Temp (F)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
60	-6.0	-6.0	-5.8	-5.7	-5.6	-5.5	-5.4	-5.3	-5.2	-5.1	-5.0	-4.9	-4.7	-4.6	-4.5	-4.4
62	-6.1	-6.1	-6.0	-5.8	-5.7	-5.6	-5.5	-5.4	-5.3	-5.2	-5.0	-4.9	-4.8	-4.7	-4.6	-4.5
64	-6.3	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.2	-5.1	-5.0	-4.9	-4.8	-4.6	-4.5
66	-6.5	-6.3	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.2	-5.0	-4.9	-4.8	-4.7	-4.6
68	-6.6	-6.5	-6.3	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.2	-5.1	-4.9	-4.8	-4.7
70	-6.8	-6.7	-6.5	-6.4	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.2	-5.1	-4.9	-4.8
72	-7.0	-6.8	-6.7	-6.5	-6.4	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.1	-5.0	-4.9
74	-7.2	-7.0	-6.9	-6.7	-6.6	-6.4	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3	-5.1	-5.0
76	-7.4	-7.2	-7.0	-6.8	-6.7	-6.5	-6.3	-6.2	-6.0	-5.9	-5.8	-5.7	-5.5	-5.4	-5.2	-5.1
78	-7.6	-7.4	-7.2	-7.0	-6.8	-6.7	-6.5	-6.3	-6.1	-6.0	-5.9	-5.8	-5.6	-5.5	-5.3	-5.2
80	-7.9	-7.7	-7.5	-7.3	-7.1	-6.9	-6.8	-6.4	-6.2	-6.1	-5.9	-5.8	-5.7	-5.6	-5.4	-5.3
82	-8.1	-7.9	-7.7	-7.5	-7.2	-7.0	-6.8	-6.6	-6.3	-6.1	-6.0	-5.8	-5.6	-5.5	-5.3	-5.1
84	-8.4	-8.2	-7.9	-7.7	-7.4	-7.2	-7.0	-6.7	-6.5	-6.2	-6.1	-5.9	-5.8	-5.6	-5.4	-5.3
86	-8.7	-8.4	-8.2	-7.9	-7.7	-7.4	-7.2	-6.9	-6.6	-6.4	-6.3	-6.1	-5.9	-5.8	-5.6	-5.4
88	-9.0	-8.7	-8.4	-8.2	-7.9	-7.6	-7.4	-7.1	-6.8	-6.6	-6.4	-6.3	-6.1	-5.9	-5.7	-5.6
90	-9.3	-9.0	-8.7	-8.4	-8.1	-7.9	-7.6	-7.3	-7.0	-6.7	-6.6	-6.4	-6.3	-6.1	-5.9	-5.7
92	-9.6	-9.3	-9.0	-8.7	-8.4	-8.1	-7.8	-7.5	-7.2	-6.9	-6.8	-6.6	-6.4	-6.3	-6.1	-5.9
94	-10.0	-9.7	-9.3	-9.0	-8.7	-8.4	-8.0	-7.7	-7.4	-7.0	-6.9	-6.7	-6.6	-6.4	-6.2	-6.1
96	-10.4	-10.0	-9.7	-9.3	-9.0	-8.6	-8.3	-7.9	-7.6	-7.2	-7.1	-6.9	-6.7	-6.6	-6.4	-6.2
98	-10.8	-10.4	-10.0	-9.6	-9.3	-8.9	-8.5	-8.2	-7.8	-7.4	-7.3	-7.1	-6.9	-6.8	-6.6	-6.4
100	-11.2	-10.8	-10.4	-10.0	-9.6	-9.2	-8.8	-8.4	-8.0	-7.6	-7.5	-7.2	-7.0	-6.8	-6.7	-6.5
102	-11.6	-11.2	-10.8	-10.4	-9.9	-9.5	-9.1	-8.7	-8.3	-7.9	-7.8	-7.4	-7.2	-7.0	-6.9	-6.7
104	-12.1	-11.6	-11.3	-10.7	-10.3	-9.9	-9.4	-9.0	-8.5	-8.1	-7.9	-7.7	-7.5	-7.3	-7.1	-6.9
106	-12.6	-12.1	-11.8	-11.1	-10.7	-10.2	-9.7	-9.3	-8.8	-8.3	-8.1	-7.9	-7.7	-7.5	-7.3	-7.1
108	-13.1	-12.6	-12.1	-11.6	-11.1	-10.6	-10.1	-9.6	-9.1	-8.6	-8.4	-8.1	-7.9	-7.7	-7.5	-7.3
110	-13.6	-13.1	-12.5	-12.0	-11.5	-11.0	-10.4	-9.9	-9.4	-8.8	-8.6	-8.3	-8.1	-7.9	-7.7	-7.5
112	-14.2	-13.6	-13.0	-12.5	-11.9	-11.4	-10.8	-10.2	-9.7	-9.1	-8.9	-8.6	-8.4	-8.2	-8.0	-7.8
114	-14.7	-14.2	-13.6	-13.0	-12.4	-11.8	-11.2	-10.6	-10.0	-9.4	-9.2	-8.9	-8.7	-8.5	-8.3	-8.1
116	-15.4	-14.7	-14.1	-13.5	-12.9	-12.3	-11.6	-11.0	-10.4	-9.7	-9.5	-9.2	-9.0	-8.8	-8.6	-8.4
118	-16.0	-15.4	-14.7	-14.0	-13.4	-12.7	-12.0	-11.4	-10.7	-10.1	-9.8	-9.5	-9.3	-9.1	-8.9	-8.7
120	-16.7	-16.0	-15.3	-14.6	-13.9	-13.2	-12.6	-11.8	-11.1	-10.4	-10.2	-9.9	-9.6	-9.4	-9.2	-9.0

Common ranges of SWP under cool weather conditions

Common ranges of SWP under normal weather conditions

Common ranges of SWP under hot weather conditions

Figure 1: Table of stem water potential values for well-watered almond under different environmental conditions (Table courtesy of Ken Shackel, Department of Pomology, University of California, Davis).



Figure2: Portable pressure bomb used for measuring stem water potential in Californian Vineyards.

DEFICIT IRRIGATION STRATEGIES USING STEM WATER POTENTIAL IN WINEGRAPES

Dr Samuel Ortega (University de Talca, Chile)

Location: Chile (Maule Region)

Experimental Set Up:

- Cabernet Sauvignon, 8 years old
- Sandy loam, 709mm rainfall
- Effective rooting depth 45cm – 60cm
- Drip irrigation 3.5 L/hr
- 4 Treatments:
  - 100% Etvine
  - 70% Etvine Set to Veraison, 40% Etvine Veraison to Harvest

    - 40% Etvine Set to Veraison, 70% Etvine Veraison to Harvest
    - 40% Etvine
- Etvine = Etr*kc (Reference crop evapotranspiration x crop coefficient)
- Soil moisture monitored by TDR
- Midday stem water potential was measured on leaves that had been bagged for two hours
- Midday stem water potential decreased (became more negative) as season progressed
- Believes –1.2 to –1.3 Mpa at veraison produces good wine (improved colour and highest grape quality)
- Treatments 3 and 4 produced smaller berries with higher skin to pulp ratios, higher phenols and anthocyanins (colour intensity improved)
- Yield was lower in treatment 3 and 4

Dr Ortega used estimated Vine evapotranspiration (FAO Handbook) to impose 4 different irrigation treatments on Cabernet sauvignon. Throughout the season midday stem water potential was measured. Although in this experiment irrigation frequency and amount was determined by estimates of Etvine, Dr Ortega believes midday stem water potential can be used as an irrigation scheduling tool. A midday stem water potential between 1.2 MPa to –1.3MPa at veraison is believed to produce Cabernet Sauvignon grapes with desirable winemaking characteristics.

Industry Relevance

Stem and leaf water potential are not measured in commercial vineyards in Australia. Although it is desirable to use a plant based measure for irrigation scheduling, the technique has two major limitations; it is labour intensive and does not have the potential for automation. The technique may be gaining popularity, however it is likely there will be superior tools available for irrigation scheduling (see comments under David Goldhamer).

Leaf water potential is routinely measured in Australian research trials. Dr Shackel's findings suggest that it may be better to measure stem water potential. The reluctance to measure stem water potential has stemmed from the necessity to bag leaves for several hours prior to measurement, however Dr Shackel has found that it is only necessary to cover leaves for approximately 10 minutes to obtain accurate readings.

1.3 Sustainable Production

GRAVEL VERTICAL MULCHING

S. Yanni (American University of Beirut, Lebanon)

Researchers in Lebanon are looking at Gravel mulching as a means for improving water use efficiency in drip irrigation systems. In drip irrigation systems a saturated zone (and sometimes a puddle) develops around the emission point and water is readily evaporated from this area. Gravel mulching beneath the emission point reduces the amount of time water remains at the soil surface and thus is believed to reduce evaporative losses. Gravel mulching may offer significant advantages in soils with low infiltration rates or surface crusting.

A trial has been conducted in the Bekaa Valley (Lebanon) on olives. The gravel mulch consists of a cylindrical tube made of iron-mesh, 5cm in diameter and 15cm in length (filled with gravel). The amount of water stored in the profile following an

irrigation was compared for gravel and non-gravel treatments at 3 irrigation levels.. It was found that both the irrigation level and the presence/ absence of gravel influenced the amount of water stored in the profile. Gravel mulch significantly increased the soil moisture content at the lowest irrigation level.

Industry relevance

Growers have used surface mulches and subsurface irrigation to reduce evaporative losses from vineyards. Vertical gravel mulching may be another way of conserving water. One foreseeable advantage of gravel mulch over organic mulch is that it would be not need to be replaced over time. Root intrusion of drip lines would also not be a problem. The potential advantages and disadvantages associated with the use of gravel mulches requires further investigation. The technique is likely to be most beneficial in deep soils, with low infiltration rates.

1.4 WATER QUALITY

EFFECTS OF RECYCLED WATER ON SOIL SALINITY LEVELS OF COOL SEASON VEGETABLES

Belinda Platts (Dole Fresh Vegetables, California)

Dole fresh vegetables Inc. are the major supplier of cool season vegetables (broccoli, cauliflower, celery, strawberries, lettuce and artichokes) to the United States. Their major production area is the northern Salinas Valley. The company generates more than $3 billion in receipts per annum. Due to ingression of seawater into coastal wells (as a result of excessive groundwater extraction) they have begun using recycled domestic water for irrigation. Recycled water has been supplied to 4,900 hectares of prime farmland since 1998. The recycled water has an SAR of approximately 4.6, with 175 ppm sodium and 245 ppm Chloride. Well water has an SAR of 1.8. Recycled water and well water are blended at a ratio of 2:1 prior to application.

Soil salinity has been measured 3 times a year (spring, summer and fall) at all sites since 1998. The samples have been analysed for pH, EC, extractable cations (B^+, Ca^{++}, Mg^{++}, Na^+, and K^+) and extractable anions (Cl^-, NO_3^-, and SO_4^{--}). After three years of recycled water use, the saturation extract increased from 2.0 to 2.9 dS/m, the SAR decreased from 2.9 to 2.6. The SAR and EC of all soil samples has remained in the range acceptable for vegetable production. To date there has been no effect on yield.

Industry Relevance

Recycled water has been successfully used to irrigate cool season vegetables in California since 1998. To date there have been no negative impacts. Importantly the consumer market has not responded negatively to the use of recycled water. The Australian viticultural industry is already using recycled water, and to date there has been no adverse consumer response. If this situation arises, the Monterey Regional Water Pollution Control Agency and the Monterey County Water Resources Agency may be able to provide information on how to best market products that have been produced using recycled water.

2. CALIFORNIA STATE UNIVERSITY – FRESNO

Meetings were held with key personnel from the Department of Viticulture and Oenology. Discussions focussed on Californian irrigation practices and the results of recent trial work. The Viticulture and Oenology Department manages approximately 150 acres of vineyard. All research conducted by the department is funded by voluntary contributions to the American Vineyard Foundation.

2.1 General Information – San Joaquin Valley

- Main source of water for San Joaquin Valley is snowmelt from Sierra Nevada range. Very low EC
- Approximately 40% of vineyards use furrow irrigation
- The most commonly used soil moisture monitoring devices are: neutron Probe, EnviroSCAN, ECHO and other capacitance devices. ECHO has had some manufacturing problems. The rate of adoption of soil moisture technology by Californian vignerons is much lower than their Australian counterparts. Crop coefficients are commonly used to schedule irrigatons.
- Very little rain is received during the growing season. In most years winter rainfall is sufficient to fully recharge the profile (growers enter the season with a soil water deficit when rainfall is less than 90 mm).
- In California vineyards are typically ripped down and across rows before planting.
- Vignerons are beginning to use differential canopy management – particularly in rows with North/ West orientation
- Grapes are the number 1 crop in Fresno. State-wide they are the second biggest agricultural sector behind dairy. The industry is worth 2.6 billion.
- Grape prices in San Joaquin Valley are currently very low (Thompson Seedless $90/t). Prices are always lower than those in the Nappa and Sonoma Valleys. There is a perception that he San Joaquin Valley (hot climate) produces low quality grapes. The San Joaquin Valley produces 60% of all grapes in California but only receives approximately 20% of the income. In 2002 Napa Valley growers earned nearly $3,000 per ton for high value grapes while Fresno area growers took in $136 per ton for lesser-quality varieties (California Department of Food and Agriculture).
- Vines are being pulled out and abandoned in the Fresno region.
- Lower grape prices are being driven by over planting, reduced consumption (due to a weakened economy) and an influx of inexpensive imports from Chile, Australia and South Africa.
- The main varieties planted are Concord, French Colombard, Ruby Cabernet and Thompson Seedless.
- The availability of water is a significant issue in the Central Valley. Competition for water from domestic users is increasing (the population of greater Fresno is 750,000 and increasing). Pumping water is becoming increasingly expensive. Pump operation is key determinant of economic viability.
- A case study has shown that although yield was reduced when irrigation was reduced, the power savings (pump operation) meant that it was economically beneficial strategy for the grower.
- According to Dr Wample irrigations should be sufficient to grow a canopy with 1-1.2m canes. Early season irrigation management should take into account winter storage. Once the canopy has been established the vines entire water requirement should be met.

2.2 Dr Robert Wample (Professor and Chair)

Sub-Surface Irrigation

Dr Robert Wample is the professor and chair of the Department of Viticulture and Oenology. He has been involved in a sub-surface irrigation trial for two years. The project shares many similarities with the GWRDC funded project "Growing grapes to specification with minimal water inputs".

Dr Wample installed netafim pressure compensated drip line at depth of 45cm two years ago. To date they have not had any problems with root intrusion, however the installation depth is insufficient – water is visible at the soil surface towards the end of an irrigation (soil is a sandy loam). The presence of water at the soil surface encourages weed growth. In the Californian trial the drip line is installed mid-row and irrigation amounts are monitored with 'in line' flow meters. The biggest technical problem the group has encountered so far is interference from Gophers (a rodent that damages the buried dripline).

The group has found that yield and pruning weights are lower on sub-surface vines compared to conventionally irrigated vines. They have also noted that subsurface berries have higher Nitrogen levels.

Industry Relevance

Dr Wample's research group have experienced very few technical problems with the sub surface installation. The Californian experience suggests that if sub-surface irrigation is to be installed in a sandy loam it should be buried at a depth greater than 45cm. "In line' flow meters provide the group with an excellent diagnostic tool. The meters, installed in the laterals (Figure 3), ensure the correct amount of water is being delivered to the vines. The yield reduction observed in this trial may be due to the mid-row positioning of the drip line (the conventional line was placed under the vine row).

Dr Wample is also investigating the use of Leaf Temperature as an irrigation scheduling tool. Preliminary results suggest that if leaf temperature is 4^0C higher than ambient temperature, the plant is under water stress. According to Dr Wample the temperature of fully irrigated leaves is less than ambient early in the season, and greater than ambient later in the season. The group have not yet developed any irrigation guidelines.

Areas identified by Dr Wample that require further investigation are:

- The relationship between vine nutrition and berry colour and
- The universality of leaf water potential.



Figure 3: 'In line' water meter used to monitor water application in sub-surface trials.

2.3 Dr Sanliang Gu (Ricchiuti Chair of Viticulture Research)

Dr Gu has recently completed a trial investigating effects of Partial rootzone Drying (PRD) on Sauvignon Blanc vines in Fresno County of San Joaquin Valley. Dr Gu's trial differs from previous PRD studies in that a conventional irrigation treatment receiving the same amount of water as the PRD vines was included in experimental design. The inclusion of this treatment means that vine responses to a water deficit can be distinguished from PRD responses.

- 4 Irrigation treatments were established:
  - Conventional Irrigation at 0.8 Etc
  - PRD at 0.8 Etc
  - Conventional Irrigation at 0.4 Etc
  - PRD at 0.4 Etc
- Pressure compensated drippers with an hourly output of 1.89L were used in all treatments. Two drippers were placed in one location to achieve crop coefficient of 0.8
- Vines were irrigated daily.
- PRD was switched every 7-14 days
- Evapotranspiration was estimated using the Modified Penman Monteith Equation
- Growing season rainfall was negligible in all three years
- Treatments were applied from fruit set to harvest
- Shoot thinning was conducted in two, of the three trial years
- Yield (bunch number, bunch weight and berry size), Vegetative growth (pruning weight, primary and secondary shoots), maturity indices (^{0}Brix, pH, TA) and plant parameters (stomatal conductance and transpiration) were recorded.
- The major findings were:
  - No reduction in yield at 0.4 Etc
  - In two of the three seasons 0.4 vines had fewer laterals, they also tended to have lower pruning weights. This was a result of reduced water application, not a result of PRD
  - Stomatal conductance and transpiration tended to be reduced in 0.4 cf 0.8 Etc treated vines, however the difference was often not statistically significant.
  - Fruit TA levels tended to be higher in 0.8 Etc vines
  - No leaf water potential data was reported

Dr Gu concludes that PRD does not confer any advantage over standard irrigation. He believes commercial implementation of PRD should not be recommended until PRD is proven advantageous over conventional irrigation at the same irrigation amount. His work is to be published in the Journal of Horticultural Science and Biotechnology in early 2004.

Industry Relevance

In a three year study on Sauvignon Blanc Dr Gu was not able to demonstrate any advantage of applying water to alternate halves of the rootzone (PRD). His results are in agreement with those presented at the Irrigation Symposium. However, it is worth noting that Dr Gu did not observe any yield reduction in the 0.4 (50%) treatment, this would suggest that all vines were supplied with adequate water. Nevertheless, the commercial implementation of PRD should be discouraged until PRD is proven advantageous in the field.

3. GOLDEN STATE VINTNERS TAILGATE MEETING

Whilst in California Yasmin Chalmers and myself attended the Golden State Vintners Tailgate meeting. The purpose of the meeting was to convey the results of a regulated deficit irrigation and mechanical pruning trial to regional growers. The trial is coordinated by staff from the California State University (Dr Robert Wample) and the University of California (Dr Nick Dokoozlian and Dr Larry Williams). The meeting was held at the experimental field site. Trial results were displayed on a painting easel and growers were given handouts. The meeting concluded with an inspection of the trial plots.

Trial Location: Fresno California
Experimental Set Up:

- Shiraz planted on sandy loam. Sandy loam extends to depth of 1m. At 1m there is a silt layer that cannot be penetrated by roots. In general roots will only establish in rip lines (row and cross row), soil is typically ripped to 1.5m.
- 3 year trial assessing 3 levels of deficit irrigation
- In this experiment threshold leaf water potentials were used as irrigation triggers. All treatments received the same irrigation until just after bloom, they were then allowed to dry down to the 'trigger' leaf water potentials. Irrigations commenced once the trigger point was reached. All treatments received the same irrigations post veraison.
- Treatment 1: Irrigations commence at a midday LWP of –12 Bar
- Treatment 2: Irrigations commence at a midday LWP of –14 Bar
- Treatment 3: Irrigations commence at midday LWP of –16 Bar.
- Leaf water potential was measured twice a week at midday.
- Dr Wample believes that in first year (2003) all treatments were over-watered until just after bloom, they were then allowed to dry down to their respective midday Leaf water potentials. He suspects vines were over-watered from this point onwards. Pre-bloom and post veraison irrigation was standard commercial practice for Shiraz (most likely crop coefficient of 0.7).
- Control vines received between 6-700 gallons per vine per (2,200 – 2,600L) season. Apply approx 900L to Barossa Valley Chardonnay
- A large irrigation just after veraison is believed to have caused a flush of regrowth and berry splitting in all treatments. The splitting appeared to be more prevalent in sun exposed fruit in –14 and –16 Bar treatments.
- Gallo Winery Assessments were conducted at veraison and harvest
- Assessment is primarily driven by sugar, but also by flavour.
- General Comments from field berry tasting:
    - Control fruit had less ripe characters ('green' characters)
    - –14 Bar 'moderate' quality fruit
    - –16 Bar exceptional fruit
- Berry tasting is conducted by winemakers and trained grower liaison officers.
- The winery technician commented that late season growth is undesirable.
- The veraison 'Gallo' score ranked the –16kPa fruit as being of slightly higher quality due to reduced tip growth in this treatment. –12kPa berries were perceived as being larger than –14 and –16kPa.
- The desired fruit weight to pruning weight ratio for reds in the San Joaquin Valley is 10-11:1.
- Dr Wample believes that applying less water imparts 'long term' efficiency on vine i.e. vine experiencing deficit conditions early in the season will be more efficient for rest of season.
- Mechanical pruning appears to result in more bunches per vine and reduced berry weights.

Industry Relevance

It is difficult to interpret the results of this trial given that one of the principal investigators believes the vines were over-watered. It is worth noting that although irrigation treatments were only applied for 4 weeks, Gallo staff rated –16Kpa fruit as being the highest quality.

4. UNIVERSITY OF CALIFORNIA KEARNEY AGRICULTURAL CENTRE

4.1 Dr David Goldhamer (Irrigation Management specialist)

Dr Goldhamer's research activities have concentrated on plant water relations and developing innovative techniques to improve water use efficiency. His recent work has focussed on the use of trunk diameter measurements for irrigation scheduling. Much of this research has been conducted on peaches and almonds.

Dr Goldhamer discussed results from a study he had conducted on peaches. In this particular study he measured a range of parameters:

- Maximum daily available soil water content fluctuations
- Minimum Daily Trunk Diameter
- Maximum daily trunk diameter
- Maximum Daily Trunk Shrinkage = max daily trunk – minimum daily trunk
- Midday Stem Water Potential
- Pre-Dawn Leaf Water Potential
- Photosynthesis
- Stomatal conductance (net photosynthesis and stomatal conductance were very similar)

He ranked each of the above parameters according to their ability to detect water stress. Dr Goldhamer found that maximum daily available soil water content fluctuations was the most sensitive parameter, followed by minimum daily trunk diameter and maximum daily shrinkage. Midday stem water potential, midday leaf water potential, maximum daily trunk diameter and pre-dawn LWP were the fourth most sensitive parameters. Photosynthesis was the least sensitive parameter. Although maximum daily available soil water fluctuations were shown to be the most sensitive indicator by statistical analysis, their sensitivity reduced as the soil profile dried and water extraction moved to lower parts of the profile. Dr Goldhamer therefore believes that Minimum Daily Trunk Diameter is best indicator of stress for field grown peach trees. In general he concluded that continuously monitored parameters are generally more sensitive to the onset of water deficits than discrete measures. Dr Goldhamer also commented that although temperature and percentage cover may be utilised by satellite technology to estimate evapotranspiration in uniform crops, it is not suitable for grapevines (due to lack of uniformity in the vineyard).

Industry Relevance

Research is required to ascertain whether trunk diameter sensors can be successfully used as irrigation scheduling tools in vineyards. Dr Goldhamer's research suggests that the plant based measure is likely to be a more sensitive indicator of water stress than soil moisture status. Trunk diameter measurements have two main advantages over leaf/ stem water potential measurements; the process is automated and readings are continuously logged. Unfortunately trunk diameter sensors do not overcome the problem of point monitoring; however if the technology became more affordable, it would be possible to simultaneously monitor numerous plants.

4.2 Professor Larry Williams

The use of leaf versus stem water potential for irrigation scheduling in vineyards was discussed with Professor Williams. Professor Williams believes that pre-dawn leaf

water potential, midday leaf water potential and midday stem water potential can all be used for assessing water status in the grapevine. However he emphasized that to obtain reliable LWP measurements the leaf should be bagged prior to excision and placed in pressure chamber within 15 seconds. According to professor Williams LWP should only be measured half an hour each side of solar noon.

Industry Relevance

Plant water status is assessed in many Australian research trials. There are three potential methods for determining plant water status: pre-dawn leaf water potential, midday leaf water potential and midday stem water potential. It is not practical to measure pre-dawn leaf water potential; therefore one must decide whether to measure midday stem or midday leaf water potential. If measurement can be completed within half an hour either side of solar noon, then leaf water potential would be the measurement of choice. If it is not possible to complete all measurements within this time frame then stem water potential should be measured. Environmental conditions should be constant throughout all measures.

APPENDIX 1

PAPER SUBMITTED FOR PUBLICATION IN ACTA HORTICULTURAE

Note the 'Draft' status of this paper as it is currently being reviewed.

Water Use Efficiency of Field Grown Chardonnay Grapevines Subjected to Partial Rootzone Drying and Deficit Irrigation

S. Pudney[1,2] and M.G. McCarthy[1,3]

[1]Cooperative Research Centre for Viticulture
Glen Osmond, South Australia

[2]South Australian Research and Development Institute
Plant Research Centre
Adelaide, South Australia

[2]South Australian Research and Development Institute
Nuriootpa Research Centre
Nuriootpa, South Australia

ABSTRACT

A major constraint to the continued development of the Australian wine grape industry is the availability of water. If vineyard expansion continues to meet forecast expectations, the amount of water available for producing wine grapes will become insufficient. At least part of the shortfall will need to be met through improvements in vineyard practices. Partial Rootzone Drying (PRD) is a technique that has been reported to give a two fold increase in water use efficiency (weight of fruit produced per unit irrigation water applied). The objective of the current study was to assess the suitability of PRD as a technique for improving water use efficiency in established vineyards. The three year trial was conducted on mature planting of Chardonnay. Five irrigation treatments were established: Full (F), Full Partial Rootzone Drying (FPRD), Split (S), Deficit (D) and Deficit Partial Rootzone Drying (DPRD). Soil moisture sensors were installed to calculate the water requirement of the FPRD treatment. Deficit treatments automatically received half the amount of water applied to the Full treatments. Split received the same amount of water as Full, however the water was applied through two drippers (rather than one). Fruit production was 18% higher in Full treatments (F and FPRD) compared to Deficit treatments (D and DPRD). WUE was highest for Deficit and lowest for the Full treatments. The WUE of F and FPRD vines was not significantly different. S vines always had the lowest water use efficiency. There was no difference between the response of D and DPRD vines to reduced water application. The results of this study suggest that closely monitored deficit irrigation can achieve the same improvement in WUE as PRD.

KEYWORDS: DRIP IRRIGATION, GRAPEVINE, PRD, YIELD, BERRY RIPENING.

INTRODUCTION

Grape growing districts that experience a hot, dry climate (Australia, South Africa, Israel, western USA and South America) use irrigation to minimise the effects of water deficit on yield and quality. The Barossa Valley (South Australia) is a premium wine grape growing district with a dry climate. The growing season is characterised by high evaporation and little effective rainfall. Irrigation allows growers to consistently produce a high quality crop. Water resources are limited (Scales, 1995) and if vineyard expansion continues to meet forecast expectations, the amount

of water available for wine grape production will become limiting. There is an obvious need to improve vineyard water use efficiency.

Partial Rootzone Drying (PRD) is an irrigation technique that may allow more vines to be watered per unit water. PRD is a strategy that exploits the grapevines natural response to water stress to improve water use efficiency. Under the conditions of PRD, half of the rootzone is well watered and half of the rootzone is allowed to dry (Stoll et al., 2000). Water savings of up to 50% have been achieved in field and pot trials where PRD has been implemented without yield loss or detrimental effects on fruit quality (Dry et al., 1996; Dry, 1997).

The objective of the current study was to assess the suitability of PRD as a technique for improving water use efficiency in established vineyards in regions such as the Barossa Valley.

MATERIALS AND METHODS

Site Information

The trial was conducted in the Barossa Valley, South Australia, Australia (34^0 48'S, 139^0 14'E, elevation 274 m). The Barossa Valley experiences a mediterranean climate with an average annual rainfall and evaporation of 502 mm and 1700 mm respectively. The soil is a Sandy Loam over a medium red clay; Chromi-Gleyic Solonetz (Calcic), (Clark et al., 2002). The majority of roots are located within 60 cm of the soil surface. Prior to the establishment of the experiment reported here, vines had been irrigated with underground water via a single dripper slightly off set (5 cm) from the vine butt. The trial was a split-plot design with two irrigation water qualities (main plots), replicated three times, with five dripper configurations as subplots. Each subplot comprised nine vines in each of three adjacent rows. Data were collected only from the middle 3 vines of the middle row. The two water qualities were 2.8 dSm^{-1} (underground water) and 0.6 dSm^{-1} (domestic water). Dripper configurations are described below.

Weather

Rainfall, relative humidity, maximum and minimum temperatures were measured at an Australian Bureau of Meteorology automatic weather station located approximately 100 m from the trial site. Class A Pan Evaporation was measured manually each day at the same site.

Plant Material

The trial was conducted on own rooted *Vitis Vinifera* cv Chardonnay. Row and vine spacings were 3.0 m and 2.25 m respectively in an east-west orientation. The vines were pruned to 40 buds (2 bud spurs) on a bilateral cordon and there was a single foliage catch wire approximately 30 cm above the cordon. At commencement of the trial, September 2000, vines were between 7 and 11years old.

Irrigation Treatments

For each of the two water qualities five irrigation treatments were established: Full (F), Full Partial Rootzone Drying (FPRD), Split (S), Deficit (D) and Deficit Partial Rootzone Drying (DPRD). F vines received a net water application of 4L per hour (through a single 4L per hour dripper). D and DPRD received a net water application of 2L per hour, (through a single 2L per hour dripper). S vines were fitted with two 2L per hour drippers, giving a net application rate of 4L per hour. All drippers were pressure compensated.

PRD and Split vines were fitted with two drippers, one each side of the vine butt off set by 50 cm. F and D treatments had one dripper positioned 5 cm from vine butt.

The S treatment differed from all others in that during an irrigation event both drippers were active; at any one time there was only 1 active dripper in the four remaining treatments. In PRD treatments the active dripper was alternated based on soil moisture status.

Irrigations were scheduled according to depletion of soil water around FPRD vines. Soil water content was measured by capacitance sensors. Four EnviroSCAN (Sentek Pty Ltd, Adelaide, SA) probes were installed alongside a representative FPRD vine. Two probes were installed on each side of the vine butt, one 10 cm from the centre of the wetted zone and one at 20 cm. Each probe had sensors positioned at 20 cm, 30 cm, 50 cm and 70 cm below the soil surface. Each 'pair' of probes will hereafter be referred to as East and West. PRD was implemented from the date of the first irrigation through to harvest.

The experiment was designed so that each time the FPRD vines were irrigated all other treatments were watered. The two dripper rates ensured that the deficit vines received 50% of the water applied to the full treatments. The aim of each irrigation was to keep the 'wet' side of the FPRD vines sufficiently moist to meet the vines water requirements. In practice this meant ensuring that soil moisture levels were replenished to a depth of 60 cm (bottom of active rootzone). Run times varied from 16 hours to 6 hours. It was usual to apply a large irrigation upon switching, smaller irrigations were applied every two or three days until the soil on the other side of the vine butt had reached the pre-determined refill point.

Berry Development and Yield

Between veraison and harvest 50 berries were collected from 3 vines in each plot for the determination of berry weight, juice °Brix, pH and titratable acidity. Berries were randomly selected from all positions in the canopy, and within bunches. Berries were immediately weighed to determine berry weight. Juice was extracted using a small hand-held press and after centrifugation °Brix was determined by a bench refractometer (Atago Pty Ltd). pH was measured using a Radiometer Copenhagen precision pH meter (PHM85TA) and an automatic burette, (Radiometer Copenhagen ABU80), connected to the pH meter was used to measure Titratable Acidity by titration to an endpoint of 8.2 pH.

At maturity (approximately 23^0 Brix) individual vines were harvested; bunch number and fruit weight was recorded. Fruit weight was adjusted for the berries removed through sampling prior to harvest. Berry number per bunch was calculated from bunch weight and mean berry weight recorded at harvest.

Data was analysed using Genstat (Fith Edition, Rothamsted Experimental Station, 2000). A split plot ANOVA with bunch number as a covariate was used to compare yield, berry weight and berry number between treatments. Bunch number was analysed by a split plot ANOVA. Maturity date was predicted by regression analysis of °Brix versus time.

RESULTS AND DISCUSSION

As there was no significant water quality treatment effect data are presented as the mean of the two treatments.

Evaporation and Rainfall

Growing season evaporation (September to March) was similar for each of the three seasons (Figure 1). Evaporation rates were highest in January, averaging 10.1 mm per day. Little effective rainfall was received during the growing season, however, a large rainfall event in February of Year 3, interrupted the scheduling of PRD (Figure 1).

Irrigation

Irrigations were scheduled according to the soil water content of the 'wet' and 'dry' side of the FPRD treatment. Soil moisture records demonstrate that spatially distinct wet and dry zones were established in FPRD treatments in all years (Figure 1a, b and c). There was no lateral spread of irrigation water from the wet to the dry side.

Water application ranged from 1.39 ML/Ha to 1.81 ML/ha for Full and Split treatments, and between 0.52 ML/ha and 0.9 ML/ha for Deficit treatments (Table 1). Irrigations commenced between 16 and 31 days after flowering over the three seasons.

When expressed as a percent of growing season evaporation (September to March) these irrigation amounts (plus rainfall) equate to Crop Factors of 0.26, 0.30 and 0.22 (Full treatments) for years 1 to 3 (Y_{1-3}) respectively. Irrigation to the fully irrigated vines was at the low end of standard commercial practice in the Barossa Valley.

Yield and Maturity Indices

In Y_1 there was no treatment effect on yield (Table 2). In Y_2 Full treatments (F and FPRD) produced approximately 18% more fruit than Deficit (D and DPRD) with the Split treatment being statistically similar to both (Table 2). In Y_3, the Split vines produced more fruit than the Deficit vines (Table 2) but not more than the Full treatments (F & FPRD).

Berry ripening followed a two-stage development in all treatments. Sugar accumulation, weight gain and acid depletion were rapid at first, however, as fruit approached maturity, berry weight stabilised, sugar accumulation slowed and the rate of acid depletion declined (data not presented). In Y_1, all fruit reached maturity (23^0 Brix) at the same time. In Y_2, fruit from Deficit treatments reached maturity approximately 1 week prior to Full treatments (12^{th} March vs 18^{th} March). S fruit reached 23^0 Brix at the same time as Deficit and Full treatments. In Y_3 a large rainfall event that occurred when the berries were approximately 22.1 °Brix minimised treatment effects.

Water Use Efficiency (tonnes of fruit produced per unit irrigation water applied) was highest in all years for the Deficit treatments (Table 3). It ranged from 6 t/ML, to 19 t/ML (Table 3). In this study the yield penalty for a 50% reduction in water application was about 18%, hence WUE was markedly improved in Deficit treatments. The improvement in WUE was similar for both D and DPRD. The Split treatment always had the lowest WUE.

Deficit treatments displayed the expected physiological responses to water stress with a reduced yield. Although water application was reduced by 50% the deficit was not severe enough to disrupt the process of berry development. WUE was equally improved in both treatments. The authors conclude that both Deficit treatments were subjected to water stress; berry size is commonly reduced under the conditions of water deficit (Matthews and Anderson, 1988). Berry size was reduced in years 2 and 3 (data not shown). There was no perceived benefit associated with PRD (alternating wetted zones) in the reduced water treatments.

SUMMARY

Partial rootzone drying was assessed in a mature vineyard with vines that had been watered via a single dripper slightly off set from the vine butt for more than 7 years. The present study found that when equivalent dripper arrangements were used, yield was more closely related to the volume of water applied than the method of application. Vines that received the same amount of water (PRD or no PRD) had equivalent WUE scores. Reducing the irrigation volume by 50%, did not adversely affect berry development, however yield was reduced by approximately 18%. Water

use efficiency was improved by the same magnitude in both of the reduced water treatments (D and DPRD). It thus concluded that PRD may not result in significant increases in WUE in all field situations; this study demonstrates that it is possible to achieve similar water savings through closely monitored deficit irrigation.

ACKNOWLEDGEMENTS

This research was supported by the Australian Grape and Wine Research Development Corporation and the Commonwealth Cooperative Research Centres Program conducted by the CRCV for Viticulture.

LITERATURE CITED

Clark, L.J., Fitzpatrick, R.W., McCarthy, M.G., Murray, R.S. and Chittleborough, D.J. 2002. Vineyard soil degradation following irrigation with saline groundwater for twenty years. Proceedings of the International Union of Soil Science, 17th World Congress of Soil Science, Bangkok, Thailand. 1115 CD-ROM.

Dry, P., Loveys, B. and During, H. 1996. Effects of partial rootzone drying on grapevine vigour, yield, composition of fruit and use of water. Proceedings of the 9th Australian Wine Industry Technical conference. Adelaide, Australia p.128-131.

Dry, P.R. 1997. Response of grapevines to partial drying of the root system. Doctoral Thesis, Dept. of Horticulture, Viticulture and Oenology. University of Adelaide, Australia.

Matthews, M.A. and Anderson, M.M. 1988. Fruit ripening in *Vitis vinifera* L.: Responses to seasonal water deficits. American Journal of Enology and Viticulture 39: 313-320.

Scales, W. 1995. Wine grape and wine industry in Australia; a report by the committee of inquiry into the wine grape and wine industry: Final Report. Canberra, Australian Government Publishing Service.

Stoll, M., Loveys, B. and Dry, P. 2000. Hormonal changes induced by partial rootzone drying of irrigated grapevine. Journal of Experimental Botany 51: 1627-1634.

Tables

Table 1: Total water application from bud burst (September) to harvest (March) in millimetres per hectare for each of the three experimental years. I = Irrigation, R_e = Effective Rainfall. An effective rainfall event is one in which an increase in soil moisture is recorded at 20cm below the soil surface. Effective rainfall = 0.85 x total rainfall.

	Year 1			Year 2			Year 3		
Treatment	I	R_e	Total	I	R_e	Total	I	R_e	Total
DPRD	52	90	142	90	111	201	70	71	141
D	52	90	142	90	111	201	70	71	141
S	103	90	193	181	111	292	139	71	210
FPRD	103	90	193	181	111	292	139	71	210
F	103	90	193	181	111	292	139	71	210

Table 2: Yield (t/ha) for years 1 to 3. A different letter following the value denotes a significant difference ($p<0.05$).

Treatment	Year 1	Year 2	Year 3
DPRD	9.3	11.6^{a}	6.9^{a}
D	9.9	11.8^{a}	7.1^{a}
S	9.5	$13.1^{a,b}$	8.1^{b}
FPRD	10.5	14.2^{b}	9.0^{c}
F	10.9	13.9^{b}	$8.4^{b,c}$

Table 3: Water Use Efficiency (t/ML) for years 1 to 3.

Treatment	Year 1	Year 2	Year 3
DPRD	18.0	12.9	10.2
D	19.0	13.0	10.5
S	9.1	7.2	6.0
FPRD	10.0	7.8	6.6
F	10.5	7.7	6.2

Figures

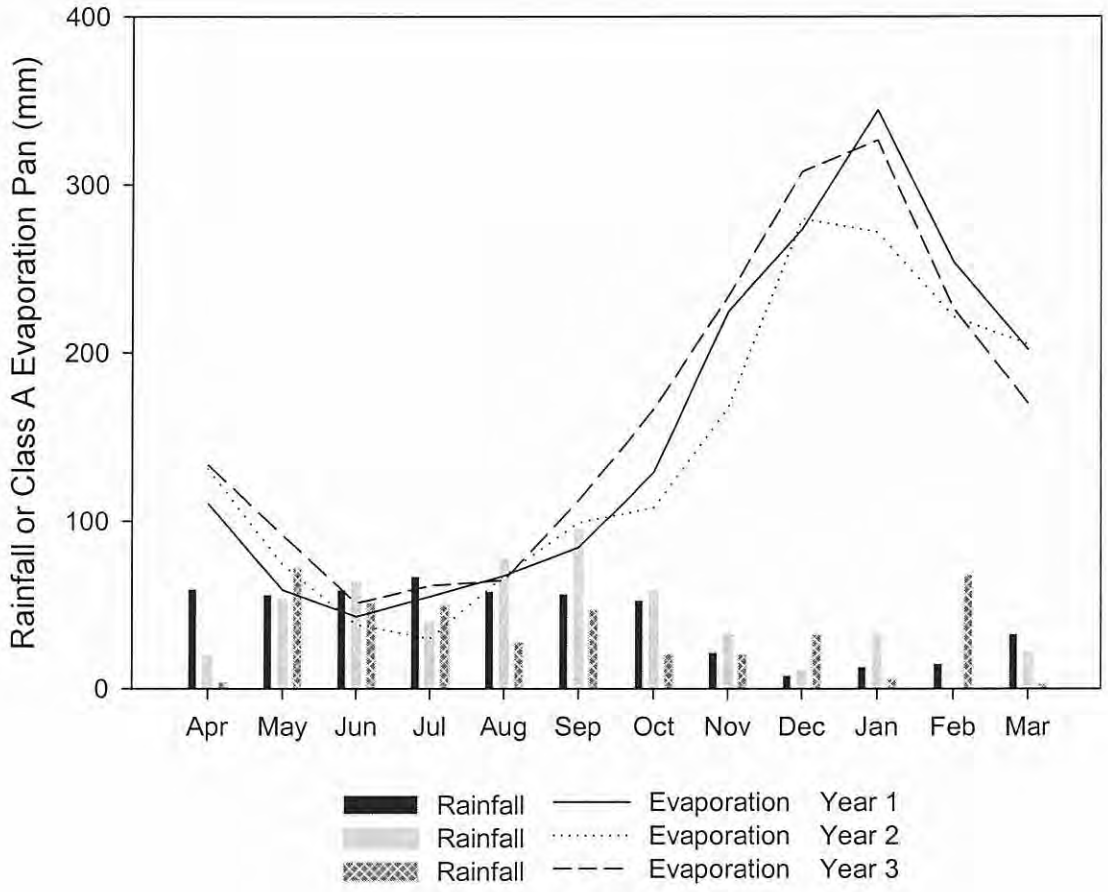


Figure 1: Monthly rainfall (mm) and Class A Pan Evaporation (mm) for years 1 to 3.

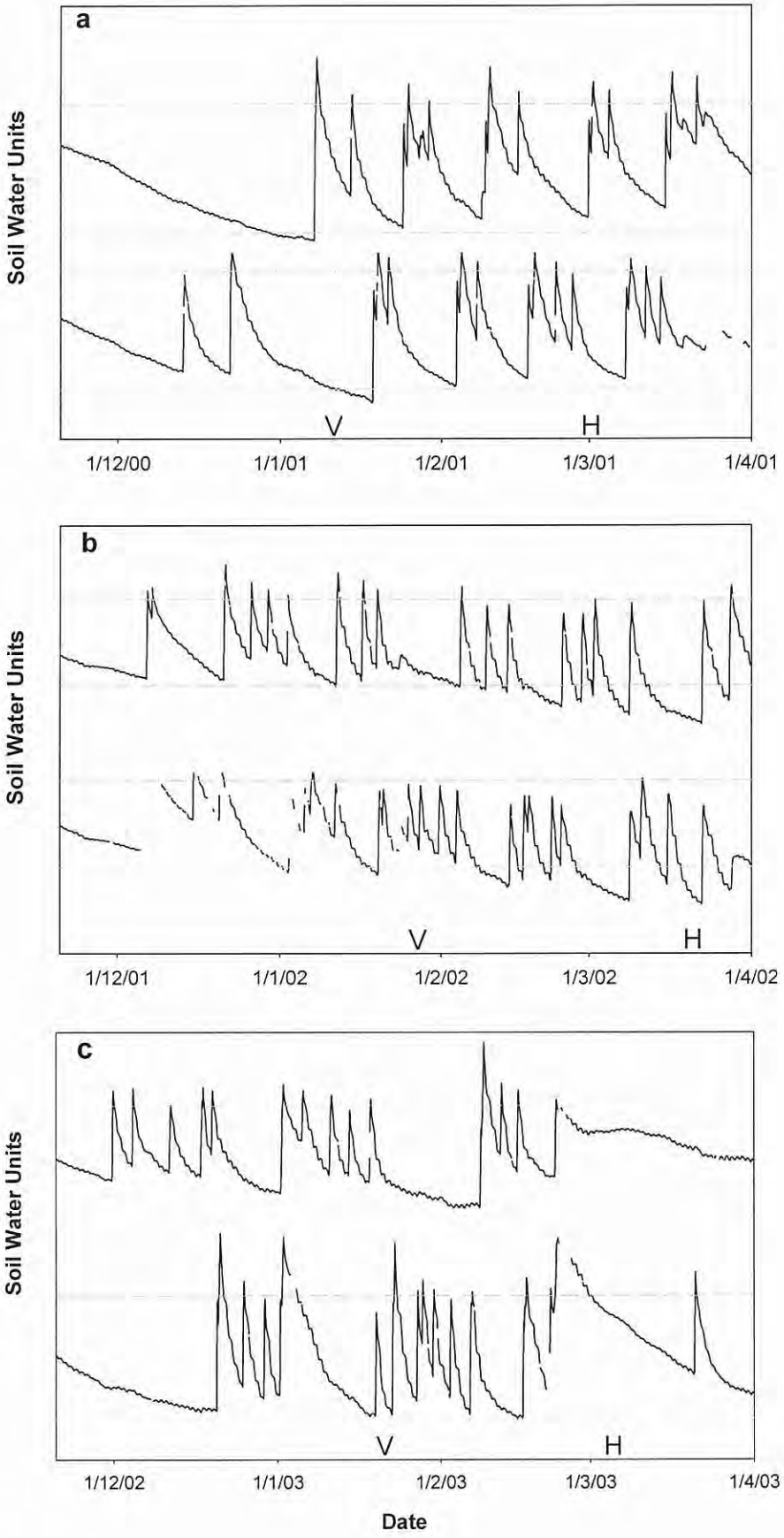


Figure 2: Soil moisture records for FPRD vines for years 1 to 3 (a, b and c respectively). Traces represent the sum of the soil moisture values recorded by sensors positioned at 20, 30, 50 and 70 cm on the 'East' (upper trace) and 'West' (lower trace) probes. Dashed lines represent the Full and Refill points used to schedule irrigations. Veraison and harvest are indicated by the letters V and H.

APPENDIX 2

ARTICLE PUBLISHED IN THE JANUARY 2004 ISSUE OF THE AUSTRALIAN AND NEW ZEALAND GRAPEGROWER AND WINEMAKER

Are plant sensors the key to irrigation scheduling? An American perspective

Shannon Pudney
Cooperative Research Centre for Viticulture (CRCV)
South Australian Research and Development Institute (SARDI)
Adelaide, South Australia

Yasmin Chalmers
Department of Primary Industries (PIR-Vic)
Mildura, Victoria

Introduction

During August-September 2003, Shannon Pudney and Yasmin Chalmers travelled to the United States of America to attend and present at the IV International Symposium on Irrigation of Horticultural Crops. The symposium was held at the University of California, Davis, and attracted delegates from Australia, Great Britain, Chile, Peru, Israel, Saudi Arabia, Italy, Spain, France, Germany, Romania, Lebanon and America. A wide range of horticultural industries (viticulture, vegetable, stone and pome fruit, and ornamental), were represented at the symposium. Discussions focused on crop water requirements, plant-based measurements, irrigation scheduling, evapotranspiration, crop coefficients, water quality and the economics of irrigation.

The use of plant-based measures for irrigation scheduling was one topic that caught the attention of the authors. Traditionally, Australian winegrape growers have used climate and/or soil-based monitoring systems to assist with irrigation scheduling. Although plant-based measures are used in Australian research trials, to date they have not been used as irrigation scheduling tools (in commercial vineyards). In recent years the commercial use of plant-based measures has been encouraged in American vineyards with widespread adoption of these methods, particularly in California.



The authors Shannon Pudney (left) and Yasmin Chalmers at the IV International Symposium on Irrigation of Horticultural Crops, held at the University of California, Davis.

viti-wet
The Better Wetter Softer Spreader



- Special purpose non-ionic surfactant designed for use on horticultural crop foliage when applying fungicides & insecticides
- Better wetting ability compared to traditional non-ionic surfactants
- Softer, less abrasive formulation compared to traditional non-ionic surfactants, thereby reducing the risk of :-
  - Flower thinning
  - Removal of the protective wax layer on leaf and fruit surfaces
  - Russet potential

SST
Surfactant Science Technology

SST AgProducts Pty Ltd Phone 1800 778 247

Plant-based measurements

Plant water status is determined by a combination of root health, the amount of water in the soil and the current atmospheric conditions. Plant-based measures are considered to be better predictors of plant water status (than soil and climate-based measures) as they are an integrated measure of the soil/plant/atmosphere continuum. There is some evidence to suggest that plant-based measures are capable of detecting water stress sooner than soil moisture sensors.

Plant water status can be measured by leaf or stem water potential and trunk diameter fluctuations (refer following section). There is some discussion as to whether leaf or stem water potential is a better measure of plant water status. Professor Larry Williams, University of California, has demonstrated that leaf and stem water potential are equivalent indicators of plant water status in vines (Williams and Araujo, 2002), however, Dr Ken Shackel, University of California, is a firm believer that stem water potential is the superior measure (Shackel *et al.* 2003). It is worth noting that the majority of Dr Shackel's work has been conducted in tree crops. Both leaf and stem water potential are currently measured in Californian vineyards.

Plant water status can also be measured by variations in trunk diameter. As with all plant-based measures, trunk diameter varies over the course of the day, reaching a minimum in the late

afternoon. Research on peaches indicates that minimum daily trunk diameter is a very reliable, sensitive indicator of plant water stress (Goldhamer *et al.* 1999). Maximum daily shrinkage has been used to successfully schedule irrigations in almond (Goldhamer and Fereres, 2003). There is very little information available on the use of Linear Variable Displacement Transducers (LVDTs) in viticulture.

Measuring water potential

Water potential can be thought of as a measure of the suction a plant exerts on water in the soil.

Leaf

Leaf water potential (LWP) is a measure of the water status of an individual leaf. The measure is used to predict the water status of the vine, hence leaf selection is critical. LWP is typically measured on recently-matured, fully sun-exposed leaves using a pressure chamber (see figure 1). LWP is measured by removing a leaf from the vine (see figure 2) and placing it into the chamber (see figure 3) with the petiole (stalk) protruding from the top (see figure 4). The tip of the petiole is observed under magnification whilst compressed nitrogen is bled into the chamber. When the pressure in the chamber equals the water potential of the leaf, sap will exude from the cut surface of the petiole. The reading on the pressure gauge indicates the plant water status of the vine, i.e. the higher the reading the more water-stressed the vine. To ensure readings are accurate the excised leaf must be bagged, removed and placed into the chamber within 15-20 seconds.



Fig. 1. Portable pressure chamber used in American vineyards to measure leaf and stem water potential. Photograph courtesy PMS Instrument Co.



Fig. 2. Measuring leaf water potential. Leaves must be bagged prior to excision.



Fig. 3. The enclosed leaf is placed inside the pressure chamber.

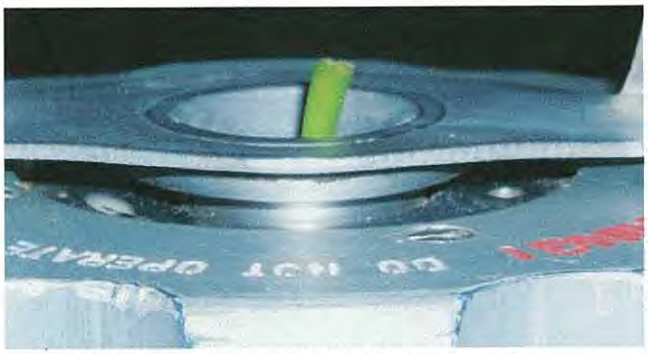


Fig. 4. The petiole protrudes from the lid of the pressure chamber.

Exid

DOUBLE BANG Scare-Gun

For over 30 years our SCARE-AWAY cannon has frightened bird and animal pests from fruit, vegetable and grain crops by means of harmless, automatic, thunderclap explosions. Now we have added a new ignition system with 2 injectors and a wind screen for all-weather operation and extra loud explosions. The SCARE-AWAY is all-steel construction, portable, and operates on LP GAS only for only 20 cents a day. A 15-day clock timer is available. Write or use our toll-free number for prices and free literature.

Dealer inquiries are invited.



Frightens birds and pests away better than ever before

National Distributor:

E.H. CAMBRIDGE & CO

"The Gas People"

9 Mt Barker Road, Mt. Barker, SA 5251
Email: sales@ehcambridge.com.au
Web: www.ehcambridge.com.au

CALL US ON TOLL FREE
1800 888 137 or (08) 8391 1688

Are you planting vines, olives or trees?

Then consider

McLEAN'S VINE & TREE GUARDS

- ❑ The proven, ingenious Australian-made device designed to protect young vines and fruit trees
- ❑ Made from UV-stabilised plastic, the environmentally-friendly protector prevents damage by animals, weeds and weather.
- ❑ The guard features a series of patented tongues and slots which lock into place for stability and strength.
- ❑ They are designed to give lasting protection to your valuable plantings

Your precious vines and olives protected in their own greenhouse

Benefits are:
- Increased growth rate
- Suitable for vines and olives
- Easy to install
- Environment-friendly green
- Stores flat
- Can be staked
- Reusable

Guards against:
- Wind
- Rabbits and hares
- Herbicide sprays
- Damage by mechanical and hand hoes
- Insect attack

McLEAN'S VINE & TREE GUARDS
RDS FARM ELECTRONICS (AUST.) PTY LTD
Aust & USA Patents
7 Boehm Drive, Hahndorf SA 5245
Phone (08) 8388 1217 Fax (08) 8388 1146

Stem

If the leaf has been enclosed in a plasticised aluminium bag for 30 minutes (or more) before measurement, the reading reflects the stem water potential. Enclosing the leaf in a plasticised, aluminum bag prevents the leaf from transpiring. Over time the LWP comes into equilibrium with the stem water potential.

Measuring trunk diameter

Linear Variable Displacement Transducers (LVDTs) can continuously and accurately monitor trunk diameter. In recent years the robustness of LVDT technology has significantly improved and they are now regarded as reliable field instruments. LVDTs can be thought of as electronic callipers (see figure 5).

Summary

It is desirable, and highly likely that plant-based measurements will form the basis of future irrigation scheduling decisions. As the measurement of leaf/stem water potential is labour intensive and does not have the potential to be automated, it is unlikely that these measurements will be utilised by commercial operators. Trunk diameter can be automatically logged at user-defined intervals; it is thus the preferred indicator of plant water status. Unfortunately, very little information is available on the use of LVDTs in viticulture. Research is required to determine the feasibility of LVDTs as irrigation scheduling tools. A project, funded by the Grape and Wine Research and Development Corporation, has been initiated to investigate the use of plant-based sensors in viticulture. The project will assess the sensitivity of various plant-based measures to water stress and determine the variability of plant-based measures across a vineyard. It is hoped that by the end of the project representative sampling procedures will have been developed. For more information contact Dr Brian Loveys (CSIRO) on (08) 8303 8615 or email Brian.Loveys@csiro.au

Acknowledgements

This project was supported by the Commonwealth Cooperative Research Centres Program and conducted by the CRC for Viticulture (CRCV) and Primary Industries Research Victoria. The authors thankfully acknowledge financial support from GWRDC, the Victorian Department of Primary Industries and SARDI.



Fig. 5. Linear Variable Displacement Transducers (LVDTs) can be thought of as electronic callipers. Photograph courtesy I. Goodwin.

References

Goldhamer, D.A. and Fereres, E. (2003). Validation of irrigation scheduling protocols using trunk diameter sensors in almond trees. Paper presented at the 4th International Symposium on Irrigation of Horticultural Crops. 1st-5th September, University of California, Davis, USA.

Goldhamer, D.A., Fereres, E., Mata, M., Girona, J., and Cohen, M. (1999). Sensitivity of continuous plant and soil water status monitoring in peach trees subjected to deficit irrigation. Journal of American Society of Horticultural Science. 124(4):437-444.

Shackel, K., Ellett, J., Johnson, S., Fulton, A. and Buchner, R. (2003). 'Midday stem water potential for RDI management and water stress diagnosis in tree and vine crops'. Paper presented at the 4th International Symposium on Irrigation of Horticultural Crops. 1st-5th September, University of California, Davis, USA.

Williams, L.E., and Araujo, F.J. (2002) Correlations among predawn leaf, midday leaf, and midday stem water potential and their correlations with other measures of soil and plant water status in *Vitis vinifera*. Journal of American Society of Horticultural Science. 127(3):448-454.

SOMETHING OF...

REELinterest FROM INDAC

The Indac Net Reel has been developed to assist in the retrieval, storage and application of bird netting in vineyards. Available in different lengths, the reel is suitable for side row, over row and multi row netting.

Flanges on the ends provide for tangle-free winding, preventing nets from becoming trapped in any part of the winding mechanism. The drive slots in each end allow compatibility with most winding systems.

Three sizes available:

- **1030B (suits 1000mm netting)**
- **1230B (suits 1200mm netting)**
- **1530B (suits 1500mm netting)**



For details on your nearest stockist, contact:

INDAC

INNOVATIVE DESIGN AND CONSTRUCTION

NZ Free Phone	0800 803 888
NZ Free Fax	0800 274 467
NZ Phone	+64 3 578 3034
NZ Fax	+64 3 578 2032
Aus Free Phone	1800 553 055
Aus Free Fax	1800 553 550

Email: info@indac.co.nz
Web: www.indac.co.nz

PHA launches plant health awareness campaign

Plant Health Australia (PHA) has launched its first national plant health awareness campaign targeting commercial plant producers with the message *Look. Be Alert. Call an Expert.* PHA is urging winegrape growers to develop and maintain their vigilance and to take action if they spot anything unusual in their crops, thereby helping to protect Australia's plant industries, collectively worth $13billion annually.

The project aims to encourage producers to develop and maintain their vigilance in checking their plants or crops for unusual pest or disease signs. If they do suspect anything unusual, they can report it immediately to the exotic plant pest hotline on 1800 084 881.

APPENDIX 3

CONTACTS

Dr Gordon Rogers Plant Physiologist Applied Horticultural Research New South Wales, Australia Ph: 02 9527 0826 Email: gordon@ahr.com.au	Dr Sanliang Gu Ricchiuti Chair of Viticulture Research Viticulture and oenology Research Center California State University Fresno, United States Ph: 559 278 4786 Email: sanliang_gu@csufresno.edu
Alan Lasko Professor and Chair_ Department of Horticultural Sciences New York State Agricultural Experimental Station - Cornell Geneva, NY, United States Ph: 315 787 2399 Email: ANL2@cornell.edu	Dr Amos Naor Golan research Institute University of Halfa Israel Ph: 972 4 6962402 Email: amosnaor@research.haifa.ac.il
Dr Robert Wample Professor and Chair Department of Viticulture and Oenology Californian State University Fresno, United States Ph: 559 278 2089 Email: Robert_wample@csufresno.edu	Diego Intrigliolo PhD Student IVIA Apartado Oficial 46113 Moncada, Valencia, Spain Ph: 34 656 682 880 Email: diego.intrigliolo@ivia.es
Dr Horst Caspari Associate Professor and State Viticulturist Colorado State University Western Colorado Research Centre Colorado, United States Ph: 81503 9621 Email: horst.caspari@colostate.edu	Professor Larry E Williams Professor Department of Viticulture and Oenology University of California, Davis United States Ph: (559) 646 6558 Email: Williams@uckac.edu
Dr David Goldhamer Irrigation Management Specialist Department of Land, Air and Water Resources University of California Davis United States Ph: (559) 646 6575 Email: dagoldhamer@ucdavis.edu	Dr Samuel Ortega Dean Faculty of Agricultural Science University de Talca Talca, Chile Ph: (56) 71 200210 200426 Email: sortega@utalca.cl