

Sustained deficit irrigation of winegrapes in a semi-arid horticultural region of Australia

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Abstract

In the Murray Darling Basin (MDB), the so called “food bowl” of Australia, there is an increasing need for agricultural and horticultural management practices that use water resources more efficiently. In the Sunraysia region of the MDB, a trial is being conducted on a Shiraz (*Vitis vinifera*) winegrape to explore the potential for improvements in water use efficiency (WUE), and the impacts on deep drainage by using subsurface drip irrigation with sustained deficit (SD) irrigation treatments. Other objectives include investigating fruit and wine quality under various water deficit levels. The treatments consist of one control (100%) and three deficits being 65, 45 and 34% of the control. In the first irrigation season (2003-2004), irrigations were scheduled on the basis of average soil matric potential of the control treatments. A higher WUE was observed as a result of lower water use in SD treatments, however the control and deficit irrigation treatments in both surface and subsurface irrigations were not statistically different in yield and quality components. The surface and subsurface treatments were not significantly different with respect to WUE and yield components. Strong spatial variation across the experimental site resulted in the vines of the eastern plots experiencing drier conditions throughout the irrigation season compared with vines at the western corner of the site. A range of measures was considered for the second irrigation season to address the impact and extent of observed spatial variability. These included an electromagnetic survey accompanied with soil sampling. An array of piezometers were installed across the site to measure the extent of seepage from the irrigation supply channel. Irrigation scheduling was changed to average of soil matric potential in the drier (eastern) portion of the site to prevent exposure of these soils to extreme stress conditions. The statistical analysis of results has been modified to include an indicator of the spatial variability as a covariance to the analysis.

Keywords: deficit irrigation, soil water potential, subsurface irrigation.



1 Introduction

In Australia, Murray Darling Basin produces forty percent of the national income through agricultural production and grazing and is called the “food bowl” of Australia. Environmental pressures such as salinity and prolonged drought conditions in the basin have created a widespread recognition that irrigation water consumption and environmental impact have to be reduced to a sustainable level. The prospect of severe restriction in water availability to the vineyard areas has negated the previously held perception (Meyer, [1]) that “water is not limiting to vineyard expansion in Australia”. As a result, there is a growing challenge to better manage irrigation practices and increase the water use efficiencies of grapevines to ensure future water availability.

Rapid conversion from traditional furrow irrigation to micro-irrigation in the vineyards and a better understanding of physiological responses to water deficit have led to development of some practical solutions to even more efficient management of water in grapevines. Regulated deficit irrigation (RDI) and partial root zone drying (PRD) are two such strategic solutions (Goodwin [2], Dry et al. [3], McCarthy et al. [4]). These strategies not only help minimise water use, but also aim to manipulate growth and optimise yield and fruit quality. RDI is based on withholding water during certain stages of grapevine growth to limit vegetative growth and control berry size. Despite some yield losses, a significant improvement in red-wine quality has been achieved when RDI is practised immediately after fruit set (Dry et al. [3]). PRD is maintaining a separate wet and dry zone in the root system to stimulate a biochemical response to water stress, while maintaining a favourable water status in the areal parts of the plant. Therefore, the method (if applied properly) should not result in any significant yield losses (McCarthy et al. [4]). It is expected that despite a reduction in water consumption, the fruit quality if not improved, is at least maintained.

Sub-surface drip irrigation (SSDI) provides a promising option, which can be managed to reduce surface evaporation by keeping the surface soil relatively dry, thus maximising the advantages of drip irrigation. SSDI has increased yield and water use efficiency (WUE) of broad acre crops (Phene et al. [5], Hutmacher et al. [6]). There is a potential for adoption of SSDI to deficit irrigation of vineyards, provided the limitations and advantages of the technique are realised. Initial costs and root intrusion are concerns with the operation of a SSDI system. Perhaps the biggest concern in adoption of this technique is the accumulation of salt where rainfall is not sufficient (Schulz, 2000). Some extra water will need to be applied to leach salts to maintain a salt balance in the root zone (Ayars et al. [7]).

2 Objectives

The specific objectives of the project were:

1. Water use efficiency (WUE) of sub-surface drip irrigated (SSDI) VS surface drip irrigated (SDI) in fully irrigated treatments, and the WUE of partially



(deficit) irrigated grapes in the two irrigation systems VS control (fully irrigated) treatments.

2. Yield and quality parameters within the above comparisons.
3. Soil evaporation and drainage losses as a possible source of difference between the outcomes from the two main treatments.

3 Materials and methods

3.1 Soil and climate

The experiment site (34° 15' S, 142° 10'E) has a semi arid climate with high water deficits during the growing period of most crops including grapevines in the region. Average annual rainfall is 283 mm and evaporation from Class A pan is 1542 mm per year. The calcareous soil of the site is typical of the aeolian plains of the area, with a sandy loam surface soil extending to a heavier texture at more than 80 cm depth.

3.2 Instrumentation

The experiment is carried out on a 0.45 ha Shiraz (*Vitis vinifera*) grafted on Ruggeri rootstock and is comprised of 23 rows of vines with 36 vines in each row and 1.8x3m vine spacing. The vines were established in 1998 and were under PRD treatments between 2001-2003. In August 2003, the PRD irrigation system was dismantled and the new irrigation system was put in place. This consisted of surface and subsurface dripper lines replicated in groups of 3 rows across the site. The subsurface laterals were put in 0.40 m deep trenches which were dug at a distance of 0.25 m from the vine trunk. In each vine row, the in-line drippers with 0.80m spacing were used. The drippers with flow rates of 1.2, 1.6, 2.3 and 3.5 l/h were joined to produce 34, 46, 66 and 100% (control) of the water delivered to the vines during each irrigation. Each treatment consisted of four vines receiving one of the above flow rates and each treatment was replicated twice along each row. From the four vines in each treatment, only the middle vines were used for sampling and monitoring and the other two were left as buffers. Likewise, from each of the three rows in the surface and subsurface irrigations, only the middle rows were selected for the experiment, and the side rows were left as buffers to minimise the interference from the adjacent treatments.

Due to the presence of the main irrigation channel at the western side of the block, a drain was installed to a depth of 2 m in the area between channel and the first vine row to intercept and collect any lateral seepage from the channel to the experimental site. It was assumed that the vine would not extract any water from below 2-meter soil depths.

Soil water content was measured by 16 EnviroSCANR (SENTEK Pty Ltd) capacitance probes, which were installed at two representative locations of the site. Each probe had 4 sensors at 20, 40, 70 and 100cm soil depth. The sensors were calibrated in field.



Soil matric potential was measured with granular matrix blocks (GbugsR, MEA Australia) which were installed at the same depths as the capacitance sensors. Soil bulk density was measured from intact soil cores taken from 10 cm soil depths at 4 locations across the site with 3 replicates to a depth of 100 cm. Samples were also taken from 4 locations for texture, pH and EC measurements. Irrigations were scheduled based on the average soil water potential in the control treatments. This was selected to be up to 60 Kpa initially, but later on it was changed to less than 40 Kpa. Climatic data was obtained from the bureau of meteorology, 14k south of the experimental site. Crop water requirement (ET_c) was estimated using FAO56 methodology for potential evapotranspiration (ET_o) multiplied by crop factors adjusted for the stage of the canopy growth (Allen et al. [8]). Effective canopy cover (ECC) of the vines was used as an index for this adjustment, which was measured by a hand-held ceptometer (AccuPARR, Decagon devices, Inc) registering the percent of light intercepted by the canopy, which was related to the canopy size. Total Irrigation was measured with a water meter installed at the eastern corner of the block. Depth of irrigation for each treatment was calculated based on the flow rate and the area associated with each treatment. In the second year (2004-2005), small water meters were connected to each treatment vine row to have a separate calculation of the treatments in one row. Pressure bomb apparatus (Soil Moisture Equipment, USA) was used in the second year to measure leaf water potential (LWP) as an indicator of plant water status out. In March 2004, harvest was carried where yield and quality components were measured on fruit samples obtained from one metre vine transects from each treatment.

4 Results

4.1 2003-2004 season

Twelve irrigations were carried out throughout the first season, which started from 9th of November 2003 and ended on 5th of March 2004. 110 mm of rain fell during the same period. The frequency of irrigation varied according to the readings of the soil matric potential, and was increased through the middle of the season when some extreme dry conditions were measured in the soils of the eastern vine row (Figure 1). A trend in the growth of the canopy and the water status of the vines from the western to the eastern rows of the site were observed.

At harvest, the deficit treatments had high Water Use Efficiency (WUE) as a result of lower water use in them (Table 1). The statistical analysis showed that the yield in surface and subsurface treatments were not statistically different, although the similarity was only marginal.

The yield and quality (Colour and Phenolics) were not significantly different in the control and deficit irrigation treatments of both surface and subsurface irrigations.



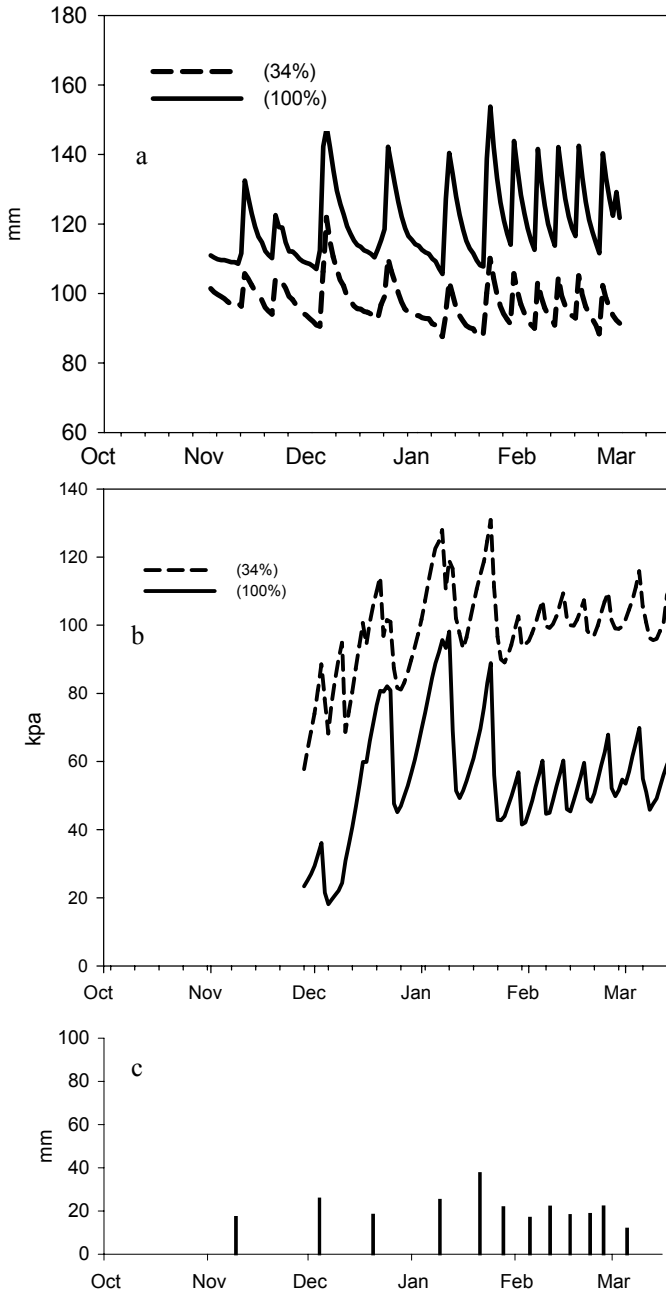


Figure 1: The soil water content (a) and soil water potential (b) change in the control and 34% deficit treatments as a response to irrigation application (c).

Table 1: The comparison of the water use and yield components in different treatments at the end of the first year of the study (2003-2004).

Water treatment	100%	100%	65%	65%	45%	45%	34%	34%
Irrigation System	S	SS	S	SS	S	SS	S	SS
Yield (t/ha)	29.6	27.0	8.7	23.8	25.3	24.5	24.7	28.6
Bunch No.	137	124	140	119	138	119	127.1	129
BerryWt. (g)	0.9	0.9	0.9	0.8	0.8	0.9	0.8	0.9
°Brix	23.5	25.7	23.7	23.9	24.1	25.0	23.7	24.4
pH	3.5	3.6	4.2	4.2	4.3	4.3	4.2	4.2
TA	4.3	4.2	3.5	3.5	3.7	3.4	4.1	4.1
Colour(mg/g)	1.3	1.1	1.3	1.1	1.2	1.1	1.3	1.2
phenolics (mg/g)	1.4	1.1	1.4	1.1	1.3	1.3	1.5	1.2
Irrigation (ML/ha)	2.6	2.6	1.7	1.7	1.1	1.1	0.9	0.9
WUE (T/ML)	11.5	10.5	17.1	14.2	21.8	21.1	28.1	32.6

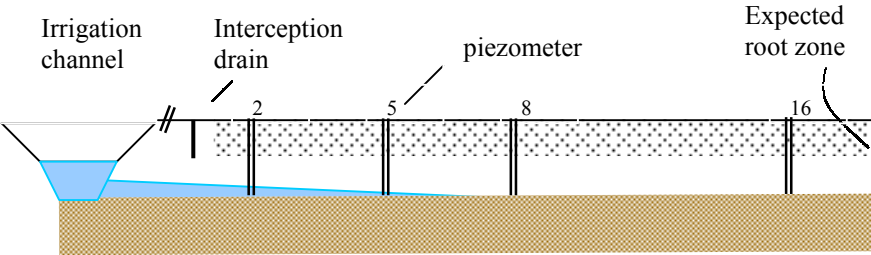


Figure 2: Schematic diagram of the relative position of irrigation channel and the piezometers installed in the vine rows (shown by numbers).

These results were contrary to what was expected. Extreme levels of deficit such as the 34% irrigation treatments should normally result in a significant reduction in the yield and berry size. A significant increase in oBrix and phenolic content of the fruit juice was also expected, however, this was not the case with the results of the first year’s harvest.

4.2 2004-2005 season

Based on the visual differences in the first season with regards to the performance of the vine rows on the western end of the block (closer to the irrigation channel), it was speculated that these vines might have access to extra reserves of water as a result of seepages from the channel. This difference in the water use could have masked the treatment effects and influenced the overall results from the first year harvest of the vines. Although installation of a drain at

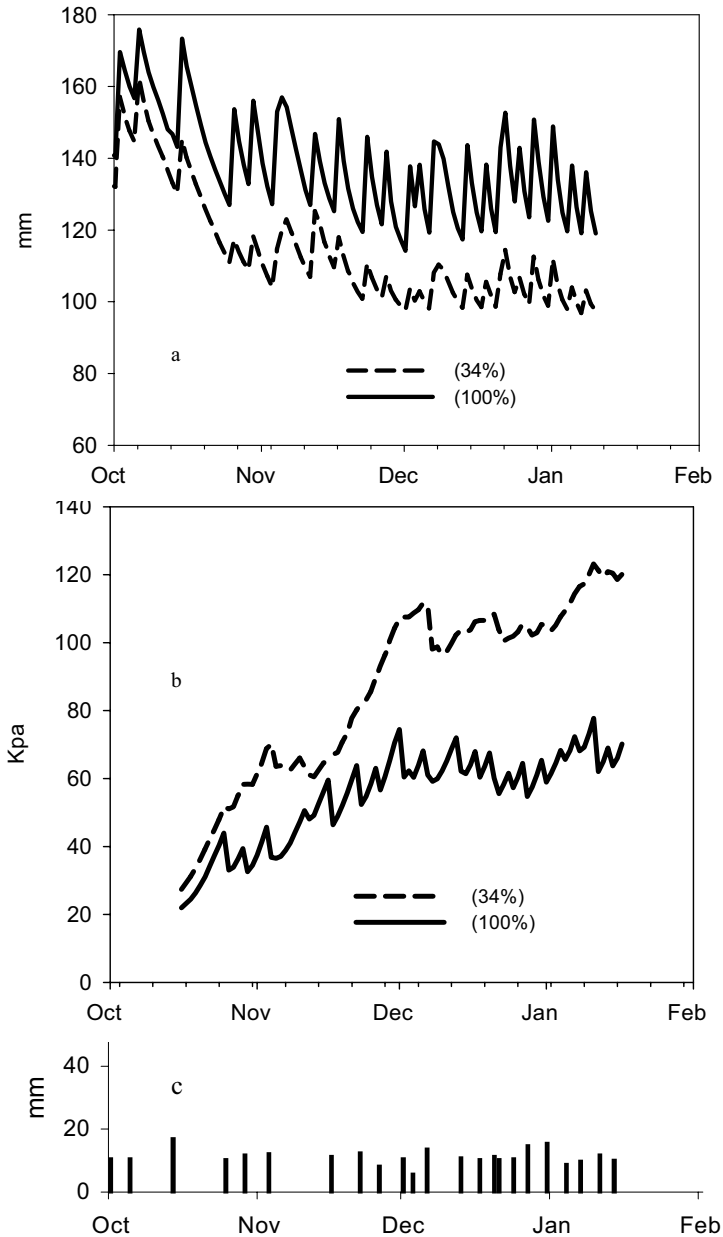


Figure 3: The soil water content (a) and soil water potential b) change in the control and 34% deficit treatments as a response to irrigation application (c) in 2004- 2005 (to date).

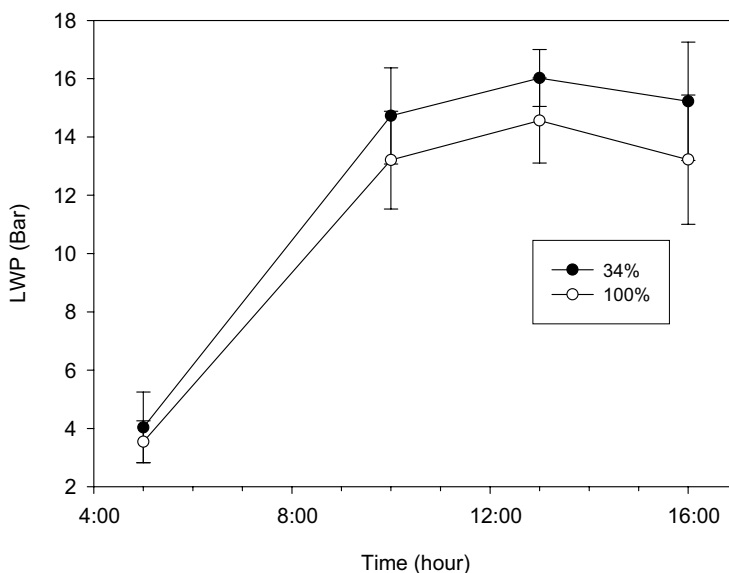


Figure 4: Diurnal changes in leaf water potential of the control and the lowest (34%) water treatments. The error bars are the standard deviation of the averages for each treatment.

two-meter depth at the start of the study was to overcome this effect, it was decided to examine the presence of water table at deeper layers. In October 2004, five piezometers were installed to a depth of 3 meters across the site and at the bottom of the vine rows 2, 8, 12, 16 and 22 on a transect perpendicular to the direction of the channel. Water was found in piezometers 2 and 8, which were closer to the channel (Figure 2). The depth to the water from the surface varied from 2.20 in October 2004, and gradually changed to 2.60 m in January 2005.

In order to avoid the extreme dry conditions in the soils of the eastern rows as observed in the first season, irrigation scheduling was changed in 2004-2005 season to the average soil water potential of the control treatments in the eastern rows. This resulted in more frequent irrigations in the second year, resulting in 25 irrigations to mid Jan (to date) compared with 12 irrigations for the whole of the first season. The soil water content responded to irrigations, accordingly (Figure 3). The growth of the canopy (ECC) was markedly higher than the first year, where the average ECC in the control plots reached a value of 0.8 compared with 0.4 for the previous year. Despite frequent irrigations, a noticeable rise in the matric potential of the soil of all treatments was observed with a gradual decline in the average water content of these soils (Figure 3). Pre-dawn leaf water potentials in 34% treatments were slightly higher than that in the control (100%) vines (4 and 3.5, respectively). The difference increased during the day, and the 34% treatments maintained a higher deficit with a maximum of 16 bar at 1.00 pm, which declined at a slower rate than the control vines (Figure 4). The data has yet to be analysed for the significance of these differences.

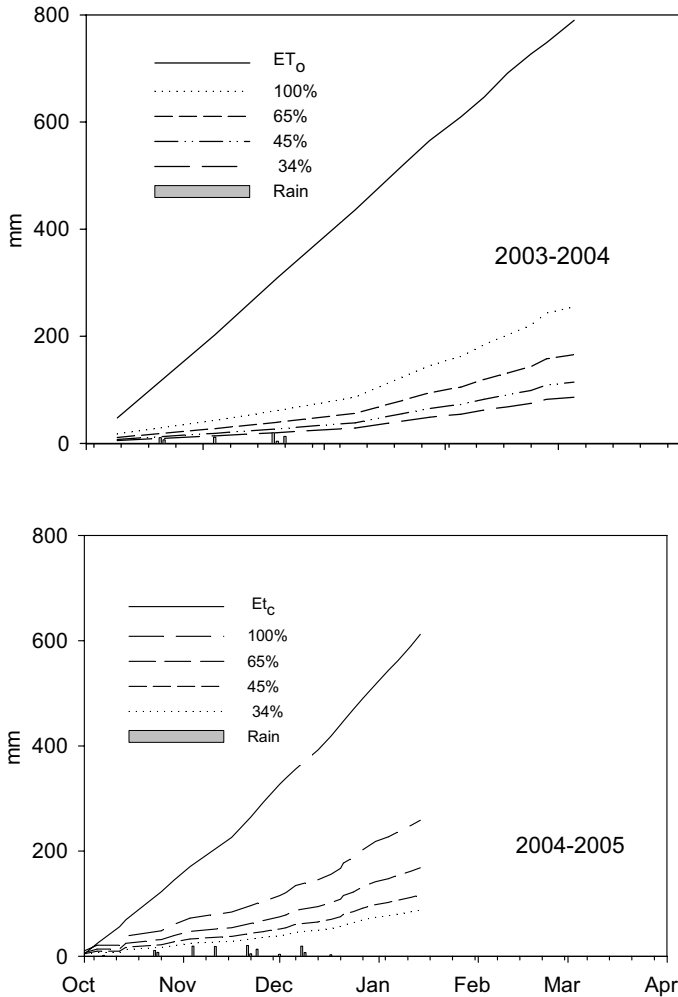


Figure 5: Cumulative irrigation application and potential evapotranspiration (ET_o) at control (100%) and deficit plots during the 2003-04 and 2004-05 (to-date).

5 Discussion

In the first year of this study a significant improvement in the water use efficiency of the vines was observed as a result of application of deficit to the vines. Subsurface irrigation did not affect the water use efficiency of the plots. Likewise, the quality components of the harvest were not significantly different in all treatments. Two possible factors have contributed to these results. Firstly, the performance of vines at any particular season is affected by their previous year's treatment. Initiation of the flower bud occurs at the end of each season,

which is long before the bud burst at the start of the following season. Therefore, the results from the second year of this study will be more indicative of potential effects from irrigation techniques or the deficit treatment in this variety of vine. Secondly, access of the vines to an extra source of water has marred the treatment effects and has generated an anomaly in the results. As it is unlikely that the vines could have accessed any water below 3-meter depth therefore, it is suggested that this influence is confined to the first few rows (Figure 2).

The change in the scheduling of irrigation in the second year, resulted in a significant growth of the vines and thus their water requirement, so that in mid January 2004, the total water use in the vines were similar to the water applied for the whole season in the first year (2.5 and 0.8 ML/ha for the control and 34% treatments, respectively) (Figure 5). Both figures are much below the average irrigation application of winegrapes in the area, (between 6-7 ML/ha).

The contribution of groundwater to the total water use in vines has not been reported in the previous studies. The current study will provide an opportunity to quantify this component of the water balance. A detailed study of fluxes of water to and from the water table in these vines is envisaged. This will be through measurement of hydraulic properties below the root zone of affected vines. Despite dry conditions in the soil of the deficit treatments (Figure 3), the water status of these vines were not very different from that of the control treatments (Figure 4), although this has to be statistically verified.

References

- [1] Meyer, W. S. (1999). Diving for water. In : Proceedings 10th Australian wine Industry Technical Conference, Sydney, Australia, 73-77.
- [2] Goodwin, I. (1995) Irrigation of vineyards. A vine grower's guide to irrigation scheduling and regulated deficit irrigation. Agriculture Victoria. Tatura. 56 pp.
- [3] Dry PR. Loveys BR. McCarthy MG. Stoll M. 2001. Strategic irrigation management in Australian vineyards. *Journal International des Sciences de la Vigne et du Vin*. 35(3):129-139, 2001 Jul-Sep.
- [4] McCarthy , M.G., B.R. Loveys, P.R. Dry and M. Stoll. 2003. Regulated deficit irrigation and partial rootzone drying as irrigation management techniques for vines. South Australian Research and Development Institute, Adelaide, Australia, CSIRO Plant Industry, Adelaide, Australia., University of Adelaide, Adelaide, Australia
- [5] Phene, C.J., Hutmacher, R.B., Davis, K.R., McCormick, R.L., Meek, D.W., 1986. Management and response of subsurface drip-irrigated tomatoes, *Proc. Int. Round 100 Conf. Micro-irrigation*, vol. III Budapest, Hungary, pp 49-56.
- [6] Hutmacher, R.B., Mead, R. M., Shouse, P.. 1996. Subsurface drip: Improving alfalfa irrigation in the west. *Irrig. J.* 45 : 48-52
- [7] Ayars, J. E., C. J. Phene, R. B. Hutmacher, K. R. Davis, R. A. Schoneman, S. S. Vail and R. M. Mead. 1999. Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research



Laboratory, Agricultural Water Management, Volume 42, Issue 1, September 1999, Pages 1-27

- [8] Allen, R, Pereira, L., Raes, D., Smith, M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56

