Precision management in viticulture – an overview of an Australian integrated approach

INTRODUCTION

To achieve a particular goal of improved yield or quality in vineyard management, it is essential to understand the impact of plant–soil–water dynamics at different phenological growth stages on plant physiology. This is not possible without the measurement of key variables, such as the effective plant rooting depth, daily crop-water use, the macroclimate and microclimate, soil type, and irrigation-system performance.

This review provides an overview of Australian technological contributions to precision management of irrigated viticulture in the past 20 years. This involves an integrated approach of mapping soil spatial properties to generate irrigation management zones, evaluation of irrigation system performance and the use of near-continuous soil-water profile dynamics in making irrigation scheduling decisions and implementing irrigation management strategies, such as regulated deficit irrigation (RDI) and partial rootzone drying (PRD).

This integrated approach is used to strategically manage soil-moisture levels in order to control growth, yield and quality parameters in the production of a range of horticultural crops including vine grapes. In the grape variety Shiraz, three primary growth stages can be identified. From flowering to fruit set, no moisture stress is allowed. RDI is applied post-flowering and prior to veraison in order to increase the pulp to skin ratio and concentration of colour and flavour, while reducing vegetative vigour. From veraison to harvest, soil moisture is maintained at sufficient levels to maintain grape turgor. Soil-moisture levels are an integral part of the strategy for both the management of sugar and anthocyanin levels during berry ripening and that of flavour compounds during the latter stages of the crop cycle.

These combined strategies can be used to overcome some underlying challenges of irrigated agriculture and at the same time provide economic and environmental benefits.

THE PROBLEM AND THE CHALLENGE

"Vineyards vary substantially in the quantity and quality of grapes they produce. Yield and various measures of quality are known to vary widely within blocks and along rows. Two consequences of this are the uncertainty in the prediction of yield and the delivery of grapes of inconsistent quality to the winery.

P. Buss, M. Dalton, S. Olden and R. Guy
Sentek Pty Ltd.

Yield uncertainty obstructs precise scheduling by winemakers faced with an increasing mismatch between the tonnage of grapes to be crushed and the crushing and storage capacity of each winery. Meanwhile, variation in fruit quality and the resultant acceptance of 'average' quality from whole vineyards, limits the opportunity to maximize the production of premium quality wines." (Bramley, 2004).

"If the industry wants to stay competitive, then it needs to measure and manage its spatial variation in yield and quality, just like any manufacturing industry is faced with significant process efficiency variation." (Bramley, 2002).

Soil variability is one of the key factors that can affect grape vine growth, fruit development, quality and yield. Soil properties that are important in viticulture include: topsoil depth, soil texture, soil structure, rootzone depth, available water capacity, soil drainage, soil salinity and soil fertility. Existing soil maps do not provide the level of detail that is desired, nor do they provide interpretations specifically for growing vine grapes (Gallagher, 2001).

The level of distribution uniformity of irrigation water within the vineyard by the irrigation system is another factor, often unnoticed, that can profoundly affect winegrape yield and quality.

The ever-changing availability of soil water in particular is a critical factor in determining fruit and wine quality. Understanding and managing the dynamic relationship between site, soil, water, phenological stage, vine and wine quality is indeed a complex challenge.

THE SOLUTION – AN INTEGRATED APPROACH IN PRECISION IRRIGATION MANAGEMENT

This review presents an integrated approach of measurement and management strategies, currently used successfully in irrigated viticulture in Australia. The combined approach and technologies have shown great potential for improving vineyard performance and achieving desired goals in terms of yield, quality and the environment.

Four key water-management strategies are presented here to constitute precision irrigation management:

- delineating strategic irrigation-management zones in the vineyard;
- optimizing the use of water (fertilizer) distribution uniformity;
- using measurement technologies to track soil-water, weather and fertility data;
- implementing RDI as a management strategy.

Delineating strategic irrigation-management zones in the vineyard

Precision viticulture delineates strategic irrigation management zones that significantly influence the irrigation and fertilizer application of the vineyard. The key to the development of a successful irrigation-scheduling plan is the integration of soil and plant factors operating at the particular production vineyard zones (Buss, 1989). To identify these management zones and ultimately develop an irrigation-scheduling plan, where vineyard zones have been portioned into areas with similar plant-available water storage and similar crop-water extraction patterns, the following approach is recommended (refer to Figure 1):

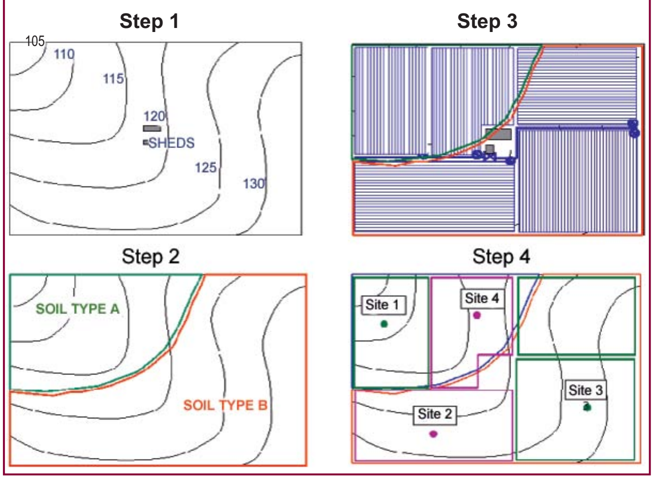
- Step 1:
  - Obtain contour data for the property.
  - Map the contours and relevant features, i.e. waterways, buildings, drainage lines, etc.
  - Locate areas of significantly different aspect.
  - Differentiate areas of different topography, i.e. hill crests, top, middle and bottom of slopes, and low-lying areas.
- Step 2:
  - Undertake a soil survey across property.

- Identify the dominant soil types and key soil properties that affect soil-water storage.
- Draw a soil map showing areas of similar irrigation-management requirements.

➢Step 3:
- Overlay the irrigation-system plan on top of the soil survey and contour plans.
- Locate areas watered by each valve and in each irrigation shift.
- Match this against the predominant soil and topographic units.
- Some modification may be required to the irrigation system.

➢Step 4
- Overlay the planting plan of crop types and varieties.
- Integrate this information to draw up irrigation-scheduling units.
- Delineate areas that have similar irrigation requirements according to soils, aspect, topographic location and vine type.
- Each different scheduling unit will require a monitoring site.
- Areas of similar soil, microclimate and plant type – e.g. one at top of hill, one in low-lying area, will require different monitoring sites.

FIGURE 1
Development of an irrigation-scheduling plan

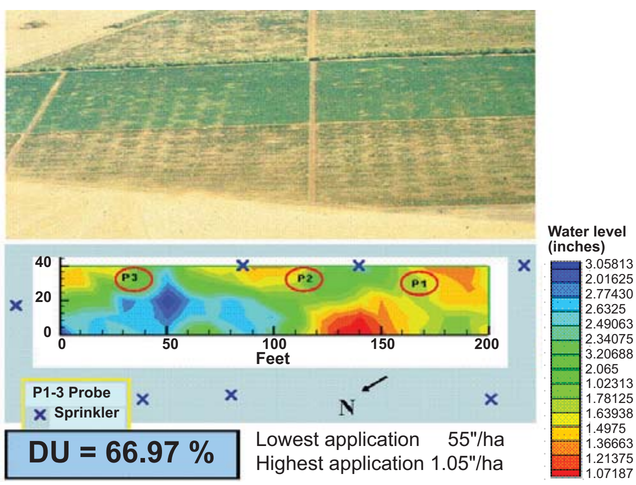


Optimizing the use of water (fertilizer) distribution uniformity

It is absolutely mandatory for precision viticulture, but often ignored, to conduct an evaluation of the irrigation system in order to measure and demonstrate the effectiveness of the existing irrigation practice. Insufficient distribution uniformity of water (Figure 2) and fertilizer application can lead to significant yield and quality losses, irrigation water losses, fertilizer losses, soil-salinity and water-table increases, and unsustainable environmental and uneconomic outcomes.

Knowledge of water distribution is also critical for microsite selection of soil-water measurement probes. Placement of probes on "wet" or "dry" areas within a water distribution pattern can lead to unrepresentative soil-water data and misleading irrigation-management recommendations. Investment in soil water monitoring is not recommended where water distribution (DU) is much lower than 75 percent (Merriam and Keller, 1978). It is better to upgrade the irrigation system first in order to

FIGURE 2
Severe distribution uniformity problems of water in an overhead-sprinkler-irrigated vineyard in South Australia and plotting the results of an irrigation-water catch-can test



Note: Picture and test results are unrelated.

improve yield and grape quality and uniformity and, therefore, build a solid platform for irrigation scheduling.

Evaluating irrigation-system performance and water distribution in a vineyard needs to become a mandatory and integral measurement in the pursuit of precision viticulture for it to deserve the name.

Methodologies to evaluate irrigation systems such as sprinkler, drip and flood are described in detail in the benchmark publication by Merriam and Keller (1978).

Using measurement technologies to track soil-water, weather and fertility data

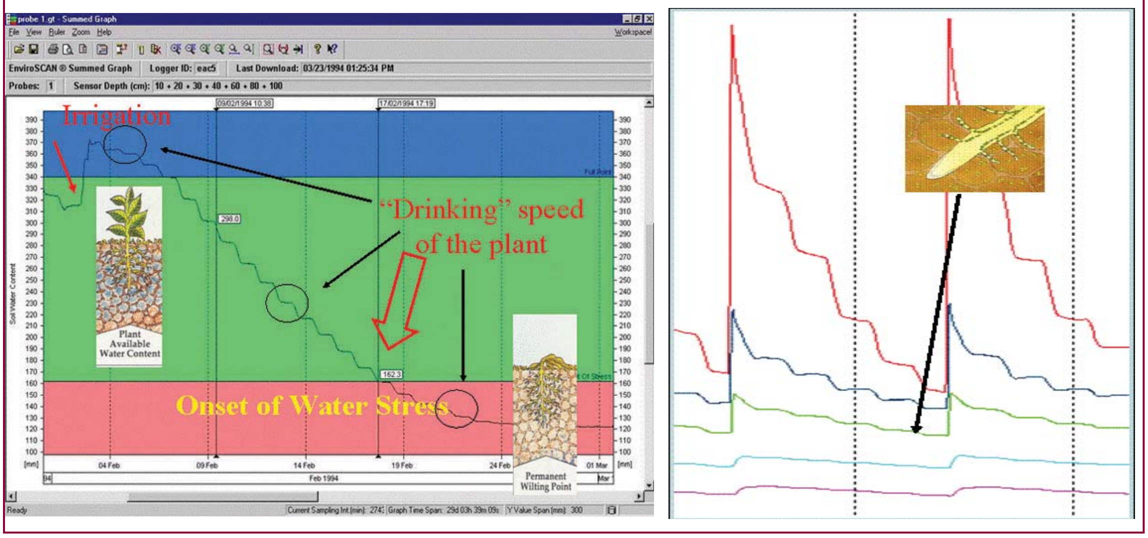
It is essential to understand the impact of plant–soil–water–atmosphere dynamics at different phenological growth stages on plant physiology and on the resultant wine quality. This is not possible without the measurement of key variables such as the effective soil-water storage, plant rooting depth, onset of water stress, and daily vine water use.

Soil-water monitoring based on near-continuous profiling data was introduced by Sentek Pty Ltd about 13 years ago, and has become an important tool in vineyard water management in Australia. The EnviroSCAN® technology serves not to only to gauge the status of soil water storage, but also to provide information-rich feedback to the irrigation manager on key vine-management variables such as:

- daily vine-water use in relation to vine variety, phenological stage, soil type, vineyard floor management, weather and other factors;
- depth of the active rootzone;
- water use from different root layers;
- onset of stress;
- refill point;
- full point;
- infiltration, drainage and percolation rates.

Summed near-continuous soil-water data have been useful in defining daily water use (through daily trend stepping) and the onset of stress and full point for a particular irrigation-management zone (Figure 3) in the vineyard. The stacked graph (Figure 3) reveals the effective root-water extraction per depth level and rootzone depth. The

FIGURE 3
Tracking soil-water data



bottom of the rootzone is the third trend line from the top of the graph illustrated by the presence of active daily uptake dynamics. The bottom two trend lines show "no stepping", indicating soil-water change through drainage only, rather than root extraction.

Note: The line in A shows a summed soil-water content, illustrating the whole profile plant-soil–water dynamics over time. B shows soil-water data dynamics within and between 10-cm depth increments in the profile.

The measurement of these key variables via the interpretation of soil-water dynamics is an essential new technology to implement a successful irrigation-management strategy.

Implementing RDI as a management strategy

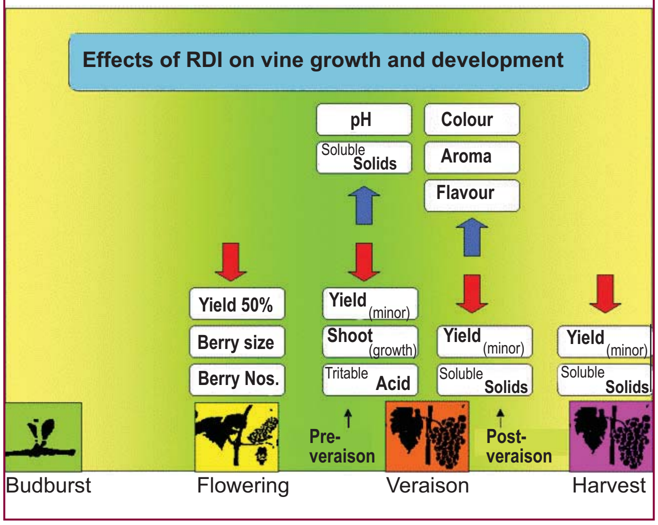
An irrigation-management strategy should include the timing and duration of irrigation during the growing season to meet an optimal yield/quality objective for a particular, delineated irrigation-management zone of the vineyard. Irrigation scheduling is the technique to fulfil the objectives of an irrigation-management strategy.

The irrigation-management strategy used in Australian viticulture known as RDI seeks to manipulate vine growth and wine quality (Figure 4). The aim of RDI is to maintain water stress within a desirable range so that the physiological reactions of the vine can be harnessed to the benefit of the vineyard and, ultimately, the quality of the wine.

The seasonal recommendations for RDI, issued by the South Australian Research and Development Institute (SARDI, 2004), are:

- Keep vines well supplied with water and nutrients and under good disease control during budburst to fruit set period.
- From fruit set to veraison – the RDI period (defined by the SARDI as being from when any signs of flowering are over and full early set is obvious, continuing to the first signs of colour change in skins, i.e. start of veraison) – start by allowing the soil around the majority of roots to dry by reducing or ceasing irrigation. Continue to dry the profile until vegetative growth slows or stops (using monitoring equipment and visual inspections). Once this has been achieved, controlled irrigations can start again if vegetative growth is not stimulated.
- Moisture monitoring continues to be useful in the period from veraison to harvest in order to keep moisture levels within a desired range for healthy growth. Monitoring can help guard against excessive water use and promotion of vigour, or at the other extreme, drying out to the point where health and yield will be affected.
- Irrigation as well as fertilizer application after harvest should be considered for maintenance of vine reserves. Monitoring soil water through winter will ensure the soil profile has good moisture levels at budburst.

FIGURE 4
Summary of effects of RDI at specific stages of growth and development of a vine

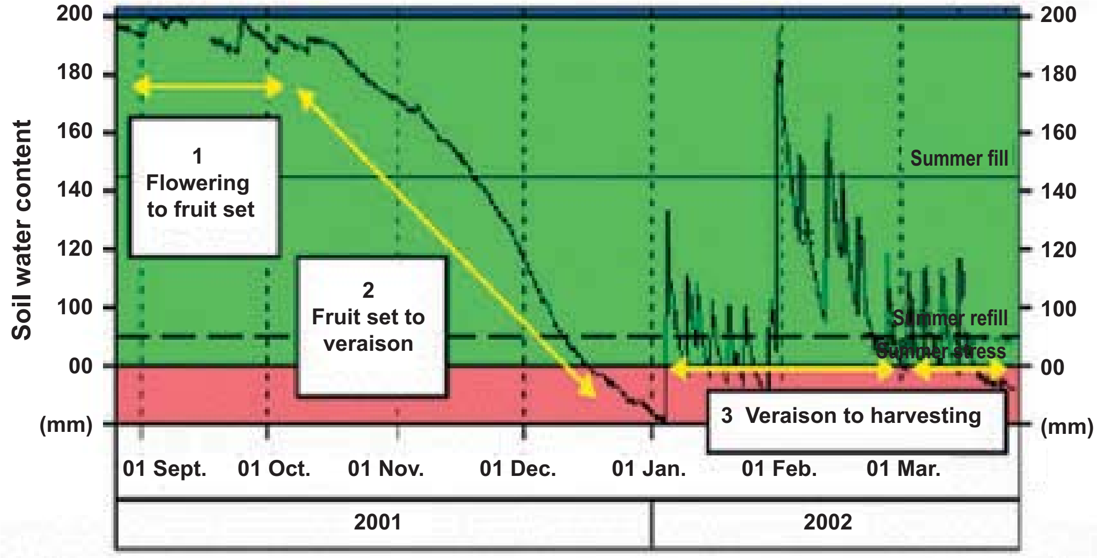


Source: Drawn using data by Goodwin, 1995.

BENEFITS OF RDI – AN EXAMPLE

Founded in 1893, Wirra Wirra Vineyards is one of Australia's leading vineyards.

FIGURE 5
Summed EnviroSCAN soil-water graph showing RDI irrigation management at Wirra Wirra Vineyards in the 2001–02 season



Situated in McLaren Vale in South Australia, Wirra Wirra Vineyard's manager has employed near-continuous soil-water monitoring since 2001 to continuously measure soil moisture and schedule the irrigation strategies in the vineyards, predominated by soils where sandy loam overlies clay. Wirra Wirra Vineyards uses drip irrigation throughout the vineyard, with the Shiraz grape variety established in 1988, being monitored by the EnviroSCAN probes. The irrigation management is based on the EnviroSCAN readings. Figure 5 shows the principle phases of RDI.

This management has yielded the following benefits:

- Annual irrigation requirements have been reduced to an average of 0.77 Mlitres/ha (depending on season). This equates to a 30-percent water saving, or about 6 Mlitres.
- On-sell of water to neighbouring vineyards for A$800–1 000/Mlitre.
- Major grape-quality improvements with a two-grade improvement to ultra premium quality.
- Revenue improvement (A$1 800–4 000/tonne).

Other benefits from RDI are published in Kriedemann and Godwin (2004).

CONCLUSIONS

Understanding and managing the dynamic relationship between site, soil, water, phenological stage, vine and wine quality is a complex challenge.

Without measurement and understanding of selected key variables, the chances of improving vine yield and quality are at best coincidental. An integrated approach in precision irrigation management, developed and used in Australia, is proposed to improve grape quality and consistency through delineation of strategic-management zones based on soil and plant properties. This approach aims to combat vineyard variability by generating more uniform irrigation units. Measuring and correcting water-distribution uniformity, employing near-continuous soil-water profiling technology within delineated units, and implementing irrigation-management strategies such as RDI or PRD will shape vineyard performance and achieve desired wine-quality goals.

The adoption of these basic but essential methods have, in combination, realized economic and environmental benefits.

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