Agriculture Notes

Managing water stress in grape vines in Greater Victoria

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Introduction

The wine growing regions in Greater Victoria normally have relatively high winter and spring rainfall, and drier conditions from mid-summer to autumn. In vineyards that rely on dams filled from small, localised catchments, irrigation water can be a limited resource in seasons where rainfall is below average. In other vineyards on reticulated irrigation schemes, water entitlements can be reduced below 100% in dry years. Combined with low soil moisture reserves from lack of winter and spring rainfall, water stress may be unavoidable. Irrigations must be rationed to minimise or avoid water stress at critical times, so that the best yield and quality is produced from the amount of water available for irrigation.

Where vineyards have access to a permanent and unlimited water source, irrigations can be managed so that water stress is controlled to increase fruit quality. This type of irrigation management is often referred to as regulated deficit irrigation (RDI). Using RDI, water stress is avoided during critical growth stages but then controlled at other times by irrigating at less than the full water requirement of the vines.

Good irrigation scheduling techniques are essential for both drought management and RDI. Water stress must be monitored to determine if irrigation is necessary during a drought or if stress levels are appropriate for RDI. This is best achieved by measuring soil moisture. Over-irrigation should be avoided because it wastes water and is detrimental to RDI management. Above all, accurate records must be kept for future reference and fine-tuning of an irrigation scheduling system.

Water stress

Water stress is a physiological reaction of a vine to insufficient water supply. Some of the physiological responses of grapevines include reduced cell division, loss of cell expansion, closing of leaf stomata, reduced photosynthesis and, in the worst case, cell desiccation and death. Most of these responses are dynamic (as the level of water stress increases so does the response). For example, leaf stomata (which affect photosynthesis and hence potential sugars in the fruit) do not completely close at the first signs of water stress, but slowly close as water stress increases.

The physiological reaction of a vine to water stress will affect the growth and development of the shoots, leaves and fruit depending on the timing and level of water stress during the season. Generally, water stress during the season will affect the most active growth processes occurring in the vine at that time. For example, berry cell division is most active immediately after flowering, so that water stress at this stage could significantly reduce berry size at harvest since berry size is to some extent dependent on cell number.

Water stress may also have less obvious or indirect effects on fruit yield and quality. For example, reducing berry size increases the skin to juice ratio, which may increase the concentration of anthocyanins and phenolics in the must and wine of red grapes. Water stress may affect the chemical breakdown or formation of important berry acids and flavours. Indirectly, water stress may reduce the shading of fruit. Shading has been shown to decrease fruit colour, and the concentration of tartrate and soluble solids, and, increase pH and the concentration of malate and potassium. The incidence of disease may also be reduced through opening up the canopy and keeping the bunches loose because berries are small.

Ideally water stress should be measured by monitoring one or more physiological responses of a vine such as leaf water potential, stomatal conductance or cell expansion. However, the techniques for these are difficult, expensive and time consuming. With current technology it is more straight forward to measure soil moisture, rather than plant water stress directly. Theoretically, this should be a good indicator of plant water stress, however, it is recommended that vine performance should also be observed to adjust soil moisture levels for irrigation scheduling.

Techniques to measure soil moisture

Soil moisture can be measured as either soil water content or soil water tension. Soil water content is a volumetric measure of how much water is in the soil and is expressed as a percent of the total soil volume or in mm depth of water. The neutron probe or various capacitance probes measures soil water content. The rate of soil water

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depletion calculated from soil water measurements is used to infer the level of water stress.

Soil water tension is a measure of how tightly water is held to the soil particles. It is a measure of the force a plant must overcome to extract water from the soil and therefore is an indirect measure of plant water stress. Soil water tension is the reverse of pressure and is measured in the same units as pressure. The standard unit is a kilopascal (kPa). As the soil dries out the soil water tension increases and the ability of the vine to extract water decreases. Soil water tension is the preferred technique of measuring vine water stress.

The two main types of sensors to measure soil water tension are gypsum blocks and tensiometers. Gypsum blocks are well suited to measure soil water tension in the range suitable for RDI or drought management. Tensiometers measure wet or moist soil, and are well suited to full irrigation to minimise water stress.

Drought management

Where the supply of water is limited, water stress cannot be regulated to the same degree as with RDI. Irrigation water must be managed to avoid excessive water stress at critical times during the season. It becomes necessary to understand the critical periods of water stress for each component of vine productivity so that a judgement can be made as to when irrigations should be applied.

Avoiding excessive yield loss

Yield is most affected by high levels of water stress during flowering and fruit set. During flowering, bunches can be completely desiccated by high levels of water stress, resulting in complete yield loss. During fruit set, high levels of water stress can reduce yield by up to 50% if berries drop or do not develop properly.

From fruit set to veraison, water stress can cause yield losses of up to 40%, mainly due to a reduction in berry size. Both cell division and cell enlargement can be affected. Some results indicate that yield can also be reduced in the following season because of lower bud fruitfulness.

For four to six weeks after veraison, yield losses of similar magnitude (ie. 40%) have been measured in response to water stress and are attributed to a reduction in berry size. Berries are growing solely from cell enlargement at that stage. From six weeks after veraison to harvest, yield is least susceptible to high levels of water stress.

Maintaining soluble solids

Accumulation of soluble solids in the fruit mainly occurs after veraison over a period of four to six weeks. Considerable experimental evidence shows that high levels of water stress during this period will significantly reduce the concentration of soluble solids (°Brix) at harvest.

The concentration of soluble solids at harvest has been shown to increase significantly if high levels of water stress occur during berry set. The effect is most likely due to a reduced crop load. Using water stress during fruit set to increase soluble solids at harvest is not recommended because the potential quality benefits are outweighed by the potential total crop loss if water stress occurs during flowering.

Post harvest to bud burst water stress

During the 1994/95 season there were many observations of restricted spring growth at bud burst and also reduced bunch number. This has been associated with the very dry conditions after harvest and through winter to bud burst in spring. If vines are severely water stressed after harvest, the accumulation of storage carbohydrate will be reduced. Stored carbohydrate is essential for the first few weeks of shoot development. Irrigating heavily after harvest, however, may cause a flush of vegetative growth which is undesirable because it uses up storage carbohydrate.

If the root zone of the vine is in dry soil during winter, desiccation of the vine wood and buds may affect the developing bud and the percentage bud burst. In addition, water stress after bud burst may restrict the growth of the shoots and the flush of new roots that grow between bud burst and flowering.

If water supply is limited, the best strategy to avoid yield loss and maintain soluble solids is:-

- if the soil is dry prior to bud burst, irrigate the majority of root zone (ie. deep)
- irrigate regularly to minimise stress during flowering and fruit set
- irrigate (if there is no summer rainfall) at veraison to reduce stress but maintain a moderate stress (ie. do not fully irrigate) for the following four weeks.
- irrigate the shallow fibrous root zone after harvest to avoid severe water stress

Other management strategies

Under drought management, the degree of water stress can be reduced by manipulating any factor that influences the demand by the vine for water and the supply of water to the vine. This paper is particularly concerned with irrigation but vineyard managers could consider other strategies apart from irrigation to reduce water stress. For example, the demand by the vine for water is a function of the weather, the canopy size and shape, and the resistance of the vine to moisture loss. Wind breaks can reduce the demand for water by the vines and reducing the canopy size and shape will reduce the total amount of water transpired by the vines. Reducing the crop load will also decrease the demand for water and assimilate by the fruit. Reducing the demand for assimilate by the fruit will enable more assimilate to be stored for the following season’s growth.

Minimising soil evaporation and weed or cover crop transpiration from the vineyard understorey can also conserve soil moisture. Removing competing ground covers and interrow swards, and mulching to prevent surface evaporation are management strategies that will reduce understorey water use and hence increase the amount of water available to the vines.

Additionally, the supply of water to the vine is a function of rainfall (and irrigation), the ability of the soil to hold water, the root distribution and density, and soil properties such as hydraulic conductivity and soil water tension. Management strategies such as improving soil structure to increase root density and water holding capacity, or deep ripping and gypsum to increase root depth, have the potential to increase water supply and could be considered if problems with drought are on-going.

Regulated deficit irrigation

Regulated deficit irrigation (RDI) is an irrigation management technique that utilises water stress as a tool to increase fruit quality. 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 grape grower.

RDI was originally developed for pome and stone fruits to control excessive vegetative growth which limits long term productivity of close-planted orchards. Irrigation strategies similar to RDI have been practised for a long time in viticulture. The primary objective of RDI in winegrapes is to increase fruit quality through the application of controlled water stress. Clear increases in quality have been shown with red grapes but with white grapes (where skin contact is minimal) the benefits are less clear. Water stress is controlled by the application of short irrigations at specific soil moisture levels (see table 1).

Table 1. Suggested soil water tensions in three soil types for RDI management.

	Suggested soil water tension (kPa)		
	Sand *(or shallow roots or hot climate)*	***Loam*** *(or medium roots or temperate climate)*	***Clay*** *(or deep roots or cool climate)*
Full irrigation (no stress)	40	50	60
RDI	100	200	400

RDI can be applied to winegrapes either from berry set to veraison, from veraison to harvest or over both periods. The effects of a moderate level of stress from RDI during each of these periods (with full irrigation to minimise water stress outside of these RDI periods) compared with full irrigation throughout the growing season can be summarised as follows.

(1) Fruit set to veraison

Before veraison, RDI offers the greatest potential to reduce excessive shoot growth. At moderate levels of water stress, vegetative growth can be significantly reduced with only a small decrease in yield. Yield reduction is attributed to smaller berries. Soluble solids (°Brix) at harvest may slightly increase (ie. maturity advanced) and this is probably related to the reduction in berry size. RDI pre-veraison may also reduce berry juice titratable acid and increase pH.

(2) Veraison to harvest

After veraison, RDI may increase wine colour, aroma and flavour. Yield will be significantly reduced due to a decrease in berry size. Soluble solids will be significantly reduced. Vegetative growth, mainly from lateral shoot development, will also be reduced. Juice titratable acid may decrease (but not to the same degree as pre-veraison RDI) and pH may increase. Total anthocyanins and phenolics will be significantly increased in red wine, most likely due to an increase in the skin to juice ratio from smaller berries.

(3) Fruit set to harvest

From fruit set to harvest, RDI will reduce vegetative growth and yield, maintain or increase the concentration of soluble solids, reduce titratable acidity and marginally increase pH. Total anthocyanins and phenolics in red wine will be increased. Wine colour, aroma and flavour may also slightly increase from red grapes. Yield reduction is attributed mostly to smaller berries.

The choice of which period to apply RDI depends on the objective of the vineyard manager. For example, if the objective is to reduce berry size but maintain soluble solids then RDI should be applied continuously throughout the season.

Irrigation scheduling

There are four key points that apply to irrigation scheduling in Greater Victoria.

(1) Measure soil moisture

Measuring soil moisture is essential for estimating the level of water stress on vines. Often irrigators "jump the gun" because the surface soil looks dry. Soil moisture should be measured over the entire root depth to avoid irrigating too early and wasting water. Also, after rain it is impossible to decide objectively when to irrigate without measuring soil moisture over the entire root zone. For instance, after 10 to 20 mm rain the surface soil may be moist but the majority of the root zone, including the fibrous root system, is in dry soil. Measuring soil moisture in the fibrous root zone would prevent over-stressing the vines.

Soil moisture can also be used to determine the extent of the irrigation wetting pattern. Short irrigations are recommended to wet a small volume of soil for RDI and for drought management at most times. Irrigation run time should be adjusted according to the soil moisture in the middle and at the bottom of the main fibrous root zone immediately following an irrigation.

(2) Short irrigations

Short irrigation run times (eg. 6 hours using one 4 litre per hour dripper per vine) will minimise over-irrigation and waste which is essential in vineyards with water shortages. However, if the entire root zone is in dry soil before bud burst, then it may be advantageous to apply a longer irrigation (only at this time) to wet the entire root zone and encourage a deeper root system to develop as a future drought management strategy.

In vineyards where it is possible to control and manage water stress, short irrigation run times to wet only part of the total root zone is a key technique for maintaining a desirable level of water stress for RDI.

In high summer rainfall areas, short irrigations will reduce the risk of losing the restraining effects of water stress if it rains after an irrigation. Periods of excessive soil moisture can more easily be avoided. Also there is a greater potential to store more water in the soil if only a small fraction of the soil is irrigated.

(3) Monitor vine performance

The scheduling of RDI should be fine-tuned according to the performance of the vines by measuring growth indicators such as pruning weights, berry size and soluble solids. Similarly, the performance of the vines should be monitored during a drought so that the irrigation strategy can be modified if necessary.

(4) Keep records

If accurate records of rainfall, irrigations, soil moisture and vine performance indicators such as those listed above are kept, irrigations can be applied consistently from year to year or slightly modified to suit the vineyard requirements. Continuous improvement will be achieved.

Summary

If water is limited, irrigations should be applied to avoid water stress during flowering and set. Excessive water stress should be avoided during berry ripening, after harvest and also prior to bud burst.

If water is unlimited, then water stress can be utilised to increase quality of the crop. This technique is known as regulated deficit irrigation (RDI). The timing of RDI during the season will depend on the objectives of the vineyard.

Soil moisture must be measured to consistently implement either a drought irrigation strategy or RDI. It must be measured repeatedly during the season over the entire root zone and the method must be accurate and reliable.

