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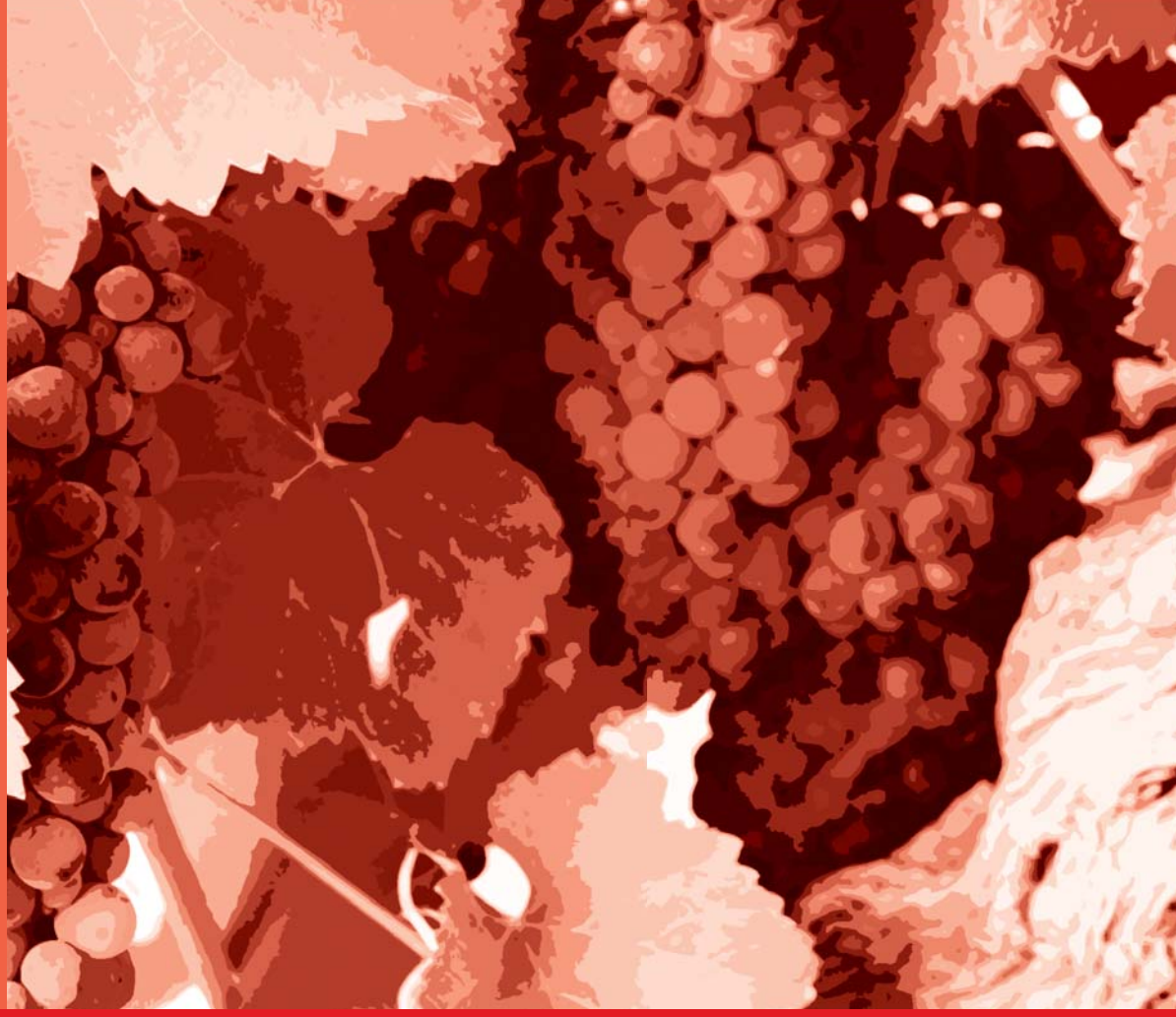

VITICARE ON FARM TRIALS

Manual 2.3 - Irrigation

Regulated deficit irrigation
Partial rootzone drying

Cooperative
Research Centre
for
Viticulture

Core Participants

About the CRCV

The Cooperative Research Centre for Viticulture is a joint venture between Australia's viticulture industry and leading research and education organisations. It promotes cooperative scientific research to accelerate quality viticultural management from vine to palate. 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.

For more information about the CRCV, please visit www.crcv.com.au.

Disclaimer

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Contents

Introduction

Introduction

The Cooperative Research Centre for Viticulture has conducted On Farm Trials since 1999. The initial trials were conducted in eight regions (Port Phillip, North East Victoria, Central Victoria, Adelaide Hills, Riverland, South West Slopes, Riverina and Hunter Valley) and provided Australian growers with the ability to formally assess and validate new science and technology. The trials were conducted over four growing seasons and helped growers to solve problems in their vineyards and improve their management practices.

In 2004 the On Farm Trials project expanded to cover more than 20 viticultural trials primarily in the Riverina, Riverland and Sunraysia regions. Rather than focusing on individual grower issues, the CRCV team has worked with regional grower groups to determine regional issues. The trials are still conducted on a participant growers' property but a team of people are involved to learn from the trial and to share the workload.

This booklet is part of a series that draws on knowledge gained from this experience in developing and delivering On Farm Trials.

Conducting a trial in your vineyard is not easy and is not a decision that should be made lightly. Although trials can be an excellent method for refining management practices, improving quality or looking for solutions to problems, there are many practical considerations involved in conducting a trial.

On Farm Trials can lead to management improvements in a number of areas. The information in this booklet will guide you through the various protocols involved with setting up On Farm Trials that aim to regulate deficit irrigation and examine partial rootzone drying.

Improving Soil Acidity

Aims

This trial aims to evaluate regulated deficit irrigation (RDI) as a management strategy to increase fruit quality and save water.

Important Points to Know

Reduced Deficit Irrigation (RDI) is an irrigation strategy where water stress is deliberately imposed at a key time during the season to increase fruit quality, reduce excessive vegetative growth and save water. By carefully timing and regulating irrigation deficits water stress can be controlled to the right level so that benefits of increasing fruit quality exceed yield losses.

RDI does not need any modifications to an existing irrigation system. It has been successfully applied by alternate row flood and furrow irrigation, by sprinkler and by all forms of micro-irrigation from mini-sprinklers to sub-surface drip. However, RDI does need a high level of management and monitoring to avoid excessive levels of water stress. It is important to realise that RDI is about applying irrigation below the maximum amount a vine can use. Withholding irrigation (i.e. not irrigating at all) during an RDI period is usually not recommended because it will result in excessive levels of water stress.

Depending on the site (mainly climate and soil type) and the quality and yield objectives of the vineyard, there are different key times during the season when RDI can be imposed.

Below is a summary of the effects of RDI from berry set to veraison, from veraison to harvest, and sustained RDI from berry set to harvest. The effects of RDI during each of these periods should be examined closely so that an RDI treatment(s) can be established and compared with a control treatment. Note that in periods outside RDI, the vines are irrigated to maintain optimum soil moisture to avoid water stress (for more detailed information and references on the summary below see Goodwin 2002).

o RDI from berry set to veraison. Veraison is the relatively short period during which the firm, green berries begin to soften and change colour. During this period the cells in each berry are dividing and expanding at a rapid rate. Berries attain approximately 50% of their harvest size by veraison. Water stress from RDI will result in smaller berries at harvest. Shoots are still growing but at a slower rate than pre-flowering. RDI will stop shoot growth and may cause early basal leaf senescence and increased fruit exposure. Generally, water stress from RDI during this period has advanced maturity and in Shiraz, has increased colour.

o RDI from veraison to harvest. During this period the cells in each berry are expanding in size and accumulating sugars at a rapid rate. Water stress from RDI will result in smaller berries at harvest. RDI will also slow down the accumulation of berry sugars (delay maturity) but may also increase berry juice pH and decrease titratable acidity. RDI may cause early basal leaf senescence and increased fruit exposure. Generally, water stress from RDI during this period has increased berry skin red colour and phenolic concentration.

o RDI from berry set to harvest. This is the combination of the two periods described above and thus covers the entire berry growth period. Water stress from RDI will result in smaller berries at harvest. RDI will stop shoot growth and cause early basal leaf senescence and increased fruit exposure. Generally, RDI will not delay maturity and will increase berry skin red colour and phenolic concentration but may increase berry juice pH and decrease titratable acidity.

Positive and Negative Aspects

It is important to determine the risks associated with comparing RDI with the normal irrigation practice at the proposed site. These risks must be weighed up against the potential benefits that a particular treatment may impart. Some risks may preclude trialing treatments on a particular site. At other sites, it may be sufficient to monitor a potential risk and have a contingency plan in place to deal with it if it occurs. The advantages and disadvantages of RDI in vineyards are listed below. These may be used as a guide to risks that may develop.

Advantages include:

- Substantial water savings (30-50% depending on timing of RDI)
- Reduces berry size
- Generally an increase in colour and phenolics (red varieties)
- Reduces vegetative growth and may improve fruit exposure
- Advances maturity if water stress is relieved at veraison by reverting to full irrigation

Disadvantages include:

- Water stress must be avoided during flowering and set
- Decreases yield
- If stress is too severe then yield loss may be high from berry drop and poor fruitfulness
- In hot climates fruit may get sunburnt from exposure
- In cool wet climates and deep rootzone environments it will be difficult to apply RDI in the period from set to veraison

In light of these issues, some questions worth considering are:

- Which risks are important at your site?
- Which risks would not prevent the trial proceeding but should be monitored?
- What plans need to be put in place to reduce the impact of any risks occurring?

Cost Benefit Analysis

In order to determine the financial viability of comparing RDI with Normal irrigation, a cost/benefit analysis should be completed, to relate the monetary requirement of the RDI techniques to a production basis. The risks associated with an irrigation comparison program in vineyards must be weighed up against the benefits. This will justify the commitment to an irrigation program in the long term.

Before You Get Started

The following points will help you prepare for this trial:

- o New plumbing will be required for the trial.
  - Cut existing irrigation lateral at each end of the RDI treatment plots (i.e. panels) and insert a length of blank lateral to divert water around RDI treatment plots;
  - Install an in-line tap at each end of the cut section of old lateral and reconnect to the new blank lateral by inserting a tee - this approach will require manual operation of each individual treatment plot at every irrigation during RDI.

OR

  - Preferably, join the old lateral onto blank lateral pipe between each RDI treatment plot and then connect the RDI laterals to an independent pressurised submain - install a solenoid (and controller) or gate valve on the submain for RDI treatment plots.
- o Measure soil moisture. Install gypsum blocks to measure soil moisture tension or either a neutron probe, capacitance probe or a time domain reflectometer to measure soil water content
- o Measure evaporation and rainfall. Install a US Class A Evaporation pan and rain gauge or auto weather station
- o Thorough understanding of irrigation scheduling based on soil moisture and evaporation.
- o Experience in the measurement of soil moisture.
- o Ability to collect data at the right time, systematically manage the data either in hand written tables or in computer spreadsheet.

Site Suitability

To successfully undertake an RDI trial the following criteria must be met:

- The vine root system must be confined to one metre depth. If the rootzone is deeper than one metre it may be difficult to dry out the rootzone and generate water stress. This is particularly relevant in cool and mild climates.
- If rain during spring and summer exceeds vineyard water use then it may be difficult to dry out the rootzone and generate water stress.
- Vine roots must not have access to a watertable.
- Outside the RDI period, vines must be irrigated to minimise water stress. In addition, when reverting to full irrigation, sufficient water must be applied to rewet a large volume of the rootzone. Either the entire block will be irrigated at this level or alternatively, the RDI treatment vines are irrigated independently of the 'Normal' treatment via a pressurised main or header tank with sufficient capacity to irrigate the trial.
- The water supply for the entire season must be reliable and available when required. The supply must not run out or deplete to a level such that low irrigation levels will cause excessive water stress.
- Irrigation systems must be designed to meet optimum water requirements at critical times during the season. The system must be sufficiently flexible for high frequency irrigation (i.e. daily). This is best achieved with automated valves and a suitable irrigation controller.
- Distribution of soil moisture from irrigation must be uniform. Soil type (depth, colour and texture) must be uniform in the trial area and the variation in emitter output must be +/- 5%.
- Irrigation water electrical conductivity (ie. salinity) must not exceed 1.2 dS/m.

Potential Treatments

1) Normal irrigation - Ideally soil moisture should be no drier than 40 kPa in top fibrous rootzone (eg. 40 to 60 cm depth). Crop Factors (US pan) should be maintained at approximately 0.5 (average canopy) to 0.7 (vigorous canopy). This treatment is equivalent to a 'full' irrigation. Often an RDI treatment will be compared with the standard vineyard irrigation practice. At times soil moisture may be drier than 40 kPa. This is OK but it is important to maintain the RDI treatment within the guidelines described below.

2) RDI - Initial irrigation starts when entire rootzone dries to 200 kPa (ie. de-watered). After de-watering rootzone aim to wet up the top 20 to 30 cm at each irrigation. Apply the next irrigation when soil at 20 to 30 cm dries to 200 kPa. Corresponding Crop Factors (US pan) using this method to irrigate RDI treatment should equate to approximately 50% of the Crop Factors for non-stressed vines (i.e. 'full' irrigation). When reverting to full irrigation, sufficient irrigation must be applied to re-wet a large volume of the rootzone and irrigations must be timed to avoid water stress.

Measurements and Monitoring

There are numerous measurements that are applicable to a RDI trial. Unfortunately there is no single set of measurements that are applicable to all trials. The correct measurements can only be selected once the trial's objectives have been clearly defined. The following is a list of potential measurements:

The following table includes potential measurements for this type of trial, their time involvement and difficulty.

Measurements	Time*	Difficulty*
Shoot length and node number	3	A
Yield	2	A
Fresh berry weight	1	A
Total soluble solids	1	A
pH	1	B
Titratable acidity	1	C
Colour (anthocyanin and phenolics)	2	C
Vine growth stages (phenology)	1	B
Daily evaporation and rainfall	1	A
Soil moisture	2	B
Pruning weight	2	A

**Time is where 1 = few minutes per replicate, 2 = 15 minutes per replicate, 3 = >30 minutes per replicate; Difficulty is where A = easy, no laboratory skills and/or measurement equipment required, B = some laboratory skills and/or measurement equipment required, and C = laboratory skills and/or sophisticated measurement equipment required. Refer to complete Table 2.2 in Section #2: Trial Design and Variability.*

Trial Timelines

Trials involving the comparison of RDI with Normal irrigation should be run for a minimum of three years. Any effect of RDI on fruitfulness will not be observed in the first year and therefore it is advisable to continue this trial for an extended time period.

The estimated time required to set up an irrigation trial would be approximately 5 days for installation of laterals (and submains), gate valves (or solenoids) and soil moisture monitoring equipment. The required time to monitor this equipment and take appropriate measurements would be approximately 2 to 4 hours per week for soil moisture measurements, 0.5 day for pruning weights and shoot length, 0.5 day for berry sampling for quality parameters at harvest, and 1 day for harvest.

Shaded areas in the following table indicate when measurements or samples suggested above are to be taken. See the measurement manual in this series for more information about measurement protocols.

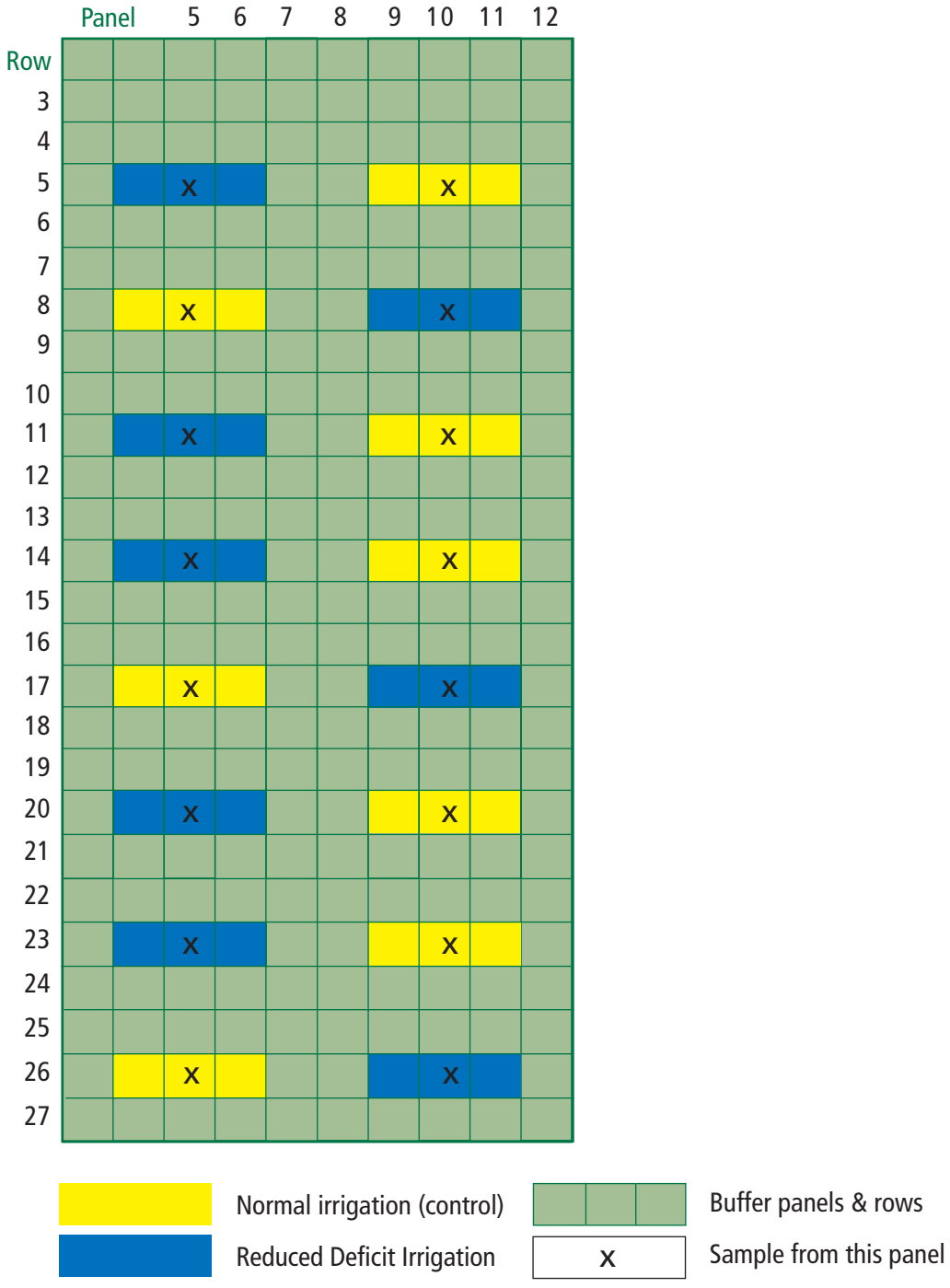
	Dormancy	Bud burst	Shoots 10 cm	Flowering	50% capfall	Berry set	Berries pea-size	Bunch closure	Veraison	Harvest	Post-harvesty
Yield											
Fresh berry Weight											
Total soluble Solids											
pH											
Titratable acidity											
Colour											
Shoot length and node no.											
Pruning weight											
Vine growth Stage											
Evaporation and rainfall											
Soil moisture											
Irrigate											

RDI Trial Designs

Treatments will need to be replicated within the trial area at least six to eight times, more if the area is not very uniform. One of the treatments should be a control, which will often be current practice. It is advised not to have more than three or four treatments, to allow enough time for management of the trial.

Plots (or experimental units) can be different shapes and sizes, but a common plot in an irrigation trial consists of three rows by three panels of vines. The middle panel is used for taking measurements (for example, Row 5 Panel 5).

Buffering is important to identify clear treatment areas and to avoid contamination between treatment areas. Buffer zones are marked as panels with grid-lines in the following designs.



Design 1 gives an example of a trial layout in which the treatments are RDI and normal irrigation. The trial has two treatments and eight replications, arranged in a randomised block design, with the blocks being rows (or, more strictly, groups of three adjacent rows).

Design 2: An example of a trial design to test reduced deficit irrigation using rows as experimental units.

Design 2 gives an example of a trial layout in which the treatments are RDI and normal irrigation. It uses rows as experimental units as opposed to panels. This can make management of the trial (i.e irrigation) a little easier.

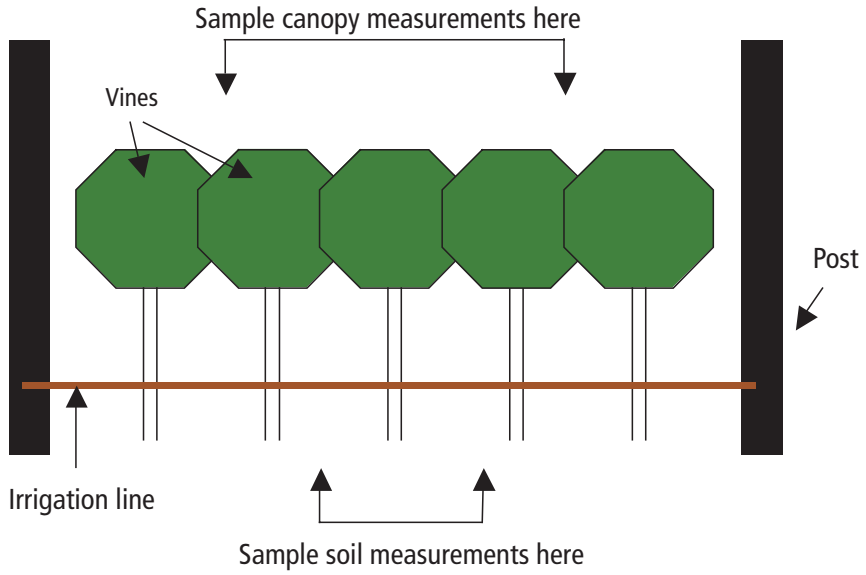
When using rows as experimental units, it is normally anticipated that a maximum of three treatments are trialed due to the potential workload expected. This trial has two treatments and six replications, again arranged in a randomised block design, with the blocks being groups of two adjacent experimental units.

It is recommended to only sample the middle vine in panels marked with an X (Designs 1 and 2) when taking vine measurements. If there are more than three vines per panel, only sample from the middle vines of the panels mentioned above (see Figure 1).

These recommendations are to ensure that there is no contamination between plots; in some situations they may be waived provided such contamination is not a possibility. The approach described here also guarantees objectivity in the sampling, thus preventing the experimenter's bias from jeopardising the results.

Measure the whole vine for pruning weight and yield. Select six shoots per panel for shoot length and node number. For measures of berry fresh weight and quality parameters collect a sample of 100 berries from 20 bunches per panel. For canopy density take 50 measurements at random across the middle three or four vines per panel (see Figure 1).

Figure 1: A diagrammatic explanation of where, within a panel, measurements can be taken.



Evaluating Partial Rootzone Drying (PRD)

Aims

To evaluate partial rootzone drying (PRD) as a management strategy to maintain yield, reduce vegetative vigour and save water.

Important Points to Know

PRD is an irrigation strategy where parts of the rootzone of each vine are exposed to alternate soil drying. A separate portion of the same vine's rootzone is kept moist with irrigation. Grapevine roots in drying soil have been shown to generate a chemical signal (i.e. a plant growth hormone) that is transported to the shoots and leaves. The response to the signal is a reduction in lateral shoot growth and closing of the pores on leaves (ie. stomata) through which water is lost to the atmosphere. The signal does not completely close the stomata such that photosynthesis can be maintained at high levels but closure is sufficient to reduce transpiration. Vine water stress is avoided by irrigating a separate portion of the vine's rootzone but the irrigation requirement is less than 'normal' because of the reduction in leaf area (lateral shoot growth) and stomatal closure. By avoiding water stress the vine is kept turgid and berry growth is maintained at peak levels so that yield is unaffected.

Research has shown that the PRD response is transient. It appears that the signal from roots in drying soil is only generated when the root's sense changes in soil water content. When there is little change in soil water content the signal stops. This usually occurs when the soil has dried out. So to maintain part of the grapevine rootzone in a continuous state of drying, and simultaneously irrigate other parts of the root system with adequate water to avoid the vine becoming stressed, the wetting pattern must be periodically moved. For this reason drip irrigation is well suited to PRD. In most cases two laterals are laid down a row with each lateral connected to separate submains so that they can be irrigated independently. Drippers are installed in each lateral offset so that they irrigate the soil between every second vine. Irrigation is applied through one lateral for a 2-week period (this may be shorter in hot climates and sandy soils) and then switched to the other lateral for the next 2-week period.

Positive and Negative Aspects

It is important to determine the risks associated with comparing PRD with the normal irrigation practice at the proposed site. These risks must be weighed up against the potential benefits that a particular treatment may impart. Some risks may preclude trialing treatments on a particular site. At other sites, it may be sufficient to monitor a potential risk and have a contingency plan in place to deal with it if it occurs. The advantages and disadvantages of PRD in vineyards are listed below. These may be used as a guide to risks that may develop.

Advantages:

- Substantial water savings are possible (30-50%);
- Yield is affected; and
- Reduces lateral shoot growth and may improve fruit exposure.

Disadvantages:

- Limited to climates, soil types and irrigations systems where the root system of a vine can be subject to discrete wet and dry zones;
- Reported quality gains are inconsistent;
- High risk of water stress if not managed and monitored in detail;
- In hot climates fruit may get sunburned from exposure; and
- Appears to require reasonably rapid soil drying to stimulate chemical signals - In cool wet climates and deep rootzone environments it may be difficult to apply PRD.

In light of these issues, some questions worth considering are:

- Which risks are important at your site?
- Which risks would not prevent the trial proceeding but should be monitored?
- What plans need to be put in place to reduce the impact of any risks occurring?

Cost Benefit Analysis

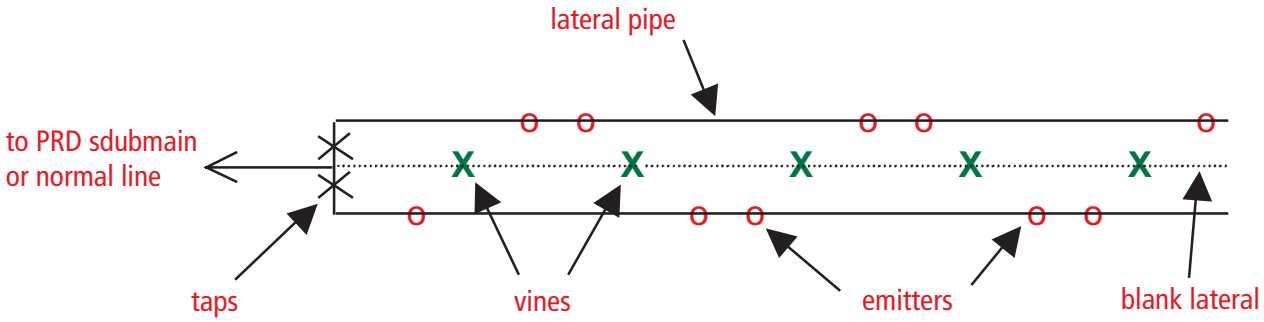
In order to determine the financial viability of comparing PRD with Normal irrigation, a cost/benefit analysis should be completed, to relate the monetary requirement of the PRD techniques to a production basis. The risks associated with an irrigation comparison program in vineyards must be weighed up against the benefits. This will justify the commitment to an irrigation program in the long term.

Before You Get Started

The following points will help you prepare for this trial:

o New plumbing will be required for the trial.
- Cut existing irrigation lateral at each end of the PRD treatment plots (i.e. panels) and insert a length of blank lateral to divert water around PRD treatment plots;
- Install 2 new laterals and in-line taps in each PRD treatment plot and insert drippers to irrigate between every 2nd vine (see Fig. 1).

Figure 1: Irrigation layout in a PRD treatment plot showing position of emitters in relation to vines.



- Connect the PRD laterals to the Normal irrigation lateral - this approach will mean that the PRD treatment plots will be irrigated at the same time as the Normal treatment

OR

- Preferably, connect the PRD laterals to an independent pressurised submain, and install a solenoid (and controller) or gate valve on the submain for PRD treatment plots

o The wetted zone must have sufficient water applied to avoid water deficits.

o On re-wetting the dry zone, sufficient water must be applied to ensure that deeper soil layers are refilled with water.

o Measure soil moisture close to the emitters in both irrigation lines so that soil moisture in the wet and drying zones is measured. Install gypsum blocks to measure soil moisture tension or either a neutron probe, capacitance probe or a time domain reflectometer to measure soil water content.

o Measure evaporation and rainfall. Install a US Class A Evaporation pan and rain gauge or auto weather station.

o Thorough understanding of irrigation scheduling based on soil moisture and evaporation.

o Experience in the measurement of soil moisture.

o Ability to collect data at the right time, systematically manage the data either in hand written tables or in computer spreadsheet.

Site Suitability

To successfully undertake a PRD trial the following criteria must be met:

- The vine root system must be confined to 1-m depth. If the rootzone is deeper than 1 m it may be difficult to stimulate chemical signals. This is particularly relevant in cool and mild climates.
- If rain during the spring and summer exceeds vineyard water use then it may be difficult to stimulate chemical signals.
- Vine roots must not have access to a water table.
- Water for irrigation must be available when required. Frequent irrigation of the wetted rootzone is required to avoid water stress. In addition, when rewetting the drying portion of the rootzone, sufficient water must be applied to ensure that deeper soil layers are refilled with water. Either the entire block will be irrigated at this level or alternatively, the PRD treatment vines are irrigated independently of the 'Normal' treatment via a pressurised main or header tank with sufficient capacity to irrigate the trial.
- The water supply for the entire season must be reliable and available when required. The supply must not run out or deplete to a level such that low irrigation levels will cause water stress.
- Irrigation system must be designed to meet PRD requirements. New laterals must be installed in PRD treatment plots so that there are discrete wet and dry zones under each vine. Taps will need to be installed to switch between laterals every 2 weeks (less depending on soil and/or climate).
- The system must be sufficiently flexible for high frequency irrigation (i.e. daily). This is best achieved with automated valves and a suitable irrigation controller.
- Distribution of soil moisture from irrigation must be uniform. Soil type (depth, colour and texture) must be uniform in the trial area and the variation in emitter output must be +/- 5%.
- Soils with restrictive clay subsoils should not be over irrigated as water can flow laterally into the drying part of the rootzone.
- Irrigation water electrical conductivity (ie. salinity) must not exceed 1.2 dS/m.

Measurements and Monitoring

There are numerous measurements that are applicable to a PRD trial. Unfortunately there is no single set of measurements that are applicable to all trials. The correct measurements can only be selected once the trial's objectives have been clearly defined. The following lists some potential measurements.

The following table includes potential measurements for a PRD trial, their time involvement and difficulty.

Measurements	Time*	Difficulty*
Shoot length and node number	3	A
Yield	2	A
Fresh berry weight	1	A
Total soluble solids	1	A
PH	1	B
Titratable acidity	1	C
Colour (anthocyanin and phenolics)	2	C
Vine growth stages (phenology)	1	B
Daily evaporation and rainfall	1	A
Soil moisture	2	B
Pruning weight	2	A

**Time is where 1 = few minutes per replicate, 2 = 15 minutes per replicate, 3 = >30 minutes per replicate; Difficulty is where A = easy, no laboratory skills and/or measurement equipment required, B = some laboratory skills and/or measurement equipment required, and C = laboratory skills and/or sophisticated measurement equipment required. Refer to complete Table 2.2 in Section #2: Trial Design and Variability.*

Trial Timelines

Trials involving the comparison of PRD with Normal irrigation should be run for a minimum of three years. Any effect of PRD on fruitfulness will not be observed in the first year and therefore it is advisable to continue this trial for an extended time period.

The estimated time required to set up an irrigation trial would be approximately five days for installation of laterals (and submains), gate valves (or solenoids) and soil moisture monitoring equipment. The required time to monitor this equipment and take appropriate measurements would be approximately four to six hours per week for soil moisture measurements, 0.5 day for pruning weights and shoot length, 0.5 day for berry sampling for quality parameters at harvest, and one day for harvest.

Shaded areas in the following table indicate when measurements or samples suggested above are to be taken. See the measurement manual in this series for more information about measurement protocols.

	Dormancy	Bud burst	Shoots 10 cm	Flowering	50% capfall	Berry set	Berries pea-size	Bunch closure	Veraison	Harvest	Post-harvesty
Yield											
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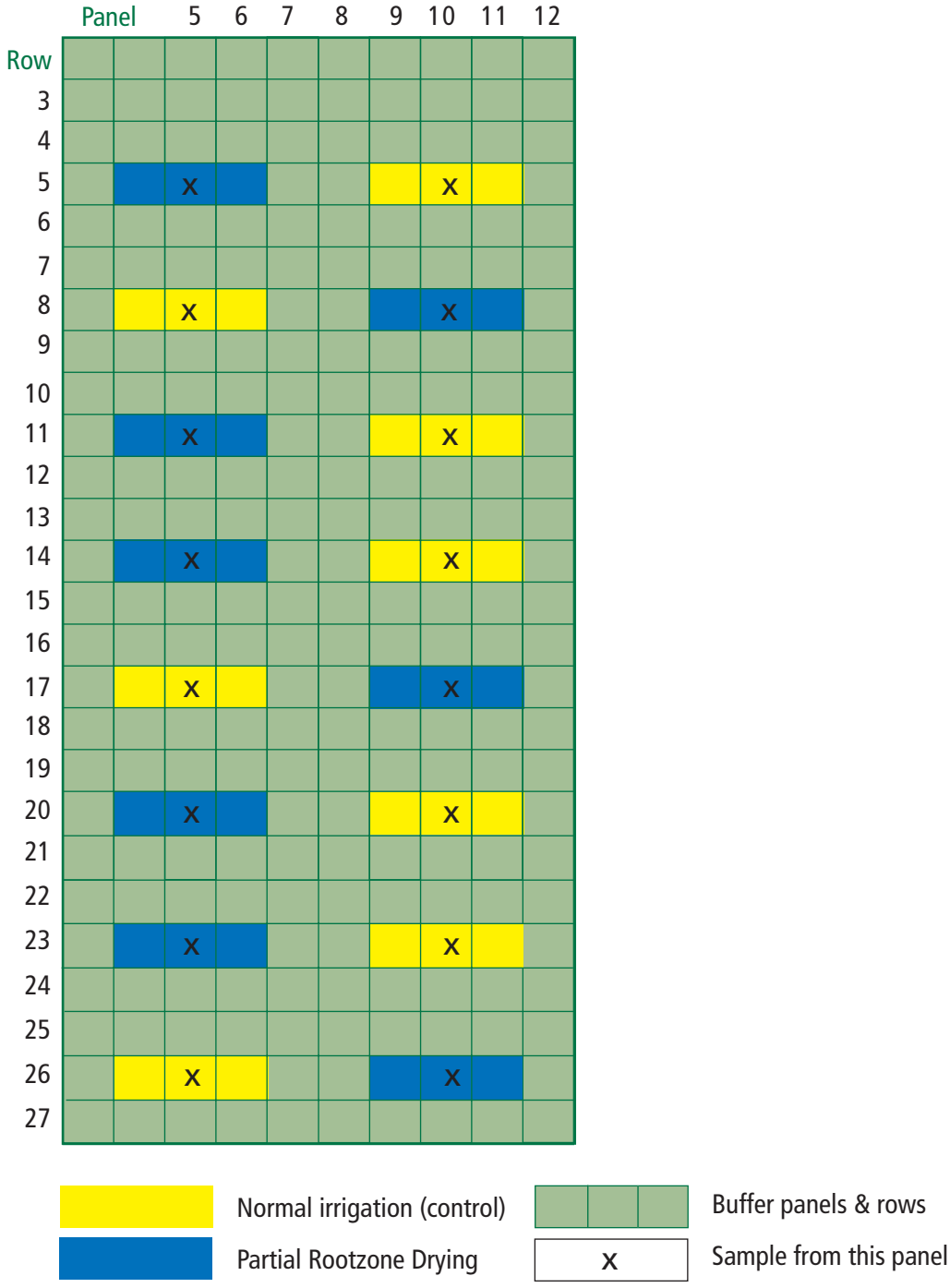
Colour											
Shoot length and node no.											
Pruning weight											
Vine growth Stage											
Evaporation and rainfall											
Soil moisture											
Irrigate											

Trial Designs for PRD

Treatments will need to be replicated within the trial area at least six to eight times, more if the area is not very uniform. One of the treatments should be a control, which will often be current practice. It is advised not to have more than three or four treatments, to allow enough time for management of the trial.

The middle panel is used for taking measurements (for example, Row 5 Panel 5). Buffering is important to identify clear treatment areas and to avoid contamination between treatment areas. Buffer zones are marked as panels with grid-lines in the following designs.

Design 1: An example of a randomised block design that could be used to test partial rootzone drying.



Design 1 gives an example of a trial layout in which the treatments are PRD and normal irrigation. The trial has two treatments and eight replications, arranged in a randomised block design, with the blocks being rows (or, more strictly, groups of three adjacent rows).

Design 2: An example of a trial design to test partial rootzone drying using rows as experimental units.

Design 2: gives an example of a trial layout in which the treatments are PRD and normal irrigation. It uses rows as experimental units as opposed to panels. This can make management of the trial (i.e irrigation) a little easier.

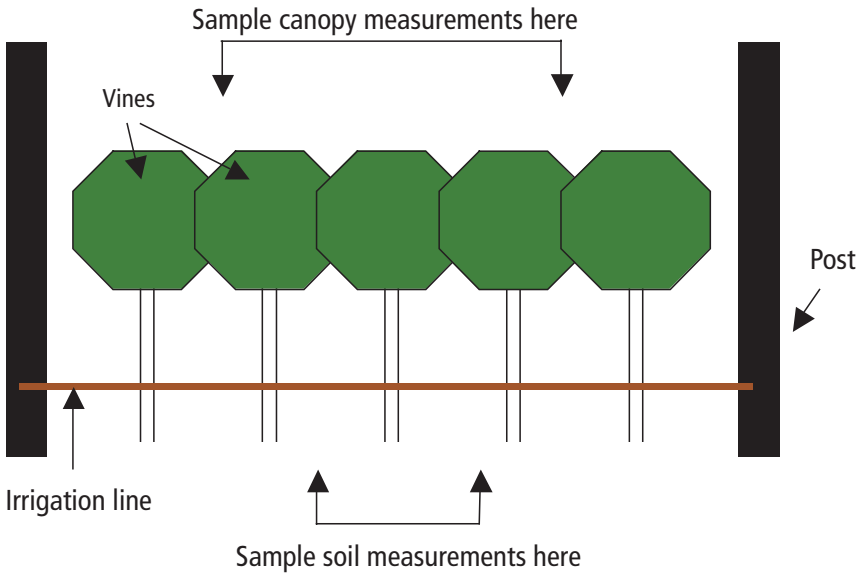
When using rows as experimental units, it is normally anticipated that a maximum of three treatments are trialed due to the potential workload expected. This trial has two treatments andsix6 replications, again arranged in a randomised block design, with the blocks being groups of three adjacent experimental units.

It is recommended to only sample the middle vine in panels marked with an X (Designs 1 and 2) when taking vine measurements. If there are more than three vines per panel, only sample from the middle vines of the panels mentioned above (see Figure 1).

These recommendations are to ensure that there is no contamination between plots; in some situations they may be waived provided such contamination is not a possibility. The approach described here also guarantees objectivity in the sampling, thus preventing the experimenter's bias from jeopardising the results.

Measure the whole vine for pruning weight and yield. Select six shoots per panel for shoot length and node number. For measures of berry fresh weight and quality parameters collect a sample of 100 berries from 20 bunches per panel. For canopy density take 50 measurements at random across the middle three or four vines per panel.

Figure 1: A diagrammatic explanation of where, within a panel, measurements can be taken.



Resources

Some useful resources for evaluating regulated deficit irrigation (RDI):

- Goodwin I. (1995) Irrigation of vineyards - A grapegrower's guide to irrigation scheduling and regulated deficit irrigation. AV Handbook
- Goodwin I. (2002) Water management - a tool for vineyard managers In: Managing Water. Proceedings of ASVO Viticulture Seminar, Mildura 12th July 2002 pp19-23
- Kriedemann P. and Goodwin I. (2003) Regulated deficit irrigation and partial rootzone drying In: Currey A. (edt.) 'Irrigation Insights No.3' (Land and Water Australia, Canberra) (in press)
- Krstic M., Moulds G., Panagiotopoulos B. and West S. (2003) Growing quality grapes to meet winery specification: quality measurement and management options for grapegrowers. Collins S. (edt.) Winetitles, Adelaide, S.A.

Some useful resources for evaluating partial rootzone drying (PRD):

- Dry P.R., Loveys B.R., Stoll M., Steward D. and McCarthy M.G. (2000) Partial rootzone drying - an update. The Australian Grapegrower and Winemaker Annual Technical Issue 438a: 35 - 39
- Kriedemann P. and Goodwin I. (2003) Regulated deficit irrigation and partial rootzone drying. In: Currey A. (edt.) 'Irrigation Insights No.3' (Land and Water Australia, Canberra) (in press)
- McCarthy M.G., Loveys B.R., Dry P.R. and Stoll M. (2002) Regulated deficit irrigation and partial rootzone drying as irrigation management techniques for grapevines In: 'Deficit irrigation practices' (FAO Water Report) 22: 79-88 http://www.fao.org/docrep/004/Y3655E/Y3655E00.HTM).