Murray Valley & Riverina Water Use Efficiency Study 2011/12

Prepared for: *Murray Valley Winegrowers' Inc. & the Riverina Wine Grapes Marketing Board*

Prepared by: *Mary Retallack, Retallack Viticulture*

September 2012

Introduction

The project report contained within this document was developed for Murray Valley Winegrowers' Inc. and the Riverina Wine Grapes Marketing Board as part of the Grape and Wine Research & Development Corporation's (GWRDC) Regional Program.

Background

In the 2011/12 season Murray Valley Winegrowers' Inc. and the Riverina Wine Grapes Marketing Board collaborated on a project to examine and compare regional wine grapes water use efficiency.

Four varieties were selected (Chardonnay, Semillon, Cabernet Sauvignon and Shiraz) for benchmarking under two different irrigation systems. The irrigation systems selected in the Murray Valley were drip and low level sprinklers; in the Riverina, drip and furrow irrigation systems were selected for study.

Growers with the selected varieties and irrigation systems were invited to participate in the project. Growers were sent a record booklet in order to collect the following information:

1. Date of irrigation
2. EL Growth Stage
3. Hours of irrigation or volume of irrigation (ML/Ha)
4. Irrigation application rate (mm/hr)

This data provided the opportunity to collect total irrigation per variety and irrigation type combination in ML/Ha and to break the irrigation application down into the following four growth periods:

1. Budburst to Flowering (EL 4 - EL 26)
2. Flowering to Veraison (EL 27 - EL 35)
3. Veraison to Harvest (EL 36 - EL 38)
4. Harvest to Leaf drop (EL 41 - EL 47)

The data collected by Murray Valley Winegrowers' Inc. and the Riverina Wine Grapes Marketing Board was sent to Mary Retallack from Retallack Viticulture for analysis and the development of the following report.

Report Error - Murray Valley - *The results displayed in this report for MV5 indicate a WUE for this particular property of 14 ML/Ha. There was a error in the data located after report completion and should have been 6.07 ML/Ha for the variety in question.*

Murray Valley Winegrowers' Inc. and the Riverina Wine Grapes Marketing Board would like to thank the Grape & Wine Research & Development Corporation (GWRDC) for the funding required to develop and run this regional project. Without the support of GWRDC, the ability of small regional associations to collect and develop quality data for extension and use by growers for improvements in efficiencies would be limited.

retallack viticulture
wine growing for the future

Assessing Yield Water Use Efficiency (WUE) in the Murray Valley and Riverina wine regions

Season 2011/12

Prepared for : Murray Valley Winegrowers' Inc and Riverina Wine Grapes Marketing Board

By : Mary Retallack

Date : 9th September 2012

Murray Valley Winegrowers' Inc

Riverina Wine Grapes Marketing Board

gwrdc regional grassroots solutions

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

EXECUTIVE SUMMARY

Murray Valley Winegrowers' Inc and Riverina Wine Grapes Marketing Board are working collaboratively to examine water use efficiency for the production of wine grapes in each region. A combined total of ninety-four individual data sets were collected from both regions, comprising sixty-two data sets from the Murray Valley and thirty-two data sets from the Riverina wine region.

Average water use and yield water use efficiency (WUE) were calculated for each region and individual summaries were prepared for each vineyard data set (supplied separately). Yield WUE is expressed as t/ML and is calculated by dividing yield (t/ha) by the volume of water applied (ML/ha) during the growing season.

Murray valley wine region

The average water use was 4.3 ML/ha for drip and 6.6 ML/ha for low level sprinkler irrigated vineyards. On average, low level sprinkler irrigated vineyards used an additional 2.3 ML/ha (or 35% more water) and produced 1.8 t/ha (or 9%) greater yield than drip irrigated vineyards in the Murray Valley wine region in season 2011/12.

- The average production for each variety was: Semillon 28.0 t/ha, Chardonnay 25.7 t/ha, Shiraz 19.9 t/ha and Cabernet Sauvignon 18.2 t/ha.
- An average yield of 21.6 t/ha was produced for all varieties on drip irrigated vineyards, compared to 23.4 t/ha on low level sprinkler irrigated vineyards in the Murray Valley.
- Average water use for each variety was: Semillon (4.7 ML/ha), Chardonnay (5.1 ML/ha), Shiraz (5.3 ML/ha) and Cabernet Sauvignon (4.9 ML/ha).

Drip irrigated vineyards are on average 31% more efficient users of water than low level sprinkler irrigated vineyards, based on yield WUE of 5.3 t/ML and 3.7 t/ML respectively.

- Yield WUE ranged from 1.3 ML/t (least efficient) to 12.9 t/ML (most efficient), with an average WUE of 4.7 t/ML for all vineyards surveyed (drip and low level sprinkler).
- It may be possible to significantly improve the average WUE, given the most efficient vineyards are 12.9 t/ML and 6.3 t/ML for drip and low level sprinkler irrigated vineyards respectively. A difference of 6.6 t/ML.

Vineyard MV5: (Chardonnay on Ramsey rootstock, drip irrigated, sandy loam) is the most efficient water user in the region, with 12.9 tonnes of grapes produced for every ML of water applied. An average of 3.0 ML/ha was applied and 39.3 t/ha was produced on this vineyard in the 2011/12 growing season.

Riverina wine region

The average water use was 2.8 ML/ha for drip and 3.7 ML/ha for furrow irrigated vineyards. On average, furrow irrigated vineyards used an additional 0.9 ML/ha (or 24% more water) and produced 1.04 t/ha (or 8%) less yield than drip irrigated vineyards in season 2011/12.

- The average production for each variety was: Semillon 14.7 t/ha, Chardonnay 14.7 t/ha, Shiraz 9.7 t/ha and Cabernet Sauvignon 12.0 t/ha.
- An average of 13.0 t/ha was produced across all varieties on drip irrigated vineyards, compared to 12.0 t/ha for furrow irrigated vineyards in the Riverina.
- Average water use for each variety was: Semillon (3.44 ML/ha), Chardonnay (3.06 ML/ha), Shiraz (2.71 ML/ha) and Cabernet Sauvignon (2.73 ML/ha).

Drip irrigated vineyards are on average 35% more efficient users of water than furrow irrigated vineyards, based on yield WUE of 5.0 t/ML and 3.2 t/ML respectively.

- Yield WUE ranged from 1.8 ML/t (least efficient) to 9.2 t/ML (most efficient), with an average WUE of 4.6 t/ML for all vineyards surveyed (drip and furrow).
- It may be possible to significantly improve the average WUE, given the most efficient vineyards are 9.2 t/ML and 5.3 t/ML for drip and furrow irrigated vineyards respectively. A difference of 3.9 t/ML.

Vineyard R7: (Chardonnay on Ramsey rootstock, drip irrigated) is the most efficient water user, with 9.2 tonnes of grapes produced for every ML of water used. An average of 2.3 ML/ha was applied and 21 t/ha was produced on this vineyard in the 2011/12 growing season.

The average irrigation applied (ML/ha) was lower for varieties planted on Ramsey rootstock with the exception of Semillon, where the vines used an average of 6% more water when planted on Ramsey rootstock.

Regional comparisons

The average water application for all varieties in the Murray Valley was 5.1 ML/ha compared to 3.0 ML/ha in the Riverina, a difference of 2.1 ML/ha (or 41%).

The average yield for all varieties in the Murray Valley was 22.2 t/ha compared to 12.8 t/ha in the Riverina, a difference of 9.4 t/ha (or 42%). While the Murray Valley applied more water per hectare, a similar increase in yield was also achieved.

In many cases, Riverina wine growers had their production capped at 12.5 t/ha for red varieties and 20 t/ha for white varieties in season 2011/12. This is one of the key drivers for lower average yield and water use in the Riverina wine region.

The average yield WUE for the Murray Valley is 4.7 t/ML compared to 4.6 t/ML in the Riverina, a difference of 0.1 t/ML (or 3%). This demonstrates that both regions are able to grow grapes with similar water use efficiencies.

However, given the broad range of yields produced for similar rates of irrigation application, this indicates that there is the potential to reduce the volume of water applied, or change the irrigation application method with no detriment to production expected, in some instances.

Similarly, the average WUE are about half that of the most efficient vineyard in each variety category and this indicates that many wine growers have the capacity to improve their WUE. Additional efficiencies are expected if drainage past the root zone is monitored.

INTRODUCTION

Retallack Viticulture Pty Ltd (Retallack Viticulture) was engaged by Murray Valley Wine growers' Inc (MVWI) and Riverina Wine Grapes Marketing Board (RWGMB) to analyse irrigation water use efficiency data for the 2011/12 growing season.

Funding for this project was provided by the Grape and Wine Research and Development Corporation (GWRDC) Regional program.

Background

Water security continues to be a major concern for wine growers despite the wet conditions experienced in the 2010/11 season and the floods experienced in the Riverina in March 2012. With future concerns about water cuts under the Murray Darling Basin plan[1] and the increasing cost of water and electricity, the need to better understand the water use requirements of vines at key times during the growing season is important, to ensure growers can optimise their vineyard performance and fruit quality.

The water use efficiency (WUE) of vineyards will be dependent on a number of factors including the irrigation method employed, wine grape variety requirements, whether vines are planted on their own roots or rootstock, soil type, the desired fruit quality requirements and regional climate parameters. Murray Valley Winegrowers' Inc and Riverina Wine Grapes Marketing Board are working are working collaboratively to examine the water use efficiency for the production of wine grapes in two warm inland regions.

It is expected that local wine growers will be able to use the information presented in this report to assess their water use efficiency and to identify areas where improvements can be made to fine-tune their approach to irrigation application.

- Average water use for each variety at key wine grape growth stages can be used to assist irrigators to fine tune their irrigation scheduling and to work towards achieving the benchmark levels.
- Wine growers can compare their WUE against regional irrigation benchmarks.
  - Growers who are below the 'average' yield WUE can strive to meet this benchmark.
  - Growers who are achieving the average WUE indicators can work towards meeting the 'most efficient' irrigator benchmarks identified.
  - The most efficient irrigators can aim to maintain these benchmark indicators or to improve them.

Information about historical WUE projects, wine grape water requirements at key growth stages, deficit irrigation strategies, and typical varietal responses to moisture stress is presented in **Appendix 1a, b, and c.**

Seasonal conditions

The weather conditions during the 2011/12 season were moderate compared to the succession of drought years experienced from 2006/07 to 2009/10 and the record 'wet' season of 2010/11. Even so, flood conditions prevailed in the Riverina in early March 2012, with many vineyards under water at the end of vintage for several weeks.

From July 2011 to June 2012 the Murray Valley received about 304 mm of rainfall, compared to 561 mm in the Riverina. Overall, conditions were slightly warmer than the long term mean maximum temperature in season 2011/12.

BoM weather data

Bureau of Meteorology (BoM) temperature and rainfall data from the 2011/12 growing season for the Murray Valley (Mildura Airport weather station) and Riverina (Griffith Airport weather station) wine growing regions is presented in **Figures 1 to 4**. Additional weather data is presented in **Appendix 2a and b.**

[1] For more information, see www.mdba.gov.au/

Growers can access weather data from a station closer to their property (or review data from previous seasons), by visiting www.bom.gov.au/climate/data/index.shtml

Mildura weather data

The rainfall from July 2011 to June 2012 was 303.8 mm (11.4 mm above the long term mean of 292.4 mm), and 620.2 mm less than the previous 'wet' season, where 924 mm fell. Rainfall was below average from July to October at the start of the growing season, and rebounded to 'above average' in November and December.

Rainfall in January was just below the long-term mean and good falls were recorded through until the end of March. Dry conditions prevailed again from April to June 2012.

A summary of the monthly rainfall recorded at the Mildura Airport weather station is presented in **Figure 1**.

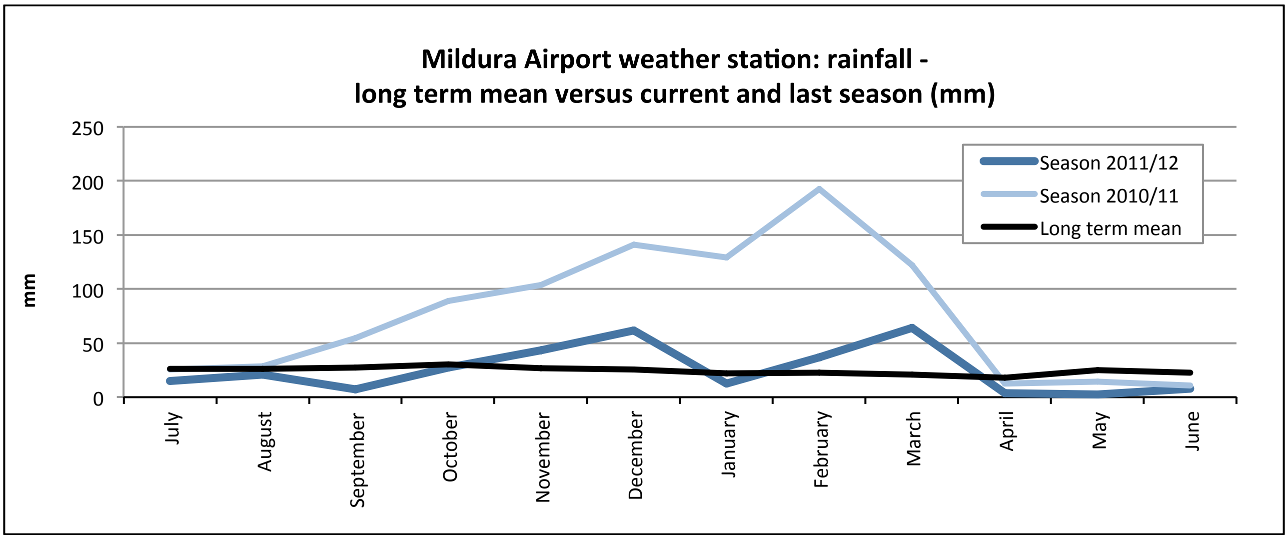

Figure 1 : Mildura Airport weather station – long term mean rainfall versus current and last season (mm)

Mean maximum temperature was warmer than normal from July to January. February and March were slightly cooler than the long term mean, and conditions were again slightly warmer than average from April to June at the end of the growing season.

A summary of the mean maximum temperature recorded at the Mildura Airport weather station is presented in **Figure 2**.

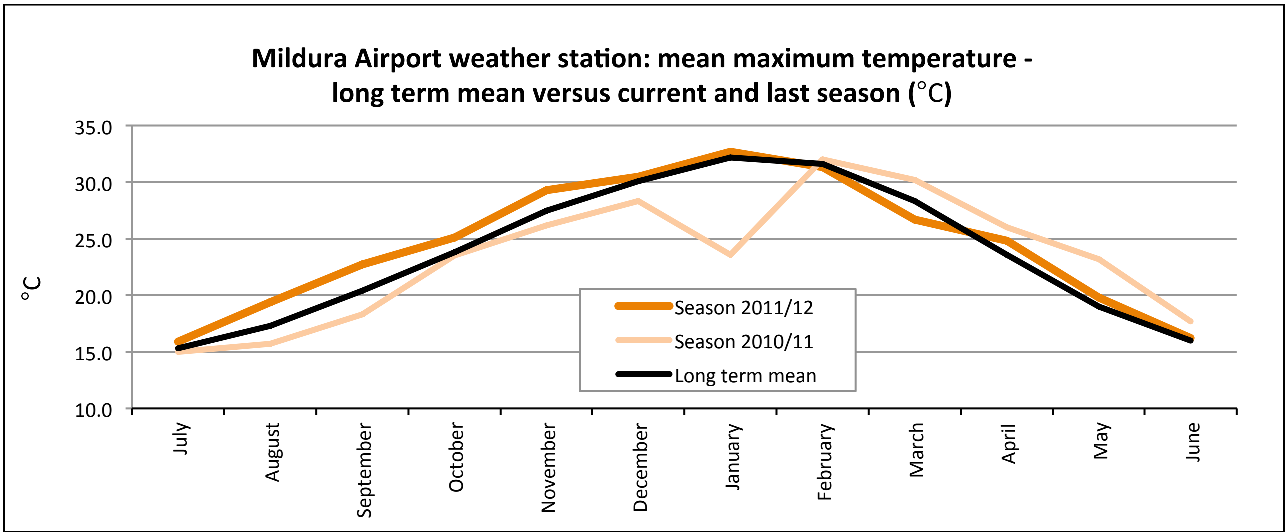

Figure 2 : Mildura Airport weather station – long term mean max temp versus current and last season (°C)

Riverina weather data

Mean monthly rainfall from July 2011 to June 2012 was 560.8 mm (155.2 mm above the long term mean of 405.6 mm), and 122.4 mm less than the previous 'wet' season, where 683.2 mm fell.

Rainfall was below average in July, but rebounded in August. The monthly rainfall in September and October was below average at the start of the growing season, and trended just above and then below, the long term mean in November and December respectively.

Rainfall was above average in January and February and peaked at 212.6 mm (or 175.8 mm above the long term mean) in March, where many vineyards were under water for several weeks at the end of vintage. Rainfall was just above the average in April and below average in May and June. A summary of the monthly rainfall recorded at the Griffith Airport weather station is presented in **Figure 3**.

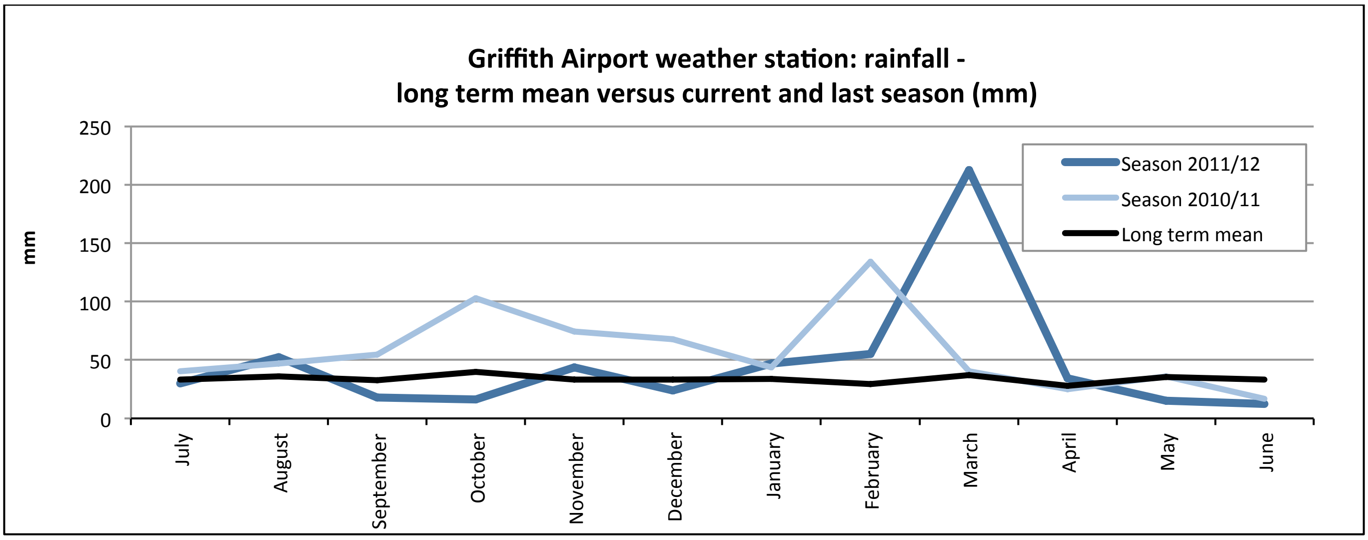

Figure 3 : Griffith Airport weather station – long term mean rainfall versus current, and last season (mm)

Mean maximum temperature was warmer than normal from July to November. December was cooler than the long term mean, and the temperature in January was significantly (or 8.6 °C) below the long term mean. Conditions were again slightly warmer than average from February to June, at the end of the growing season. A summary of the mean maximum temperature recorded at the Griffith Airport weather station is presented in **Figure 4**.

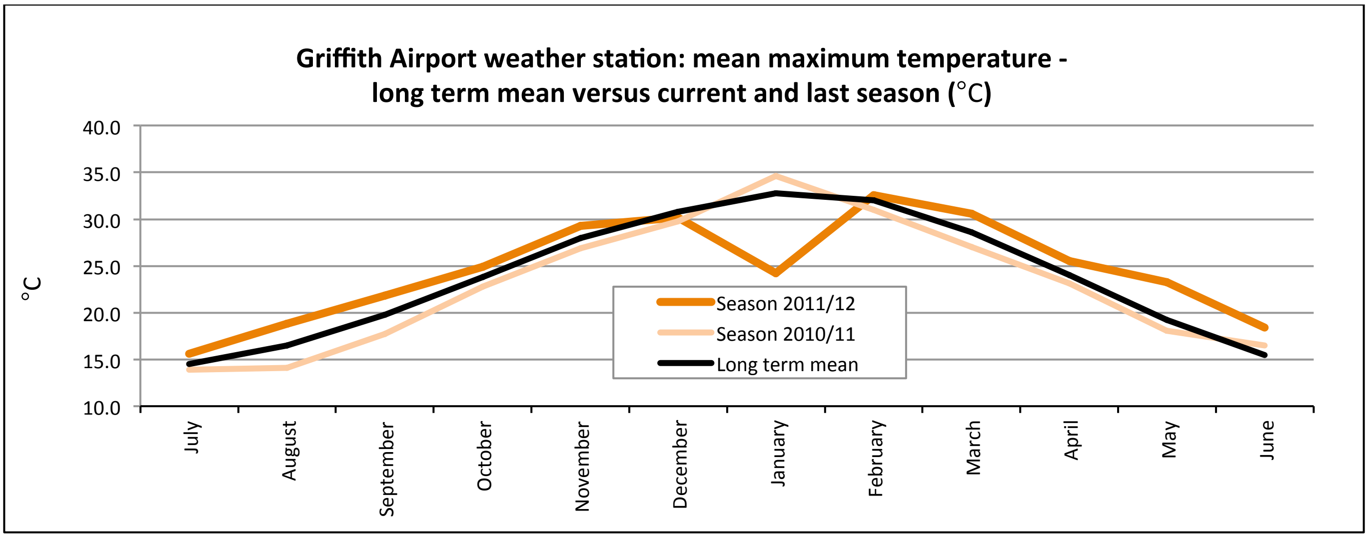

Figure 4 : Griffith Airport weather station – long term mean max temp versus current, and last season (°C)

METHODOLOGY

Data collection

Irrigation, phenology and yield data was collected by Liz Singh and April Winckel from MVWI and Kristy Bartrop from RWGMB for the 2011/12 growing season. This is the first season of this study. A data coding system was used to maintain grower confidentiality.

The following regional data codes were used:

- Murray Valley wine region - 'Vineyard **MV**'# 1 to 62, and
- Riverina wine region - 'Vineyard **R**#' 1 to 32.

Data collected from each region varied in detail and comprised:

- **Murray valley wine region**
  - Variety (Semillon, Chardonnay, Shiraz and Cabernet Sauvignon),
  - Own roots or rootstock (Ramsey, Ruggeri 140, Paulsen 1103, Schwarzmann, Richter 99, 101-14, Kober 5BB, K51-40),
  - Drip or low level sprinkler irrigation,
  - Yield (t/ha), bunch weight (g), berry weight (g),
  - Soil type, and
  - Water applied throughout the growing season (ML/ha) and collated by the key EL growth stages.
- **Riverina wine region**
  - Variety (Semillon, Chardonnay, Shiraz and Cabernet Sauvignon),
  - Own roots or Ramsey rootstock,
  - Drip or furrow irrigation,
  - Yield (t/ha), and
  - Water applied throughout the growing season (ML/ha) and collated by the key EL growth stages.

A copy of the data presented for analysis for each region is presented in **Appendix 3a and b**.

Data analysis and reporting

A combined total of ninety four individual data sets was collected from both regions. Sixty two data sets received from the Murray Valley and thirty two data sets received from the Riverina, were forwarded to Mary Retallack from Retallack Viticulture for analysis. Data is presented using key grapevine growth stages and standard units of measurement.

Key grapevine growth stages

Key grapevine growth stages used in this study are:

- Bud burst (EL 4) to flowering (EL 26),
- Fruit set (EL 27) to veraison (EL 35),
- 100% Veraison (EL 36) to harvest (EL 38), and
- Post harvest (EL 41) to end of leaf fall (EL 47).

The modified E-L system is used to describe each growth stage and is presented in **Appendix 4**.

Benchmark indicators

Hectare has been adopted as the standard unit of measurement. The following indicators of irrigation performance have been used in this report:

- Yield is expressed as tonnes per hectare (t/ha),
- Water applied is expressed as megalitres per hectare (ML/ha), and
- Yield WUE is expressed as tonnes per megalitre (t/ML).

Tonnes per hectare (t/ha)

The weight of fruit (t) produced per hectare (ha) can be used as a direct measure of production over a standard area. However, in isolation, this does not capture the optimal production capacity of a particular management unit in relation to the volume of water applied, or the quality of fruit produced in relation to end use specifications.

Megalitres per hectare (ML/ha)

The volume of water applied in megalitres (ML) per hectare (ha) can be used as a direct measure of water use for a standard unit of measurement. However it is not always a good indicator of WUE. For example, an irrigator that applies the lowest ML/ha may not be the most efficient water user. Similarly, the volume of water applied may not result in increased production or fruit quality. The volume of water applied per vine may also differ depending on the row and vine spacing, emitter spacing and output.

The volume of water derived via rainfall in each region can be estimated from historical BoM records, see **Appendix 2a and b**. As a general rule of thumb for every 100 mm that falls, this equates to 1 ML/ha.

Yield WUE = Y/I

Water use efficiency is defined in this study as the relationship between the yield (Y) produced at harvest, divided by the volume of irrigation (I) applied between budburst to harvest.

Yield is expressed as tonnes per hectare (t/ha), and volume of irrigation is expressed as megalitres of water applied per hectare (ML/ha).

Yield WUE is expressed as t/ML and is calculated by dividing 'Y' (t/ha) by the volume of water 'I' (ML/ha). This provides an indication of how efficiently each tonne of grapes is produced for each megalitre of water applied. This measure does not take into account parameters such as fruit quality.

Virtual WUE

Alternatively, a calculation such as megalitres used to produce a tonne of fruit (ML/t) can be used, and is calculated by dividing the volume of water (ML/ha) applied during the growing season by the yield (t/ha).

More commonly, litres used to produce a kilogram of fruit (L/Kg) are often quoted when calculating 'virtual' water use for different crops. To convert (ML/t) to litres per kilogram (L/kg), multiply by 1000.

Alternative WUE criteria

There are a number of other factors that may be assessed when looking at WUE that have not been addressed here. They include:

- End point use of fruit,
- Application efficiency (irrigation water applied less drainage losses). A high proportion of water may go directly to drainage where irrigation application practices are poorly understood or managed,
- A differentiation between 'standard' and 'deficit irrigation' application in different seasons,
- Rainfall and winter irrigation application is not included in the irrigation application figures,
- The minimum irrigation application required to limit the build-up of salinity is not identified, and
- The economic WUE ($/ML) is not assessed.

RESULTS AND DISCUSSION

Murray Valley wine region

Data received

A total of 62 irrigation data sets were received from Murray Valley wine growers. A summary of the data set received is presented in **Appendix 1b.** A breakdown of data by variety, application method, own roots and Ramsey rootstock is presented in **Tables 1 to 3** and **Figure 5**.

Table 1 : Murray Valley irrigation data received by variety

Number of data sets	Variety				
	Semillon	Chardonnay	Shiraz	Cabernet Sauvignon	Total
	4	23	22	12	**62**

Table 2 : Murray Valley irrigation data received by application method (drip or low level sprinkler)

Number of data sets	Irrigation application method		
	Drip	Low level sprinkler	Total
	40	22	**62**

Table 3 : Murray Valley vines grown on own roots or rootstock

Number of data sets	Vines on own roots or rootstock			
	Own roots	Rootstock	Unspecified	Total
	20	40	2	**62**

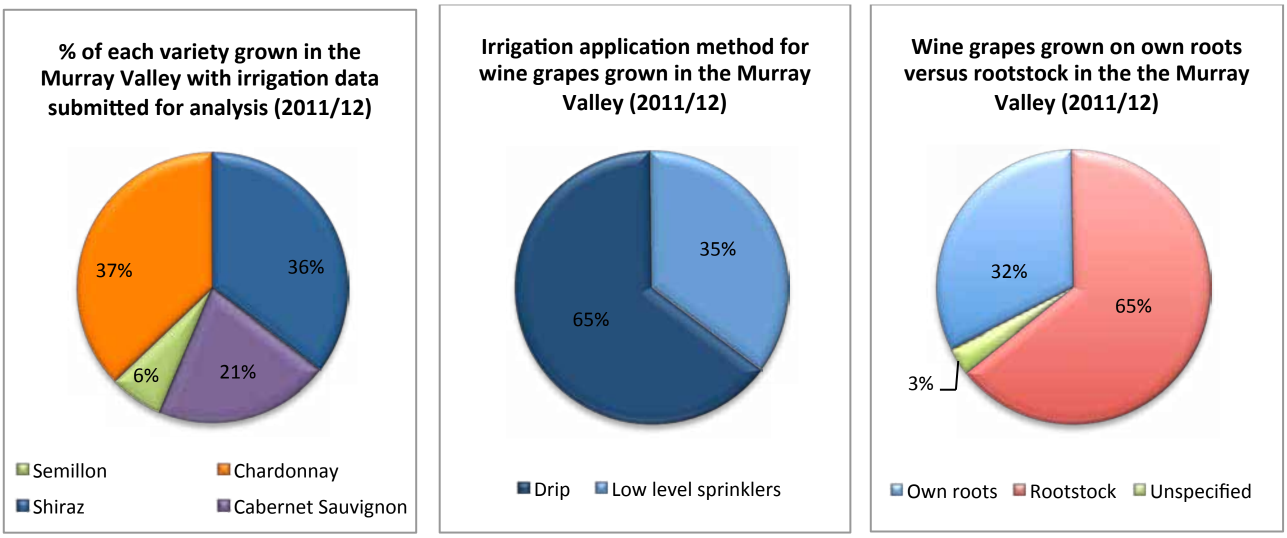

Figure 5 : Irrigation data by variety, application method, own roots or rootstock in the Murray Valley

Murray Valley data set

Key observations for season 2011/12 include:

- The yields across all varieties varied from 5.3 t/ha (Vineyard MV30 - Shiraz on own roots, drip) to 45.7 t/ha (Vineyard MV46 - Semillon on Ramsey rootstock, drip), with an average yield of 22.2 t/ha produced across all vineyards surveyed in the Murray Valley, see **Figure 6**.
  - The average production for each variety was: Semillon 28.0 t/ha, Chardonnay 25.7 t/ha, Shiraz 19.9 t/ha and Cabernet Sauvignon 18.2 t/ha.
  - An average yield of 21.6 t/ha was produced for all varieties on drip irrigated vineyards, compared to 23.4 t/ha on low level sprinkler irrigated vineyards in the Murray Valley.

- The average irrigation applied across all varieties from budburst to leaf fall, varied from 1.9 ML/ha to 14.7 ML/ha, see **Figure 7**.
  - The average irrigation applied was 4.3 ML/ha for drip and 6.6 ML/ha for low level sprinkler irrigated vineyards.
- On average, low level sprinkler irrigated vineyards used an additional 2.3 ML/ha (or 35% more water) and produced 1.8 t/ha (or 9%) greater yield than drip irrigated vineyards in season 2011/12.

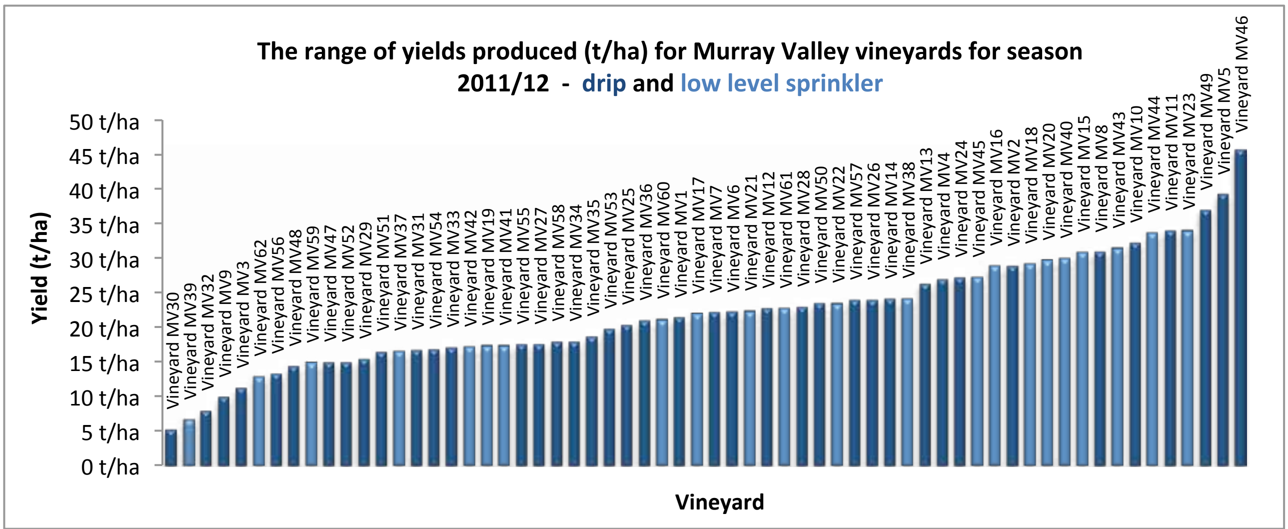

Figure 6 : The range of yields (t/ha) for Murray Valley vineyards (low level sprinkler marked in light blue)

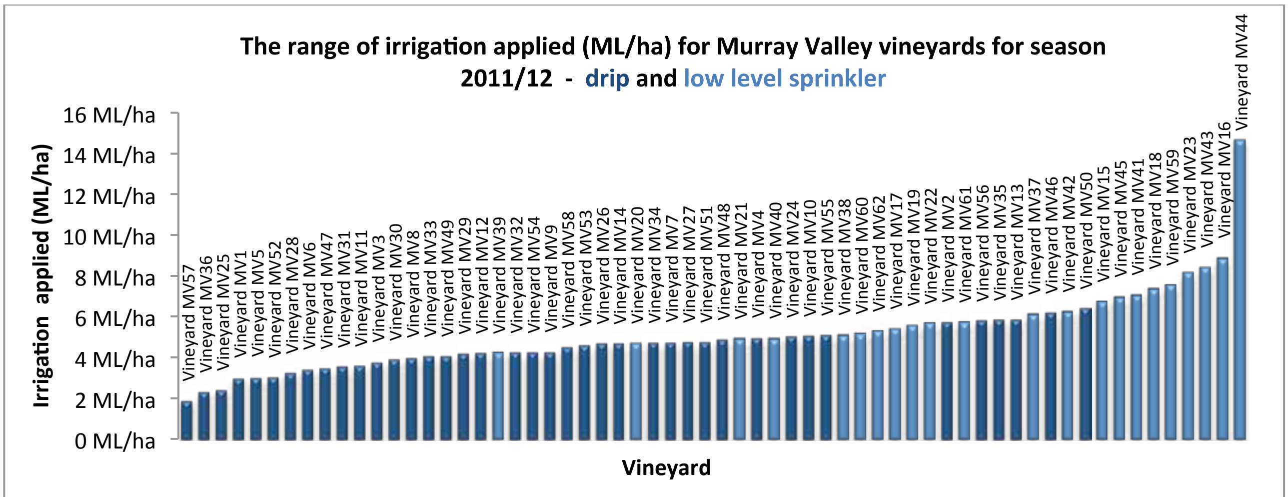

Figure 7 : Irrigation application for Murray Valley vineyards (low level sprinkler marked in light blue)

There is a broad range of both high and low yields (t/ha) produced where similar rates of irrigation (ML/ha) have been applied, see **Figure 8.**

As the rate of irrigation application increases, a similar increase in yield may not occur. Similarly, the vineyards applying the lowest volume of water (ML/ha) are not necessarily the most efficient users of water.

- For example to produce a Chardonnay yield of 29 t/ha, irrigation ranging from 5.7 ML/ha to 8.9 ML/ha (Vineyard MV2 - drip and MV16 – low level sprinkler) was applied in 2011/12, a difference of 3.2 ML/ha. This indicates that there is the potential to reduce the volume of water applied or irrigation application method, with no detriment to production expected, in some instances.

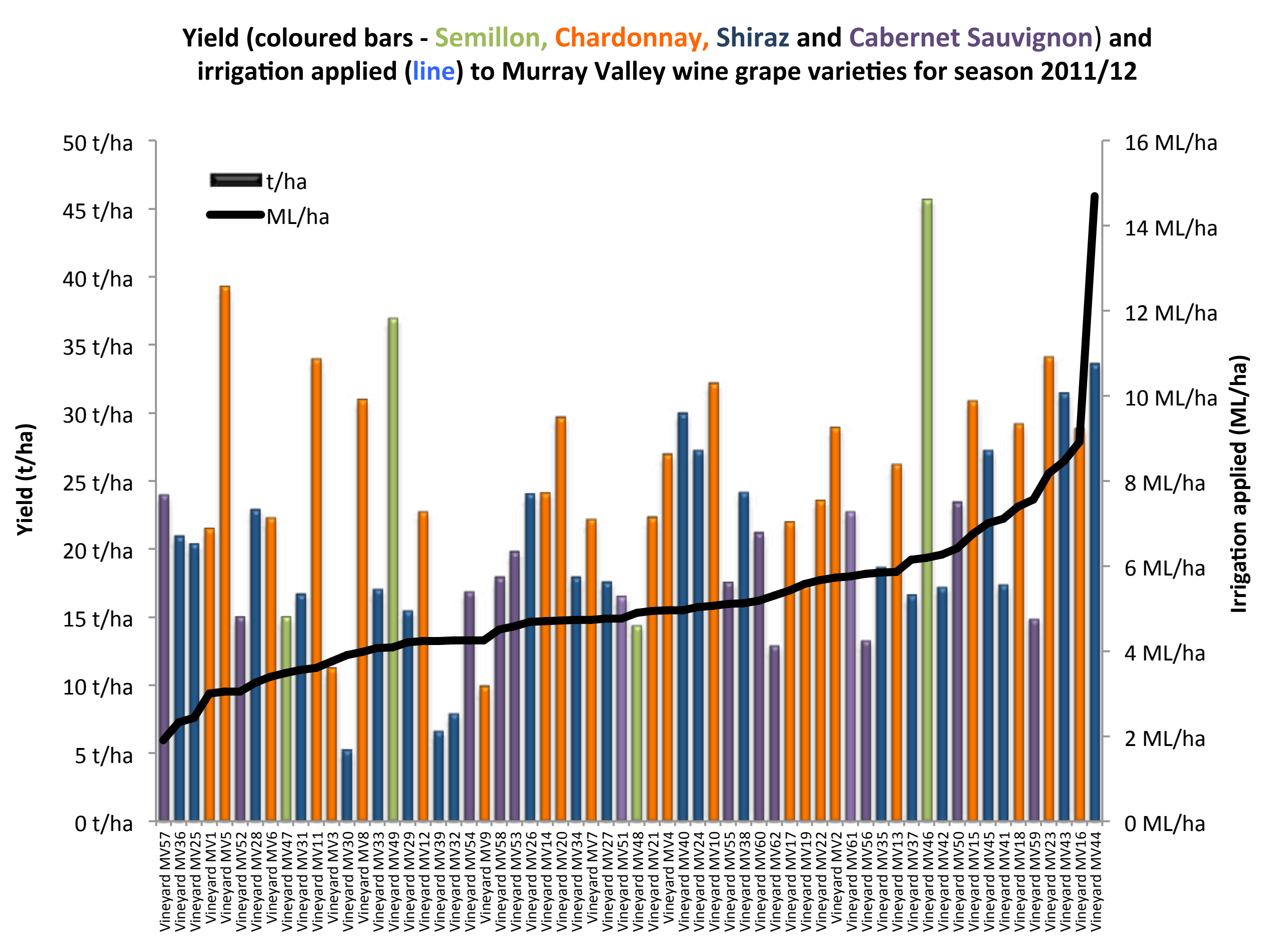

Figure 8 : The range of yields produced (t/ha) and irrigation applied (ML/ha) for Murray Valley vineyards

Yield water use efficiency (WUE)

Key yield WUE benchmarks for season 2011/12 include:

- Yield WUE ranged from 1.3 ML/t (least efficient) to 12.9 t/ML (most efficient), with an average WUE of 4.7 t/ML for all vineyards surveyed (drip and low level sprinkler), see **Figure 9**.
  - **Drip irrigated:** Yield WUE for drip irrigated vineyards ranged from 1.3 t/ML (least efficient) to 12.9 t/ML (most efficient), with an average WUE of 5.3 t/ML.
  - **Low level sprinkler irrigated:** Yield WUE for low level sprinkler irrigated vineyards ranged from 1.6 t/ML (least efficient) to 6.3 t/ML (most efficient), with an average WUE of 3.7 t/ML.
  - Drip irrigated vineyards are on average 31% more efficient users of water than low level sprinkler irrigated vineyards.

The WUE of producing wine grapes via drip and low level sprinkler irrigation is presented in **Table 4.**

Table 4 : Average yield WUE for drip and low level sprinkler irrigated vineyards in the Murray Valley

Yield WUE	Drip irrigated	Low level sprinklers irrigated	Difference	
Most efficient	12.9 t/ML	6.3 t/ML	6.6 t/ML	51%
Average	**5.3 t/ML**	**3.7 t/ML**	**1.7 t/ML**	**31%**
Least efficient	1.3 t/ML	1.6 t/ML	-0.2 t/ML	-16%

The spread of WUE figures is presented in **Figure 9** and discussed below:

- **Most efficient - Vineyard MV5:** (drip irrigated, sandy loam) is the most efficient water user, with 12.9 tonnes of grapes produced for every ML of water applied. An average of 3.0 ML/ha was applied and 39.3 t/ha of Chardonnay (Ramsey rootstock) was produced on this vineyard in the 2011/12 growing season.
- **Least efficient - Vineyard MV30:** (drip irrigated, sandy clay loam) is the least efficient water user, with only 1.3 tonnes of grapes produced for every ML of water applied. An average of 3.9 ML/ha was applied and 5.3 t/ha of Shiraz (own roots) was produced on this vineyard in the 2011/12 growing season.
- Vineyard MV 5 (Chardonnay on Ramsey, drip irrigated, sandy loam) and MV 57 (Cabernet Sauvignon on Ramsey, drip irrigated, soil type unspecified) are in the top 10% of yield WUE for the region.
- Vineyard MV57 applied the lowest volume of water per hectare (1.9 ML/ha) and produced a crop of 24.0 t/ha with a WUE of 12.6 t/ML (the second most efficient vineyard).
- Vineyard MV44 applied the highest volume of water per hectare (14.7 ML/ha) and produced a crop of 33.7 t/ha, with a WUE of 2.3 t/ML (the fourth least efficient vineyard).

Table 5 : Most and least efficient vineyards by variety in the Murray Valley

Variety	WUE	Vineyard	Own roots or rootstock	Irrigation method	Yield t/ha	Irrigation applied ML/ha	WUE t/ML
Semillon	**Most efficient**	Vineyard MV49	Kober 5BB	Drip	37.0 t/ha	4.1 t/ha	9.1 t/ML
	Least efficient	Vineyard MV48	Ramsey	Drip	14.4 t/ha	4.9 t/ha	2.9 t/ML
Chardonnay	**Most efficient**	Vineyard MV5	Ramsey	Drip	39.3 t/ha	3.0 t/ha	12.9 t/ML
	Least efficient	Vineyard MV9	Schwarzmann	Drip	10.0 t/ha	4.2 t/ha	2.3 t/ML
Shiraz	**Most efficient**	Vineyard MV36	101-14	Drip	21.0 t/ha	2.3 t/ha	9.0 t/ML
	Least efficient	Vineyard MV30	Own roots	Drip	5.3 t/ha	3.9 t/ha	1.3 t/ML
Cabernet Sauvignon	**Most efficient**	Vineyard MV57	Ramsey	Drip	24.0 t/ha	1.9 t/ha	12.6 t/ML
	Least efficient	Vineyard MV59	Own roots	Low level sprinklers	14.9 t/ha	7.6 t/ha	2.0 t/ML

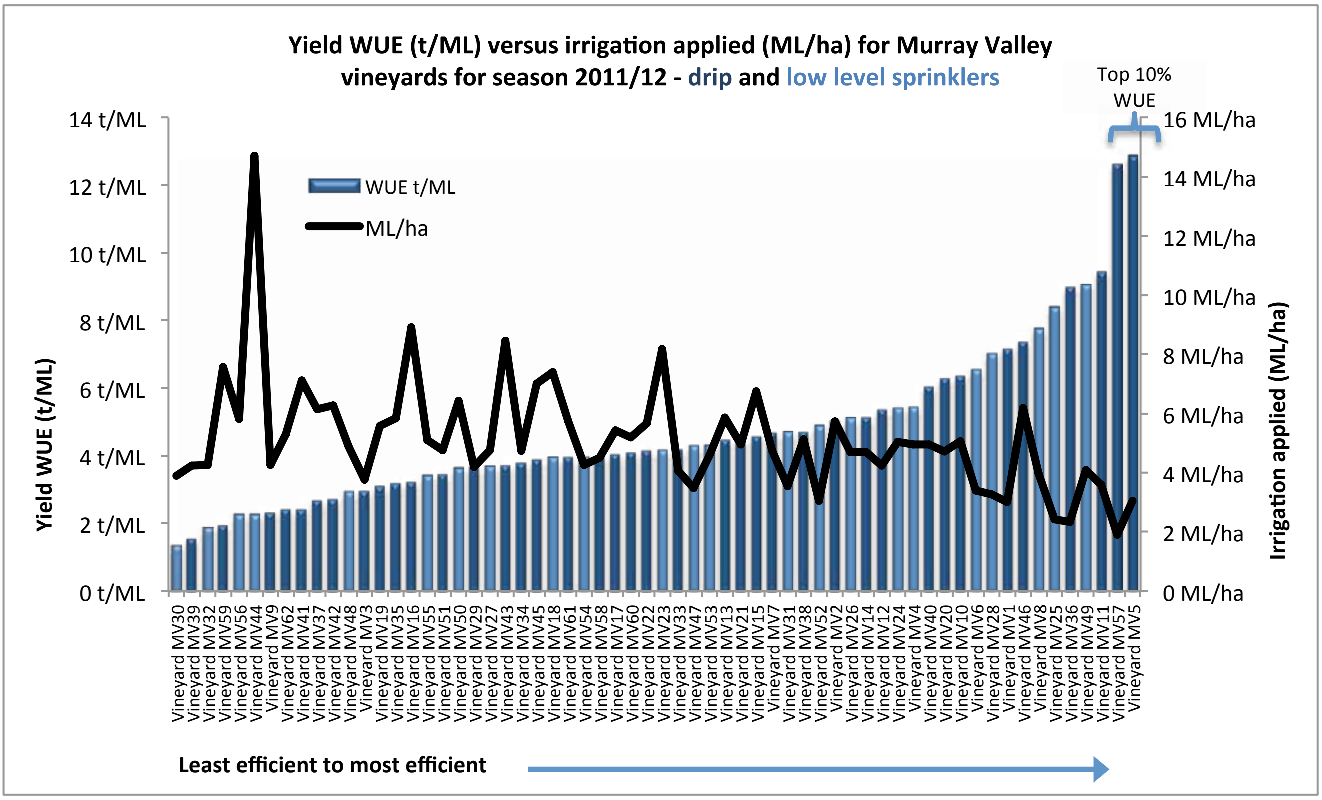

Figure 9 : The range of yield WUE values (t/ML) for vineyards in the Murray Valley in season 2011/12

Observations by growth stage

Key observations for each growth stage for 2011/12 include:

- **Drip irrigation:** An average of 4.3 ML/ha was applied during the growing season, with approximately 16% applied from bud burst to flowering, 36% applied between fruit set and veraison, 30% applied between veraison and harvest and 18% applied post harvest and prior to leaf fall.
- **Low level sprinkler irrigation:** An average of 6.6 ML/ha was applied during the growing season, with approximately 25% applied from bud burst to flowering, 37% applied between fruit set and veraison, 25% applied between veraison and harvest and 13% applied post harvest and prior to leaf fall.

Table 6 : Average irrigation applied at key growth stages by irrigation method in the Murray Valley

Yield WUE	Bud burst (EL 4) - Flowering (EL 26)	Fruit set (EL 27) - Veraison (EL 35)	100% veraison (EL 36) - Harvest (EL 38)	Post Harvest (EL 41) - End of leaf fall (EL 47)	Total
Drip	0.7 ML/ha	1.5 ML/ha	1.3 ML/ha	0.8 ML/ha	**4.3 ML/ha**
Low level sprinklers	1.6 ML/ha	2.4 ML/ha	1.7 ML/ha	0.9 ML/ha	**6.6 ML/ha**

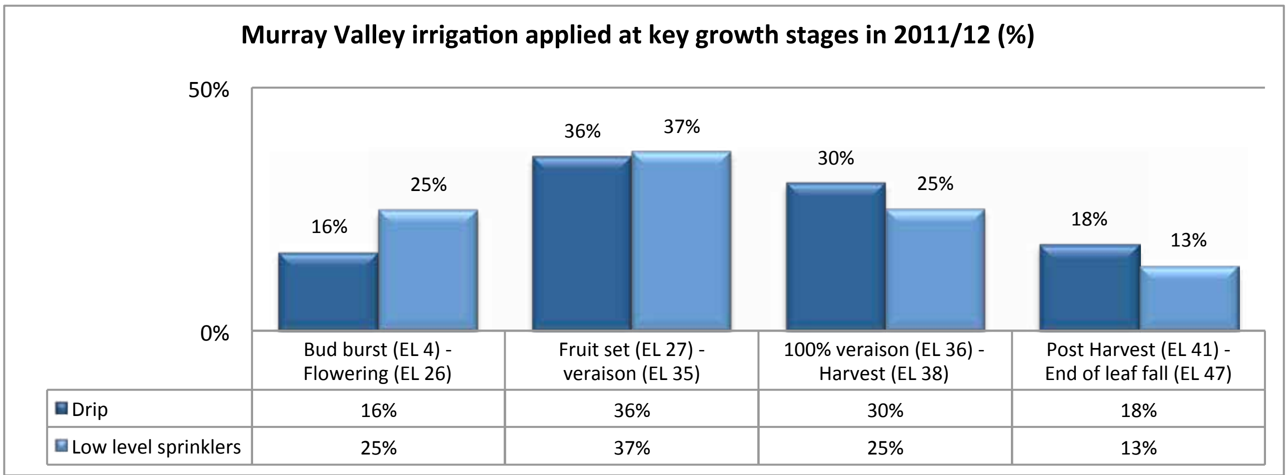

Figure 10 : Average irrigation applied at key wine grape growth stages (%) in the Murray Valley

Observations by variety

Average irrigation applied for each variety was: Semillon (4.7 ML/ha), Chardonnay (5.1 ML/ha), Shiraz (5.3 ML/ha) and Cabernet Sauvignon (4.9 ML/ha). Average irrigation applied by variety and dripper versus low level sprinkler irrigation is presented in **Figure 11**.

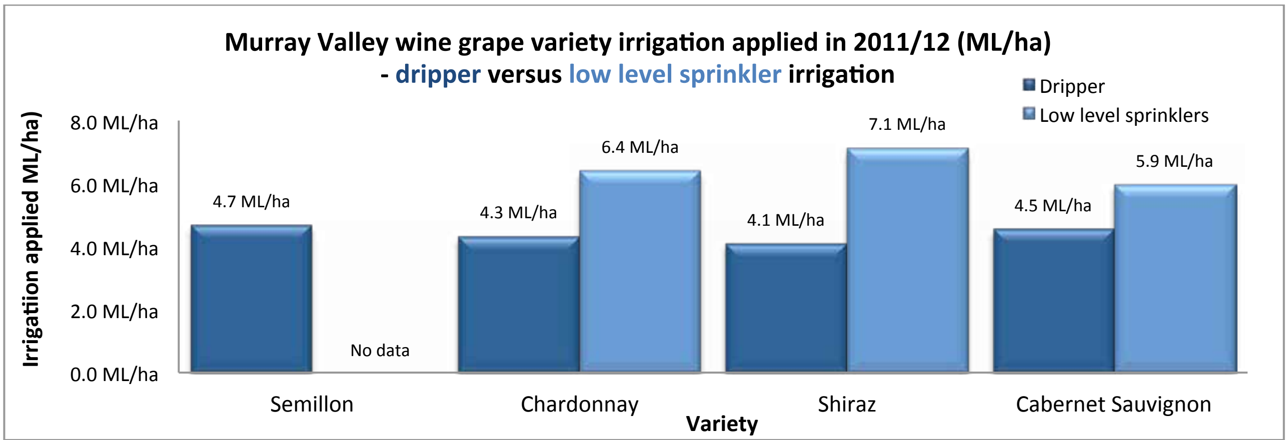

Figure 11 : Average irrigation applied at key wine grape growth stages (ML/ha) in the Murray Valley

The average irrigation applied at key growth stages by variety is presented in **Table 7**

Table 7 : Average irrigation applied at key growth stages by variety in the Murray Valley

Yield WUE	Bud burst (EL 4) - Flowering (EL 26)	Fruit set (EL 27) - Veraison (EL 35)	100% veraison (EL 36) - Harvest (EL 38)	Post Harvest (EL 41) - End of leaf fall (EL 47)	Total
Semillon	0.8 ML/ha	1.2 ML/ha	1.9 ML/ha	0.8 ML/ha	**4.7 ML/ha**
Chardonnay	0.9 ML/ha	1.7 ML/ha	1.4 ML/ha	1.0 ML/ha	**5.1 ML/ha**
Shiraz	1.2 ML/ha	2.1 ML/ha	1.4 ML/ha	0.6 ML/ha	**5.3 ML/ha**
Cabernet Sauvignon	1.0 ML/ha	1.9 ML/ha	1.4 ML/ha	0.7 ML/ha	**4.9 ML/ha**

- The average irrigation applied for wine grape varieties in the Murray Valley in season 2011/12 was:
  - Approximately 4.7 ML/ha to 5.1 ML/ha for white varieties, with 18% of the water budget applied from bud burst to flowering, 26% to 33% applied between fruit set and veraison, 28% to 40% applied between veraison and harvest and 16% to 20% applied post harvest and prior to leaf fall.
  - Approximately 4.9 ML/ha to 5.3 ML/ha for red varieties, with 19% to 23% of the water budget applied from bud burst to flowering, 38% to 40% applied between fruit set and veraison, 25% to 28% applied between veraison and harvest and 12% to 14% applied post harvest and prior to leaf fall.

Observations by own roots or rootstock

The four wine grape varieties studied in this project were planted on a range of different rootstocks, or on their own roots. Given the range of rootstocks used and the low sampling size per variety, it is not possible to make comparisons between own rooted vines and vines planted onto specific rootstock. The average irrigation applied for own roots versus rootstocks (all) for each variety is presented in **Figure 12.**

General observations include:

- **Semillon** planted onto Ramsey (3 data sets), or Kober 5BB (1 data set) rootstock. Average irrigation applied was 4.7 ML/ha, with 4.9 ML/ha for Ramsey and 4.1 ML/ha for the single Kober 5BB planting.
- **Chardonnay** planted onto Ramsey, Ruggeri 140, Paulsen 1103, Schwarzmann and Kober 5BB. Overall, vines planted on rootstocks (5.3 ML/ha), used 1.2 ML/ha (or 23%) more water compared to own roots (4.1 ML/ha) and produced an additional 11 t/ha (or 39%) greater yield.
- **Shiraz** planted onto Ramsey, Paulsen 1103, Richter 99, 101-14 and Kober 5BB. Overall, vines planted on rootstocks (5.0 ML/ha), used 0.7 ML/ha (or 13%) less water compared to own roots (5.7 ML/ha) and produced a similar (20t/ha) yield.
- **Cabernet Sauvignon** planted onto Ramsey, Schwarzmann and K51-40). Overall, vines planted on rootstocks (4.7 ML/ha), used 0.6 ML/ha (or 11%) less compared to own roots (5.2 ML/ha) and produced an additional 5 t/ha (or 31%) greater yield.

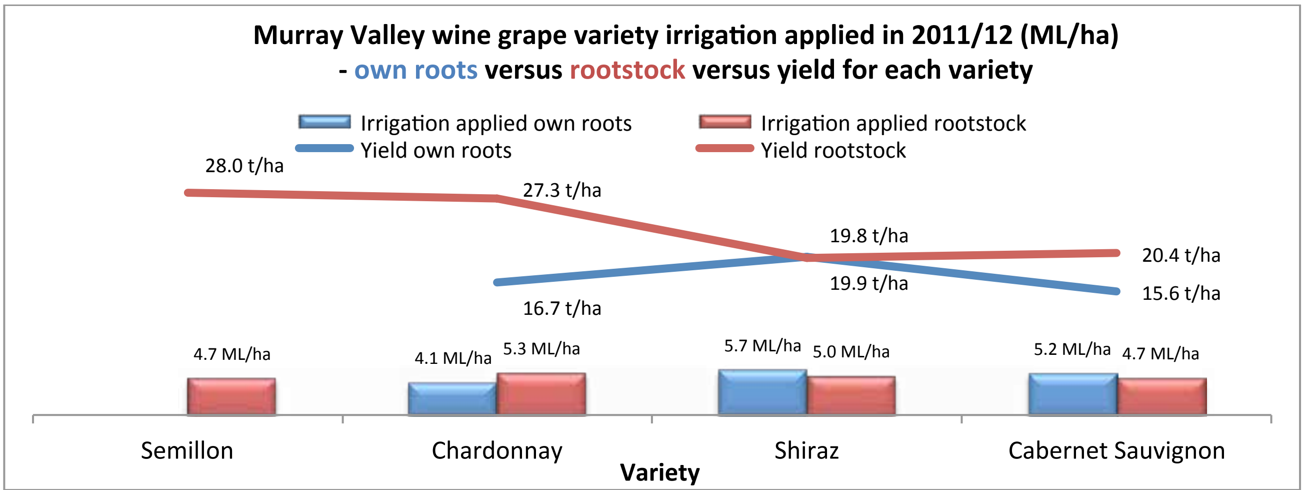

Figure 12 : Own roots or rootstock average irrigation applied in the Murray Valley in season 2011/12

Riverina wine region

A total of 32 irrigation data sets were received from Riverina wine growers. A summary of the data set received is presented in **Appendix 1b.** A breakdown of data by variety, application method, own roots and Ramsey rootstock is presented in **Tables 8 to 10** and **Figure 13**.

Data received

Table 8 : Riverina irrigation data received by variety

Number of data sets	Variety				
	Semillon	Chardonnay	Shiraz	Cabernet Sauvignon	Total
	9	9	10	4	32

Table 9 : Riverina irrigation data received by application method (drip or furrow)

Number of data sets	Irrigation application method		
	Drip	Furrow	Total
	25	7	32

Table 10 : Riverina vines grown on own roots or Ramsey rootstock

Number of data sets	Vines on own roots or Ramsey rootstock		
	Own roots	Ramsey rootstock	Total
	14	18	32

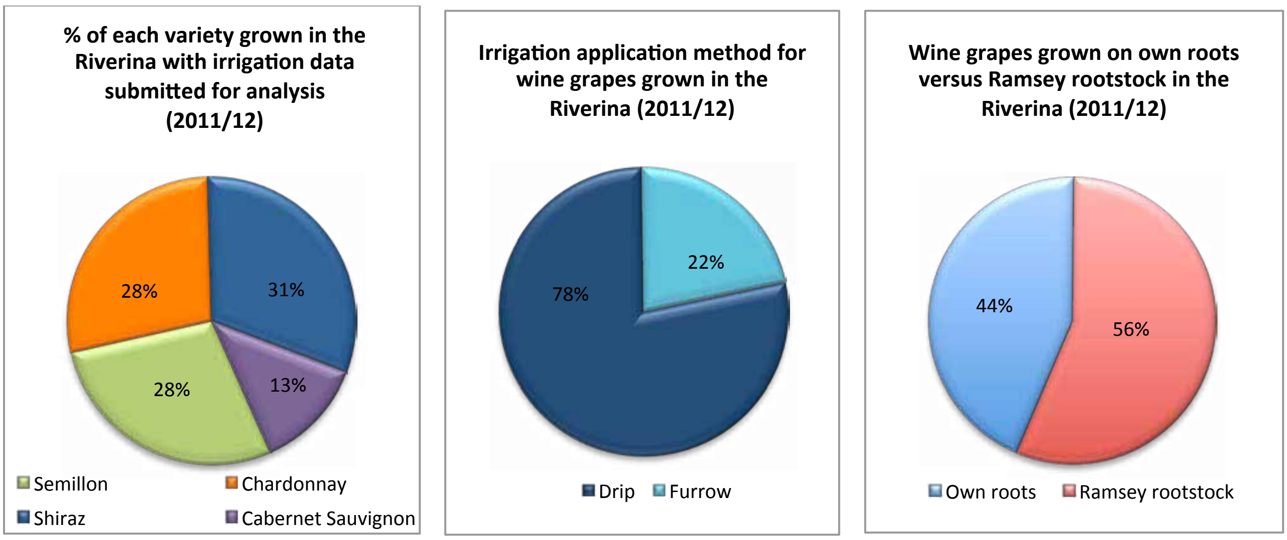

Figure 13 : Irrigation data by variety, application method, own roots or rootstock in the Riverina

Riverina data set

Key observations for season 2011/12 include:

- The yields across all varieties varied from 4.4 t/ha (Vineyard R28 - Semillon on Ramsey rootstock, furrow) to 23.4 t/ha (Vineyard R27 - Semillon on Ramsey rootstock, furrow), with an average yield of 12.8 t/ha produced across all vineyards surveyed in the Riverina, see **Figure 14**.
  - The average production for each variety was: Semillon 14.7 t/ha, Chardonnay 14.7 t/ha, Shiraz 9.7 t/ha and Cabernet Sauvignon 12.0 t/ha.
  - An average of 13.0 t/ha was produced across all varieties on drip irrigated vineyards, compared to 12.0 t/ha for furrow irrigated vineyards in the Riverina.

- The average irrigation applied across all varieties from budburst to leaf fall varied from 1.2 ML/ha to 6.2 ML/ha, see **Figure 15.**
  - The average irrigation applied was 2.8 ML/ha for drip and 3.7 ML/ha for furrow irrigated vineyards.
- On average, furrow irrigated vineyards used an additional 0.9 ML/ha (or 24% more water) and produced 1.04 t/ha (or 8%) less yield than drip irrigated vineyards in season 2011/12.

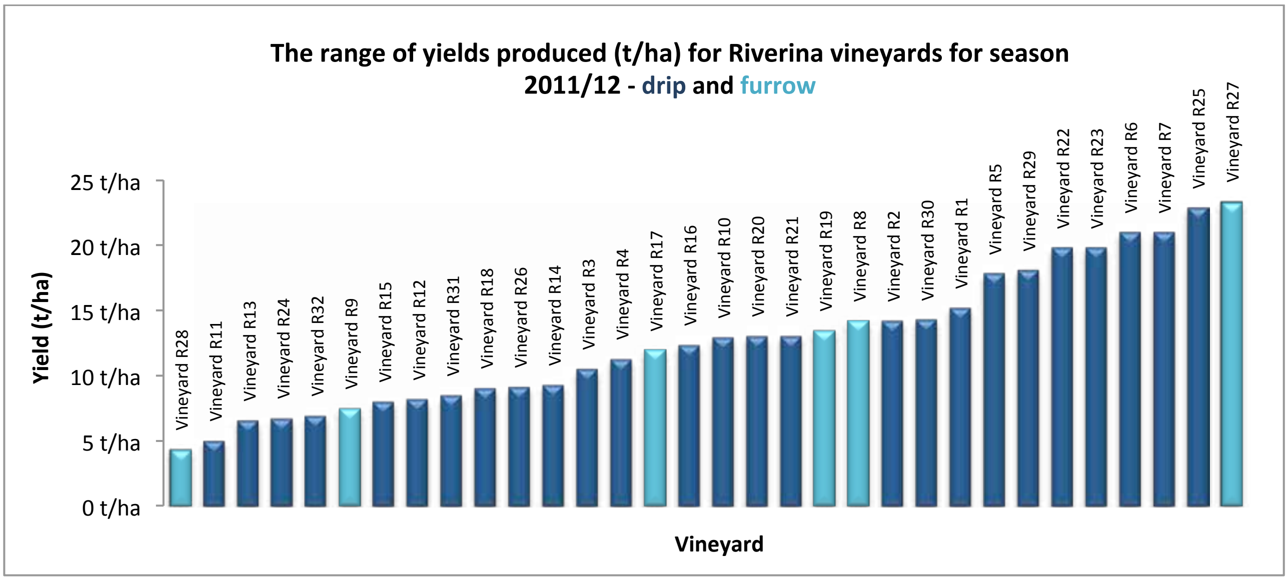

Figure 14 : The range of yields (t/ha) for Riverina vineyards (furrow marked in teal)

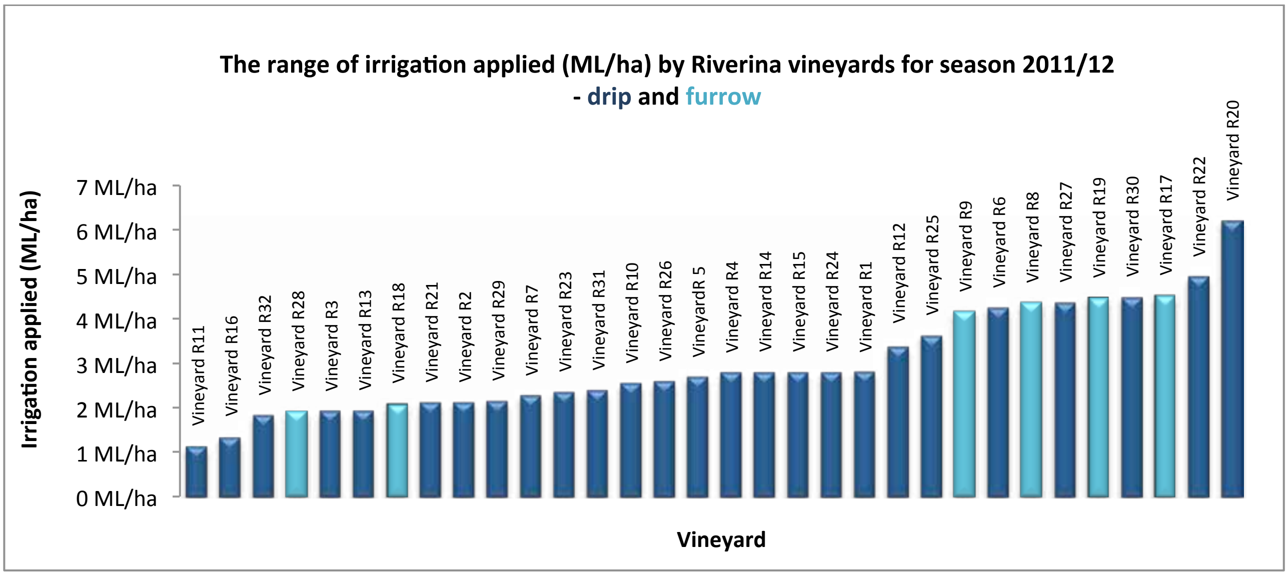

Figure 15 : The range of irrigation applied (ML/ha) for Riverina vineyards (furrow marked in teal)

There is a broad range of both high and low yields (t/ha) produced where similar rates of irrigation (ML/ha) have been applied, see **Figure 16**. As the rate of irrigation application increases, a similar increase in yield may not occur. Similarly, the vineyards applying the lowest volume of water (ML/ha), are not necessarily the most efficient users of water.

- For example to produce a Semillon yield of 13.1 t/ha, irrigation ranging from 2.1 ML/ha to 6.2 ML/ha (Vineyard R20 and R21 – both drip irrigated) was applied in 2011/12, a difference of 4.1 ML/ha. This indicates that there is the potential to reduce the volume of water applied, with no detriment to production expected, in some instances.

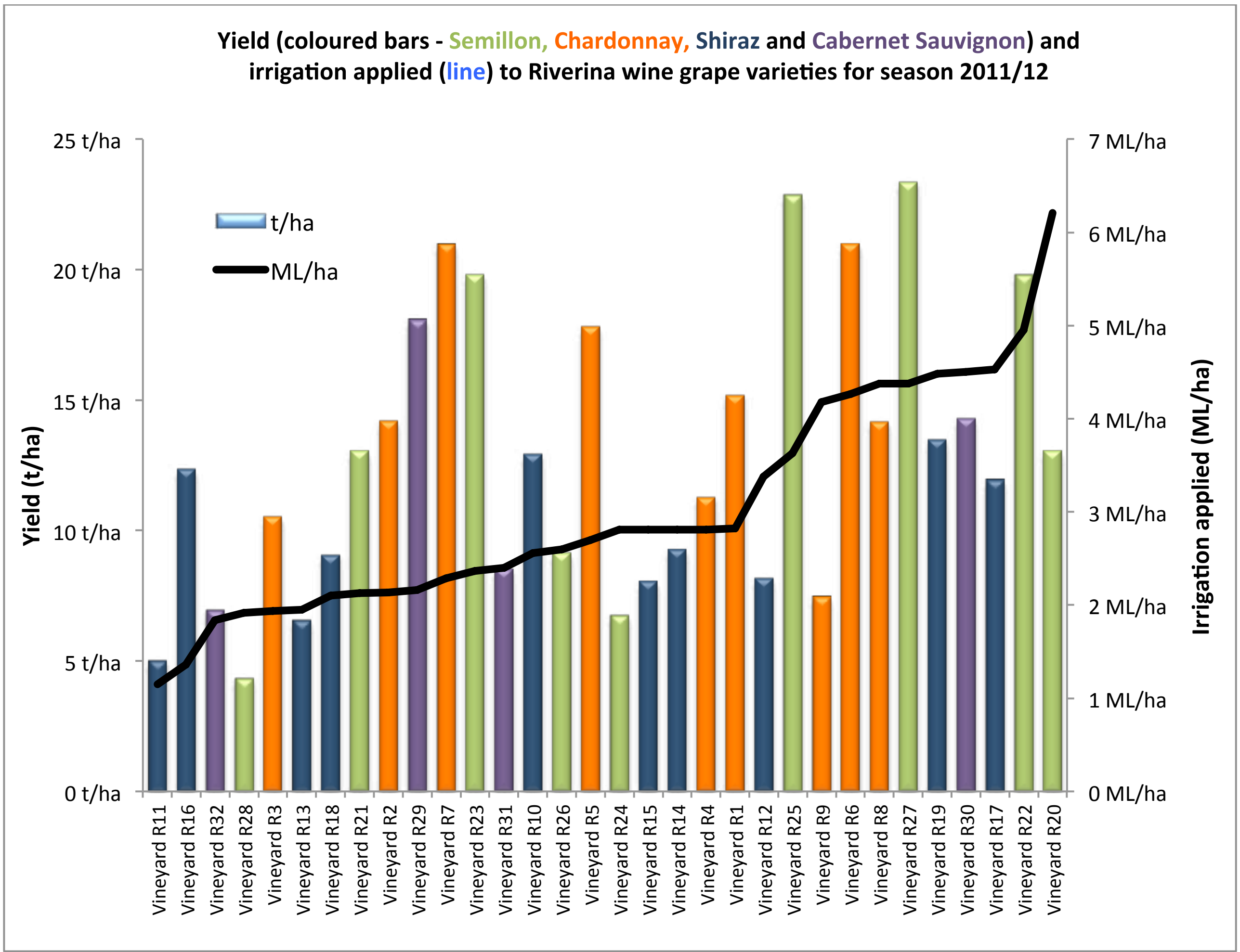

Figure 16 : The range of yields produced (t/ha) and irrigation applied (ML/ha) for Riverina vineyards

Yield water use efficiency (WUE)

Key yield WUE benchmarks for season 2011/12 include:

- Yield WUE ranged from 1.8ML/t (least efficient) to 9.2t/ML (most efficient), with an average WUE of 4.6 t/ML for all vineyards surveyed (drip and furrow).
  - **Drip irrigated:** Yield WUE for drip irrigated vineyards ranged from 2.1 t/ML (least efficient) to 9.2 t/ML (most efficient), with an average WUE of 5.0 t/ML.
  - **Furrow irrigated:** Yield WUE for furrow irrigated vineyards ranged from 1.8 t/ML (least efficient) to 5.3 t/ML (most efficient), with an average WUE of 3.2 t/ML.
  - Drip irrigated vineyards are on average 35% more efficient users of water than furrow irrigated vineyards.

The water use efficiency of producing wine grapes via drip and furrow irrigation is presented in **Table 11.**

Table 11 : Average yield WUE for drip and furrow irrigated vineyards in the Riverina

Yield WUE	Drip irrigated	Furrow irrigated	Difference	
Most efficient	9.2 t/ML	5.3 t/ML	3.8 t/ML	42%
Average	**5.0 t/ML**	**3.2 t/ML**	**1.7 t/ML**	**35%**
Least efficient	2.1 t/ML	1.8 t/ML	0.3 t/ML	15%

The spread of WUE figures is presented in **Figure 17** and discussed below:

- **Most efficient - Vineyard R7:** (drip irrigated) is the most efficient water user, with 9.2 tonnes of grapes produced for every ML of water used. An average of 2.3 ML/ha was applied and 21 t/ha of Chardonnay (Ramsey rootstock) produced on this vineyard in the 2011/12 growing season.
- **Least efficient - Vineyard R9:** (furrow irrigated) is the least efficient water user, with only 1.8 tonnes of grapes produced for every ML of water used. An average of 4.2 ML/ha was applied and 7.5 t/ha of Chardonnay (own roots) produced on this vineyard in the 2011/12 growing season.
- Vineyard R7, R16, R23 and R29 are in the top 10% of WUE for the region.
- Vineyard R11 applied the lowest volume of water per hectare (1.2ML/ha) and produced a crop of 5t/ha with a WUE of 4.4t/ML (just below the average WUE of 4.6 t/ML).
- Vineyard R20 applied the highest volume of water per hectare (6.2 ML/ha) and produced a crop of 13.1 t/ha, with a WUE of 2.1 t/ML (the second least efficient vineyard).

Table 12 : Most and least efficient vineyards by variety in the Riverina

Variety	WUE	Vineyard	Own roots or Ramsey rootstock	Irrigation method	Yield t/ha	Irrigation applied ML/ha	WUE t/ML
Semillon	Most efficient	Vineyard R23	Ramsey	Drip	19.8 t/ha	2.4 t/ha	8.4 t/ML
	Least efficient	Vineyard R20	Ramsey	Drip	13.1 t/ha	6.2 t/ha	2.1 t/ML
Chardonnay	Most efficient	Vineyard R7	Ramsey	Drip	21.0 t/ha	2.3 t/ha	9.2 t/ML
	Least efficient	Vineyard R9	Own roots	Furrow	7.5 t/ha	4.2 t/ha	1.8 t/ML
Shiraz	Most efficient	Vineyard R16	Own roots	Drip	12.4 t/ha	1.4 t/ha	9.1 t/ML
	Least efficient	Vineyard R12	Ramsey	Drip	8.2 t/ha	3.4 t/ha	2.4 t/ML
Cabernet Sauvignon	Most efficient	Vineyard R29	Ramsey	Drip	18.1 t/ha	2.2 t/ha	8.4 t/ML
	Least efficient	Vineyard R30	Own roots	Drip	14.3 t/ha	4.5 t/ha	3.2 t/ML

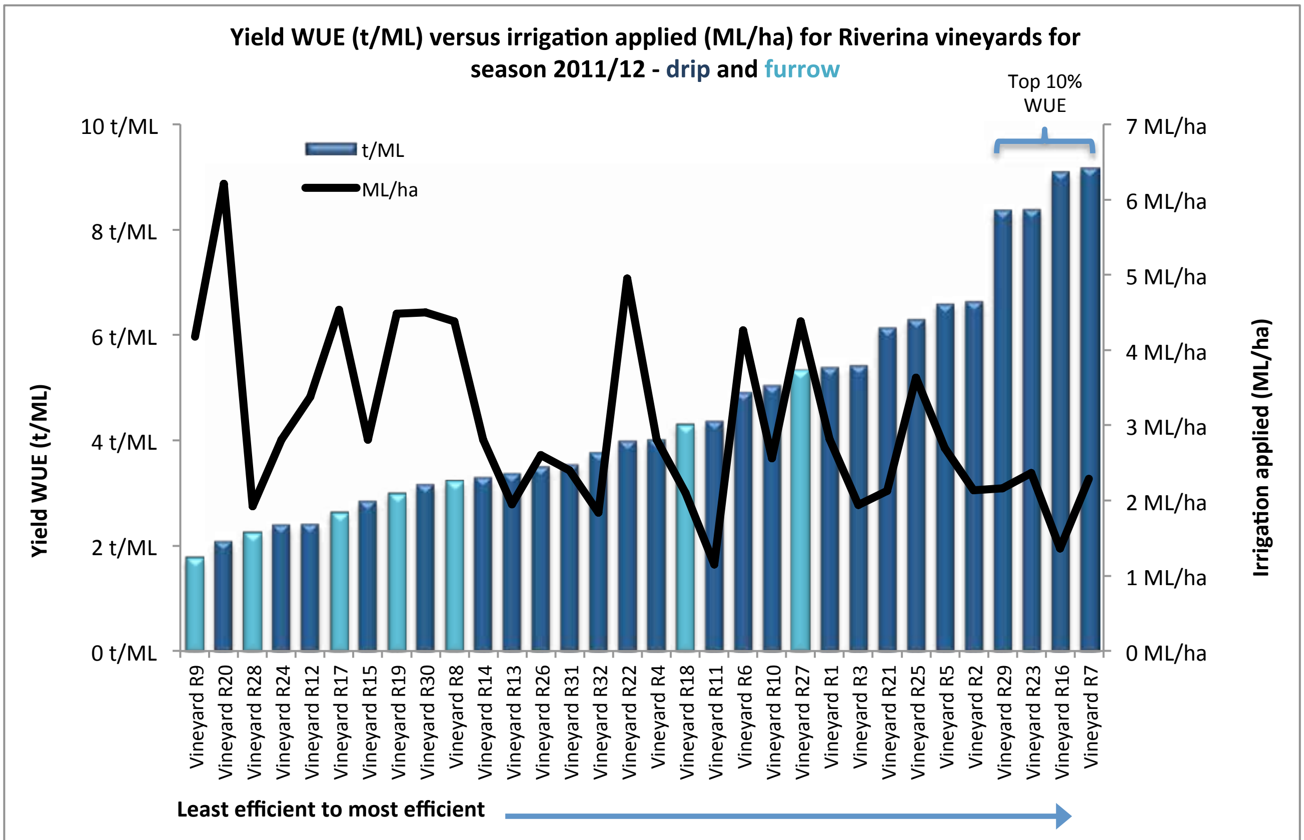

Figure 17 : The range of yield WUE values (t/ML) for vineyards in the Riverina in season 2011/12

Observations by growth stage

Key observations for each growth stage for 2011/12 include:

- **Drip irrigation:** An average of 2.8 ML/ha was applied during the growing season, with approximately 25% of the water budget applied from bud burst to flowering, 45% applied between fruit set and veraison, 25% applied between veraison and harvest, and 6% applied post harvest and prior to leaf fall.
- **Furrow irrigation:** An average of 3.7 ML/ha was applied during the growing season, with approximately 32% of the water budget applied from bud burst to flowering, 44% applied between fruit set and veraison, 15% applied between veraison and harvest, and 8% applied post harvest and prior to leaf fall.

Table 13 : Average irrigation applied at key growth stages by irrigation method in the Riverina

Yield WUE	Bud burst (EL 4) - Flowering (EL 26)	Fruit set (EL 27) - Veraison (EL 35)	100% veraison (EL 36) - Harvest (EL 38)	Post Harvest (EL 41) - End of leaf fall (EL 47)	Total
Drip	0.7 ML/ha	1.3 ML/ha	0.7 ML/ha	0.2 ML/ha	**2.8 ML/ha**
Furrow	1.2 ML/ha	1.6 ML/ha	0.6 ML/ha	0.3 ML/ha	**3.7 ML/ha**

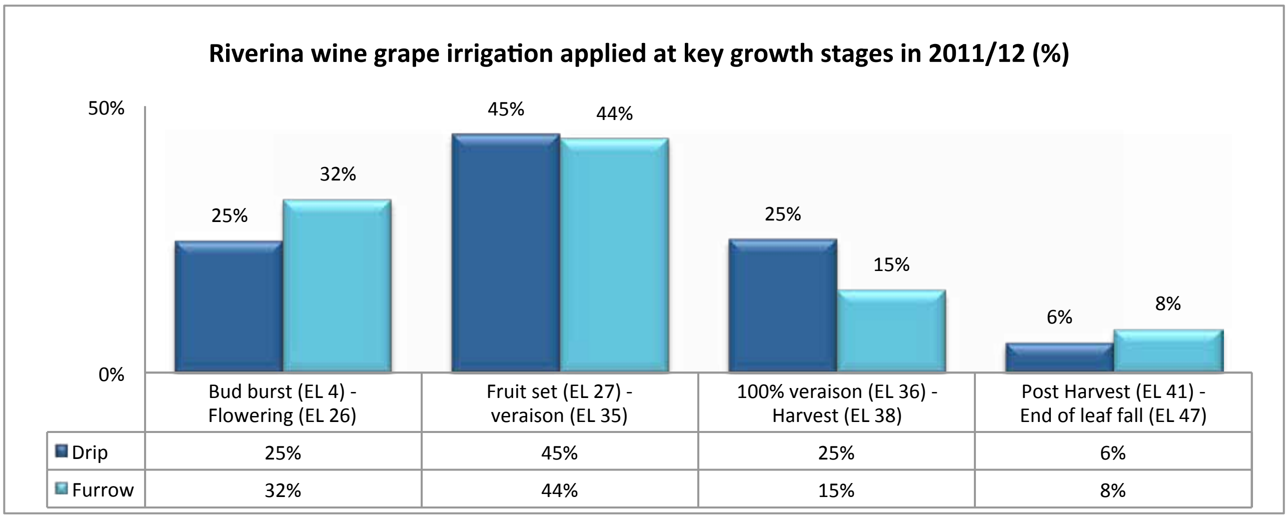

Figure 18 : Average irrigation applied at key wine grape growth stages (%) in the Riverina

Observations by variety

Average irrigation applied for each variety was: Semillon (3.44 ML/ha), Chardonnay (3.06 ML/ha), Shiraz (2.71 ML/ha) and Cabernet Sauvignon (2.73 ML/ha). Average irrigation applied by variety and dripper versus furrow irrigation is presented in **Figure 19**.

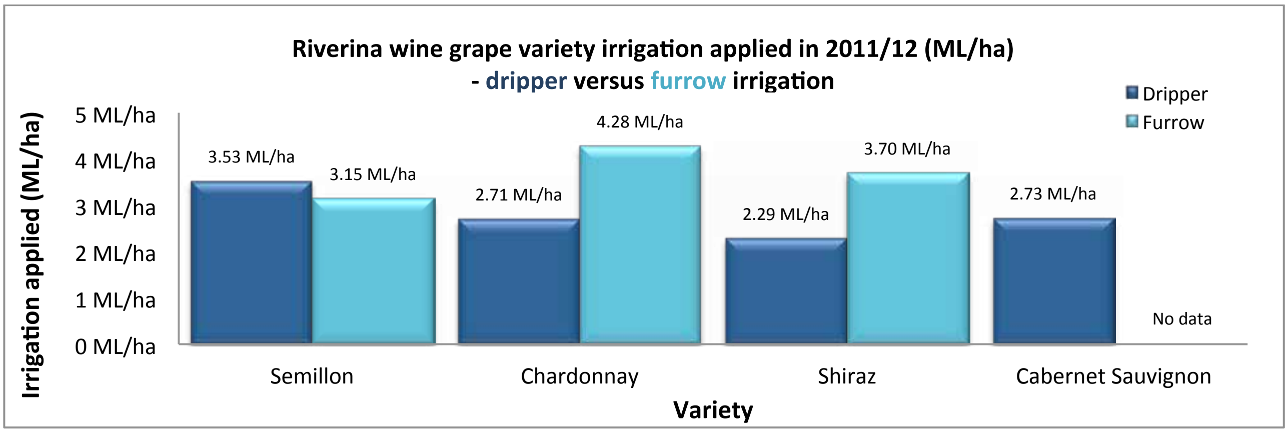

Figure 19 : Average irrigation applied at key wine grape growth stages (ML/ha) in the Riverina

The average irrigation applied at key growth stages by variety is presented in **Table 14**

Table 14 : Average irrigation applied at key growth stages by variety in the Riverina

Yield WUE	Bud burst (EL 4) - Flowering (EL 26)	Fruit set (EL 27) - Veraison (EL 35)	100% veraison (EL 36) - Harvest (EL 38)	Post Harvest (EL 41) - End of leaf fall (EL 47)	Total
Semillon	1.0 ML/ha	1.5 ML/ha	0.7 ML/ha	0.2 ML/ha	**3.4 ML/ha**
Chardonnay	0.8 ML/ha	1.4 ML/ha	0.6 ML/ha	0.3 ML/ha	**3.1 ML/ha**
Shiraz	0.7 ML/ha	1.1 ML/ha	0.7 ML/ha	0.2 ML/ha	**2.7 ML/ha**
Cabernet Sauvignon	0.6 ML/ha	1.3 ML/ha	0.7 ML/ha	0.1 ML/ha	**2.7 ML/ha**

- The average irrigation applied for wine grape varieties in the Riverina in season 2011/12 was:
  - Approximately 3.1 ML/ha to 3.4 ML/ha for white varieties, with 26% to 29% of the water budget applied from bud burst to flowering, 45% applied between fruit set and veraison, 20% to 21% applied between veraison and harvest, and 6% to 8% applied post harvest and prior to leaf fall.
  - Approximately 2.7 ML/ha for red varieties, with 24% to 27% of the water budget applied from bud burst to flowering, 42% to 49% applied between fruit set and veraison, 25% to 26% applied between veraison and harvest, and 3% to 6% applied post harvest and prior to leaf fall.

Observations by own roots or rootstock

Ramsey rootstock is known for its capacity to produce higher yields than vines planted on their own roots. Its deep rooting behaviour makes vines planted onto Ramsey rootstocks well suited to drought conditions and maximising yield produced per hectare, resulting in a high WUE.

The following irrigation applications were made for each variety in the Riverina:

- The average irrigation applied (ML/ha) was lower for varieties planted on Ramsey rootstock, with the exception of Semillon, where the vines used an average of 6% more water on Ramsey.

- The water savings for all other varieties versus own roots was 4% for Chardonnay, 14% for Shiraz and 28% for Cabernet Sauvignon, see **Figure 20**.

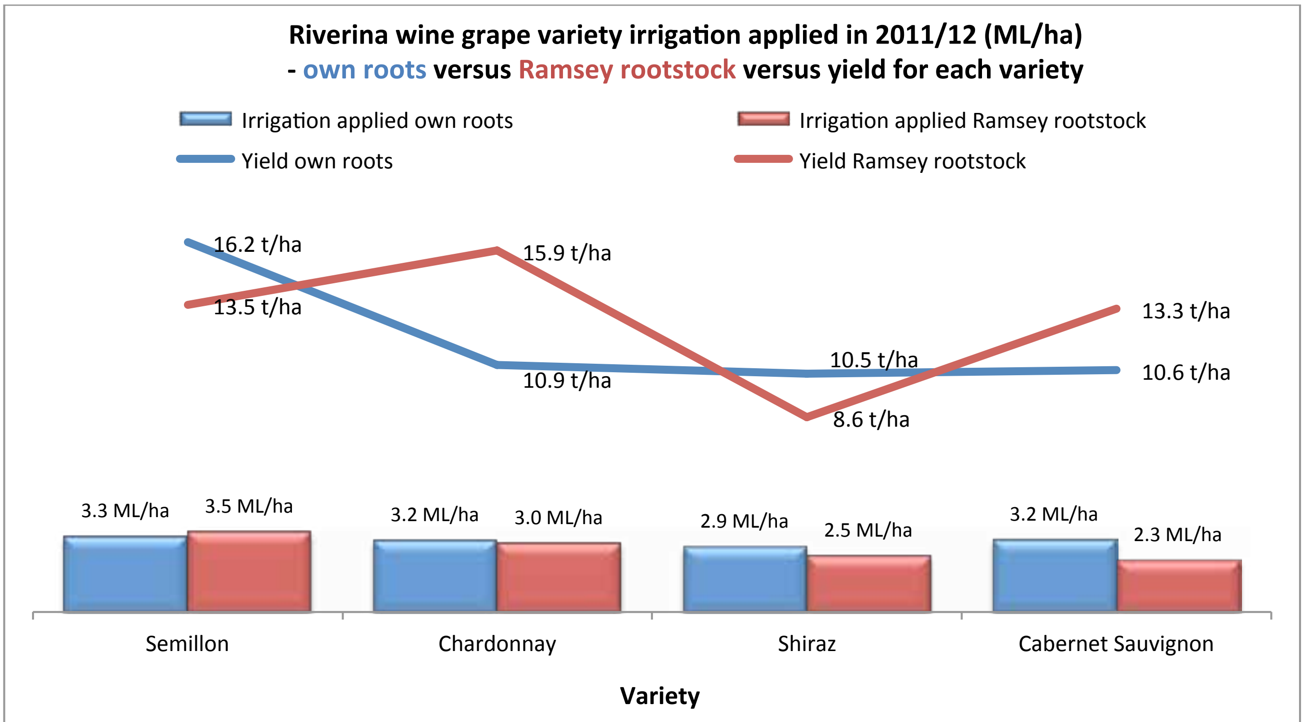

Figure 20 : Own roots or rootstock average irrigation applied in the Murray Valley in season 2011/12

REGIONAL COMPARISONS

Average water applied by application method

The average water application for all varieties in the Murray Valley was 5.1 ML/ha compared to 3.0 ML/ha in the Riverina, a difference of 2.1 ML/ha (or 41%). The average yield for all varieties in the Murray Valley was 22.2 t/ha compared to 12.8 t/ha in the Riverina, a difference of 9.4 t/ha (or 42%). While the Murray Valley applied more water per hectare, a similar increase in yield was achieved.

The average water application for drip irrigated vineyards was 4.3 ML/ha in the Murray Valley and 2.8 ML/ha in the Riverina, across all varieties. Murray Valley vineyards used on average 1.5 ML/ha (or 35%) more water per hectare and produced 5.6 t/ha (or 40%) more yield, see **Figure 21.**

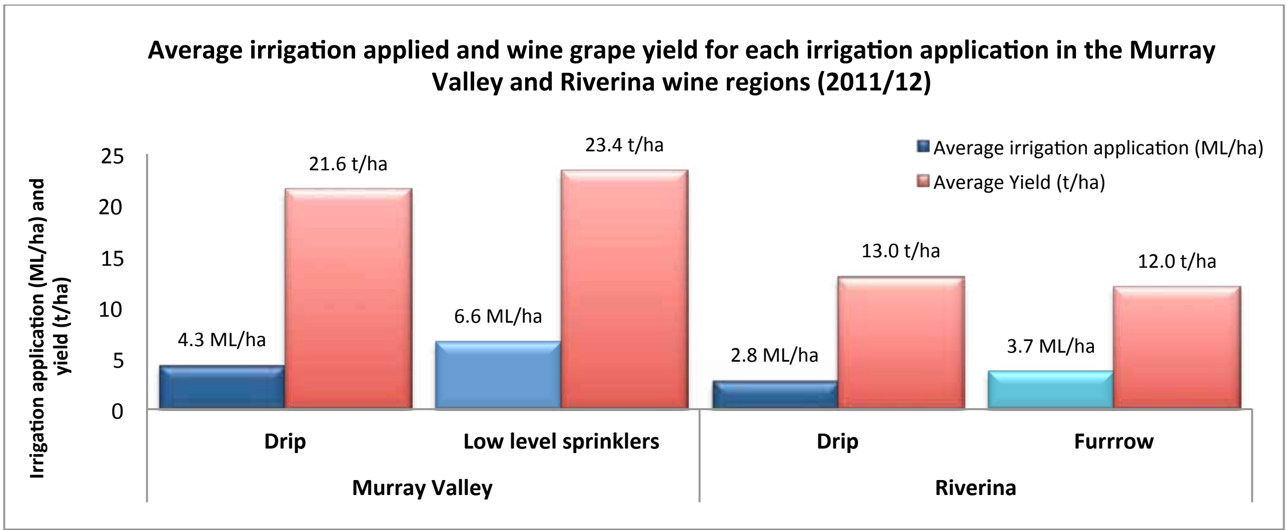

Figure 21 : Average irrigation applied and wine grape yield for each irrigation method in each region

Average irrigation applied and yield produced for each variety

The average water applied and yield produced for each variety in 2011/12 are:

- **Semillon:** The average water applied for Semillon was 4.7 ML/ha in the Murray Valley compared to 3.4 ML/ha in the Riverina, a difference of 1.2 ML/ha (or 26%). The average yield produced for Semillon was 28.0 t/ha in the Murray Valley compared to 14.7 t/ha in the Riverina, a difference of 13.3 t/ha (or 48%).
- **Chardonnay:** The average water applied for Chardonnay was 5.1 ML/ha in the Murray Valley compared to 3.1 ML/ha in the Riverina, a difference of 2.1 ML/ha (or 40%). The average yield produced for Chardonnay was 25.7 t/ha in the Murray Valley compared to 14.8 t/ha in the Riverina, a difference of 10.9 t/ha (or 42%).
- **Shiraz:** The average water applied for Shiraz was 5.3 ML/ha in the Murray Valley compared to 3.1 ML/ha in the Riverina, a difference of 2.1 ML/ha (or 40%). The average yield produced for Shiraz was 19.9 t/ha in the Murray Valley compared to 9.7 t/ha in the Riverina, a difference of 10.2 t/ha (or 51%).
- **Cabernet Sauvignon:** The average water applied for Cabernet Sauvignon was 4.9 ML/ha in the Murray Valley compared to 2.7 ML/ha in the Riverina, a difference of 2.2 ML/ha (or 45%). The average yield produced for Cabernet Sauvignon was 18.2 t/ha in the Murray Valley compared to 12.0 t/ha in the Riverina, a difference of 6.2 t/ha (or 34%).

The irrigation applied and yield achieved for each variety is presented in **Figure 22 and 23.**

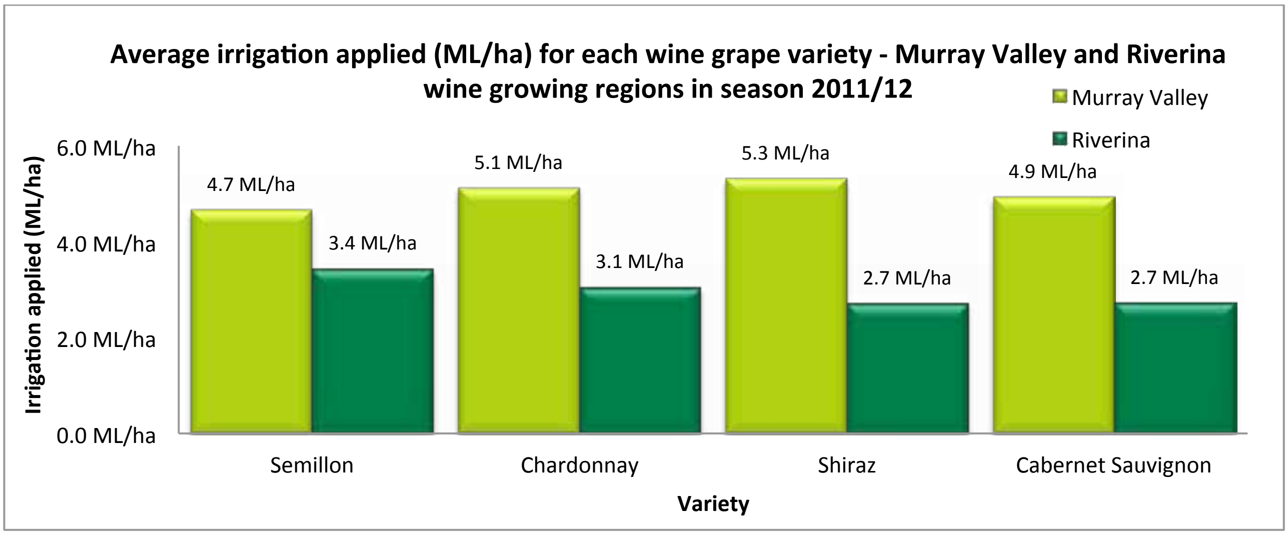

Figure 22 : Average irrigation applied (ML/ha) for each wine grape variety in each region

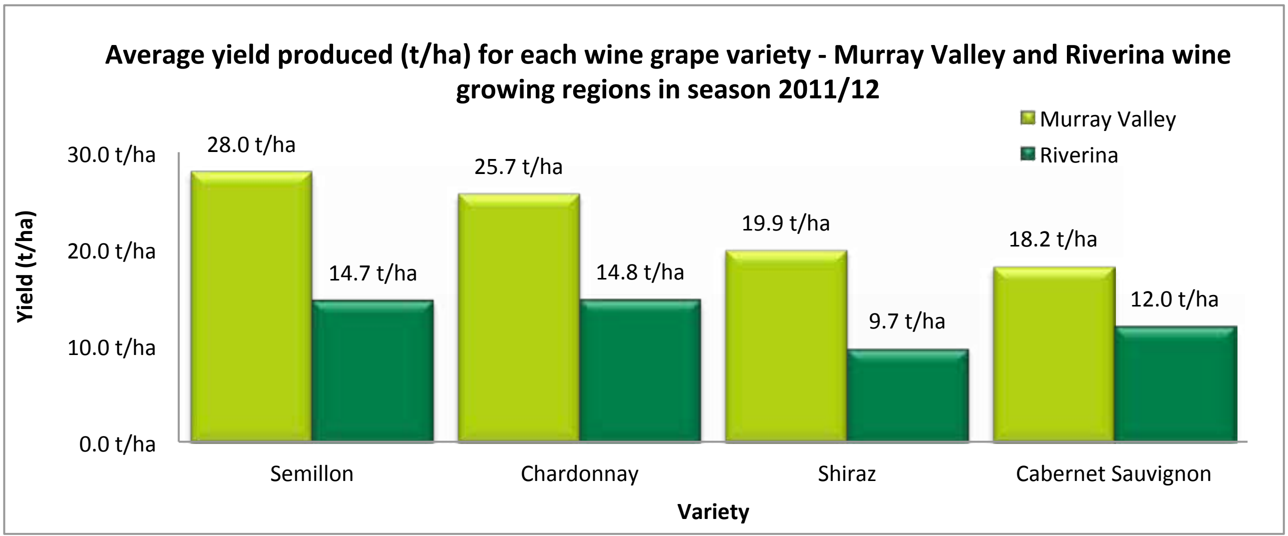

Figure 23 : Average yield produced (t/ha) for each wine grape variety in each region

Average WUE for each region

The average yield WUE for the Murray Valley is 4.7 t/ML compared to 4.6 t/ML in the Riverina, a difference of 0.1 t/ML (or 3%). The differences for individual varieties for each region are:

- **Semillon:** The average yield WUE in the Murray Valley is 5.9 t/ML compared to 4.5 t/ML in the Riverina, a difference of 1.4 t/ML (or 24%). Semillon was grown more efficiently in the Murray Valley in season 2011/12.
- **Chardonnay:** The average yield WUE in the Murray Valley is 5.4 t/ML compared to 5.2 t/ML in the Riverina, a difference of 0.1 t/ML (or 3%). Chardonnay was grown with similar efficiencies in both regions.
- **Shiraz:** The average yield WUE in the Murray Valley is 4.2 t/ML compared to 4.0 t/ML in the Riverina, a difference of 0.1 t/ML (or 3%). Shiraz was grown with similar efficiencies in both regions.
- **Cabernet Sauvignon:** The average yield WUE in the Murray Valley is 4.2 t/ML compared to 4.7 t/ML in the Riverina, a difference of -0.5 t/ML (or 10%). Cabernet Sauvignon was grown more efficiently in the Riverina in season 2011/12.

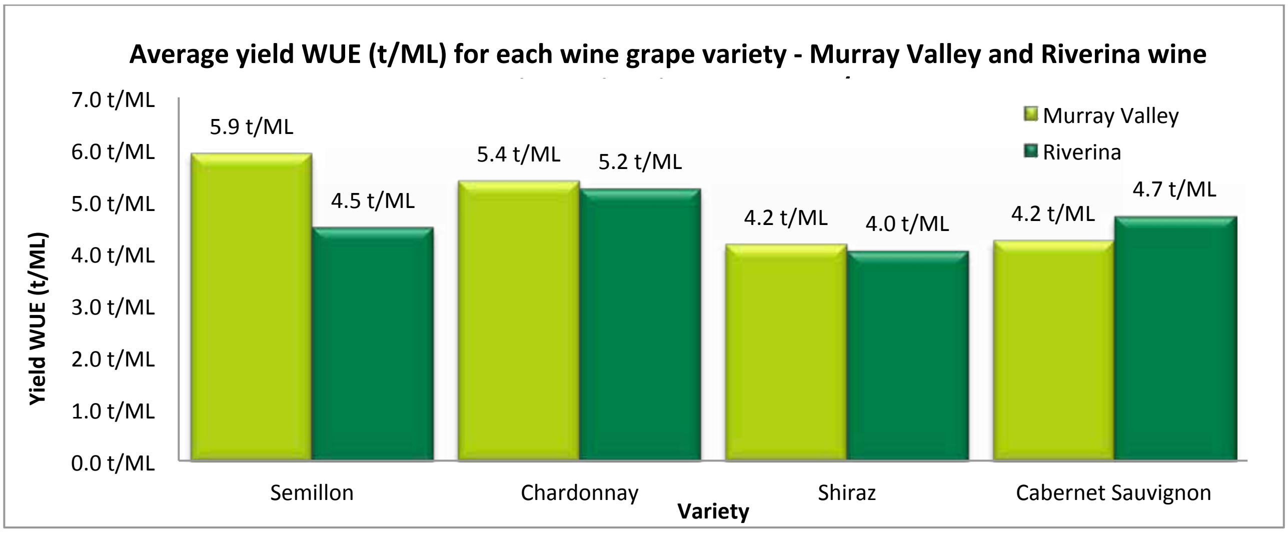

Figure 24 : Average yield WUE (t/ML) for each wine grape variety in each region

Virtual water

The term 'virtual water' is sometimes used to measure of the amount of water required to produce a unit of a particular product, normally expressed as litres per kilogram (L/kg).

An average of 261 L of water is used to produce every kg of grapes in the Murray Valley.

- An average of 236 L of water was used for drip irrigation.
- An average of 306 L of water was used for low level sprinkler irrigation.
- An additional 71 L/kg of water is used to produce the same volume of wine grapes if they are irrigated using low level sprinklers in the Murray Valley.

An average of 263 L of water is used to produce every kg of grapes in the Riverina.

- An average of 239 L of water was used for drip irrigation.
- An average of 348 L of water was used for furrow irrigation.
- An additional 109 L/kg of water is used to produce the same volume of wine grapes when they are furrow irrigated in the Riverina.

The WUE in L/kg for each variety in each region is presented in **Figure 25.**

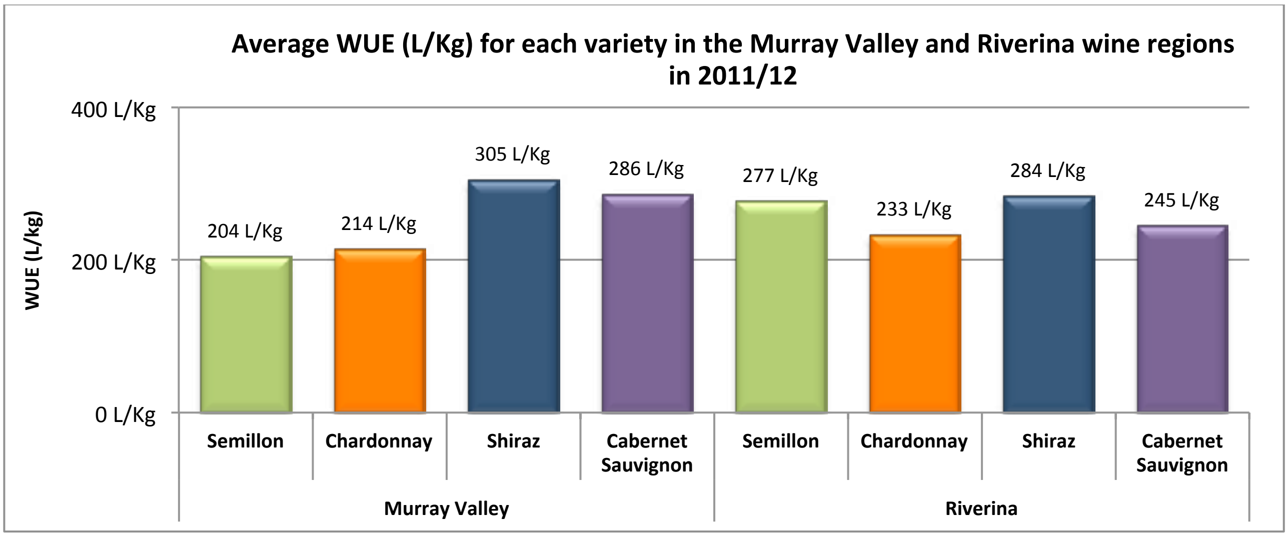

Figure 25 : The average 'virtual' water requirement for each variety (L/kg)

Yield drivers in the Murray Valley

The relationship between yield produced (t/ha) and bunch weight is positive but weak due to the amount of scatter present (ie where bunch weight was high this did not necessarily result in a higher crop load). This may have been due to the vine producing higher bunch weights if less bunches were produced, see **Figure 26**. There was a positive and stronger correlation between berry weights and bunch weight, ie where berry weight was higher so was the bunch weight. Similarly vines may have increased berry weights to compensate, if there were less berries per bunch (berry number per bunch were not assessed).

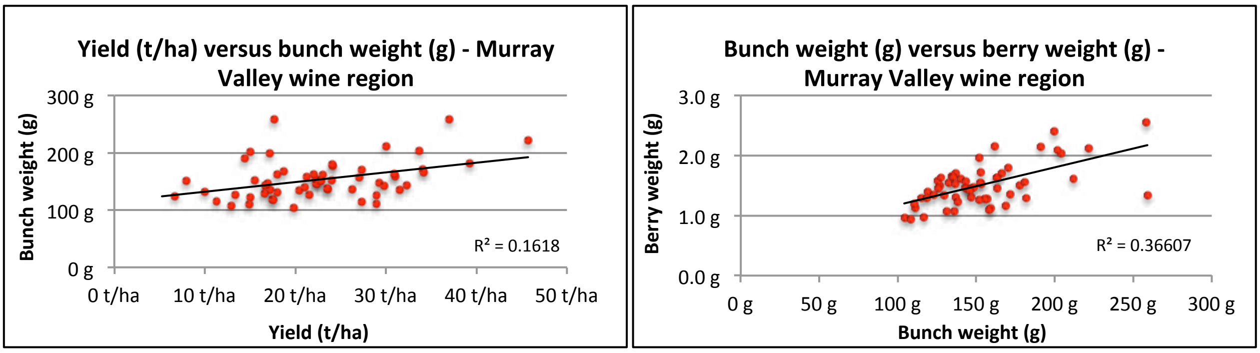

Figure 26 : Yield versus bunch weight and berry weight versus bunch weight in the Murray Valley

Relationships between irrigation applied and yield

The relationship between the volume of water applied (ML/ha) and the yield produced (t/ha) is positive but weak for drip irrigated vineyards, and stronger in the low level sprinkler irrigated vineyards in the Murray Valley. This indicates a high level of scatter in the drip irrigated vineyards (many vineyards did not produce greater yield in relation to the volume of water applied). Conversely, there was a stronger correlation between these parameters for the vineyards irrigated using low level sprinklers, see **Figure 27.**

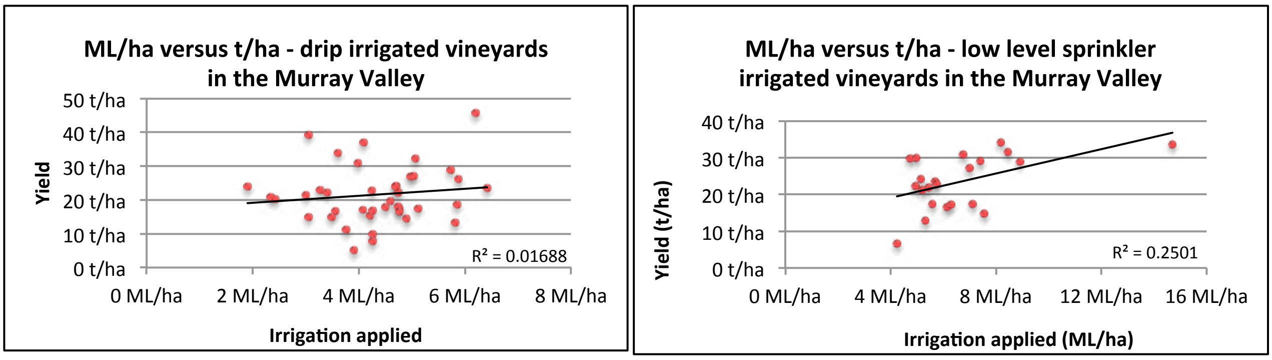

Figure 27 : Irrigation applied versus yield for each irrigation application method in the Murray Valley

A similar trend is apparent for the Riverina drip irrigated vineyards, where a positive but weak (stronger than the Murray Valley), correlation exists between the volume of water applied and the yield produced. A stronger correlation exists for the furrow irrigated vineyards in the Riverina see **Figure 28.**

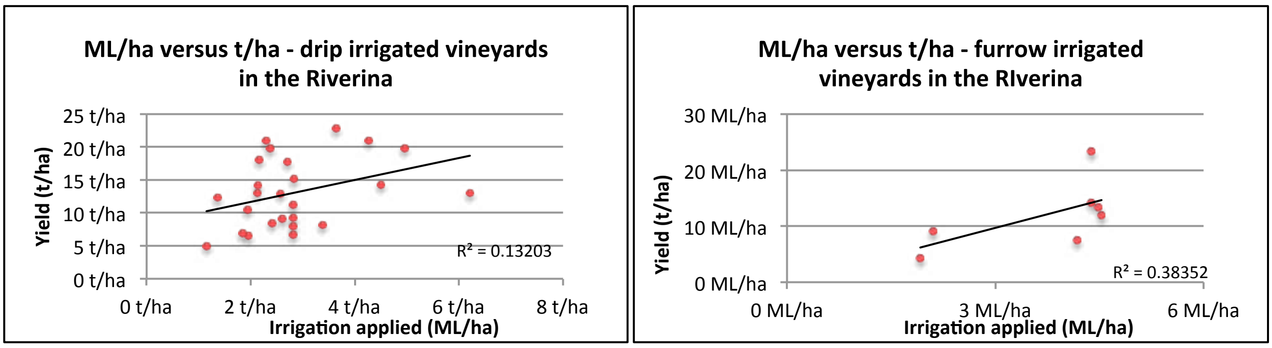

Figure 28 : Irrigation applied versus yield for each irrigation application method in the Riverina

IMPROVING WUE

There are a number of variables that may occur between data sets. For example a particular variety may have a higher or lower water use requirement, and vines planted on their own roots may have different water requirements than those planted on drought tolerant rootstocks etc. Some of these differences have been explored above.

In addition, the water holding capacity of the soil may differ, mulch may be used to retain soil moisture for longer, the annual rainfall may reduce or increase the need for irrigation, additional irrigation applications may be required during a heat wave, or a grower may apply irrigation to achieving a particular fruit style or quality parameter.

Regardless of these differences there are a number of strategies that growers can employ to improve WUE. They include:

- Comparing your water use to the yield WUE benchmarks identified in this report and tailoring your approach to maximise WUE strategies which are appropriate for your site,
- Assessing the 'effective' irrigation applied and reducing the portion which is lost to drainage (the CSIRO 'Full stop' detector www.fullstop.com.au can be used to monitor the wetting front),
- Planting vines onto drought resistant rootstocks,
- Growing varieties that have a lower water requirement,
- Converting from overhead sprinklers, low level sprinklers, or furrow irrigation to drip irrigation,
- Installing subsurface irrigation,
- Applying undervine mulch and/or improving soil organic matter, and
- Matching canopy to fruit ripening requirements (don't grow a large canopy if it is not required as it will require greater water inputs).

For more information about best irrigation management practices (BIMPs) for viticulture, see http://www.crcv.com.au/resources/Irrigation%20and%20Water/Additional%20Resources/MDB%20Irrigation%20Booklet.pdf

CONCLUDING REMARKS

This is the first year of the water use efficiency study and it provides a starting point to benchmark WUE for different varieties, and irrigation application methods in two regions. It also provides a platform to discuss the different ways growers can improve their WUE and demonstrate continual improvement, resulting in time and cost savings.

The study highlights that the yield WUE between the Murray Valley and Riverina are very similar based on the irrigation applied. However, as the data is interrogated by variety and application method it is possible to identify WUE improvements between the regions and at the vineyard level between wine growers.

Thank you to the wine growers from the Murray Valley and Riverina who contributed a combined ninety four data sets for the 2011/12 season. Without your support it would not be possible to provide these regional yield WUE benchmarking results.

RETALLACK VITICULTURE PTY LTD

MRetallack

MARY RETALLACK
Managing Director / Viticulturist
Macintosh HD:Users:RetallackViti:Documents:Retallack Viticulture:RV Clients:MVWI:WUE:Rmjr090912MVWI&RiverinaWUEFINAL.docx

Appendix 1a

Historical WUE project findings

HISTORICAL WUE PROJECT FINDINGS

Several studies have been carried out in the Murray Valley in the past to assess water use efficiency (WUE) and they are discussed below. While water use studies have been carried out for a number of varieties in the Riverina in the past, no specific WUE benchmarks were found for this wine region.

Murray Valley wine region

An irrigation benchmark survey was carried out for the Murray Valley from 1998 to 2002. A total of 64 sites were benchmarked over three seasons for wine grape varieties including Sultana, Colombard, Chardonnay, Ruby Cabernet, Shiraz, Cabernet Sauvignon and Merlot.

Key findings[1] from this study include:

- **White varieties**
  - Average yield for white varieties in 1999 to 2000 was 26.3 t/ha (ranging from 12.4 t/ha to 55.9 t/ha).
  - Average irrigation applied was 5.1 ML/ha (ranging from 2.0 ML/ha to 7.9 ML/ha).
- **Red varieties**
  - Average yield for red varieties in 1999 to 2000 was 20.0 t/ha (ranging from 12.2 t/ha to 34.6 t/ha).
  - Average irrigation applied was 4.6 ML/ha (ranging from 2.1 ML/ha to 7.9 ML/ha).
- The last two years of the study showed an average irrigation application of approximately 6 ML/ha.
- The amount of water applied was not strongly related to the yield produced. There was enormous variation in the water applied across sites producing similar yields. This suggests that there is the potential to reduce annual water applications (or fine tune the timing of the application) with no detriment to production in some instances.

Key findings[2] from a separate study conducted in the Murray Valley from 1999 to 2003 include:

- Ramsey is the most water use efficient rootstock for Chardonnay (based in tonnes per ML applied) under both normal and sustained deficient irrigation, while a range of rootstocks appear to be equally water use efficient for Shiraz.
- The average irrigation applied over the five seasons was 5.5 ML/ha (drip), 6.6 ML/ha (overhead) and 6.3 ML/ha (low level sprinkler).
- Irrigators using RDI used less water over all seasons (range 4.5 ML/ha to 5.4 ML/ha).

Key findings[3] from a four year study conducted from 2000 to 2004 assessing the WUE of wine grapes in Merbein and Loxton include:

- Chardonnay WUE at full irrigation of 4.4 t/ML and 5.9 t/ML at reduced irrigation.
- Shiraz WUE at full irrigation of 2.9 t/ML and 2.8 t/ML at reduced irrigation.

General

General water use values used as assumptions in the 'Economics of Drip Irrigation Tool'[4] include:

- Furrow 9 ML/ha,
- Low level sprinkler 7 ML/ha, and
- Drip 5 ML/ha.

[1] Giddings, J., Kelly, S., Chalmers, Y., and Cook, H. (2002) 'Winegrape irrigation benchmarking Murray Darling and Swan Hill 1998-2002', in Proceedings of Seminar 'Managing Water' ASVO, Mildura.

[2] Walker, R. and Boland, A-M. (2004) 'Improving water use efficiency in viticulture in the Murray Darling basin: Development and adoption of BMP for improved WUE and effectiveness for irrigated vines'. Final report to GWRDC. PN I1011, GWRDC, Adelaide.

[3] Walker, R. (2004) 'Application of carbon isotope discrimination technology to understanding and managing wine grape water use efficiency'. Final report to GWRDC. PN CRV 99/10, GWRDC, Adelaide.

[4] Economics of Drip Irrigation Tool Assumptions, http://www.gwrdc.com.au/webdata/resources/files/Mod2-ConversionToDripPPT.pdf

Appendix 1b

Wine grape water requirements at key growth stages and deficit irrigation strategies

wine growing for the future

WINE GRAPE WATER REQUIREMENTS

Vine water requirements at different stages of growth will depend on a number of variables including:

- The wine grape variety,
- Whether the vines are planted on their own roots, or the rootstock to scion interaction,
- Soil water holding capacity (RAW, topography, variation, texture and depth),
- Seasonal variables (rainfall – frequency and amount, evaporation – wind and temperature),
- Canopy size, crop load, fruit quality parameters, end point use,
- The need for a salt leaching fraction, additional water needed for frost control or during heatwaves,
- The volume of water available (maximum extractable water supply), and the water quality.

Irrigation considerations for each growth period

Bud burst to berry set

- Start the growing season with a full soil profile.
- Avoid water stress early in the growing season as this period is important for root growth, shoot growth and flower development.
- Ensure you have adequate shoot length 100 to 120 cm to sufficiently ripen the crop by flowering.
- Vine stress in the lead up to flowering may result in a smaller more compact rachis that may present a disease risk later in the season.
- Vines are particularly sensitive to stress at flowering. Ensure you have adequate soil moisture available during this period to ensure fruit set is maximised and poor fruit set, or aborted berries is minimised.

Berry set to veraison

- Once berries are set they go through a period of rapid growth via cell division and cell elongation.
- Shoot growth starts to slow as photosynthates are redirected from the shoot tip to the developing bunch of grapes (new sink).
- Regulated deficit irrigation (RDI) can be used during this period to stop shoot growth and reduce berry size. However, severe water stress and low carbohydrate reserves can result in reduced bud fruitfulness.

Veraison to harvest

- Berries go through a period of cell expansion, accumulate colour (anthocyanin), sugar (fructose and glucose); pH increases, acid concentration decreases and flavour develops.
- Ensure adequate soil moisture is maintained to allow these processes to occur uninterrupted, without excessive stress or the unwanted promotion of vegetative vigour.
- Deficit irrigation can reduce yield and delay ripening and fruit quality if there are not sufficient leaves to ripen the crop. Avoid the premature senescence and/or loss of leaves from the bunch zone.
- Keep some water reserves set aside in case there is a heatwave to ensure you vines do not defoliate and can bounce back quickly from a prolonged period of stress.

During the growing season

- Vines are sensitive to moisture stress. RDI or sustained deficit irrigation (SDI) can be used to reduce vine vigour. Prolonged periods of vine stress can result in reduced vegetative vigour, shorter shoots, smaller leaves and reduced photosynthetic capacity.

Post harvest

- After harvest photosynthates will be stored as carbohydrates in the woody parts of the vine.
- Apply post harvest irrigation to ensure carbohydrate reserves are replenished (especially if the crop load has been high). Be careful not to encourage new shoot growth during this period.
- Prolonged or excessive water stress may lead to restricted or slow shoot growth the following spring, and contribute to reduced bud fruitfulness.

Deficit irrigation[1]

Deficit irrigation is a method that can be used to reduce the overall volume of water applied resulting in water and cost savings, and/or to manipulate berry size and fruit quality attributes in red wine grape varieties. There are several different types of deficit irrigation strategies available to wine growers which are discussed below.

Partial root zone drying (PRD)

Partial root zone drying traditionally involves the installation of two drip lines, one either side of the vine trunk, with offset dripper spacings. Vines are watered with each lateral avoiding water deficit, alternatively each time the vines are irrigated.

One side of the vine root zone is deprived of water every time irrigation is applied. As the root zone dries out, the levels of abscisic acid (ABA) synthesised in the vine roots increases in response to stress. This sends a message to the vine's leaves to partially or completely close the stomates, resulting in the reduction of evapotranspiration losses. However, because the vines still have access to adequate soil moisture, they maintain their leaf water potential and continue to grow and produce fruit, without any adverse side effects. The main benefit of utilising PRD is the reduction in the volume of water applied, as the vines are able to utilise the water available more efficiently.

Regulated deficit irrigation (RDI)

When RDI is applied, soil moisture is carefully controlled and restricted for a short period after fruit set to reduce berry size and improve fruit quality on red varieties. This is achieved by reducing the level of cell division and elongation in the developing berries. Normal irrigation recommences from veraison to ensure optimal ripening conditions are maintained in the lead up to harvest.

RDI applied to Shiraz can result in a reduction in berry size by 20 to 30%. Cabernet Sauvignon berries are naturally smaller than many red varieties and RDI may not be as desirable as the pulp to skin ratio can be low, resulting in the production of a higher ratio of skins and seeds to juice.

Deficit irrigation can also be used on red or white varieties to reduce the rate of shoot growth and limit unnecessary vegetative growth, which may otherwise have a greater water use requirement during the season.

Sustained deficit irrigation (SDI)

Sustained deficit irrigation involves the application of deficit irrigation, or some degree of water stress over the entire growing season. This may be done in response to water restrictions or the desire to reduce the vegetative vigour of vines i.e. 80% of the normal water volume is applied. It is important to carefully monitor soil moisture to ensure excessive vine stress does not result.

[1] Modified from Retallack, M. (2012) 'The role of hormones in grapevines' notes for Murray Valley Winegrowers' Inc, Mildura.

Appendix 1c

Typical varietal responses to moisture stress

Varietal responses to moisture stress

Different varieties will have different water use requirements. Similarly, if they are grown on their own roots or rootstock, this may also affect their capacity to use water efficiently.

- Grapevines that keep their stomates open for longer, during hot weather are called **anisohydric** and are said to have an 'optimistic' outlook. They tend continue to transpire hoping that conditions will improve.
- Varieties that close their stomates more readily during hot weather are called **isohydric** and are said to have a 'pessimistic' outlook. They tend to conserve water in case conditions do not improve.

These classifications are not absolute; the response of a particular variety may be relative to weather, site conditions and the irrigation strategy employed. Some general 'rules of thumb' are presented below.

Semillon

- Semillon (along with Chardonnay, Verdelho and Merlot) tends to exhibit anisohydric (optimistic), behaviour. Stomata tend to stay open for longer during hot weather resulting in higher transpiration rates during hot weather.

Chardonnay

- Chardonnay is also said to be anisohydric (optimistic) and tends to have tighter control over stomatal conductance than Shiraz. This enables Chardonnay to have similar levels of photosynthesis to Shiraz at lower levels of stomatal conductance and transpiration[1].

Shiraz

- During hot weather Shiraz continues transpiring and uses more stored soil water than, for example, Grenache, which stops transpiring and saves water (isohydric or pessimistic behaviour).
- Shiraz vines will readily show signs of water stress (tendrils drooping, leaves folding) compared to other varieties, and these visual signs (along with soil moisture monitoring equipment) are a useful way of managing moisture stress for this variety.
- Shiraz vines will normally respond quickly when irrigation is applied.

Cabernet Sauvignon

- Cabernet Sauvignon (along with Sangiovese, Riesling and Grenache) is said to be isohydric (pessimistic behaviour). These varieties tend to be more sensitive to water loss and have better stomatal control. Stomata tend to close more quickly during hot weather, preventing water loss.
- Cabernet Sauvignon does not respond as well to abrupt changes in soil moisture and detrimental impacts on fruit quality (berry shrivel) may occur before visual signs of stress occur in the canopy.

---

[1] Walker, R. and Boland, A-M. (2004) 'Improving water use efficiency in viticulture in the Murray Darling basin: Development and adoption of BMP for improved WUE and effectiveness for irrigated vines'. Final Report, PN 1011, GWRDC, Adelaide.

Appendix 2a

BoM weather data for Mildura Airport

wine growing for the future

BoM Weather Data for Murray Valley wine region – Mildura Airport

Table 1: Mildura Airport weather station – daily rainfall (mm) for season 2011/12

Mildura Airport weather station: daily rainfall (mm)												
Season	**2011**						**2012**					
Day	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**
1st	0.0	0.0	0.0	5.6	0.0	0.0	0.0	**27.2**	0.0	0.0	0.0	0.0
2nd	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0
3rd	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0
4th	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0	0.0
5th	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
6th	0.0	2.8	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7th	0.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8th	0.0	2.0	0.0	0.0	1.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0
9th	0.0	2.6	0.2	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10th	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11th	0.6	1.0	0.6	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
12th	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13th	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14th	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
15th	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16th	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	6.6	0.0	0.0	0.0
17th	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
18th	4.8	0.0	0.0	0.0	0.0	**58.0**	0.0	0.0	0.0	0.0	0.0	0.0
19th	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20th	0.0	0.2	0.0	0.0	5.2	0.0	0.0	0.8	0.0	0.0	0.0	0.0
21st	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22nd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	3.0
23rd	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.2
24th	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
25th	0.0	0.0	0.0	13.2	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26th	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0
27th	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
28th	0.0	0.0	0.0	0.0	0.0	0.0	1.4	**33.4**	0.0	0.0	0.0	0.0
29th	0.0	0.0	5.6	3.8	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0
30th	0.2	0.0	0.8	0.0	0.0	0.0	1.0		14.0	0.0	0.0	0.0
31st	1.0	0.0		0.0		0.0	0.0		0.0		0.0	
Monthly total (mm)	**15 mm**	**21 mm**	**7 mm**	**28 mm**	**43 mm**	**62 mm**	**13 mm**	**64 mm**	**37 mm**	**4 mm**	**2 mm**	**8 mm**
Season total (mm)	**304 mm**											

NB: Daily rainfall above 25mm is highlighted in blue

Table 2: Mildura Airport weather station – mean monthly rainfall (mm)

Mildura Airport weather station: mean monthly rainfall (mm)											
Month	**Season 2002/03**	**Season 2003/04**	**Season 2004/05**	**Season 2005/06**	**Season 2006/07**	**Season 2007/08**	**Season 2008/09**	**Season 2009/10**	**Season 2010/11**	**Season 2011/12**	**Long Term Mean**
July	5.6	14.2	22.0	39.8	30.8	22.8	19.6	11.8	25.6	15	26
August	13.8	55.2	25.0	21.2	6.0	2.2	34.2	8.2	28.8	21	26
September	7.0	6.8	9.8	39.0	9.8	3.2	2.0	30.4	54.8	7	27
October	5.0	33.6	3.8	63.0	0.0	8.4	3.0	10.8	88.8	28	30
November	19.8	17.0	42.0	27.2	7.0	29.2	42.6	65.6	103.6	43	27
December	66.0	89.4	28.4	15.0	3.6	19.2	34.8	13.2	141.0	62	26
January	0.2	3.0	23.8	4.6	56.4	19.4	0.8	8.4	129.4	13	22
February	36.8	0.8	3.2	1.2	3.2	0.0	0.0	19.8	192.6	37	23
March	0.0	0.6	3.6	24.6	15.8	11.4	24.0	35.8	122.0	64	21
April	0.6	0.0	3.4	17.8	35.4	4.8	21.8	18.8	12.6	4	18
May	28.0	7.0	3.0	6.4	25.0	15.8	9.4	51.2	14.2	2	25
June	22.0	30.8	35.6	11.4	2.0	14.4	37.0	14.6	10.6	8	22
Total	**205 mm**	**258 mm**	**204 mm**	**271 mm**	**195 mm**	**151 mm**	**229 mm**	**289 mm**	**924 mm**	**304 mm**	**292 mm**
Difference versus long term mean	***-88 mm***	***-34 mm***	***-89 mm***	***-21 mm***	***-97 mm***	***-142 mm***	***-63 mm***	***-4 mm***	***632 mm***	***11 mm***	

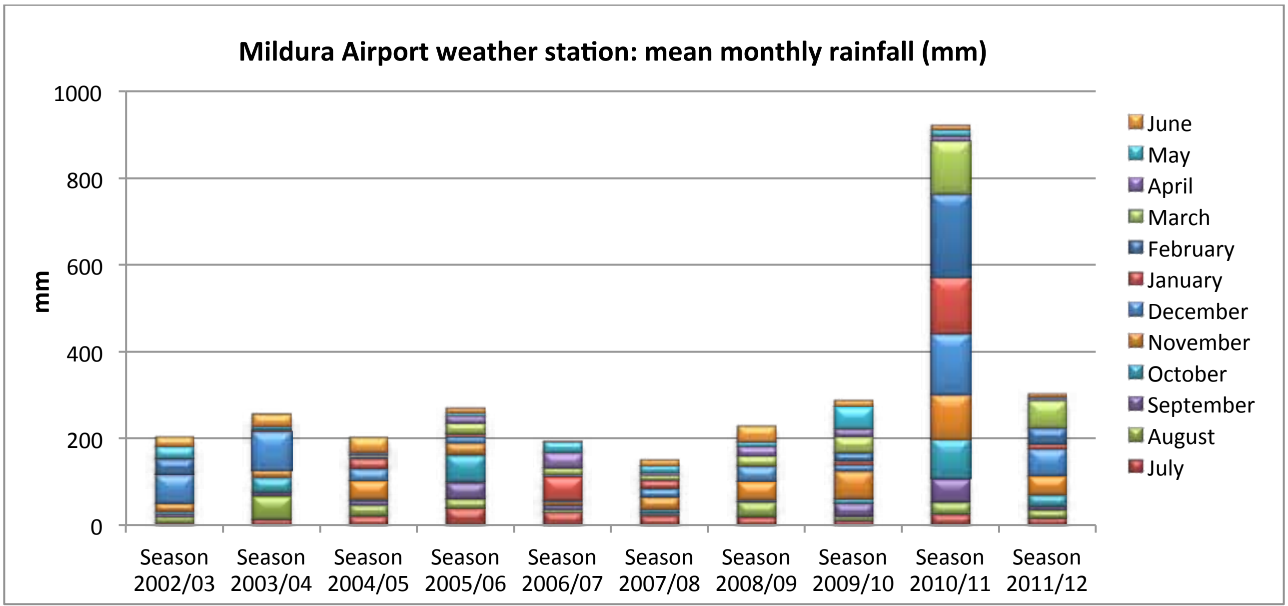

Figure 1 : Mildura Airport weather station – mean monthly rainfall (mm)

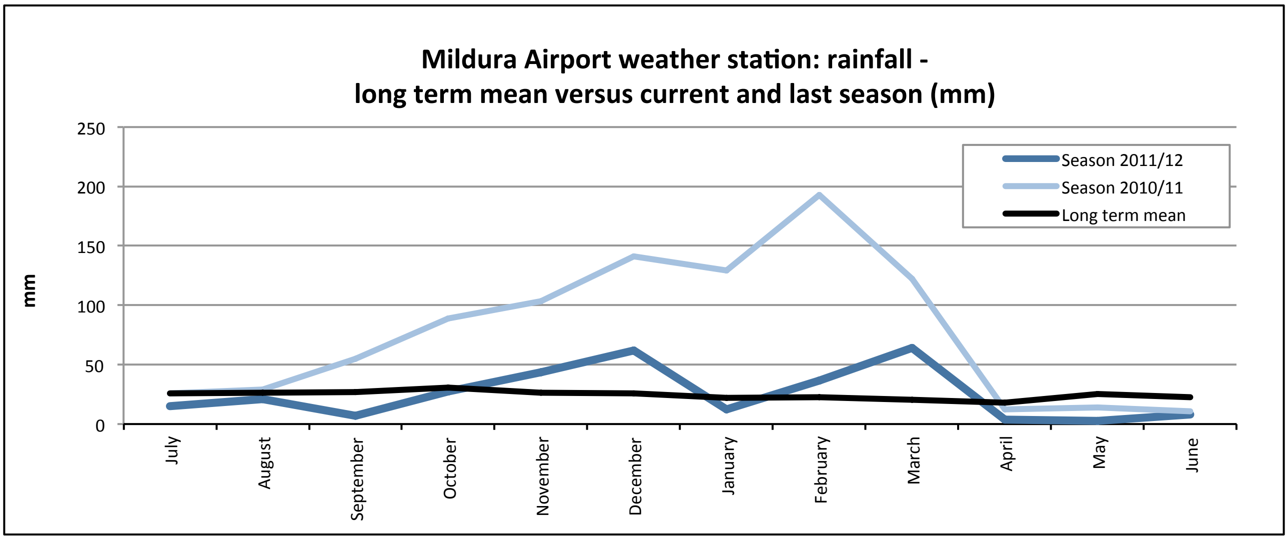

Figure 2 : Mildura Airport weather station – long term mean rainfall versus current and last season (mm)

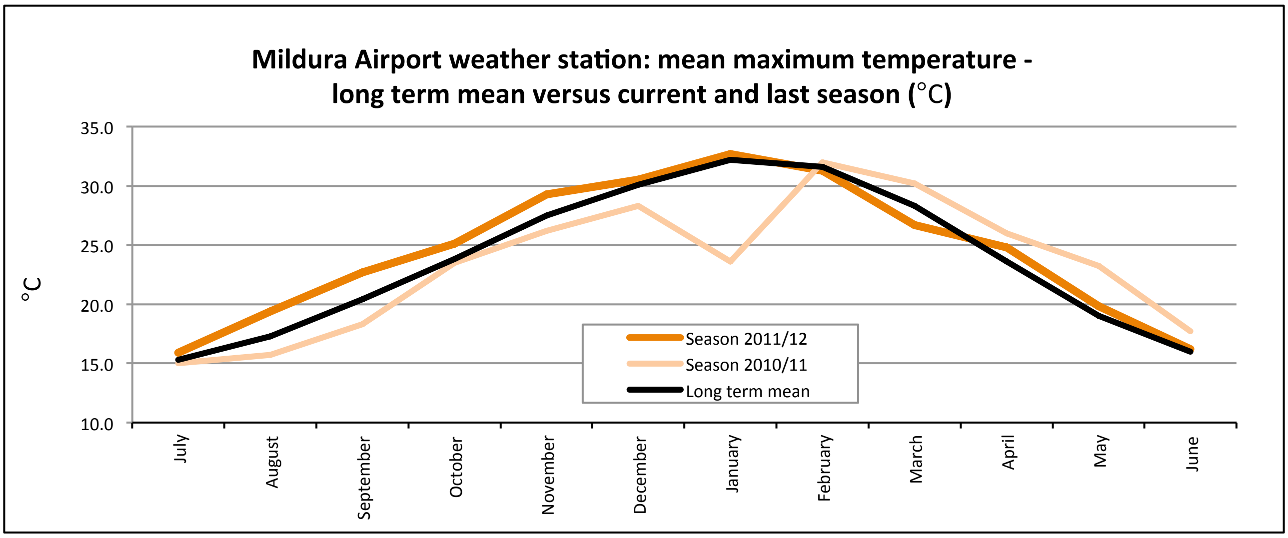

Figure 3 : Mildura Airport weather station – long term mean max temperature versus current and last season (°C)

Appendix 2b

BoM weather data for Griffith Airport

wine growing for the future

BoM Weather Data for Murray Valley wine region – Griffith Airport

Table 1: Griffith Airport weather station – daily rainfall (mm) for season 2011/12

Griffith Airport weather station: daily rainfall (mm)												
Season	**2011**						**2012**					
Day	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**
1st	0	0	0	2.4	0	1.8	0.0	0.0	**26.8**	0.0	0.0	0.0
2nd	0	0	0	1.4	0	0	0.0	0.0	8.4	1.0	7.8	0.0
3rd	0	0	0	0	0	0	0.0	0.0	13.4	0.0	0.0	0.0
4th	7		0	0	0	0	0.0	0.0	**133.2**	0.0	0.0	0.0
5th	0	0.4	0.4	0	0	0	0.0	0.0	0.2	0.0	0.0	4.4
6th	0.2	8.6	0	7.4	0	0	0.0	0.0	0.0	0.0	0.0	0.0
7th	0	0	2.6	0.4	6.6	0	0.0	0.0	0.0	0.0	0.0	0.0
8th	0	3.2	0.2	0	0	0	0.6	0.0	0.0	0.0	0.0	0.0
9th	0	2.6	0	0	1.6	0	0.8	0.0	0.0	0.0	0.0	0.0
10th	0	0	2	0	**25.6**	1.6	0.0	0.0	0.0	0.0	0.0	0.2
11th	0.6	0.2	0	0	0.2	7	0.0	0.0	0.0	0.0	0.2	0.0
12th	0	0.2	0	0	0	0	0.0	0.0	0.0	0.0	0.2	0.0
13th	0	0	0.2	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
14th	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
15th	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
16th	0	0	0	0	0	0	0.0	0.0	6.8	0.0	0.0	5.8
17th	0.6	2.4	0	0	0	0.2	0.0	0.2	23.6	0.0	0.0	0.6
18th	6.8	22	0	0	0	0	0.0	0.0	0.2	0.0	0.0	0.0
19th	13.2	12.8	0	0	0	5.4	2.0	0.0	0.0	7.8	0.0	0.0
20th	0	0	0	0	3.2	0	0.0	1.0	0.0	19.4	0.0	0.0
21st	0	0.2	0	0	0.6	0	0.0	9.8	0.0	0.2	0.0	0.2
22nd	0	0	0	0	0	0	0.0	0.2	0.0	2.0	0.0	1.0
23rd	0	0	0	0	0	0	0.0	11.0	0.0	0.0	0.0	0.0
24th	0	0	0	0	0	0	0.0	0.0	0.0	1.4	0.0	0.0
25th	1	0	0	4	3.6	0	0.0	0.0	0.0	2.8	3.6	0.0
26th	0.2	0	0	0	0.6	7.8	8.2	0.4	0.0	0.0	2.4	0.0
27th	0	0	0	0	1.2	0	0.0		0.0	0.0	1.0	0.0
28th	0	0	0.2	0	0.2	0	0.0	2.6	0.0	0.0	0.2	0.0
29th	0	0	11	0.4	0	0	1.2	**30.2**	0.0	0.0	0.0	0.0
30th	0	0	1.2	0	0	0	**30.4**		0.0	0.0	0.0	0.0
31st	0.2	0		0		0	4.0		0.0		0.0	
Monthly total (mm)	**30 mm**	**53 mm**	**18 mm**	**16 mm**	**43 mm**	**24 mm**	**47 mm**	**55 mm**	**213 mm**	**35 mm**	**15 mm**	**12 mm**
Season total (mm)	**561 mm**											

NB: Daily rainfall above 25mm is highlighted in blue

Table 2: Griffith Airport weather station – mean monthly rainfall (mm)

Griffith Airport weather station: mean monthly rainfall (mm)											
Month	**Season 2002/03**	**Season 2003/04**	**Season 2004/05**	**Season 2005/06**	**Season 2006/07**	**Season 2007/08**	**Season 2008/09**	**Season 2009/10**	**Season 2010/11**	**Season 2011/12**	**Long Term Mean**
July	8.8	39.4	19.2	39.6	41.6	28.8	28.8	23.4	40.2	29.8	33.4
August	3.8	66.1	31.6	44.6	2.2	4.8	14.6	13.2	47.0	52.6	36.2
September	21.4	12.6	7.8	40.2	12.2	2.2	23.0	19.4	54.4	17.8	32.9
October	0.0	43.2	11.0	94.4	0.0	10.0	19.6	19.0	102.6	16.0	40.0
November	4.4	15.0	40.4	45.4	17.2	97.4	49.8	27.8	74.6	43.4	33.5
December	4.0	51.0	26.4	28.0	0.6	76.4	41.4	77.6	68.0	23.8	33.3
January	12.2	17.0	3.6	15.8	13.2	35.6	2.8	8.6	43.6	47.2	33.7
February	47.0	5.4	34.2	3.0	2.4	12.4	19.2	41.8	134.4	55.4	29.3
March	0.2	1.2	4.6	10.6	14.4	8.4	6.8	64.0	40.6	212.6	36.8
April	11.2	17.0	9.2	10.8	12.0	2.2	21.4	20.8	25.0	34.6	27.9
May	13.2	24.4	2.0	1.2	37.4	6.6	4.0	62.6	36.2	15.4	35.3
June	15.0	24.8	61.4	33.6	13.2	40.0	74.8	20.8	16.6	12.2	33.3
Total	**141 mm**	**317 mm**	**251 mm**	**367 mm**	**166 mm**	**325 mm**	**306 mm**	**399 mm**	**683 mm**	**561 mm**	**405.6 mm**
Monthly rainfall versus long term mean	***-264 mm***	***-89 mm***	***-154 mm***	***-38 mm***	***-239 mm***	***-81 mm***	***-99 mm***	***-7 mm***	***278 mm***	***155 mm***	

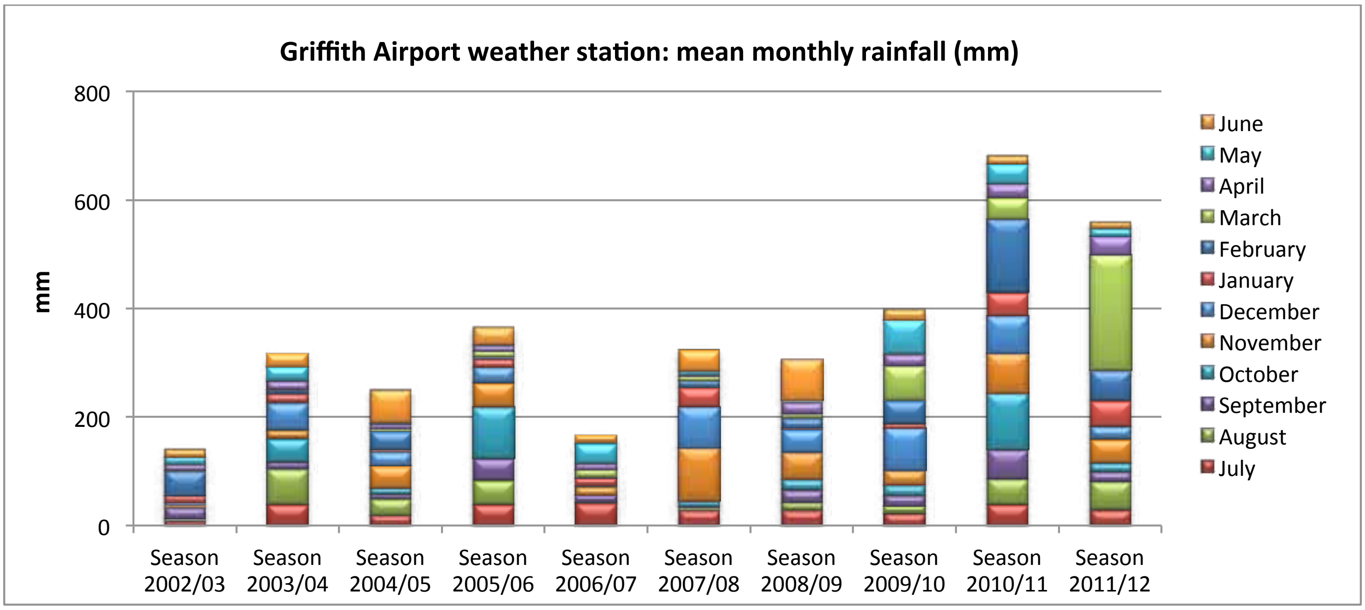

Figure 1 : Griffith Airport weather station – mean monthly rainfall (mm)

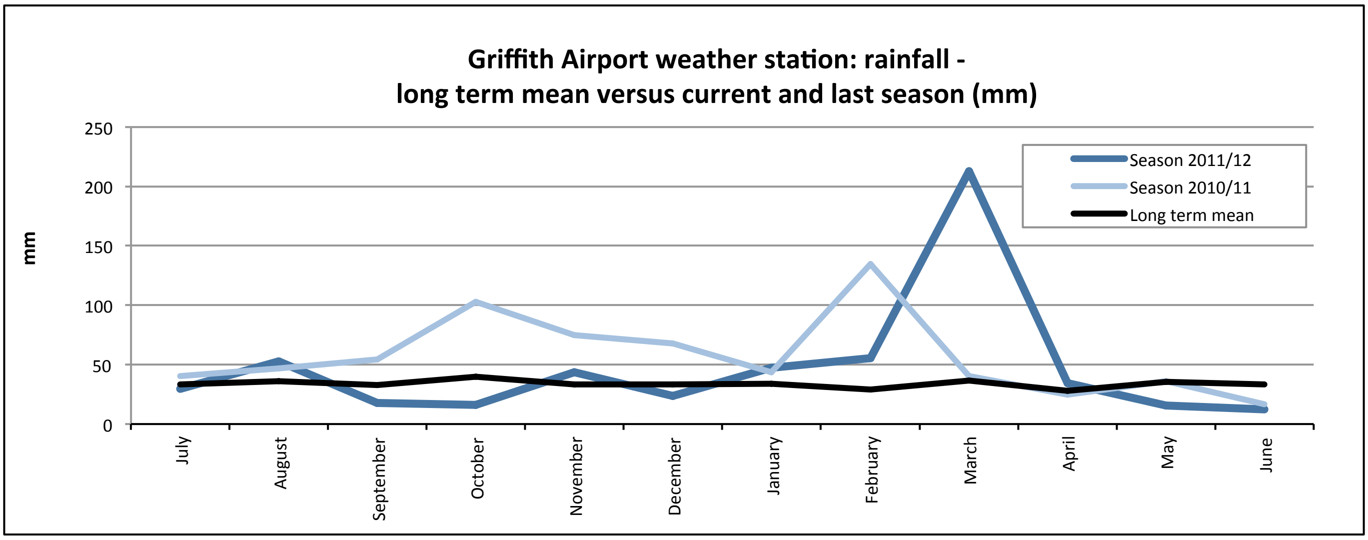

Figure 2 : Griffith Airport weather station – long term mean rainfall versus current and last season (mm)

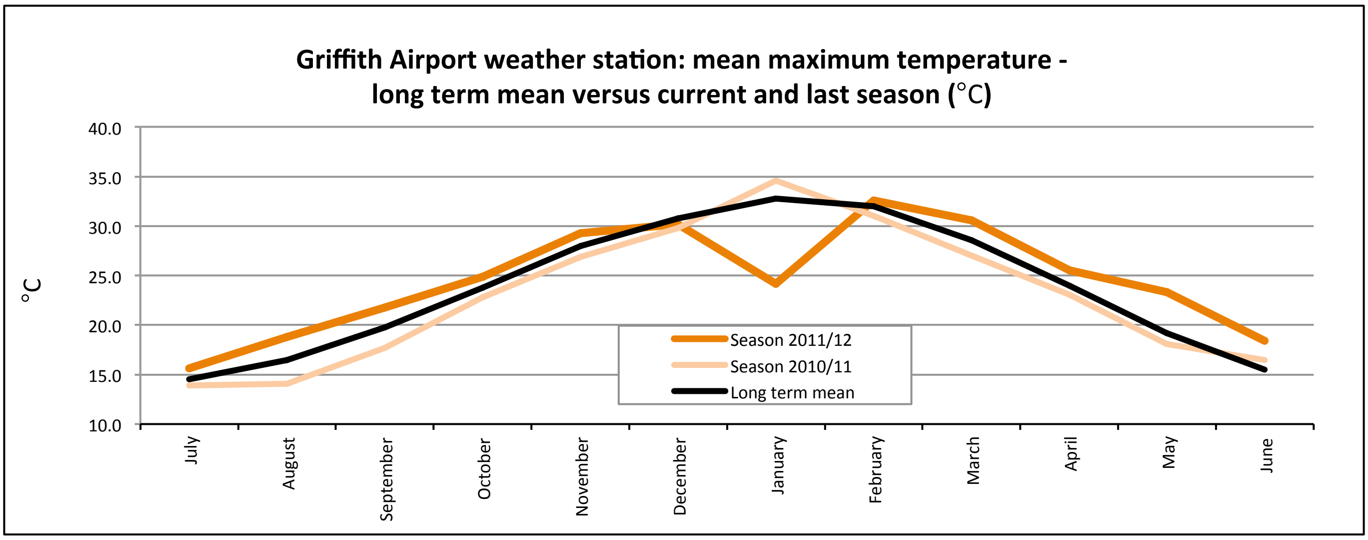

Figure 3 : Griffith Airport weather station – long term mean max temperature versus current and last season (°C)

Appendix 3a

Murray valley irrigation data for season 2011/12

wine growing for the future

Table 1: Murray Valley wine region irrigation data set for season 2011/12

WUE Project Grower ID	Rootstock	Variety	t/ha	Irrigation	WUE for key phenological periods				ML/ha	WUE L/Kg	WUE t/ML	Soil Type	Bunch weight (g)	Berry weight (g)
				Drip or Low level sprinklers	Budburst EL 4 - flowering EL 26	Fruitset EL 27 - Verasion EL 35	100% veraison EL 36 - Harvest EL 38	Post Harvest EL 41 - end of leaf fall EL 47						
Vineyard MV1	Own roots	Chardonnay	21.5 t/ha	Drip	0.6 ML/ha	0.5 ML/ha	0.9 ML/ha	1.0 ML/ha	3.0 ML/ha	140 L/Kg	7.2 t/ML		127 g	1.50 g
Vineyard MV2	Ruggeri	Chardonnay	28.9 t/ha	Drip	0.8 ML/ha	1.4 ML/ha	2.1 ML/ha	1.4 ML/ha	5.7 ML/ha	198 L/Kg	5.1 t/ML	Sandy Loam	126 g	1.46 g
Vineyard MV3	Own roots	Chardonnay	11.3 t/ha	Drip	0.4 ML/ha	2.4 ML/ha	0.7 ML/ha	0.2 ML/ha	3.8 ML/ha	334 L/Kg	3.0 t/ML		116 g	0.98 g
Vineyard MV4	Ramsey	Chardonnay	27.0 t/ha	Drip	0.5 ML/ha	2.5 ML/ha	1.3 ML/ha	0.7 ML/ha	5.0 ML/ha	184 L/Kg	5.4 t/ML	Sandy Loam	157 g	1.28 g
Vineyard MV5	Ramsey	Chardonnay	39.3 t/ha	Drip	0.1 ML/ha	1.6 ML/ha	1.3 ML/ha	0.1 ML/ha	3.0 ML/ha	78 L/Kg	12.9 t/ML	Sandy Loam	182 g	1.30 g
Vineyard MV6	Ramsey	Chardonnay	22.3 t/ha	Drip	0.2 ML/ha	1.7 ML/ha	1.3 ML/ha	0.1 ML/ha	3.4 ML/ha	152 L/Kg	6.6 t/ML	Sandy Loam	147 g	1.46 g
Vineyard MV7	Ramsey	Chardonnay	22.2 t/ha	Drip	0.4 ML/ha	0.9 ML/ha	2.5 ML/ha	1.0 ML/ha	4.7 ML/ha	213 L/Kg	4.7 t/ML	Sandy Clay Loam	155 g	1.28 g
Vineyard MV8	Paulsen 1103	Chardonnay	31.0 t/ha	Drip	0.3 ML/ha	1.5 ML/ha	2.2 ML/ha	0.0 ML/ha	4.0 ML/ha	128 L/Kg	7.8 t/ML	Loamy Clay	159 g	1.12 g
Vineyard MV9	Schwarzmann	Chardonnay	10.0 t/ha	Drip	0.8 ML/ha	1.2 ML/ha	1.0 ML/ha	1.3 ML/ha	4.2 ML/ha	426 L/Kg	2.3 t/ML	Heavy Clay	132 g	1.55 g
Vineyard MV10	Paulsen 1103	Chardonnay	32.2 t/ha	Drip	0.4 ML/ha	2.4 ML/ha	1.1 ML/ha	1.1 ML/ha	5.1 ML/ha	157 L/Kg	6.4 t/ML	Sandy Loam	144 g	1.45 g
Vineyard MV11	Ramsey	Chardonnay	34.0 t/ha	Drip	0.9 ML/ha	1.6 ML/ha	0.6 ML/ha	0.5 ML/ha	3.6 ML/ha	106 L/Kg	9.5 t/ML	Sandy Clay Loam	171 g	1.36 g
Vineyard MV12		Chardonnay	22.8 t/ha	Drip	0.4 ML/ha	1.4 ML/ha	1.1 ML/ha	1.3 ML/ha	4.2 ML/ha	186 L/Kg	5.4 t/ML		153 g	1.53 g
Vineyard MV13	Ramsey	Chardonnay	26.3 t/ha	Drip	1.0 ML/ha	1.8 ML/ha	0.9 ML/ha	2.1 ML/ha	5.9 ML/ha	223 L/Kg	4.5 t/ML	Sandy Loam	137 g	1.71 g
Vineyard MV14	Ramsey	Chardonnay	24.1 t/ha	Drip	0.8 ML/ha	1.1 ML/ha	1.4 ML/ha	1.3 ML/ha	4.7 ML/ha	195 L/Kg	5.1 t/ML	Sandy Loam	178 g	1.51 g
Vineyard MV15	Schwarzmann	Chardonnay	30.9 t/ha	Low level sprinklers	2.0 ML/ha	1.9 ML/ha	1.4 ML/ha	1.4 ML/ha	6.8 ML/ha	218 L/Kg	4.6 t/ML	Sandy Clay Loam	163 g	1.45 g
Vineyard MV16	Paulsen 1103	Chardonnay	28.9 t/ha	Low level sprinklers	3.6 ML/ha	2.1 ML/ha	2.1 ML/ha	1.1 ML/ha	8.9 ML/ha	308 L/Kg	3.2 t/ML	Sandy Loam	111 g	1.13 g
Vineyard MV17	Ruggeri 140	Chardonnay	22.0 t/ha	Low level sprinklers	0.9 ML/ha	2.0 ML/ha	1.0 ML/ha	1.6 ML/ha	5.4 ML/ha	247 L/Kg	4.1 t/ML	Sandy Loam	163 g	1.64 g
Vineyard MV18	Ramsey	Chardonnay	29.2 t/ha	Low level sprinklers	1.4 ML/ha	2.0 ML/ha	2.5 ML/ha	1.6 ML/ha	7.4 ML/ha	253 L/Kg	3.9 t/ML	Sandy Loam	148 g	1.48 g
Vineyard MV19	Own roots	Chardonnay	17.4 t/ha	Low level sprinklers	2.2 ML/ha	2.5 ML/ha	0.9 ML/ha	0.0 ML/ha	5.6 ML/ha	321 L/Kg	3.1 t/ML	Sandy Clay Loam	119 g	1.40 g
Vineyard MV20	Kober 5BB	Chardonnay	29.8 t/ha	Low level sprinklers	1.2 ML/ha	1.5 ML/ha	0.6 ML/ha	1.4 ML/ha	4.7 ML/ha	159 L/Kg	6.3 t/ML	Sandy Loam	143 g	1.47 g
Vineyard MV21	Ramsey	Chardonnay	22.4 t/ha	Low level sprinklers	0.0 ML/ha	1.6 ML/ha	2.8 ML/ha	0.6 ML/ha	5.0 ML/ha	221 L/Kg	4.5 t/ML	Sandy Clay Loam	146 g	1.42 g
Vineyard MV22	Ruggeri	Chardonnay	23.6 t/ha	Low level sprinklers	1.2 ML/ha	1.4 ML/ha	1.5 ML/ha	1.6 ML/ha	5.7 ML/ha	241 L/Kg	4.2 t/ML	Clay Loam	137 g	1.31 g

Table 1: Murray Valley wine region irrigation data set for season 2011/12 - continued

WUE Project Grower ID	Rootstock	Variety	t/ha	Irrigation	WUE for key phenological periods				ML/ha	WUE L/Kg	WUE t/ML	Soil Type	Bunch weight (g)	Berry weight (g)
				Drip or Low level sprinklers	Budburst EL 4 - flowering EL 26	Fruitset EL 27 - Verasion EL 35	100% veraison EL 36 - Harvest EL 38	Post Harvest EL 41 - end of leaf fall EL 47						
Vineyard MV23	Paulsen 1103	Chardonnay	34.1 t/ha	Low level sprinklers	1.6 ML/ha	2.7 ML/ha	2.0 ML/ha	1.8 ML/ha	8.2 ML/ha	240 L/Kg	4.2 t/ML	Sandy Loam	166 g	1.71 g
Vineyard MV24	Own roots	Shiraz	27.3 t/ha	Drip	0.9 ML/ha	2.6 ML/ha	0.7 ML/ha	0.8 ML/ha	5.0 ML/ha	184 L/Kg	5.4 t/ML	Sandy Clay Loam	115 g	1.30 g
Vineyard MV25	Own roots	Shiraz	20.4 t/ha	Drip	0.2 ML/ha	1.8 ML/ha	0.0 ML/ha	0.4 ML/ha	2.4 ML/ha	119 L/Kg	8.4 t/ML	Sandy Loam	134 g	1.66 g
Vineyard MV26	Schwarzmann	Shiraz	24.0 t/ha	Drip	0.4 ML/ha	2.0 ML/ha	1.8 ML/ha	0.5 ML/ha	4.7 ML/ha	195 L/Kg	5.1 t/ML	Heavy Clay	181 g	1.56 g
Vineyard MV27	Schwarzmann	Shiraz	17.6 t/ha	Drip	0.5 ML/ha	1.3 ML/ha	2.4 ML/ha	0.5 ML/ha	4.8 ML/ha	271 L/Kg	3.7 t/ML	Sandy Loam	259 g	1.34 g
Vineyard MV28	Own roots	Shiraz	23.0 t/ha	Drip	0.1 ML/ha	1.5 ML/ha	1.7 ML/ha	0.0 ML/ha	3.3 ML/ha	142 L/Kg	7.0 t/ML	Clay Loam	162 g	2.16 g
Vineyard MV29	Schwarzmann	Shiraz	15.5 t/ha	Drip	0.7 ML/ha	1.2 ML/ha	1.7 ML/ha	0.6 ML/ha	4.2 ML/ha	271 L/Kg	3.7 t/ML	Sandy Loam	153 g	1.72 g
Vineyard MV30	Own roots	Shiraz	5.3 t/ha	Drip	1.6 ML/ha	1.9 ML/ha	0.3 ML/ha	0.1 ML/ha	3.9 ML/ha	741 L/Kg	1.3 t/ML	Sandy Clay Loam		1.44 g
Vineyard MV31	Own roots	Shiraz	16.8 t/ha	Drip	0.8 ML/ha	1.1 ML/ha	1.5 ML/ha	0.2 ML/ha	3.6 ML/ha	212 L/Kg	4.7 t/ML	Clay	135 g	1.65 g
Vineyard MV32	Schwarzmann	Shiraz	7.9 t/ha	Drip	1.0 ML/ha	1.2 ML/ha	0.7 ML/ha	1.3 ML/ha	4.2 ML/ha	535 L/Kg	1.9 t/ML	Sandy Loam	152 g	1.97 g
Vineyard MV33	Richter 99	Shiraz	17.1 t/ha	Drip	1.0 ML/ha	1.6 ML/ha	0.9 ML/ha	0.6 ML/ha	4.1 ML/ha	238 L/Kg	4.2 t/ML	Sandy Loam	200 g	2.40 g
Vineyard MV34		Shiraz	18.0 t/ha	Drip	1.1 ML/ha	1.4 ML/ha	1.0 ML/ha	1.3 ML/ha	4.7 ML/ha	263 L/Kg	3.8 t/ML	Sandy Clay Loam	163 g	1.64 g
Vineyard MV35	Ramsey	Shiraz	18.7 t/ha	Drip	1.0 ML/ha	2.5 ML/ha	1.8 ML/ha	0.5 ML/ha	5.8 ML/ha	312 L/Kg	3.2 t/ML	Sandy Loam	169 g	1.17 g
Vineyard MV36	101-14	Shiraz	21.0 t/ha	Drip	0.6 ML/ha	1.0 ML/ha	0.2 ML/ha	0.6 ML/ha	2.3 ML/ha	111 L/Kg	9.0 t/ML		140 g	1.62 g
Vineyard MV37	Paulsen 1103	Shiraz	16.6 t/ha	Low level sprinklers	0.5 ML/ha	3.0 ML/ha	2.8 ML/ha	0.0 ML/ha	6.2 ML/ha	370 L/Kg	2.7 t/ML		143 g	1.57 g
Vineyard MV38	Own roots	Shiraz	24.2 t/ha	Low level sprinklers	1.3 ML/ha	1.4 ML/ha	1.9 ML/ha	0.6 ML/ha	5.1 ML/ha	212 L/Kg	4.7 t/ML	Clay Loam		
Vineyard MV39	Own roots	Shiraz	6.6 t/ha	Low level sprinklers	1.2 ML/ha	1.0 ML/ha	1.1 ML/ha	0.9 ML/ha	4.2 ML/ha	639 L/Kg	1.6 t/ML	Sandy Loam	125 g	1.58 g
Vineyard MV40	Kober 5BB	Shiraz	30.0 t/ha	Low level sprinklers	1.4 ML/ha	2.1 ML/ha	0.7 ML/ha	0.7 ML/ha	5.0 ML/ha	165 L/Kg	6.0 t/ML	Sandy Loam	212 g	1.62 g
Vineyard MV41	Own roots	Shiraz	17.4 t/ha	Low level sprinklers	2.7 ML/ha	2.4 ML/ha	2.0 ML/ha	0.0 ML/ha	7.1 ML/ha	409 L/Kg	2.4 t/ML	Loam		
Vineyard MV42	Own roots	Shiraz	17.2 t/ha	Low level sprinklers	1.2 ML/ha	2.2 ML/ha	2.2 ML/ha	0.7 ML/ha	6.3 ML/ha	364 L/Kg	2.7 t/ML	Clay Loam	136 g	1.53 g

Table 1: Murray Valley wine region irrigation data set for season 2011/12 - continued

WUE Project Grower ID	Rootstock	Variety	t/ha	Irrigation	WUE for key phenological periods				ML/ha	WUE L/Kg	WUE t/ML	Soil Type	Bunch weight (g)	Berry weight (g)
				Drip or Low level sprinklers	Budburst EL 4 - flowering EL 26	Fruitset EL 27 - Verasion EL 35	100% veraison EL 36 - Harvest EL 38	Post Harvest EL 41 - end of leaf fall EL 47						
Vineyard MV43	Ramsey	Shiraz	31.5 t/ha	Low level sprinklers	2.4 ML/ha	1.6 ML/ha	3.0 ML/ha	1.4 ML/ha	8.5 ML/ha	269 L/Kg	3.7 t/ML	Sandy Loam	136 g	1.07 g
Vineyard MV44	Own roots	Shiraz	33.7 t/ha	Low level sprinklers	4.5 ML/ha	9.5 ML/ha	0.0 ML/ha	0.7 ML/ha	14.7 ML/ha	436 L/Kg	2.3 t/ML	Sandy Loam	204 g	2.04 g
Vineyard MV45	Own roots	Shiraz	27.3 t/ha	Low level sprinklers	1.5 ML/ha	2.2 ML/ha	1.4 ML/ha	1.9 ML/ha	7.0 ML/ha	257 L/Kg	3.9 t/ML		170 g	1.80 g
Vineyard MV46	Ramsey	Semillon	45.7 t/ha	Drip	1.0 ML/ha	1.6 ML/ha	2.4 ML/ha	1.2 ML/ha	6.2 ML/ha	135 L/Kg	7.4 t/ML	Sandy Loam	222 g	2.13 g
Vineyard MV47	Ramsey	Semillon	15.0 t/ha	Drip	0.3 ML/ha	0.3 ML/ha	2.2 ML/ha	0.6 ML/ha	3.5 ML/ha	232 L/Kg	4.3 t/ML	Sandy Loam	202 g	2.10 g
Vineyard MV48	Ramsey	Semillon	14.4 t/ha	Drip	1.1 ML/ha	1.1 ML/ha	2.1 ML/ha	0.6 ML/ha	4.9 ML/ha	340 L/Kg	2.9 t/ML	Sandy Loam	191 g	2.15 g
Vineyard MV49	Kober	Semillon	37.0 t/ha	Drip	1.0 ML/ha	1.8 ML/ha	0.8 ML/ha	0.6 ML/ha	4.1 ML/ha	110 L/Kg	9.1 t/ML	Sandy Loam	258 g	2.55 g
Vineyard MV50	Schwarzmann	Cabernet Sauvignon	23.5 t/ha	Drip	1.1 ML/ha	1.2 ML/ha	1.9 ML/ha	2.2 ML/ha	6.4 ML/ha	273 L/Kg	3.7 t/ML		138 g	1.23 g
Vineyard MV51	Ramsey	Cabernet Sauvignon	16.5 t/ha	Drip	0.4 ML/ha	1.6 ML/ha	1.8 ML/ha	1.0 ML/ha	4.8 ML/ha	288 L/Kg	3.5 t/ML		130 g	1.34 g
Vineyard MV52	Own roots	Cabernet Sauvignon	15.0 t/ha	Drip	0.7 ML/ha	1.1 ML/ha	1.2 ML/ha	0.1 ML/ha	3.0 ML/ha	203 L/Kg	4.9 t/ML	Sandy Clay Loam	123 g	1.35 g
Vineyard MV53	Own roots	Cabernet Sauvignon	19.8 t/ha	Drip	0.7 ML/ha	3.0 ML/ha	0.7 ML/ha	0.2 ML/ha	4.6 ML/ha	231 L/Kg	4.3 t/ML	Loam	104 g	0.96 g
Vineyard MV54	Schwarzmann	Cabernet Sauvignon	16.9 t/ha	Drip	1.0 ML/ha	1.2 ML/ha	1.3 ML/ha	0.7 ML/ha	4.2 ML/ha	251 L/Kg	4.0 t/ML	Sandy Loam	147 g	1.31 g
Vineyard MV55	Own roots	Cabernet Sauvignon	17.6 t/ha	Drip	0.7 ML/ha	1.1 ML/ha	0.8 ML/ha	2.4 ML/ha	5.1 ML/ha	291 L/Kg	3.4 t/ML	Sandy Loam	118 g	1.30 g
Vineyard MV56	Own roots	Cabernet Sauvignon	13.3 t/ha	Drip	1.0 ML/ha	2.2 ML/ha	1.9 ML/ha	0.7 ML/ha	5.8 ML/ha	437 L/Kg	2.3 t/ML	Sandy Clay Loam	127 g	1.64 g
Vineyard MV57	Ramsey	Cabernet Sauvignon	24.0 t/ha	Drip	0.7 ML/ha	1.0 ML/ha	0.1 ML/ha	0.1 ML/ha	1.9 ML/ha	79 L/Kg	12.6 t/ML		152 g	1.55 g
Vineyard MV58	Schwarzmann	Cabernet Sauvignon	18.0 t/ha	Drip	0.7 ML/ha	1.5 ML/ha	1.7 ML/ha	0.6 ML/ha	4.5 ML/ha	250 L/Kg	4.0 t/ML		131 g	1.07 g
Vineyard MV59	Own roots	Cabernet Sauvignon	14.9 t/ha	Low level sprinklers	2.5 ML/ha	2.5 ML/ha	2.5 ML/ha	0.0 ML/ha	7.6 ML/ha	507 L/Kg	2.0 t/ML	Sandy Clay Loam	110 g	1.20 g
Vineyard MV60	Schwarzmann	Cabernet Sauvignon	21.3 t/ha	Low level sprinklers	1.0 ML/ha	1.2 ML/ha	2.3 ML/ha	0.7 ML/ha	5.2 ML/ha	244 L/Kg	4.1 t/ML	Clay	158 g	1.10 g
Vineyard MV61	K51-40	Cabernet Sauvignon	22.8 t/ha	Low level sprinklers	1.1 ML/ha	2.7 ML/ha	1.4 ML/ha	0.7 ML/ha	5.8 ML/ha	252 L/Kg	4.0 t/ML	Sandy Clay Loam	152 g	1.26 g
Vineyard MV62	Own roots	Cabernet Sauvignon	12.9 t/ha	Low level sprinklers	0.9 ML/ha	4.2 ML/ha	0.3 ML/ha	0.0 ML/ha	5.3 ML/ha	411 L/Kg	2.4 t/ML	Sandy Loam	108 g	0.94 g
		Average	**22.2 t/ha**		**1.0 ML/ha**	**1.9 ML/ha**	**1.4 ML/ha**	**0.8 ML/ha**	**5.1 ML/ha**	**261 L/Kg**	**4.7 t/ML**	Clay Loam	**153 g**	**1.51 g**

Appendix 3b

Riverina irrigation data for season 2011/12

wine growing for the future

Table 1: Riverina wine region irrigation data set for season 2011/12

WUE Project Grower ID	Rootstock	Variety	t/ha	Irrigation	WUE for key phenological periods (ML/ha)				Average ML/ha	WUE L/Kg	WUE t/ML
				Drip or Furrow	Bud burst (EL 4) - Flowering (EL 26)	Fruit set (EL 27) - Verasion (EL 35)	100% veraison (EL 36) - Harvest (EL 38)	Post Harvest (EL 41) - End of leaf fall (EL 47)			
Vineyard R1	Ramsey	Chardonnay	15.2 t/ha	Drip	0.5 ML/ha	0.9 ML/ha	1.0 ML/ha	0.4 ML/ha	2.8 ML/ha	186 L/Kg	5.4 t/ML
Vineyard R2	Own Roots	Chardonnay	14.2 t/ha	Drip	0.3 ML/ha	1.5 ML/ha	0.1 ML/ha	0.2 ML/ha	2.1 ML/ha	150 L/Kg	6.6 t/ML
Vineyard R3	Ramsey	Chardonnay	10.5 t/ha	Drip	0.4 ML/ha	0.6 ML/ha	0.5 ML/ha	0.4 ML/ha	1.9 ML/ha	184 L/Kg	5.4 t/ML
Vineyard R4	Ramsey	Chardonnay	11.3 t/ha	Drip	1.0 ML/ha	1.0 ML/ha	0.8 ML/ha	0.0 ML/ha	2.8 ML/ha	249 L/Kg	4.0 t/ML
Vineyard R5	Ramsey	Chardonnay	17.8 t/ha	Drip	0.5 ML/ha	1.2 ML/ha	0.6 ML/ha	0.4 ML/ha	2.7 ML/ha	151 L/Kg	6.6 t/ML
Vineyard R6	Ramsey	Chardonnay	21.0 t/ha	Drip	1.0 ML/ha	2.3 ML/ha	0.8 ML/ha	0.2 ML/ha	4.3 ML/ha	203 L/Kg	4.9 t/ML
Vineyard R7	Ramsey	Chardonnay	21.0 t/ha	Drip	0.6 ML/ha	1.2 ML/ha	0.4 ML/ha	0.1 ML/ha	2.3 ML/ha	109 L/Kg	9.2 t/ML
Vineyard R8	Ramsey	Chardonnay	14.2 t/ha	Furrow	1.7 ML/ha	2.2 ML/ha	0.5 ML/ha	0.0 ML/ha	4.4 ML/ha	308 L/Kg	3.2 t/ML
Vineyard R9	Own Roots	Chardonnay	7.5 t/ha	Furrow	1.2 ML/ha	1.4 ML/ha	0.8 ML/ha	0.7 ML/ha	4.2 ML/ha	558 L/Kg	1.8 t/ML
Vineyard R10	Ramsey	Shiraz	12.9 t/ha	Drip	0.6 ML/ha	1.0 ML/ha	0.8 ML/ha	0.3 ML/ha	2.6 ML/ha	198 L/Kg	5.1 t/ML
Vineyard R11	Ramsey	Shiraz	5.0 t/ha	Drip	0.0 ML/ha	0.4 ML/ha	0.6 ML/ha	0.2 ML/ha	1.2 ML/ha	229 L/Kg	4.4 t/ML
Vineyard R12	Ramsey	Shiraz	8.2 t/ha	Drip	0.5 ML/ha	2.2 ML/ha	0.6 ML/ha	0.0 ML/ha	3.4 ML/ha	412 L/Kg	2.4 t/ML
Vineyard R13	Own Roots	Shiraz	6.6 t/ha	Drip	0.4 ML/ha	0.6 ML/ha	0.8 ML/ha	0.1 ML/ha	2.0 ML/ha	296 L/Kg	3.4 t/ML
Vineyard R14	Own Roots	Shiraz	9.3 t/ha	Drip	1.0 ML/ha	1.0 ML/ha	0.8 ML/ha	0.0 ML/ha	2.8 ML/ha	303 L/Kg	3.3 t/ML
Vineyard R15	Ramsey	Shiraz	8.0 t/ha	Drip	1.0 ML/ha	1.0 ML/ha	0.8 ML/ha	0.0 ML/ha	2.8 ML/ha	350 L/Kg	2.9 t/ML
Vineyard R16	Own Roots	Shiraz	12.4 t/ha	Drip	0.3 ML/ha	0.4 ML/ha	0.5 ML/ha	0.1 ML/ha	1.4 ML/ha	110 L/Kg	9.1 t/ML
Vineyard R17	Own Roots	Shiraz	12.0 t/ha	Furrow	1.2 ML/ha	2.5 ML/ha	0.8 ML/ha	0.0 ML/ha	4.5 ML/ha	379 L/Kg	2.6 t/ML
Vineyard R18	Own Roots	Shiraz	9.1 t/ha	Furrow	0.7 ML/ha	0.8 ML/ha	0.3 ML/ha	0.3 ML/ha	2.1 ML/ha	232 L/Kg	4.3 t/ML
Vineyard R19	Own Roots	Shiraz	13.5 t/ha	Furrow	1.6 ML/ha	1.4 ML/ha	0.8 ML/ha	0.7 ML/ha	4.5 ML/ha	332 L/Kg	3.0 t/ML
Vineyard R20	Ramsey	Semillon	13.1 t/ha	Drip	2.7 ML/ha	2.6 ML/ha	0.8 ML/ha	0.1 ML/ha	6.2 ML/ha	475 L/Kg	2.1 t/ML
Vineyard R21	Own Roots	Semillon	13.1 t/ha	Drip	0.3 ML/ha	0.9 ML/ha	0.3 ML/ha	0.5 ML/ha	2.1 ML/ha	163 L/Kg	6.1 t/ML
Vineyard R22	Own Roots	Semillon	19.8 t/ha	Drip	1.3 ML/ha	2.6 ML/ha	0.9 ML/ha	0.2 ML/ha	5.0 ML/ha	250 L/Kg	4.0 t/ML
Vineyard R23	Ramsey	Semillon	19.8 t/ha	Drip	0.6 ML/ha	1.3 ML/ha	0.4 ML/ha	0.1 ML/ha	2.4 ML/ha	119 L/Kg	8.4 t/ML
Vineyard R24	Ramsey	Semillon	6.8 t/ha	Drip	1.0 ML/ha	1.0 ML/ha	0.8 ML/ha	0.0 ML/ha	2.8 ML/ha	415 L/Kg	2.4 t/ML
Vineyard R25	Own Roots	Semillon	22.9 t/ha	Drip	0.4 ML/ha	1.3 ML/ha	1.5 ML/ha	0.4 ML/ha	3.6 ML/ha	159 L/Kg	6.3 t/ML
Vineyard R26	Own Roots	Semillon	9.2 t/ha	Drip	0.4 ML/ha	1.3 ML/ha	0.7 ML/ha	0.3 ML/ha	2.6 ML/ha	284 L/Kg	3.5 t/ML
Vineyard R27	Ramsey	Semillon	23.4 t/ha	Furrow	1.7 ML/ha	2.2 ML/ha	0.5 ML/ha	0.0 ML/ha	4.4 ML/ha	187 L/Kg	5.3 t/ML
Vineyard R28	Ramsey	Semillon	4.4 t/ha	Furrow	0.5 ML/ha	0.8 ML/ha	0.3 ML/ha	0.4 ML/ha	1.9 ML/ha	441 L/Kg	2.3 t/ML
Vineyard R29	Ramsey	Cabernet Sauvignon	18.1 t/ha	Drip	0.5 ML/ha	1.2 ML/ha	0.4 ML/ha	0.0 ML/ha	2.2 ML/ha	119 L/Kg	8.4 t/ML
Vineyard R30	Own Roots	Cabernet Sauvignon	14.3 t/ha	Drip	1.2 ML/ha	2.8 ML/ha	0.5 ML/ha	0.0 ML/ha	4.5 ML/ha	315 L/Kg	3.2 t/ML
Vineyard R31	Ramsey	Cabernet Sauvignon	8.5 t/ha	Drip	0.4 ML/ha	0.8 ML/ha	1.0 ML/ha	0.2 ML/ha	2.4 ML/ha	282 L/Kg	3.5 t/ML
Vineyard R32	Own Roots	Cabernet Sauvignon	7.0 t/ha	Drip	0.4 ML/ha	0.6 ML/ha	0.8 ML/ha	0.1 ML/ha	1.8 ML/ha	265 L/Kg	3.8 t/ML
		Average	**12.8 t/ha**		**0.8 ML/ha**	**1.3 ML/ha**	**0.7 ML/ha**	**0.2 ML/ha**	**3.0 ML/ha**	**263 L/Kg**	**4.6 t/ML**

Appendix 4

Grapevine growth stages – The modified E-L system

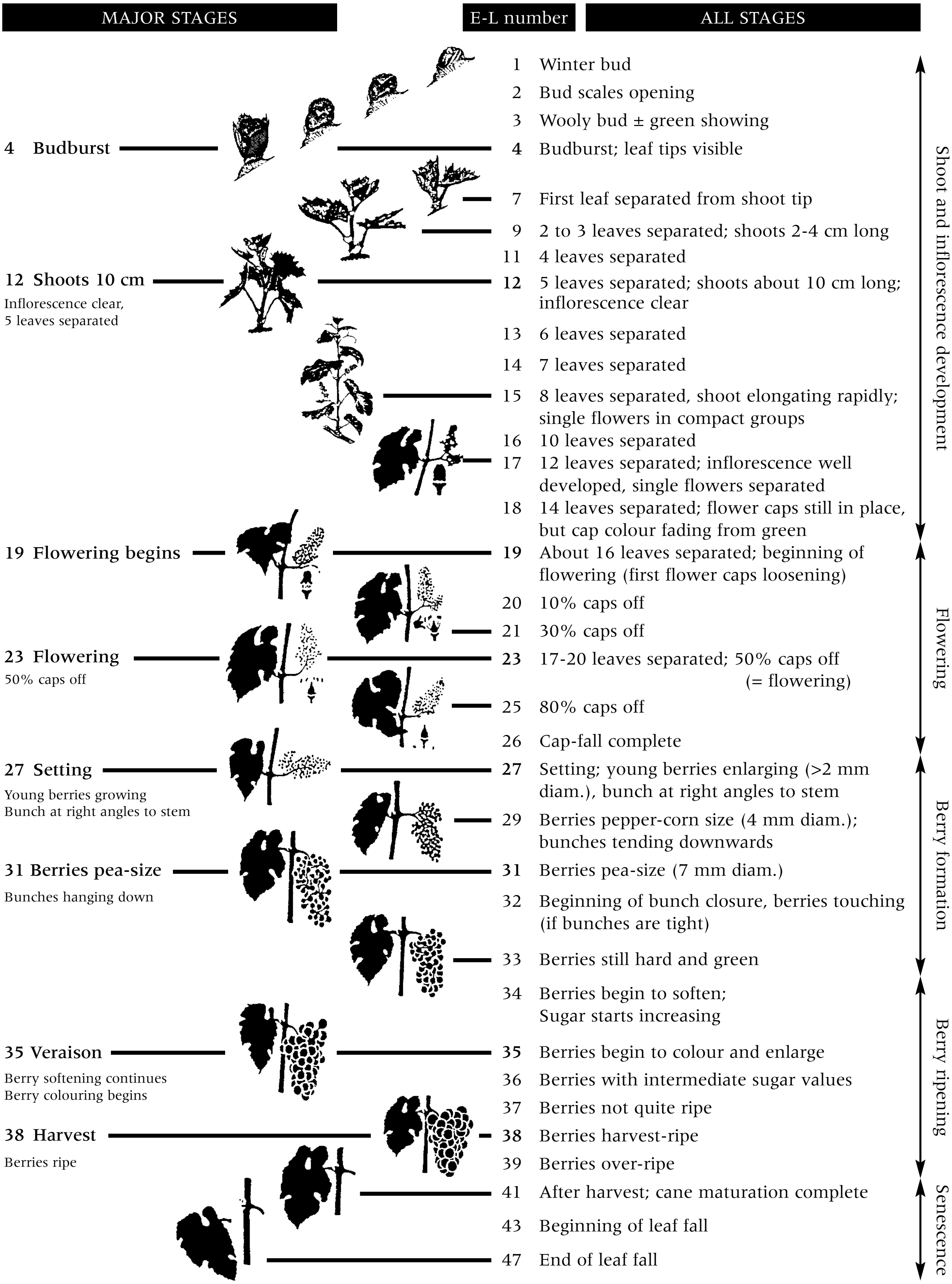

Figure 7.3 Modified E-L system for identifying major and intermediate grapevine growth stages (revised from Coombe 1995). Note that not all varieties show a woolly bud or a green tip stage (May 2000) hence the five budburst stages in the modified original 1995 system have been changed slightly by removing stage 4 and allocating the definition of budburst to what was formerly stage 5.
Revised version of "Grapevine growth stages – The modified E-L system" Viticulture 1 – Resources. 2nd edition 2004. Eds. Dry, P. and Coombe, B. (Winetitles)

retallack viticulture

wine growing for the future

Retallack Viticulture Pty Ltd

ABN 161 3501 6232

125 Sheoak Road, CRAFERS WEST South Australia 5152

Mob: +61 (0) 408 393 324
Tel: +61 8 8339 3324
Fax: +61 8 8339 4331

mary@viti.com.au
www.viti.com.au

Murray Valley
Winegrowers' Inc