Growing Cabernet Sauvignon with minimal water inputs: berry ripening and wine quality

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Introduction

Competition for water resources and the implementation of environmental policies in many New World vinegrape regions is increasing pressure to improve water use efficiency. Several strategic irrigation practices such as regulated deficit irrigation (RDI) and partial rootzone drying (PRD) and management techniques such as surface mulching and subsurface irrigation are increasingly being used to achieve these improvements (Dry and Loveys 2000; McCarthy 1997; Stewart and McIntyre 1997).

A range of trials has described the relative water savings of these individual irrigation and mulching strategies. Whilst it has been demonstrated that these practices lead to significant improvements in water use efficiency (WUE), to our knowledge, they have not been integrated into a single, commercial management system to determine potential water savings.

Such a trial was established in Langhorne Creek, South Australia, to determine which irrigation and mulching strategies resulted in the highest water use efficiency whilst still producing grapes to a predetermined winery specification. Six irrigation techniques, in combination with a mulching treatment, were integrated into a single management system in a commercial Cabernet Sauvignon vineyard. Each treatment was managed with the objective of ensuring that fruit produced was as close as possible to a pre-determined winery quality specification. Fruit maturation was monitored from veraison to harvest for each treatment and small lot wines were produced from selected treatments in 2004, 2005 and 2006.

Materials and methods

Trial site

The trial site was located within the Orlando Wines vineyard in the Langhorne Creek wine grape region, 60 km south east of Adelaide. The region has an annual rainfall of approximately 400 mm, a Mean January Temperature of 21°C and an average annual pan evapotranspiration of approximately 1710 mm.

The 1.4-hectare block was planted on own roots in 1996 with a row spacing of 2.5 m and vine spacing 1.8 m. The predominant soil type is loamy sand over loamy medium clay. Six irrigation treatments, Conventional Drip (CD), On-Ground Conventional Drip (OGCD), Sub-Surface Conventional Drip (SSCD), Conventional Partial Rootzone Dying (CPRD), Sub-Surface Partial Rootzone Drying (SSPRD) and Deficit Irrigation, were randomised across three replicates in a split-plot block design in 2001. A mulching treatment (Nitramulch™) was applied to a depth of five centimetres along half the length of each vine row.

Irrigation

Soil water was monitored using capacitance sensors and gypsum blocks installed in each irrigation treatment. Timing, volume of water applied and switching of PRD treatments were managed separately for each irrigation treatment and were based on historical full and refill points known to produce fruit to an Orlando Wines specification. Water Use Efficiency (WUE) was calculated as yield (t/ha) divided by the total volume of applied water (ML/ha).

Grape specification

Fruit was produced from each irrigation and mulch treatment combination with the aim of meeting the specification for quality and composition. All fruit had to be at least semi-premium quality and free from disease or defects. Fruit had to ripen steadily from veraison to harvest and obtain winemaking ripeness in the last week of March or first week of April. Total soluble solids had to measure 14.5°Baume, titratable acidity between 4 and 6 g/L and pH between 3.5 and 3.7. No specification was made for colour, phenolics or tannin.

Berry ripening

Berry ripening was monitored each year from veraison in late January to harvest in late March. One hundred berry samples were collected weekly from each treatment combination. Fifty berries were crushed for determination of total soluble solids (TSS), titratable acidity and pH and the remaining 50 berries were frozen for later analysis of colour and phenolics (Iland 2004). Frozen berry samples from the 2005 season were analysed for tannin using the methyl cellulose precipitation (MCP) assay (Sarneckis et al. 2006) with modifications to polymer volume, in early 2006.

Small lot wines

In 2004, 2005 and 2006, duplicate small lot wines were produced from ferments of 50 kilograms of grapes from the CD, CPRD and Deficit treatments. Wines were not made from the subsurface irrigation treatments due to uncertainty of the actual amount of water delivered because of dripper blockage and OGCD was omitted because of its similarity to CD. No small lot wines were made from mulched treatments.

Wines were subject to both spectral analysis for a suite of measures including total colour and total phenolics using the Somers method (Somers 1977) and ‘in-house’ informal sensory analysis by Orlando Wines winemakers.

Results and discussion

Yield and irrigation

To keep vines in a healthy state for adequate ripening, 0.88 ML/ha water was applied to CD, OGCD and SSCD treatments in 2006. PRD and Deficit treatments received half of this volume (0.44 ML/ha) in 2006 (Table 1). In 2004 and 2005 volume of water required for PRD and Deficit was 30% of conventionally irrigated treatments (not shown).

Despite a 50% reduction in applied water, yield was highest for CPRD treatment in 2006, significantly more than CD. Deficit irrigation, which received the same volume of irrigation water as
PRD but without alternating drippers, produced the lowest yield. WUE was highest for PRD treatments (Table 1). This result was also observed in 2005 and 2004. In all years mulch increased yield across all treatments, resulting in improved water use efficiency compared to non-mulched treatments (Table 1).

**Berry ripening**

**Berry weight**

In each season, each irrigation treatment significantly (P<0.05) influenced berry weight (Figure 1). CD treatment produced the largest berries every year (0.9 g at harvest), followed by OGCD, CPRD, SSPRD and Deficit. SSCD treatment produced the smallest berries every year (0.8 g at harvest), despite theoretically receiving the same amount of applied water as CD. We hypothesise that dripper blockages resulted in less water actually being applied to SSCD vines, resulting in a season-long deficit irrigation effect. Dripper blockages have not been observed to such an extent for SSPRD; however, it is possible that water delivery was also affected. Consequently, results from both SS treatments were potentially compromised and are therefore omitted from results presented here. OGCD has also been omitted from results due to its similarities in response with CD treatment.

In the years that data has been collected, mulch has not significantly affected berry size. However, each year non-mulched treatments consistently produced larger berries compared to mulched treatment (not shown).

**Total soluble solids**

Changes in total soluble solids (TSS) were not influenced by irrigation treatment in any season; however, the TSS of berries from mulched treatments was significantly lower (P<0.05) than non-mulched at each sampling time between veraison and harvest in each season (Figure 2a).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Irrigation (ML/ha)</th>
<th>Yield (t/ha)</th>
<th>WUE (t/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>0.88</td>
<td>16.2</td>
<td>18.5</td>
</tr>
<tr>
<td>OGCD</td>
<td>0.88</td>
<td>15.8</td>
<td>18.1</td>
</tr>
<tr>
<td>SSCD</td>
<td>0.88</td>
<td>15.8</td>
<td>18.1</td>
</tr>
<tr>
<td>CPRD</td>
<td>0.44</td>
<td>16.5</td>
<td>37.9</td>
</tr>
<tr>
<td>SSPRD</td>
<td>0.44</td>
<td>15.3</td>
<td>34.9</td>
</tr>
<tr>
<td>Deficit</td>
<td>0.44</td>
<td>14.6</td>
<td>33.4</td>
</tr>
<tr>
<td>Mulch</td>
<td>0.64</td>
<td>17.5</td>
<td>30.6</td>
</tr>
<tr>
<td>No Mulch</td>
<td>0.68</td>
<td>13.4</td>
<td>23.0</td>
</tr>
</tbody>
</table>

In contrast, irrigation treatment did significantly influence solutes per berry (°Brix × berry weight/100). Solutes per berry were similar for CPRD and Deficit and higher for CD treatment from veraison to harvest in 2006 (Figure 2b). Mulching treatment also significantly influenced solutes per berry, which was higher for non-mulched treatments (Figure 2c).

As TSS met winery specification of 14.5 Baume or 25 to 26 °Brix for all treatments in the same week each season, all plots were harvested on the same day.

**Titratable acidity and pH**

There was no effect of irrigation or mulch treatment on either titratable acidity or pH in any of the three seasons. At harvest, titratable acidity and pH were within the required range for all irrigation and mulch treatments.

![Figure 2a](image1.png) Change in total soluble solids (°Brix) with days after veraison in 2006 for mulched and non-mulched treatments.

![Figure 2b](image2.png) Change in solutes per berry with days after veraison in 2006 for CD, CPRD and Deficit irrigation treatments.

![Figure 2c](image3.png) Change in solutes per berry with days after veraison in 2006 for mulched and non-mulched treatments.
Colour
Colour, measured as anthocyanins per berry, increased steadily from veraison to harvest for all irrigation and mulch treatments in 2004 and 2005. In both years, colour per berry and per gram fresh berry weight was significantly (P<0.05) reduced with mulch, as shown for 2005 (Figures 3a and 3b). Irrigation treatment combination did not significantly influence anthocyanins per berry or per gram berry weight.

Total phenolics
Grape phenolics (absorbance at 280 nm) were measured on 2005 samples. Total phenolics per gram and per gram berry weight increased steadily from veraison to harvest for all irrigation and mulch treatments. Mulch significantly reduced total phenolics per berry (Figure 4a) and per gram fresh berry weight (Figure 4b) in this trial. Irrigation treatment had no significant effect on berry phenolic content.

Tannin
Berry samples collected in 2005 were analysed for tannin using the methyl cellulose precipitation or MCP tannin assay (Sarneckis et al. 2006). Tannin concentration (epicatechin equivalents/L) for CD treatment increased in the first three weeks of ripening and then declined to a minimum concentration after 42 days before increasing rapidly to a maximum concentration 49 days after veraison (two days before harvest) (Figure 5a). Tannin concentration for CPRD and Deficit treatments fluctuated significantly during ripening, however, as was observed for CD, tannin concentration increased significantly in the final week of ripening to reach a maximum just before harvest.
(Figures 5a and b). This pattern was observed consistently across all irrigation and mulch treatments and in all replicates.

Fluctuating tannin levels have previously been observed during berry ripening (Somers 1976). However, rapid increase in tannin concentration in the final week of ripening is atypical as most literature reports maximum tannin concentrations (skin and seeds) occurring around veraison and declining thereafter (Downey et al. 2003; Downey and Krstic 2005; Herderich et al. 2004). Discrepancies between our results and those previously reported may be due to different analytical techniques, variety, berry maturity or climate.

There was no significant irrigation or mulch treatment effect on tannin per berry or per gram berry weight at any stage during berry ripening.

**Small lot wines**

Before harvest, fruit from each treatment combination was assessed in the field to determine whether it met with winery quality specification. In 2004, berry sensory assessment took place in the laboratory, however, data obtained was extremely variable and consequently, a general winemaker vineyard assessment was used for berry analysis pre-harvest in 2005 and 2006. In 2005 and 2006 all fruit achieved an Orlando Wines Q3 rating, or semi-premium quality. In summary, based on berry assessment, the aim of producing grapes to a grape specification for irrigation and mulch strategies was met.

As there was little difference in TSS between treatments, fruit for small lot winemaking was hand picked at the end of March each year on the same day for all selected treatments. Each year, duplicate small lot wines were produced from three of the six irrigation treatments: CD, CPRD and Deficit, all without mulch.

**Spectral analysis**

The spectral properties of 2004 and 2005 small lot wines were analysed several months after bottling. In 2004, there were significant differences between treatments for chemical age indices one and two, the degree of ionisation of anthocyanins and red wine colour density. Deficit treatment wines had the highest degree of ionisation of anthocyanins and red wine colour density (Table 2).

In 2006, the small lot wines made in the 2004 vintage were re-analysed. In a year, chemical age and colour hue had increased and phenolics, anthocyanins and colour density had decreased, however, there were no longer any significant differences between spectral parameters for irrigation treatments (not shown).

The small lot wines made in 2005 were analysed in 2006. Total anthocyanin concentration and colour were both slightly lower density and slightly higher hue for 2005 small lot wines compared with the analyses of the 2004 wines that were conducted at the same time. Only total anthocyanins were significantly different between treatments, with CPRD and Deficit treatment measuring a higher concentration than CD (not shown). 2006 wines have been bottled and will be analysed in late 2006.

**Sensory assessment**

Sensory properties of 2004, 2005 and 2006 small lot wines were informally assessed by Orlando Wines’ senior winemakers each year several months after bottling.

In 2004, wines from all treatments achieved a ranking of semi-premium or higher. In addition, winemakers also noted perceptible differences in the sensory characteristics of the wines from the three irrigation treatments from the young 2004 wines. For wines from the CD treatment, they noted ‘cherry’, ‘tinnny’ and ‘green’ characters, typical of Langhorne Creek Cabernet Sauvignon. Wine made from the CPRD treatment was noted as being richer, fuller, softer and brighter than that from the CD treatment. The wine made from the deficit treatment was also found to be sweeter, riper and brighter than wine from the conventionally irrigated treatment.

However, no differences were noted between the treatments in the 2005 small lot wines. Again, wines met with quality specification, however, varying style and sensory characteristics could not be discerned between the irrigation treatments and there was no difference in wine score. In 2006, small lot wines also met with quality specification, but again, there were no perceptible differences in wine sensory characteristics or wine score.

In 2006, wines from the 2004 and 2005 harvests were re-assessed. No difference in sensory characteristics was perceived and wine scores were not significantly different.

This result contrasts with other trials where there were significant differences in the sensory attributes of small lot wines made from Cabernet Sauvignon under different treatments (Chapman et al. 2005). However, in reported work, volumes of water applied have varied more significantly between treatments.

**Conclusion**

In each of the three years reported here, both irrigation style and mulch treatments required the application of different volumes of applied water to achieve similar vine growth and health resulting in significantly different water use efficiency. Mulching significantly improved yield and water use efficiency with CPRD treatment achieving the highest yield and WUE of all irrigation treatments.

Fruit from mulched and non-mulched treatments satisfied winery specification, however, fruit from mulched treatments had lower TSS, solutes per berry, colour and phenolics in all weeks from veraison to harvest. There was little effect of irrigation treatment on berry ripening indices except for berry size and solutes per berry.

Fruit from all irrigation treatments met winery specifications for quality. There were significant differences in some spectral characteristics of 2004 small lot wines several months after bottling, which was reflected in sensory assessment. However, when re-assessed after one year, there were no differences in spectral parameters or sensory characteristics of 2004 small lot wines.

Only total anthocyanins varied significantly in 2005 small lot wines and there were no differences in the quality rating or sensory characteristics between irrigation treatments. Similarly, there were no perceptible differences in the sensory characteristics of 2006 small lot wines and each treatment met with winery specification.

**Table 2.** Spectral parameters measured three months after bottling for 2004 small lot wines. Parameters highlighted in grey indicate significant difference (P<0.05) between treatments.

<table>
<thead>
<tr>
<th>Spectral Parameters</th>
<th>CD</th>
<th>CPRD</th>
<th>Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical age index #1</td>
<td>0.35</td>
<td>0.33</td>
<td>0.47</td>
</tr>
<tr>
<td>Chemical age index #2</td>
<td>0.11</td>
<td>0.10</td>
<td>0.18</td>
</tr>
<tr>
<td>Total anthocyanins (mg/L)</td>
<td>476</td>
<td>542</td>
<td>389</td>
</tr>
<tr>
<td>Total phenolics (a.u.)</td>
<td>44</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Red wine colour–density (a.u.)</td>
<td>10.8</td>
<td>10.6</td>
<td>14.1</td>
</tr>
<tr>
<td>Red wine colour–hue</td>
<td>0.61</td>
<td>0.62</td>
<td>0.59</td>
</tr>
<tr>
<td>Degree of ionisation of anthocyanins (%)</td>
<td>15.0</td>
<td>13.2</td>
<td>22.8</td>
</tr>
<tr>
<td>Degree of ionisation of anthocyanins (no SO2 effect)</td>
<td>24</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Free SO2 (mg/L)</td>
<td>2.37</td>
<td>3.17</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Therefore, it may be concluded that in this trial, a 30-50% reduction in applied water for CPRD and Deficit treatments did not significantly influence berry ripening or small lot wine quality of Langhorne Creek Cabernet Sauvignon at the trial site from 2004 to 2006. These results suggest that even in situations where irrigation application is closely monitored to ensure high wine grape quality the opportunity still exists for further improvement in water use efficiency in drip irrigated vineyards.

References