Relationships between yield and water in winegrapes

Yasmin Chalmers, DPI-Mildura
Overview

- Section 1: Components of yield development
- Section 2: Definition of water relations in grapevines
- Section 3: Quantifying water use
- Section 4: Water deficit effects on grapevine physiology
- Section 5: Water deficit effects on grapevine yield
- Section 6: What happens to grapevine yields under limited water?
Section 1: Yield Development

Annual growth cycle includes a vegetative and fruiting (reproductive) cycle.
Section 1: Yield Development

There are five stages of development during a grapevine’s annual growth cycle.

Adapted from Coombe & McCarthy (2000) AJGWR

http://waterandvine.gwrdc.com.au
Section 1: Yield Development

The cycle of yield development for grapevines extends over two growing seasons.

From Krstic et al. (2005), ASVO proceedings, Mildura
Section 2: Water relations in grapevines

- Water loss is controlled by varying the stomatal aperture
- Stomates have a dual role:
  1) Diffuse carbon dioxide (CO₂)
  2) Release oxygen (O₂) and water (H₂O) to the environment

Stomates balance transpiration and prevent excessive water loss, whilst maintaining adequate photosynthesis for healthy growth.
Section 2: Water relations in grapevines

The approximate annual percentage of water required by a grapevine at each growth stage varies depending on:

- Variety
- Rootstock
- Climate (rainfall/evaporation)
- Soil type/depth
- Crop load
Section 2: Water relations in grapevines

Early season water use:
Stage 1 (budburst to flowering) and Stage 2 (flowering to fruit-set)

When combined these stages utilize approximately 14% of the annual water requirement

Water stress at flowering may result in poor fruit set or aborted fruit → yield reduction

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Section 2: Water relations in grapevines

**Mid season water use:**
Stage 3 (fruit-set to veraison)

This stage utilises approximately 35% of the annual water requirement.

Berry expansion occurs during stage 3.

Deficit irrigation strategies applied during stage 3 will tend to reduce berry size.

Severe water stress can affect bud fruitfulness.

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Section 2: Water relations in grapevines

**Mid-late season water use:**
Stage 4 (veraison to harvest)

This stage utilises approximately 36% of the annual water requirement.

Deficit irrigation can reduce yield and even affect ripening and fruit quality.

Severe deficits will cause leaf defoliation.
Section 2: Water relations in grapevines

**Late season water use:**
Stage 5 (Harvest to leaf fall)

This stage utilises approximately 14% of the annual water requirement.

Need to maintain healthy leaf function to build up reserves for dormancy and next season.

Water stress may lead to restricted growth symptoms in spring.
Section 3: Quantifying water use

Water-efficient management strategy + Well-maintained irrigation system = Improved irrigation efficiency
Section 3: Quantifying water use

Using crop coefficients to calculate crop water use

\[ K_c = \text{crop coefficient} \]
\[ K_e = \text{evaporation} \]
\[ K_{cb} = \text{transpiration} \]
\[ E_{To} = \text{reference crop evaporation} \]
\[ E_{Tc} = \text{crop water use} \]

Equation 1: \[ E_{Tc} = K_c \times E_{To} \]

Equation 2: \[ E_{Tc} = (K_{cb} \times E_{To}) + (K_e \times E_{To}) \]

Allen et al. (1998), FAO No. 56

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Section 3: Quantifying water use

Using crop coefficients to calculate crop water use

\( K_e = \) evaporation
\( ET_o = \) reference crop evaporation
\( EAS = \) effective area of shade
\( ECC = \) effective canopy cover
\( ET_c = \) crop water use

Equation 3: \( ET_c = (1.1 \times EAS \times ET_o) + (K_e \times ET_o) \)

Equation 4: \( ET_c = (1.5 \times ECC \times ET_o) + (K_e \times ET_o) \)

O’Connell & Goodwin (2007) AJAR, 58.
Section 3: Quantifying water use

Using crop factors to calculate crop water use

\[ C_f = \text{crop factor} \]
\[ ET_{\text{pan}} = \text{evaporation pan} \]
\[ ET_c = \text{crop water use} \]

Equation 5: \[ ET_c = C_f \times ET_{\text{pan}} \]

- \( E_{\text{pan}} \) readings are generally obtained from the Bureau of Meteorology stations.
- Crop factors are provided by industry or obtained from government sources.
Suggested winegrape crop factors and coefficients for mature vines in the Sunraysia region. Winegrape average water use based on Mildura BoM weather records (July 1970 - June 2007).

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<thead>
<tr>
<th>Month</th>
<th>FAO56</th>
<th>Epan</th>
<th>ETo (FAO56)</th>
<th>ETc (Epan * Cf)</th>
<th>ETc (ETo * Kc)</th>
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<td>crop factor (Cf)</td>
<td>crop coefficient (Kc)</td>
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<td>cumulative</td>
<td>monthly</td>
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<td>94</td>
<td>156</td>
<td>66</td>
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<td>0.3</td>
<td>135</td>
<td>291</td>
<td>93</td>
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<td>0.2</td>
<td>0.3</td>
<td>200</td>
<td>491</td>
<td>134</td>
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<td>0.7</td>
<td>313</td>
<td>1060</td>
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<td>0.7</td>
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<td>0</td>
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<td>55</td>
<td>2169</td>
<td>41</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2169</td>
<td>1414</td>
<td>719</td>
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</table>
Monthly (left) and cumulative (right) pan evaporation (Epan), reference crop evaporation (ETo) calculated according to Allen et al. (1998) and estimated crop water use ETc.
Section 4: Water deficit effects on grapevine physiology

- When soil water is limiting vines close their stomates to minimise transpiration and water loss.
- A decrease in photosynthesis can also occur that leads to a decrease in carbohydrate production.
- When carbohydrate production is limited vines prioritise its use (partitioning rules).
- Fruit growth > Root growth > Shoot Growth
Readily Available Water (field capacity)

Deficit Available Water

Deficit irrigation strategies

Permanent Wilting Point

Plant Damage

Drainage (saturated)
Drainage (saturated)

Readily Available Water
(field capacity)

Deficit Available Water
Deficit irrigation strategies

Permanent Wilting Point
Plant Damage
Section 4: Water deficit effects on grapevine physiology

- Different grapevine cultivars have evolved various strategies to deal with water deficit.

  **Isohydric (pessimist)** – conserves available resources by early stomatal closure and subsequent reduced gas exchange.

  **Anisohydric (optimist)** – maintains a higher rate of gas exchange for immediate gain at the expense of stored soil water.

- Rootstock genotypes may vary in sensitivity to soil moisture levels and subsequent hormonal production

Soar et al., (2006) AJGWR, 12

http://waterandvine.gwrdc.com.au
Section 5: Water deficit effects on grapevine yield

The effect of water deficit on yield differs depending on the stage of growth that the water deficit was applied.

The deficit irrigation strategy used to apply the water deficit may also influence yield levels i.e.

- Regulated Deficit Irrigation (RDI)
- Partial Rootzone Drying (PRD)
- Sustained Deficit Irrigation (SDI)
RDI requires a controlled application of irrigation water at less than the crop water use applied at a specific vine growth stage (temporal deficit).

Graph courtesy Ian Goodwin, DPI-Tatura
PRD involves applying alternate irrigations to each side of the grapevine to create discrete wet and dry zones around the root system (spatial deficit).

Diagram courtesy Peter Dry, University Adelaide

http://waterandvine.gwrdc.com.au
SDI creates a soil water deficit by applying less water than the optimum required at each irrigation event for the entire season.

### Cabernet Sauvignon/140-Ruggeri

<table>
<thead>
<tr>
<th>Irrigation Volume (ML/ha)</th>
<th>100%</th>
<th>70%</th>
<th>52%</th>
<th>43%</th>
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<td>3.1</td>
<td>2.6</td>
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<tr>
<td>2004/2005</td>
<td>6.6</td>
<td>4.6</td>
<td>3.4</td>
<td>2.8</td>
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<tr>
<td>2005/2006</td>
<td>7.5</td>
<td>5.3</td>
<td>3.9</td>
<td>3.2</td>
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<tr>
<td>Dripper flow rate (L/h)</td>
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<td>1.6</td>
<td>1.2</td>
<td>1.2</td>
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<tr>
<td>Dripper spacing (m)</td>
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<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
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</tbody>
</table>

### Shiraz/140-Ruggeri

<table>
<thead>
<tr>
<th>Irrigation Volume (ML/ha)</th>
<th>100%</th>
<th>65%</th>
<th>45%</th>
<th>34%</th>
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<tbody>
<tr>
<td>2003/2004</td>
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<td>2.2</td>
<td>1.5</td>
<td>1.2</td>
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<tr>
<td>2004/2005</td>
<td>5.7</td>
<td>3.7</td>
<td>2.6</td>
<td>1.9</td>
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<tr>
<td>2005/2006</td>
<td>5.9</td>
<td>3.8</td>
<td>2.6</td>
<td>2.0</td>
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<tr>
<td>Dripper flow rate (L/h)</td>
<td>3.5</td>
<td>2.3</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Dripper spacing (m)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Data from Chalmers (2007) PhD thesis
Section 6: What happens to grapevine yields under limited water?

- The effect of irrigation on yield is not a linear relationship.
- Theoretically there is an irrigation threshold that maximizes yield & productivity.

- Show 2007/08 regional max. & min. temperatures plus effective rainfall.
- Effective rainfall is ≥5mm rain in 24 hours.
- Regional case studies showing yield vs water use data.
Irrigation & Rainfall

Yield

Increased water
Increased yield

Yield

Irrigation & Rainfall

http://waterandvine.gwrdc.com.au
Irrigation & Rainfall

Yield

Increased water
No change in yield

Irrigation & Rainfall
Irrigation & Rainfall

Yield

Increased water
Decreased yield

Irrigation & Rainfall

http://waterandvine.gwrdc.com.au
Irrigation & Rainfall

Yield

No positive yield response beyond this point

Wasted water

http://waterandvine.gwrdc.com.au
Quality of horticultural produce is critical
Section 6: Regional weather data

Average monthly maximum and minimum temperatures and total effective rainfall for the Murray Valley from September to April 2007/08.
Section 6: Regional yield and water data

Data from Chalmers (2007) PhD thesis

Treatments within a season followed by the same letter are not significantly different at P<0.05.
Section 6: Regional yield and water data

Cabernet Sauvignon

% yield (t/ha) to the control

SDI Treatment

2004 2005 2006

70% 52% 43%

http://waterandvine.gwrdc.com.au
Section 6: Regional yield and water data

Treatments within a season followed by the same letter are not significantly different at P<0.05.

Data from Chalmers (2007) PhD thesis
Section 6: Regional yield and water data

Shiraz

% yield (t/ha) to the control

SDI treatment

http://waterandvine.gwrdc.com.au
Section 6: Regional yield and water data

Below is a table that could be used by a regional representative to fill in for the respective varieties.

<table>
<thead>
<tr>
<th>Region name</th>
<th>2006/07</th>
<th>2007/08</th>
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</thead>
<tbody>
<tr>
<td>Variety</td>
<td>Irrigation volume (ML/ha)</td>
<td>Yield (t/ha)</td>
</tr>
<tr>
<td>Shiraz</td>
<td>3.9</td>
<td>9.0</td>
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<tr>
<td>Cabernet Sauvignon</td>
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<tr>
<td>Merlot</td>
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<td></td>
</tr>
<tr>
<td>Chardonnay</td>
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</tbody>
</table>
Government and the winegrape industry have accepted that severe shortages of water for irrigation will continue.

Irrigation is now a substantial cost and in some regions will limit wine production.

Limited scientific knowledge on the relationship between yield and water, particularly in white wine grapes i.e. Chardonnay.

Knowledge gap as to the implications on productivity of applying a sustained or strategic water deficit.

Impact of reduced water allocations on salinity and drought induced erosion problems.
Useful websites

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http://waterandvine.gwrdc.com.au