Measured effects of elevated temperature on vine phenology, yield, berry and wine attributes

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Department of Agriculture, Fisheries and Forestry

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Aims

Methods, data sources and reliability

Measured effects of elevated temperature on:
  time of harvest
  yield
  berry traits
  juice and wine attributes
Papers retrieved searching “temperature” + “grapevine” (Web of Science)
Effect of temperature on vines and wines: indirect vs direct methods

**Indirect methods**

comparison between regions, vintages, row orientation…

large confounded effects

**Direct methods**

side-by-side experimental comparison of treatments involving different temperatures

large to small confounded effects
Regional or seasonal comparisons confound temperature with radiation, humidity, etc (+ soil, + management)

Indirect methods cannot prove cause and effect

Regional classification as a function of temperature is ok for marketing but is an oversimplification

Sadras & Petrie 2011 Austr J Grape Wine Res 17, 199
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Sadras & Petrie 2011 Austr J Grape Wine Res 17, 199
Large scale open-top heating systems
(9 vines per rep x 3 reps + buffers)

Passive, daytime +2 to 4 °C

Active/Passive, day & night +2 °C

Experiments 1 and 2

Experiment 3
1. Reproduces the daily and seasonal cycles of temperature and vapour pressure deficit.

2. Does not increase relative humidity, hence allowing for increased vapour pressure deficit.

3. Minimises biologically important secondary effects.

4. Has structural strength to withstand the weather (particularly wind) to ensure a reasonable longevity.

5. Allows for number and size of replicates required for statistical resolution and viticultural needs, including sufficient fruit for meaningful wine production.
Probing for experimental artefacts
Sweetman et al (unpublished)
Days after anthesis

Living tissue (%)

Thermal time after anthesis (°Cd)

Control

Heated

Experiments

Exp 1
2 temperatures (high, control) x 4 varieties x 3 seasons

Exp 2 (Shiraz)
2 temperatures x 2 fruit loads (thinned, control) x 2 seasons

Exp 3 (Shiraz)
2 temperatures x 2 water regimes (irrigated, deficit) x 2 seasons
experiments explored a good range of Barossa seasonal variation
Traits

Phenology
Yield and components
Pruning weight and components
Starch reserves in trunk and roots

Stomatal conductance, density and size
Photosynthesis
Leaf chlorophyll
Pre-dawn and mid-day leaf water potential
Canopy and bunch temperature
Sap flow

Berry: dynamics of TA, pH, TSS and anthocyanins
Berry progression of cell death

Sensory traits in berries and wines
Developmental stage in control (°Brix)

Temperature effect (°Brix)

Shiraz, Exp. 1, irrigated 2010-11
Shiraz, Exp. 1, deficit 2010-11
Shiraz, Exp. 2, unthinned 2010-11
Shiraz, Exp. 2, thinned 2010-11
Cab Franc, Exp. 3 2010-11
Chardonnay, Exp. 3 2010-11
Semillon, Exp. 3 2010-11
Shiraz, Exp. 3 2010-11
Shiraz, Exp. 1, irrigated 2011-12
Shiraz, Exp. 1, deficit 2011-12
Shiraz, Exp. 2, unthinned 2011-12
Shiraz, Exp. 2, thinned 2011-12
Cab Franc, Exp. 3 2011-12
Chardonnay, Exp. 3 2011-12
Semillon, Exp. 3 2011-12
Shiraz Exp. 3 2010-11

lag-phase to onset of rapid sugar accumulation
active sugar accumulation in fruit

Sadras & Moran 2013 Agric Forest Meteorol 173:107
Experiments
Approx 3 d °C⁻¹

Indirect methods
6.6 ± 0.92 d °C⁻¹ (Petrie and Sadras 2008)
8 d °C⁻¹ (Tomasi et al 2011)
9.8 ± 0.94 d °C⁻¹ (Sadras and Petrie 2011)
Traits

Phenology
Yield and components
Pruning weight and components
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Berry: dynamics of TA, pH, TSS and anthocyanins
Berry progression of cell death

Sensory traits in berries and wines
asymmetric effect of warming on yield
46% reduction to 177% increase

Sadras & Moran 2013 Agric Forest Meteorol 173:116
Temperature effect on bunch number (%)

-50 0 50 100

Temperature effect on yield (%)

-100 -50 0 50 100

Residuals (%)

-40 -20 0 20 40

\( r^2 = 0.92 \)

\( P < 0.0001 \)

Temperature effect on berries per bunch (%)

-40 -20 0 20 40

\( r^2 = 0.28 \)

\( P = 0.01 \)

Bunch number in control (vine -1)

0 40 80 120

Temperature effect on bunch number (%)

-40 0 40 80 120

\( r^2 = 0.32 \)

\( P = 0.03 \)
Temperature effect on bunch number (%)

-50
0
50
100

Temperature effect on yield (%)

-100
-50
0
50
100
150
200

Temperature effect on berries per bunch (%)

-40
-20
0
20
40
60

Residuals (%)

-40
-20
0
20
40

$r^2 = 0.92$

$P < 0.0001$

Bunch number in control (vine$^{-1}$)

0
40
80
120

Temperature effect on bunch number (%)

$r^2 = 0.32$

$P = 0.03$
elevated temperature reduced starch concentration in trunk

Sadras & Moran 2013 Agric Forest Meteorol 173:116
leaves formed under high temperature had larger stomata

Sadras et al. 2012 Agric Forest Meteorol 165:35
Traits

Phenology
Yield and components
Pruning weight and components
Starch reserves in trunk and roots

Stomatal conductance, density and size
Photosynthesis
Leaf chlorophyll
Pre-dawn and mid-day leaf water potential
Canopy and bunch temperature
Sap flow

Berry: dynamics of TA, pH, TSS and anthocyanins
Berry progression of cell death

Sensory traits in berries and wines
The temperature effect on TA and pH is strongly dependent on variety.

<table>
<thead>
<tr>
<th>Vintage</th>
<th>Variety</th>
<th>TA (g L(^{-1}))</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>control</td>
<td>heated</td>
<td>control</td>
</tr>
<tr>
<td>2010</td>
<td>Semillon</td>
<td>6.4 ±0.12</td>
<td>5.1 ±0.39</td>
</tr>
<tr>
<td></td>
<td>Chardonnay</td>
<td>4.9 ±0.16</td>
<td>3.9 ±0.12</td>
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<tr>
<td></td>
<td>Shiraz</td>
<td>5.7 ±0.35</td>
<td>7.5 ±0.41</td>
</tr>
<tr>
<td></td>
<td>Cab Franc</td>
<td>5.3 ±0.15</td>
<td>4.3 ±0.10</td>
</tr>
<tr>
<td>2011</td>
<td>Semillon</td>
<td>4.9 ±0.18</td>
<td>5.7 ±0.69</td>
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<tr>
<td></td>
<td>Chardonnay</td>
<td>5.3 ±0.20</td>
<td>4.5 ±0.17</td>
</tr>
<tr>
<td></td>
<td>Shiraz</td>
<td>7.2 ±0.10</td>
<td>6.7 ±0.18</td>
</tr>
<tr>
<td></td>
<td>Cab Franc</td>
<td>6.6 ±0.06</td>
<td>6.0 ±0.16</td>
</tr>
</tbody>
</table>

Source of variation:

- variety (V): 0.0001 0.0001
- temperature (T): 0.0185 0.0001
- season (S): 0.0011 0.332
- V x T: 0.0010 0.0008
- V x S: 0.0002 0.0001
- T x S: 0.7135 0.9675
- V x T x S: 0.0001 0.5544
Phenotypic plasticity allows for complex variety x environment interaction.
text-book expected increase in pH and reduction in TA with high temperature is an oversimplification

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Thermal decoupling is the consequence of differential responses of related traits.
elevated temperature decoupled anthocyanins and sugars in Shiraz and Cab franc

Sadras & Moran 2012 Austr J Grape & Wine Res 18, 115
elevated temperature decoupled anthocyanins and sugars

Sadras & Moran 2012 Austr J Grape & Wine Res 18, 115
elevated temperature decoupled anthocyanins and sugars by delaying pigment development in a brix scale

Exp. 3, Shiraz

Anthocyanins (mg/g) vs. TSS (°Brix)

- Control
- Heated

Graph showing the relationship between anthocyanins and TSS for control and heated samples.
Water deficit partially restored the anthocyanin : sugar balance.
Sadras et al. 2012 Austr J Grape & Wine Res 19, 95
temperature decoupled sensory berry traits

Cabernet Franc 2010

Sadras et al. 2012 Austr J Grape & Wine Res 19, 95
strong variety x season x temperature effect on wine sensory traits

2010 vintage

Wine attribute

Conclusions
In a warmer Barossa

Nonlinear effect on phenology

Smaller than expected effect on maturity (3 days per °C)

Asymmetric effect on yield mediated by bunch number
46% reduction to 177% increase

Apparent depletion of starch in trunks?

Larger, more open stomata; ↑ leaf transpiration and photosynthesis per unit leaf area

Variety-dependent responses (pH, TA)

Decoupling of berry traits and wine attributes
Can we shift phenology and restore berry and wine balance with late pruning?

By Paul Petrie, this meeting