EFFECTS OF CULTURAL PRACTICES ON WINEGRAPE COMPOSITION

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COOPERATIVE EXTENSION SPECIALIST
Desirable Aspects

- Uniformly ripe fruit
- Sound fruit
- An abundance of flavor
  - With correct composition
- Reaches peak at ideal time
  - Avoiding inclement weather
  - Winery logistics
## General responses to elevated light and temperature

<table>
<thead>
<tr>
<th>Berry growth</th>
<th>Light</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>+/−</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Berry composition:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Organic acids</td>
<td>+/−</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Anthocyanins</td>
<td>*</td>
<td>+/−</td>
</tr>
<tr>
<td>Phenolics</td>
<td>*</td>
<td>+/−</td>
</tr>
<tr>
<td>Methoxypyrazines</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Monoterpenes</td>
<td>*</td>
<td>−</td>
</tr>
</tbody>
</table>
Temperature Thresholds of *Vitis*

**86 – 95°F**
- Many metabolic processes slowed or halted
- Anthocyanins
  1. genetic repression
  2. degradation

**95 - 105°F**
- Inhibition of carbon assimilation and skin tissue formation

**77°F**
Optimal day temperature
Berry anatomy

- Flesh (pulp)
  - Juice
  - Hydroxycinnamates
- Seed
  - Tannins (bitter taste)
  - Flavan-3-ols
- Skin
  - Color pigments
  - Tannins (astringent, tactile sensations)
  - Flavan-3-ols
  - Flavonols

Figure 1: Structure of a ripe grape berry partially sectioned on the long and central axis to show internal parts. Illustration by Jordan Koutroumanidis, Winetitles.
Berry development
Why study tannin composition, rather than content?

- Red wine mouthfeel drivers

**Tannin Concentration**
- Measure of concentration

**Wine Matrix**
- Acidity
- Ethanol
- Residual Sugars
- Mannoproteins
- Polysaccharides

**Tannin Activity**
- Composition:
  - Skin/Seed
  - Red Color
  - Oxidation
  - Molecular Size
Where do they come from?
Anthocyanins

- Berry: attractant to animals (i.e. seed dispersal) and photoprotection
- Wine: visual perception, stability and age-ability of wine matrix, and antioxidative properties
Flavonols

- **Photo-protection**
  - highly responsive to visible light and U-V
  - particularly **UVB**
    - less clear regarding temperature
    - studies show concentration not reliably paralleled with berry skin mass

- **Cofactor of co-pigmentation in wine matrix**
Flavanols

- Monomeric
- Polymeric (condensed tannins)

- Berry
  - deterrent towards animals

- Wine
  - bitterness and astringency (seed vs. skin)
  - critical for wine matrix stability and age-ability
Radiation Effects on Whole Canopy

Irrigation regimes

- **Sustained Deficit Irrigation (SDI)**
  - 80% $\text{ET}_c$ from bloom to harvest

- **Regulated Deficit Irrigation (RDI)**
  - 80% $\text{ET}_c$ from bloom to fruit set, 50% $\text{ET}_c$ from fruit set to veraison, 80% $\text{ET}_c$ from veraison to harvest

- Moving forward…
  - Calculating $\text{ET}_c$
Irrigation scheduling

- \( E_{t_c} = K_c \times E_{T_o} \)
- \( K_c = \) crop coefficient
  - Calculated by weekly shade estimates
  - Remotely sensed and extrapolated from energy balance models
- \( E_{T_o} = \) reference crop evapotranspiration
- \( E_{T_c} = \) cultivar specific evapotranspiration
- Strongly affected by drought
- $K_c \cdot ET_o = ET_c$
- $ET_o =$ reference evapotranspiration

*Based on wheat*
**Why use a crop coefficient ($K_c$)?**

* $K_c$ based on canopy development; changes as season progresses, only irrigating effective rooting zone

*If no grape $K_c$ used, over-irrigating to full field capacity the entire season*
How can we relate this information to tactile and taste sensation?

- **Increase Tannin Molecular Size** → increase astringency/chalky
  
  

- **Increase %ECG** → increase drying and chalkiness
  

- **Increase %EGC** → lower coarseness
  

- **Increase Color Incorporation** → less astringent
  
Light exposure and applied water amounts

- **Leaf removal**
  - Pre-bloom leaf removal
    - reduced fruit set (yield control)
    - increase in skin mass
    - improved phenolic composition
  - Post-fruit set leaf removal
    - no reduction in fruit set
    - improved phenolic composition
    - berry sunburn an issue in warm climate
    - overexposure to sunlight reduces phenolic composition
    - increase in total soluble solids

- **Applied water**
  - Deficit irrigation
    - reduced berry size
    - reduction in vegetative growth
    - increase in anthocyanin concentration
    - accelerated ripening
Plant Material and Research Site

- Merlot (01)/Freedom
- Planted in 1998
- Located in Merced County
- 80 acre research site
- 7’ x 11’ spacing (N-S)
- Whitney and Rocklin Sandy-Loam soil
- Drip irrigated
- Head trained and cane pruned to six-canies
Canopy Architecture
North Valley Cane-Pruned
Mechanical Leaf Plucker - Clemens EL

- Conducted on East side of canopy
- Opened 50cm window in the fruiting zone
- Takes two men, 14 minutes per row

Treatments

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Pre-Bloom</th>
<th>Post-Fruit Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>No leaf removal</td>
<td>Single application prior to bloom (EL-17)</td>
<td>Single application following fruit set (EL-29)</td>
</tr>
</tbody>
</table>

Leaf Removal Treatments
Irrigation Treatments

Irrigation hours
- calculated based on weekly CIMIS $E_{to}$

Sustained Deficit Irrigation (SDI)
- control treatment
- received 80% of $E_{tc}$ from bloom to harvest
- dynamic grape coefficient factor ($K_c$) included
- leaf $\psi$ maintained at -1.2 Mpa

Regulated Deficit Irrigation (RDI)
- received 80% of $E_{tc}$ from bloom to set and from veraison to harvest
- received 50% of $E_{tc}$ from set to veraison
- dynamic grape coefficient factor ($K_c$) included
- leaf $\psi$ maintained at -1.4 Mpa
Results
# Daily Ambient Temperature Maxima

<table>
<thead>
<tr>
<th>Number of Days</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 32°C</td>
<td>61</td>
<td>71</td>
</tr>
<tr>
<td>&gt; 37°C</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

![Graph showing daily ambient temperature maxima over days after budbreak for 2013 and 2014.]
Irrigation Treatment Difference:
0.34 ML/ha
Seasonal Water Relations
2014

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Irrigation Treatment
Difference: 0.48 ML/ha
Mid-day leaf water potential

A

-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5

Mid-day leaf water potential (MPa)

0 20 40 60 80 100 120 140 160 180

Days after budbreak

- Sustained deficit irrigation
- Regulated deficit irrigation

B

-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5

Mid-day leaf water potential (MPa)

0 20 40 60 80 100 120 140 160 180

Days after bud break

- Sustained deficit irrigation
- Regulated deficit irrigation
Leaf Layer Number

**2013**
- 3-May: 5
- 7-Jul: 5
- 9-Aug: 5

**2014**
- 30-April: 4
- 20-June: 4
- 1-August: 4

*Legends:*
- **Control**
- **Pre-Bloom**
Functional Leaf Area/m

Mechanical Severity  – approx. 20% reduction in leaf area
Vegetative Compensation Response

- Critical factor in determining lasting effects of improved microclimate and yield status
- Response dependent on severity, timing, and frequency of LR

- Pre-Bloom
  - Recovery response observed but incomplete
    - Mechanical blower effect on incipient and lateral shoot tips
    - Positive effects of defoliation long lived

- Post-fruit set
  - In 2013 vines re-filled soon after defoliation
  - In 2014 recovery occurred but remained more open
    - Due to cane pulling as observed in previous studies
## Yield components

<table>
<thead>
<tr>
<th></th>
<th>Berry mass (g)</th>
<th>Berry skin mass (mg)</th>
<th>Yield (kg/m)</th>
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<tbody>
<tr>
<td><strong>Leaf removal</strong></td>
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</tr>
<tr>
<td>Control</td>
<td>1.36&lt;sup&gt;a&lt;/sup&gt; a</td>
<td>55.0 a</td>
<td>6.64</td>
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<tr>
<td>Pre-bloom</td>
<td>1.27 b</td>
<td>51.7 a</td>
<td>6.34</td>
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<tr>
<td>Post-fruit set</td>
<td>1.28 b</td>
<td>45.0 b</td>
<td>6.78</td>
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<tr>
<td>Pr&gt;F</td>
<td>0.0216</td>
<td>0.002</td>
<td>0.4996</td>
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<td><strong>ET&lt;sub&gt;c&lt;/sub&gt; fraction</strong></td>
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<tr>
<td>SDI</td>
<td>1.34 a</td>
<td>51.3</td>
<td>6.86</td>
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<tr>
<td>RDI</td>
<td>1.26 b</td>
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<tr>
<td>LR × ET&lt;sub&gt;c&lt;/sub&gt; fraction</td>
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<td><strong>2014</strong></td>
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<tr>
<td><strong>Leaf removal</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.09</td>
<td>45.3 a</td>
<td>6.17 a</td>
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<tr>
<td>Pre-bloom</td>
<td>1.07</td>
<td>42.9 ab</td>
<td>6.10 a</td>
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<td>Post-fruit set</td>
<td>1.11</td>
<td>39.5 b</td>
<td>4.46 b</td>
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<td>0.5314</td>
<td>0.031</td>
<td>0.0016</td>
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<td><strong>ET&lt;sub&gt;c&lt;/sub&gt; fraction</strong></td>
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<td></td>
<td></td>
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<tr>
<td>SDI</td>
<td>1.14 a</td>
<td>42.7</td>
<td>6.08 a</td>
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<tr>
<td>RDI</td>
<td>1.04 b</td>
<td>42.3</td>
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<tr>
<td>Pr&gt;F</td>
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<td>0.6963</td>
<td>0.0003</td>
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<tr>
<td>LR × ET&lt;sub&gt;c&lt;/sub&gt; fraction</td>
<td>0.4878</td>
<td>0.5892</td>
<td>0.0053</td>
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Chemical Composition
## Fruit Composition

<table>
<thead>
<tr>
<th></th>
<th>TSS (%)</th>
<th>Juice pH</th>
<th>TA (g/L)</th>
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<td><strong>Leaf removal</strong></td>
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<tr>
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<td>3.57</td>
<td>5.26</td>
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<tr>
<td>Pre-bloom</td>
<td>24.7 a</td>
<td>3.59</td>
<td>4.78</td>
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<tr>
<td>Post-fruit set</td>
<td>24.0 b</td>
<td>3.58</td>
<td>5.06</td>
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<tr>
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<td>0.0171</td>
<td>ns</td>
<td>ns</td>
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<tr>
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<td>24.2 b</td>
<td>3.59</td>
<td>5.04</td>
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<td>24.7 a</td>
<td>3.57</td>
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<td><strong>Leaf removal</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>24.3</td>
<td>3.60</td>
<td>4.83</td>
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<tr>
<td>Pre-bloom</td>
<td>24.1</td>
<td>3.62</td>
<td>4.66</td>
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<tr>
<td>Post-fruit set</td>
<td>24.2</td>
<td>3.64</td>
<td>4.69</td>
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<tr>
<td>Pr&gt;F</td>
<td>ns</td>
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<tr>
<td><strong>Deficit irrigation</strong></td>
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<td></td>
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<tr>
<td>SDI</td>
<td>23.9 b</td>
<td>3.63</td>
<td>4.83</td>
</tr>
<tr>
<td>RDI</td>
<td>24.5 a</td>
<td>3.61</td>
<td>4.62</td>
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<tr>
<td>Pr&gt;F</td>
<td>0.0199</td>
<td>ns</td>
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</table>
Mechanical leaf removal effects on flavonoid composition (Merlot/Freedom) in mg/kg

<table>
<thead>
<tr>
<th></th>
<th>quercetin</th>
<th>myricetin</th>
<th>Total skin anthocyanin</th>
<th>Astringency</th>
</tr>
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<tbody>
<tr>
<td><strong>2013</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No leaf removal</td>
<td>180 b</td>
<td>16.4 b</td>
<td>2066.4 b</td>
<td>14.1ab</td>
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<tr>
<td>Pre-bloom</td>
<td>335 a</td>
<td>23.7 a</td>
<td>2763.9 a</td>
<td>13.9 b</td>
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<tr>
<td>Post-fruit set</td>
<td>262 a</td>
<td>22.9 a</td>
<td>2381.5ab</td>
<td>15.9a</td>
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<tr>
<td><em>Pr&gt;F</em></td>
<td>0.0003</td>
<td>0.0133</td>
<td>0.0055</td>
<td>0.0172</td>
</tr>
<tr>
<td><strong>2014</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No leaf removal</td>
<td>325 b</td>
<td>17.9 b</td>
<td>1554.1 b</td>
<td>20.2 a</td>
</tr>
<tr>
<td>Pre-bloom</td>
<td>390 ab</td>
<td>22.0 a</td>
<td>2135.3 a</td>
<td>17.9 b</td>
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<tr>
<td>Post-fruit set</td>
<td>432.1 a</td>
<td>22.3 a</td>
<td>2044.9 a</td>
<td>18.6 a</td>
</tr>
<tr>
<td><em>Pr&gt;F</em></td>
<td>0.0132</td>
<td>0.0395</td>
<td>0.0014</td>
<td>0.0454</td>
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</table>
Effect of applied water amounts on anthocyanin composition in presence of leaf removal

<table>
<thead>
<tr>
<th>Applied water amount</th>
<th>Less stable (%)</th>
<th>More stable (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td></td>
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<tr>
<td><strong>Year 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustained deficit irrigation</td>
<td>22.9 a</td>
<td>77.1 b</td>
</tr>
<tr>
<td>Regulated deficit irrigation</td>
<td>20.5 b</td>
<td>79.5 a</td>
</tr>
<tr>
<td>$Pr&gt;F$</td>
<td>0.0011</td>
<td>0.0483</td>
</tr>
<tr>
<td><strong>Year 2</strong></td>
<td></td>
<td></td>
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<tr>
<td>Sustained deficit irrigation</td>
<td>15.9 a</td>
<td>84.1 b</td>
</tr>
<tr>
<td>Regulated deficit irrigation</td>
<td>12.1 b</td>
<td>87.9 a</td>
</tr>
<tr>
<td>$Pr&gt;F$</td>
<td>0.0012</td>
<td>0.0011</td>
</tr>
</tbody>
</table>
Effect of light exposure on skin and seed tannin concentration
Effects of light exposure and applied water on skin tannin conversion yield
Effects of light exposure and applied water on skin tannin on coarseness

![Graph showing effects of light exposure and applied water on skin tannin on coarseness](image-url)
Summary

• Pre-Bloom Leaf Removal
  • allowed increased light filtration earlier in season
  • canopy open throughout season to 20% ambient PAR
  • promoted skin tissue formation (acclimation is key)
  • maximum phenolic concentration without loss of yield
  • Less skin tannin, but more stable and less coarse

• Post-Set Leaf Removal
  • often performed poorly, seemingly better in 2014 but loss of yield
  • sudden increase in light and temperature detrimental to phenolic biosynthesis
  • More tannin concentration
  • Subject to oxidation
  • Coarser skin tannin
Summary

• Applied water
  • no effect on majority of parameters, direct and positive compositional shift towards tri-OH anthocyanins with RDI, yield may be reduced
  • allows growers to reduce costs

• Applied water
  • No effect on tannin content or composition
  • Ability to apply less to reduce costs
Acknowledgements

• The American Vineyard Foundation
• Lab members: Michael Cook, Cliff Yu, Geoffrey Dervishian, Clint Nelson, Andrew Beebe, Andy Mendez, Nilgun Gorgec, Tiffany Gunduz, and Yaritza Aguirre