Physiology vs. culture

Plant physiologists are primarily interested in learning how [vines] grow, while [viticulturists] are interested primarily in how to grow [vines] efficiently. The two objectives are more closely related than generally supposed because in order to grow [vines] efficiently one must understand the basic physiological processes which control growth and how they are affected by environmental factors and cultural processes...The greatest overall progress will occur when physiologists learn more about how [vines] grow while [viticulturists] learn more about the physiology of [vines]...

*Physiology of Woody Plants*  
(Kramer and Kozlowski, 1979)
Structure and properties of WATER
Size, shape, and polarity

Taiz and Zeiger (2010)
High surface tension

[Diagram showing gas and water with arrows indicating surface tension]

Surface tension of several liquids at 20°C (N/m)

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Surface Tension (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% gelatin</td>
<td>0.0083</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.0228</td>
</tr>
<tr>
<td>Phenol</td>
<td>0.0409</td>
</tr>
<tr>
<td>Water</td>
<td>0.0728</td>
</tr>
</tbody>
</table>

Talz and Zeiger (2010)
Cohesion, adhesion, and capillarity

(A) "Wettable" (hydrophilic substrate)

θ < 90°

H₂O

θ > 90°

H₂O

Hydrophobic substrate

(B) Force from surface tension

Net force

Gravity

θ ~ 0°

H₂O

θ = 140°

Hg

Taiz and Zeiger (2010)
High tensile strength

Taiz and Zeiger (2010)
Water
TRANSPORT PROCESSES
Diffusion
Osmosis
Bulk or mass flow
Water movement through SOIL-PLANT-ATMOSPHERE CONTINUUM
Water potential ($\Psi$)

- $\Psi = 0$ MPa
  - Pure water
- $\Psi = -1.0$ MPa
- $\Psi = -10$ MPa

"Water flows downhill"

Decreasing potential energy
Stomates: connection to atmosphere

H$_2$O from xylem

H$_2$O

RH = ~100%

H$_2$O

CO$_2$

Leaf

Atmosphere
Xylem: specialized pipes
Gradient from soil to root cell
Water flow through vines

\[ \Psi = -100 \text{ MPa} \]

\[ \Psi = -0.8 \text{ MPa} \]

\[ \Psi = -0.03 \text{ MPa} \]
Daily and seasonal

VINE WATER RELATIONS
Time lag between water loss and uptake

![Graph showing time lag between water loss and uptake](image)
Diurnal course of water potential
Seasonal course of midday $\Psi_{\text{leaf}}$
Cultivar-specific stomatal behavior

![Graph showing stomatal conductance against midday leaf water potential for different cultivars.]

- Tannat
- Cab. Sauv.
- Petit Verdot

Levin et al. (In revision)
Midday $\Psi_i$ (MPa)

Irrigation Treatment
(fraction of estimated $ET_c$)

5C
110R
Freedom
1103P
140Ru

L. E. Williams (2010)
Factors affecting VINE WATER USE
Solar radiation drives vine ET
Crop coefficient depends on row spacing
Crop coefficient depends on trellis type

![Graph showing crop coefficient over day of year for different trellis types: Lysimeter, Quad Cordons, CA Sprawl, Horizontal Split, VSP.]
Water use declines with soil water depletion

\[ y = -0.524 + 0.059x \]

\[ R^2 = 0.82^{***} \]
Effects of water deficits on VEGETATIVE GROWTH
General plant response to water stress

- Growth adjustment
- "Drought management"
- "Drought escape"

Bradford and Hsiao 1982
Rating tendrils

Photo by AD Levin
Rating shoot tips

Rapid Growth  Slowing Growth  Almost Stopped  Stopped  Dead Tip

Photo by Advanced Viticulture, Inc.
Effects of water stress on organ growth

Growth stops at:
- 10 bars for leaves
- 12 bars for internodes
- 13 bars for tendrils

Growth most sensitive in:
1. Tendrils
2. Leaves
3. Internodes

Schultz and Matthews 1988
Leaf angle and sun avoidance
Effect of water potential on leaf angle

Levin et al (unpublished data)
### Effect of cultivar on leaf angle

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Leaf angle (degrees from horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freisa</td>
<td>-78.6 c</td>
</tr>
<tr>
<td>Petit Verdot</td>
<td>-77.3 c</td>
</tr>
<tr>
<td>Souzão</td>
<td>-77.3 c</td>
</tr>
<tr>
<td>Refosco</td>
<td>-76.4 c</td>
</tr>
<tr>
<td>Touriga Nacional</td>
<td>-73.5 bc</td>
</tr>
<tr>
<td>Tempranillo</td>
<td>-72.9 abc</td>
</tr>
<tr>
<td>Grenache noir</td>
<td>-69.0 abc</td>
</tr>
<tr>
<td>Syrah</td>
<td>-66.8 abc</td>
</tr>
<tr>
<td>Tannat</td>
<td>-59.7 ab</td>
</tr>
<tr>
<td>Cabernet Sauvignon</td>
<td>-58.0 a</td>
</tr>
</tbody>
</table>

More horizontal or erect

Levin et al (unpublished data)
Leaf senescence and desiccation
Effect of water potential on leaf drop

Levin et al (unpublished data)
Water deficits reduce shoot growth

[Graph showing the relationship between shoot length (cm) and day of year, with different water deficit levels (1.4, 1.0, 0.6, 0.2).]

Williams et al. (2010)
Pruning weight response to midday $\Psi_{\text{leaf}}$

\[ y = 41.8 + 31.9x \]
\[ r = 0.94 \]
Effects of water deficits on reproductive growth
Reproductive growth is less sensitive
Berry growth occurs in two phases:

- Veraison
- Harvest

Graph showing berry weight (g) over time.
Diurnal berry contraction pre- and postveraison

Berry Diameter (mm)

Days Relative to Berry Coloration

Matthews and Shackel 2005
Contraction more sensitive preveraison

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Graph showing the relationship between Berry Contraction (% of diameter) and Midday Leaf Ψ (MPa). The graph compares Pre-veraison and Post-veraison data, with Pre-veraison having a higher correlation coefficient ($r^2 = 0.61$) compared to Post-veraison ($r^2 = 0.09$).

Reference: Greenspan, Shackel, Matthews 1995
Growth rate more sensitive preveraison
THANKS A BUNCH!

QUESTIONS?

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