VINEYARD WATER MANAGEMENT
SCHEDULING, MONITORING AND STRATEGIES

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Concepts to discuss

- Physiology of vine water stress
- Water management practices and strategies
  - Irrigation minimization
  - Wine style manipulation
- Irrigation management
  - Scheduling
  - Efficient water use
  - Measurement & monitoring techniques
Water – deficit and drought

- Water is held within soil matrix by adhesive properties of water
- More water – thicker film and water available from larger pores
- As soil dries, water film thins out and water nearer to surfaces requires more energy for extraction

\[ \Psi_m \approx -0.1 \text{ bar to } -0.3 \text{ bars (kPa)} (-30 \text{ cbars: Field Capacity}) \]
\[ \Psi_m \approx -3 \text{ bars (-300 cbars, kPa): mid-range, slight-moderate stress} \]
\[ \Psi_m \approx -15 \text{ bars (-1500 cbars, kPa): Permanent Wilting} \]
Water – deficit and drought

- Water flow in vine primarily via transpiration
  - Evaporation of water in sub-stomatal cavity
  - Water is “pulled” through the vine by cohesion of water molecules
- Plant water stress is from either or both:
  - Drying soil, so lower (more negative) $\Psi_m$
  - Higher evaporative demand (VPD)
- As transpiration exceeds uptake:
  - Cell turgor declines
  - Cell volume declines
  - Solute concentration within cells increases
    - $\Psi_\pi$ of cell decreases (more negative, higher magnitude)
  - Moderate water stress: $\Psi_{leaf} = -12$ to $-15$ bars
  - Severe water stress: $\Psi_{leaf} < -15$ bars
Water – deficit and drought

- Stomata close to prevent water loss and prevent xylem cavitation
- Xylem cavitation (embolism) is a common occurrence in grapevine
- Not an adaptation
Hormonal response

- Abscisic acid (ABA) and cytokinins are primary hormones affected by water stress

- ABA production stimulated **rapidly** in response to water stress
- Cytokinlin production declines during water stress, but **slowly**
- Root ABA may be delayed in getting to leaves, but hydraulic “signal” (declining turgor) induces rapid production of ABA in the leaves
- ABA: stomatal closure; reduces auxin effects in stimulating vegetative growth; effect on ripening
- Cytokinin: cell division; leaf abscission
Plan to manipulate vine water status during the growing season

Strategies may be imposed to change wine style in any given vineyard

Strategies may be imposed to make efficient use of limited water resources

Red varieties are more amenable to water deficit strategies than are white varieties
Budbreak

- Control shoot growth
- Avoid stress during fruit set
- Avoid excess shoot growth
- Affect vegetative character of wines

Bloom & Fruit Set

- Control berry size
- Skin:Pulp ratio
- Stimulate ripening enzymes
- Avoid heat stress
- Affect tannin and structure of red wines

Veraison

- Maintain and stimulate ripening process
- Avoid heat stress
- Avoid berry shrivel
- Affect “ripe fruit” and jammy wine characteristics

Maturity

- Avoid stress during fruit set
- Avoid excess shoot growth
- Affect vegetative character of wines
Budbreak to Bloom

- Vegetative growth very sensitive to water availability
- Do not provide too much water to over-stimulate shoots
- Do not over-stress vines. May cause poor fruit set

- Too much stress $\rightarrow$ (LWP < -11 bars)
  - * poor to very poor fruit set
  - * insufficient canopy growth

- Too little stress $\rightarrow$ (LWP > -8 bars)
  - * excessive vegetative growth
  - * vegetative flavors in wine
  - * elevated disease risk
  - * additional farming costs
Budbreak to Bloom

- In wet winter climates, the soil profile is full at budbreak
- Prolong the uptake of water in the soil by delaying irrigation for as long as possible
- Avoid luxurious growth of canopy by appropriate cover crop management
- In a wet winter climate, biggest mistake is to irrigate too early with drip irrigation !!!
Visual Indicators

Growing  Slowing  Stopped  Dead Tip
Cover crops to slow growth
Or, early tillage (?) & mowing
Water – deficit and drought

- Shoot growth most sensitive process to water stress
Delayed irrigation initiation for wet winter climates

Delayed Irrigation

Early Irrigation
Deliberate water stress

- Deficit irrigation: applying less water via irrigation than is being transpired, this reducing soil moisture reserves
  - Control shoot growth before veraison
  - Root growth less sensitive than shoot growth to water deficits
  - Control berry size between set and veraison
  - Stimulate ripening processes at and after veraison **
    - ABA stimulates enzymes involved with ripening processes
    - Elevated ABA is desired at veraison in red varieties
    - Maintain moderate stress during ripening without excessive stress
Pre-Veraison Shoot Sap Flow Schematic

- Xylem Flow
- Phloem Flow
- Transpiration

Width of line indicates relative amount of flow.
Post-Veraison Shoot Sap Flow Schematic

- **Shoot Tip**
- **Leaf**
- **Stem**
- **Berry**

Width of line indicates relative amount of flow

- **Xylem Flow**
- **Phloem Flow**
- **Transpiration**
Water relations and water status

- Berry size less sensitive to short-term water deficits; hence less yield impact
- Severe water stress can:
  - retard sugar production and accumulation
  - reduce canopy effectiveness; possible defoliation
  - trigger premature berry desiccation
- Insufficient water stress can:
  - dilute phloem sap and retard sugar accumulation
  - reduce effect of veraison stress
  - possibly induce vegetative growth
Strategies Simplified

- Whites benefit less from water deficit than reds
- Three berry growth periods: Fruit set-near veraison / near-veraison / veraison to harvest
- Set to veraison deficit:
  - Smaller berries – good for tight-clustered cultivars
  - More intense tannin in wines, but can give too much astringency
  - Reduction in vegetative character in large canopies
- “Magic window” – about 2 weeks before veraison
- Veraison to harvest deficit:
  - Enhancement / acceleration of ripe characteristics
  - Prevention of canopy growth and slow sugar accumulation
Irrigation Flowchart

- Determine Site Characteristics
  - Rooting Depth
  - Soil “Type”

- Install Soil Moisture Sensors to:
  - Determine ideal volume
  - Determine nominal interval

- Monitor
  - Continuous soil moisture profile
  - Plant water status

- Check against target levels
  - Soil Moisture
  - Plant water status

- Adjust
  - Interval
  - Volume
Proper volume and interval
Proper volume and interval
Irrigation Scheduling

- **Volume and Interval**
- Need to learn about your soils and your root systems

|                  | Shallow (< 24”) | Deep (>36”)
|------------------|-----------------|-------------
| Light Textured and/or gravelly | Very Low Vol. & Very Frequent | Moderate Vol. & Frequent |
| Heavy Textured   | Low Vol. & Frequent | High Volume & Infrequent |

Hillsides

Valley Floor
Identify rooting depth
Rooting depth map
Irregular root zone and/or soil

Determining proper volume
Irregular root zone and/or soil

Irrigation volume to weakest portion of block
Scheduling

- How much and how often?

Evapotranspiration (ET)

versus

Soil moisture based scheduling
Irrigation Scheduling

*ET-based*

Greenspan, M.D. Integrated Irrigation Management in California. Practical Winery and Vineyard.

Part 1: March/April 2005
Part 2: May/June 2005

Irrigation (inches) = ETo (inches) * Kc * Km

Where:
- ETo is reference ET
- Kc is crop coefficient
- Km is “management coefficient” (% full ET)
Irrigation Scheduling

*Soil moisture based*

Uses soil-moisture sensors to determine depth of irrigation and depletion of soil moisture to determine intervals.
Soil Moisture Measurement

- Measure at multiple levels to determine depth of irrigation
- Measure continuously (electronic datalogger)!
- For drip irrigation, measure close to the dripper (4in., 10cm)
- Use to determine nominal irrigation **volume per application**
- Use to determine nominal irrigation **interval between applications**
- Use in conjunction with plant moisture measurements to adjust **intervals**
Electronic Soil Moisture measurement

➡️ Soil matric potential sensors

Soil water content sensors & probes ↓→
## Comparison of soil moisture sensor types

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volumetric</strong></td>
<td><strong>Matric Potential</strong></td>
</tr>
<tr>
<td>• Available in multi-level</td>
<td>• True physical measurement</td>
</tr>
<tr>
<td>• Easy to interpret patterns</td>
<td>• Does not require calibration</td>
</tr>
<tr>
<td>• Getting less expensive</td>
<td>• Inexpensive*</td>
</tr>
<tr>
<td></td>
<td>• Discrete sensors not available in multi-level</td>
</tr>
<tr>
<td></td>
<td>• Measures only the wetter portion of SM</td>
</tr>
</tbody>
</table>

* Cost is increased with multiple sensors
# Comparison of portable versus fixed soil moisture sensors

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Portable</strong></td>
<td>• One instrument measures many locations</td>
<td>• Snapshots only</td>
</tr>
<tr>
<td></td>
<td>• Therefore, lower cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Neutron probe accuracy</td>
<td></td>
</tr>
<tr>
<td><strong>Fixed</strong></td>
<td>• Continuous measurement</td>
<td>• More expensive due to multiple instruments</td>
</tr>
<tr>
<td></td>
<td>• Patterns of wetting and depletion can be very useful</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May be delivered by telemetry</td>
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Total soil moisture in profile

Upper limit of RAW

Progressive stress reflected in slope

Set a reference volume for refill point

Lower limit of RAW
Plant Water status measurement

Pressure Chamber →

Porometer ←

Petiole Diameter →
Pressure chamber

- Measures “suction” in the xylem vessels
- Advantages: Portability; repeatability; ruggedness
- Disadvantages:
  - No indication of vine physiological response; reading depends on time since last irrigation, grape variety, daytime conditions, etc.
  - Reading can be misleading on its own
- IMPORTANT: Place leaves in plastic bags immediately before removal and during measurement
Porometer

- Measures stomatal conductance (facility of pores to transpire water)
- Advantages: Portability; vine response to water status; indirect indication of photosynthesis
- Disadvantages: Less rugged instrument; sensitive to environmental conditions; more variability than leaf water potential measurements
What are stomata?

Carbon dioxide enters, while water and oxygen exit, through a leaf’s stomata.
<table>
<thead>
<tr>
<th>Variety</th>
<th>Stomatal density (mm(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabernet Sauvignon</td>
<td>180.0</td>
</tr>
<tr>
<td>Chardonnay</td>
<td>225.5</td>
</tr>
<tr>
<td>Flame Seedless</td>
<td>189.3</td>
</tr>
<tr>
<td>Merlot</td>
<td>174.5</td>
</tr>
<tr>
<td>Pinot Noir</td>
<td>184.0</td>
</tr>
<tr>
<td>Riesling</td>
<td>232.6</td>
</tr>
<tr>
<td>Sauvignon Blanc</td>
<td>213.4</td>
</tr>
<tr>
<td>Semillon</td>
<td>190.1</td>
</tr>
<tr>
<td>Shiraz</td>
<td>167.4</td>
</tr>
<tr>
<td>Sultana</td>
<td>162.0</td>
</tr>
</tbody>
</table>
Units are in mmol/m^2/s

500 450 400 350 300 250 200 150 100 50 0

“Luxury”  Mid-Range  Slight Stress  Mod. Stress  High Stress  Extreme Stress

Target Range for White varieties  Target Range for Red varieties
Romero et al., 2010 AJEV 61:300-312
Case: Napa Cab – young block

Soil Moisture Graph

Sensor Value vs Time

Aug 1  Aug 15  Aug 29  Sep 12

[5102:6.1] 4” Aeck SM
[5102:6.2] 8” Aeck SM
[5102:6.3] 16”heck SM
[5102:6.4] 24”heck SM
[5102:6.5] 32”heck SM
[5102:6.6] 40”heck SM
[5102:20] SM
Case: Napa Cab – young block
Problem irrigation
Problem irrigation
Problem irrigation
Soil moisture before irrigation
Irrigation imminent
Irrigation not imminent
• Water management
• Nutrition management
• General viticulture
• Vineyard design
• Vineyard management
• Vineyard development

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