Methods and Tools for Irrigation Scheduling

UC ANR Wine Grape Irrigation Short Course
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1) Review some Basics of Crop Water Use

2) Methods and Tools for Scheduling Irrigation

3) Discuss Advantages and Drawbacks of these Methods
WHAT DRIVES GRAPEVINE WATER USE (ET)?

✓ Water use is driven by the amount of energy intercepted by canopy

✓ The canopy encounters this energy as direct radiation from the sun, and indirect energy sources (warm air, wind, advection)

✓ The combined effect of these direct & indirect energy sources on the plants’ canopy determine vine water use when soil moisture is not limited.
IRRIGATION SCHEDULING

It provides answers to the following questions:

1) When to irrigate our crops?
   Before plants face water deficit (or at specific deficit/stress levels beneficial for yield & quality)

2) How much water to apply?
   The amount of water used by the crop since the last irrigation or rainfall (or a portion of ET max to maintain a target stress level)

3) How to best apply the necessary amount of water?
   Uniformly or Site-specifically
   Frequent-light or Infrequent-deep
   Application rate and volume compatible with the soil infiltration and storage capacity, or energy rates
METHODS FOR IRRIGATION SCHEDULING

**Weather-based**
- Estimate of Crop Water Use (ET)
- Very common
- Requires data & calculations

**Soil-based**
- Assess Soil Water Status
- Equipment intensive
- Good for periodic check

**Plant-based**
- Detects Plant Water Status
- Labor intensive
- Well-developed for some crops, not all

All irrigation scheduling methods require skilled on-farm personnel & capacity for trouble-shooting.
WEATHER OR ET-BASED SCHEDULING

Basic criterion:
replenish the amount of water used by the crop (ET<sub>C</sub>) since the last irrigation

Crop ET = Reference ET x Crop Coefficient

\[ ET_C = ET_O \times k_C \]

1) Use historical ET averages (ET<sub>C</sub>, or ET<sub>O</sub> and K<sub>c</sub> values)
2) Use real-time ET<sub>O</sub> and K<sub>c</sub> values
3) Use ETo forecast and K<sub>c</sub> values
Historical $\text{ET}_C$ average estimates

http://www.itrc.org/projects/cacrop.htm

### ZONE 10 $\text{ET}_C$ - drip & micro-spray – DRY YEAR

<table>
<thead>
<tr>
<th>ETc Zone 10 - drip &amp; micro-spr - dry year</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
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<th>OCT</th>
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<td>Immature Peaches, Nectarines, etc</td>
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<td>24.9</td>
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<td>4.9</td>
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<td>Citrus (no ground cover)</td>
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<td>4.2</td>
<td>4.0</td>
<td>3.9</td>
<td>4.1</td>
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<td>2.6</td>
<td>1.9</td>
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<td>1.4</td>
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<td>5.9</td>
<td>5.1</td>
<td>3.6</td>
<td>2.0</td>
<td>0.8</td>
<td>0.2</td>
<td>35.8</td>
</tr>
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</table>
Historical ET₀ average estimates: [http://wwwcimis.water.ca.gov/cimis](http://wwwcimis.water.ca.gov/cimis)
ETc = ETo \times Kc
DRAWBACKS OF ET-BASED SCHEDULING

ET estimated with generalized Kc values may be quite different from the actual ET in the site-specific conditions of our vineyard.

RISK OF OVER-IRRIGATION OR UNDER-IRRIGATION

Most of the available Kc information was developed for:

- Infrequent irrigation methods, such as surface or sprinkler irrigation
- Well-drained soils, and level (flat) grounds
- Crop varieties, rootstocks, plant densities, and canopy management practices that were quite different from the current

MICRO-IRRIGATION IS A GAME-CHANGER
(SPOON-FEEDS WATER AND NUTRIENTS TO CROPS)

Looking only at ET may be limiting for Fruit and Nut Crops

NEED TO LOOK AT THE PLANT WATER AND SOIL WATER STATUS
- Cabernet sauvignon (clone 15)
- Planted in 2000 - density of 3,703 vines ha\(^{-1}\) (spacing 1.8 x 1.5 m.)
- Vine rows oriented in a north-south direction.
- Vines were trained as (VSP) and pruned to 14, 2-bud spurs per vine.

- Loam soil with a typical depth to 60 cm (SSURGO).
- The slope (RTK GPS) 24.4% N and 25.4% S
Cumulative ET (mm/day) and cumulative precipitation + irrigation (mm/day) on North and South facing slopes at Safari Vineyards (April 8-Oct 18, 2016)

(D. Zaccaria, L. Wunderlich, R. Snyder, K. Shackel)

Cumulative ET or Precipitation + Irrigation (mm/day)

S: 320 gal/vine (17.0 ac-inch)
N: 313 gal/vine (16.6 ac-inch)
N ave. 186 gal/vine (8.8 ac-inch)
S ave. 143 gal/vine (7.6 ac-inch)
VINE WATER USE (ET) INCREASE LINEARLY WITH THE % OF GROUND SURFACE SHADED BY THE VINES’ CANOPY (L. Williams, 2002)

\[ K_c = 0.002 + 0.017 \times \% \text{ Shaded Area} \]

Simplified formula: \[ K_c = 1.7 \times \% \text{ Shaded Area} \]

**Calculation example**

7-foot vine spacing x 11-foot row spacing = 77 sq-ft. x vine

Shaded area: 31 sq-ft./77 sq-ft. = 40%

\[ K_c = 1.7 \times 0.40 = 0.68 \]
<table>
<thead>
<tr>
<th>Date</th>
<th>Light interception N block (%)</th>
<th>Light interception S block (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2</td>
<td>18.0</td>
<td>16.5</td>
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<tr>
<td>May 17</td>
<td>36.5</td>
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<tr>
<td>May 23</td>
<td>43.5</td>
<td>35.5</td>
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<tr>
<td>June 1</td>
<td>53.5</td>
<td>44.0</td>
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<td>June 8</td>
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<td>June 13</td>
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<td>June 20</td>
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<td>June 29</td>
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<td>July 6</td>
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<td>July 18</td>
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<td>July 26</td>
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<td>August 2</td>
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<td>August 13</td>
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<td>August 24</td>
<td>44.0</td>
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<tr>
<td>September 4</td>
<td>43.5</td>
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</tbody>
</table>

Grapevine light interception in N (blue) and S (red) blocks - 2018
SOIL MOISTURE-BASED IRRIGATION SCHEDULING

1. Observe soil moisture frequently
2. Start irrigation at target level of soil moisture (allowable depletion, allowable matric potential or tension)
3. Stop irrigation when soil moisture reaches target levels
SOIL MOISTURE MONITORING

Keeps track of what happens in the root zone with regard to:

1. How much water infiltrates during an irrigation
2. How much water is taken up by plants between irrigations
3. Maintaining good soil water conditions for plants growth & production
S.M.M. HELPS ANSWERING THE FOLLOWING QUESTIONS

✓ When to start irrigation (and when to stop it)?

✓ Has enough water infiltrated the root zone during an irrigation?

✓ Are we applying enough, insufficient, or excessive water?

✓ Is there any deep soil water reserve for crop water uptake during periods of no irrigation, or at bud-break/green-up/harvest?
HOW IS SOIL MOISTURE MEASURED?

SOIL MOISTURE CONTENT (%, in/ft, mm/m)
How much water is available per unit of soil?
% weight = \( \frac{\text{weight of water}}{\text{weight of dry soil}} \times 100 \)
% volume = \( \frac{\text{volume of water}}{\text{volume of soil}} \times 100 \)

Depth = (inch of water/foot of soil) => MOST COMMON AND PRACTICAL

SOIL MOISTURE TENSION (centibars, kPa)
How strongly water is held by soil particles
The higher the tension, the drier the soil and the more difficult is for plant to extract water

Depth

- 5 kPa
- 30 kPa
- 150 kPa

SOIL MOISTURE CONTENT

- 45%
- 55%
- 55%
- 30%
- 10%
Some sensors measure soil water content and others measure soil water tension.

In reality all sensors measure some properties/parameters that are related to soil moisture content or soil moisture tension through a specific calibration.
SOIL WATER TENSION

- Read from 0 to 200 centibars
  - Low soil moisture tension indicates moist soil
  - High soil moisture tension indicates dry soil
- Saturated soil after irrigation or rainfall
  - Reading < 5-10
  - Don’t need further calculations; easy to interpret
  - Robust and reliable in field conditions
  - Buffers against salinity
  - Can be hooked up with data loggers and telemetry and monitor in continuous mode

GYPSUM BLOCKS (tension)

- Very cheap & Maintenance free
- Can last 1-5 years (soil moisture)
- Sensitive to soil temperature
- Corrosion of electrodes
North Station

Root Depth = 0.75 - 0.95 m

36 in (0.9 m) → It was not installed because soil has a lot of rock

12 in (0.3 m)

24 in (0.6 m)

South Station

Root Depth = 0.75 - 0.95 m

36 in (0.9 m) → It was not installed because soil has a lot of rock

12 in (0.3 m)
Recommended values of soil moisture tension at which irrigation should occur (50% of PAW)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Soil Moisture Tension (centibars)</th>
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</thead>
<tbody>
<tr>
<td>Sand or loamy sand</td>
<td>40-50</td>
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<tr>
<td>Sandy loam</td>
<td>50-70</td>
</tr>
<tr>
<td>Loam</td>
<td>60-90</td>
</tr>
<tr>
<td>Clay loam or clay</td>
<td>90-120</td>
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</table>

Soil moisture content at which irrigation should occur (@ 50% of PAW depleted)

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Soil Moisture Content (%)</th>
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<tbody>
<tr>
<td>Sand</td>
<td>7</td>
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<tr>
<td>Loamy Sand</td>
<td>12</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>15</td>
</tr>
<tr>
<td>Loam</td>
<td>20</td>
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<tr>
<td>Silt Loam</td>
<td>23</td>
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<tr>
<td>Silty Clay Loam</td>
<td>28</td>
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<tr>
<td>Clay Loam</td>
<td>27</td>
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<tr>
<td>Sandy Clay Loam</td>
<td>24</td>
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<td>Sandy Clay</td>
<td>22</td>
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<tr>
<td>Silty Clay</td>
<td>30</td>
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<td>Clay</td>
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</table>
Plants may face water stress even under well-watered soil conditions (salinity/sodicity, hypoxia, soil-water piling up due to perched water table or compaction layers)
WITH MICRO-IRRIGATION THERE MAY BE SOME PREFERENTIAL WATER FLOW AND NON-HOMOGENEOUS SOIL MOISTURE

SM CAN BE USED AS FEEDBACK INFORMATION AFTER IRRIGATIONS

NEED TO LOOK AT THE PLANT WATER AND SOIL WATER STATUS
Methods to Monitor Plant Water Status (and Stress)

Leaf/Stem Water Potential  Sap Flow  Canopy Temperature
Pressure Chamber to Measure Leaf/Stem Water Potential

✓ Pressure bombs consist of a chamber that can be brought to different pressures using nitrogen gas or air.

✓ The petiole of a leaf protrudes from the chamber so that one can see when water bubbles from the end.

✓ By slowly stepping up the pressure in the chamber one can determine the water potential in the leaf.

✓ The higher pressure, the more the leaf is water stressed.
Dendrometers and Other Plant Sensors
COMBINATIONS OF DIFFERENT APPROACHES

- **Plant-based (Monitoring plant water status)**
- **Weather-based (Estimating the crop water use)**
- **Soil-based (Monitoring soil moisture)**

→ **Proper Irrigation Timing**
→ **Adequate Irrigation Amount**
→ **Check for Feedback**
Mild-Moderate water deficits in the period pre-veraison to veraison can control expansive vegetative growth while still allowing photosynthesis at unaffected rates to produce carbohydrates.
Experimentation in the Sacramento Valley and North Coast showed that -12 to -13 bars for white varieties and -14 to -15 bars for red varieties are reasonable water deficit thresholds to start irrigation.

A RDI after the deficit threshold can be selected to reduce vegetative growth, ensure continued photosynthesis, adequate fruit cover to protect from heat and sunburn, and to prevent new vegetative growth.
BENEFITS OF IRRIGATION SCHEDULING

1) Increase on-farm profit (reduced water and energy costs, increased yields and/or production quality, etc.)

2) Control vegetative growth

3) Reduce pruning costs, edging and shoots/leaves removal

4) Improve fruit quality and value

5) Prevent/mitigate frost/heat damages

6) Reduce losses of fertilizers and chemicals by deep percolation and off-site runoff
INACCURATE IRRIGATION SCHEDULING OFTEN LEADS TO:

- **Higher costs** (labor, water, nutrients, pumping)
- **Crop yield lower than max potential** (or alternate bearing)
- **Leaching nutrients, fertilizers and pesticides**
- **Uneven/slow plants development & production**
First Step for Water-Efficient Irrigation of Vineyards

Define the Irrigation Strategy
(to Pursue Yield/Quality Targets)

- Full Irrigation
  (full replenishment of water needs)
- Partial (Deficit) Irrigation or RDI
  (partial replenishment of water needs)

Timing & Levels of Water Deficits
WEATHER-BASED SCHEDULING

It relies on measurements of solar radiation, relative humidity, air temperature and wind speed to estimate reference (grass) ET (ETo).
Can ET be used also to determine when to irrigate?

We can define an accounting system (check-book) with a threshold for no-stress called Maximum Allowable Depletion (MAD)

Like in a Bank Account, we withdraw money until a certain threshold is reached. At that level, we have to deposit some money to refill the account and avoid deficit (RED)

Estimate Maximum Allowable Depletion (ft.)

1. Rooting depth of the crop (ft.)
2. Water holding capacity of soil (in./ft.)
3. Maximum depletion of available soil moisture (40-60%)
Crop: Grapevine
Effective Root depth: 4.0 ft.
Soil: Sandy Loam
Water holding capacity: 1.5 in/ft
MAD: 60 %
Maximum Allowable Depl.: 3.6 in.
SOLAR ENERGY DRIVES CROP EVAPOTRANSPIRATION
How much energy is being used to evaporate or transpire water?
How much energy is being used to evaporate or transpire water?

Energy used to heat the air or canopy

Energy conducted into or out of the ground

$\text{LE} = \text{ETa}$

$\text{LE} = R_n - G - H$
Residual of Energy Balance Method for Calculating Actual Crop Evapotranspiration

\[ LE = \frac{R_n - G - H}{\text{measured}} \]
Mid-day Stem Water Potential

✓ A popular measure of water potential in trees and vines.
✓ Leaf is covered with a bag to block out light during the midday period when a tree is undergoing the most water stress.
✓ After 10-15 minutes the stomata of the leaf close and the water potential of the leaf equilibrates with the water potential of the tree.
✓ Values of stem water potential have been calibrated to shoot growth, and fruit quality in a few crops (almonds, grapes, etc.).

Figure D-8. Relative rate vs. leaf water potential

Percentage

Expansive Growth

Net Photosynthesis

Midday Leaf Water Potential (-bars)

Figure 2. Schematic showing how water potential is measured in a severed leaf and stem (petiole) using a handheld pump-up pressure chamber. Source: Adapted from Plant Moisture Stress (PMS) Instrument Company.
TAKE-HOME MESSAGES

- Define your irrigation strategy based on:
  - Targets of yield and quality
  - Economics (water cost, energy cost, labor availability and cost, price rewards for yield or quality, or both)
  - Site-specific conditions (soil, water supply, slope, aspect, labor etc.)

- Learn how to implement your strategy - it takes a few crop seasons to learn how to do it
  - Select what parameter to monitor over the crop season (ET, Soil, Plant, or a combination of the three)
  - Schedule irrigation according to your strategy, but get feedback on schedule implementation

- Do not rely only on your experience & Think beyond the current crop season
  - Every year is different and there are things you are not experienced
  - What happens in this season will have some effects on the next couple of seasons