Pistachio Irrigation: Determining Water Needs and Managing Drought

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WHY?
• Irrigation system
• Soil
• Water quantity and quality
• Cultivar, spacing, rootstock
• Environment

HOW?
Irrigation to achieve our productive objectives

Outline
• Irrigation and yield
• Crop evapotranspiration (how much?)
• Soil and plant monitoring (when?)
• Deficit irrigation
Leaf Water Use

STOMATAL CONDUCTANCE

H₂O

CO₂

Irrigation and yield

ET = EVAPORATION + TRANSPIRATION

Irrigation objectives

Max yield

Yield reduction

A = Over irrigation without impacting yield
B = Over irrigation impacting yield
C = Deficit irrigation without impacting yield
D = Deficit irrigation impacting yield

Irrigation and yield

ET = EVAPORATION + TRANSPIRATION

Irrigation objectives

Max yield

Yield reduction

A = Over irrigation without impacting yield
B = Over irrigation impacting yield
C = Deficit irrigation without impacting yield
D = Deficit irrigation impacting yield
Crop Evapotranspiration (ETc)

\[ \text{ET}_c = \text{ET}_o \times K_c \]

- \( \text{ET}_o \) accounts for weather factors
- \( K_c \) accounts for crop differences

\( \text{ET}_o \) = Reference ET

\( K_c \) = Crop coefficient

Reference Evapotranspiration (ETo)

- \( \text{ET}_o \) = a measure of evaporative demand
- \( \text{ET}_o \) = ET of 0.12 m tall, cool-season grass

[Image of Weather Station for ETc]

https://cimis.water.ca.gov/
Reference Evapotranspiration (ETo)

California Irrigation Management Information System (CIMIS)

CIMIS Monthly Report
January 2019 - December 2019
Printed on Friday, November 6, 2020

Merced - San Joaquin Valley - Station 148

Crop coefficient (Kc)
Crop Evapotranspiration (ETc)

$$\text{ETc} = \text{ETo} \times K_c$$

<table>
<thead>
<tr>
<th>Month</th>
<th>Historical</th>
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<th>Actual</th>
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<td></td>
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<td>Kc</td>
<td>ETc</td>
<td>ETo</td>
<td>Kc</td>
<td>ETc</td>
<td>Difference</td>
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<td>4.0</td>
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<td>0.59</td>
<td>2.3</td>
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<td>TOT</td>
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<td>53.5</td>
<td>40.1</td>
<td>40.1</td>
<td>4.4</td>
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</table>

Calculations

<table>
<thead>
<tr>
<th>Case Scenario</th>
<th>Formula</th>
<th>Calculation per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merced in July</td>
<td>ETc = ETo x Kc</td>
<td>2.1*1.19 = 2.5 in</td>
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</tbody>
</table>

Adjustment for site specific conditions

1 – Canopy cover

[Mature Orchard E.T. vs. % Shade by Canopy in Midsummer graph]

- 75% CC
- 40% CC

-20%
Adjustment for site specific conditions

1 – Young Trees

% of ET for Developing Pistachios

<table>
<thead>
<tr>
<th>Age of Orchard</th>
<th>Drip</th>
<th>Fan Jet</th>
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<tbody>
<tr>
<td>Year 1</td>
<td>0.10</td>
<td>0.40</td>
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<tr>
<td>Year 2</td>
<td>0.20</td>
<td>0.45</td>
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<tr>
<td>Year 3</td>
<td>0.30</td>
<td>0.52</td>
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<tr>
<td>Year 4</td>
<td>0.40</td>
<td>0.59</td>
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<td>Year 5</td>
<td>0.52</td>
<td>0.65</td>
</tr>
<tr>
<td>Year 6</td>
<td>0.65</td>
<td>0.70</td>
</tr>
<tr>
<td>Year 7</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>Year 8</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>Year 9 (&gt;65% cover)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

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<td>Merced in July</td>
<td>ETC = ETo * Kc 2.1*1.19=2.5 in</td>
<td></td>
</tr>
<tr>
<td>Orchards with 40% CC</td>
<td>ETC * 0.80 2.5 in * 0.80 = 2 in</td>
<td></td>
</tr>
</tbody>
</table>

Adjustment for site specific conditions

2 - Soil properties

IRIGATION RAIN

RUNOFF

LEACHING
2 - Soil properties

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Field Capacity (in/ft)</th>
<th>Wilting point (in/ft)</th>
<th>Available water (in/ft)</th>
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<tr>
<td>Sand</td>
<td>1.2</td>
<td>0.5</td>
<td>0.7</td>
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<tr>
<td>Loam</td>
<td>3.2</td>
<td>1.4</td>
<td>1.8</td>
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<tr>
<td>Silty clay</td>
<td>4.8</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Clay</td>
<td>4.8</td>
<td>2.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>3.4</td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Clay loam</td>
<td>3.8</td>
<td>2.2</td>
<td>1.6</td>
</tr>
<tr>
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<td>2.4</td>
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</tr>
<tr>
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<td>4.8</td>
<td>2.6</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Adjustment for site specific conditions

3 - Root zone

Available Water for trees = AW per feet of soil depth * Root Depth

\[ AW = 4 \text{ ft of root depth} = 1.8 \text{ in/feet} \times 4 \text{ feet} = 9 \text{ inches of water} \]

Adjustment for site specific conditions

FIELD CAPACITY

WILTING POINT

AVAILABLE WATER

ALLOWABLE DEPLETION

50 %

IRRIGATION

RAIN

TRANSPIRATION

EVAPORATION

Allowable depletion = \( \frac{AW}{2} = \frac{9}{2} = 4.5 \text{ in} \)

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<td>( ETC = ETo \times Kc )</td>
<td>2.1 \times 1.13 = 2.3 in</td>
</tr>
<tr>
<td>Young orchards (40% CC)</td>
<td>( ETC = 0.80 \times ETi )</td>
<td>2.5 \times 0.80 = 2 in</td>
</tr>
<tr>
<td>Silt-loam soil, 4 m root depth</td>
<td>( AD = \frac{AW \times RD}{2} )</td>
<td>( 1.8 \times 4 \times 2 = 4.5 \text{ in} )</td>
</tr>
</tbody>
</table>
Adjustment for site specific conditions

4 – Effective rain

Assume only 50% is effective

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<tr>
<td>Merced in July</td>
<td>ETo * Kc * 0.5 * 2.5</td>
<td>2.1 * 1.19 * 2.5 in</td>
</tr>
<tr>
<td>Young orchards (40% CC)</td>
<td>ETo * 0.80</td>
<td>2.5 * 0.80 * 2 in</td>
</tr>
<tr>
<td>No rains</td>
<td>NIR = ETc – Re</td>
<td>2 – 0 = 2 in</td>
</tr>
<tr>
<td>Silt-loam soil, 4 m root depth</td>
<td>AO = (AW * RD)/2</td>
<td>12.8 * 4/2 = 4.5 in</td>
</tr>
</tbody>
</table>

Effective rain (Re): Rain (in) / 2
Net irrigation requirement (NIR): ETc - Re

Calculations

<table>
<thead>
<tr>
<th>Irrigation System</th>
<th>AE (%)</th>
<th>Wetted Area</th>
<th>WA (%)</th>
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<tbody>
<tr>
<td>Flood</td>
<td>65-80</td>
<td>Single line drip</td>
<td>20-30</td>
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<tr>
<td>Micro-sprinkler</td>
<td>85-90</td>
<td>Double line drip</td>
<td>20-50</td>
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<tr>
<td>Drip</td>
<td>90-95</td>
<td>Microsprinkler</td>
<td>30-60</td>
</tr>
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<td>ETc * 0.80</td>
<td>2.5 in * 0.80 = 2 in</td>
</tr>
<tr>
<td>No rains</td>
<td>NIR-ETc:irri</td>
<td>2 – 0 = 2 in</td>
</tr>
<tr>
<td>Micro drip irrigation (95% AE)</td>
<td>GIR=IR/AE</td>
<td>2/0.95 = 2.1 in</td>
</tr>
<tr>
<td>Silt-loam soil, 4 m root depth</td>
<td>AD = (AW * RD)/2</td>
<td>(1.8 * 4)/2 = 4.5 in</td>
</tr>
<tr>
<td>Micro drip irrigation (40% WA)</td>
<td>AD*WA</td>
<td>4.5*0.40 = 1.8 in</td>
</tr>
</tbody>
</table>

SOIL MONITORING

Soil and plant monitoring

Soil Monitoring

In micro irrigated orchard it is very important selecting the monitoring point.
Soil Monitoring: direct soil moisture by feel

1) Direct soil moisture by feel

- Simple
- Time consuming
- Subjectivity

Wet medium-textured soil
Dry medium-textured soil


Soil Monitoring: soil tension

Soil tension

- Measures the surface tension that the water is held to the soil
- The tension increases as soils dry, plants spend more energy
- Measurement unit centibars (cb)

Types
- Tensiometer
- Resistance blocks

Soil Monitoring: soil tension

- Tensiometer

  Pros:
  - no power needed
  - Not affected by salinity
  - Easy to install
  - Not expensive

  Cons:
  - Requires maintenance
  - Not good for dry soil - can lose soil contact
  - Manually read and keep records
Soil Monitoring: soil tension

• **Modified electrical resistance**

  • **Pros:**
    - No maintenance
    - Least cost
    - Can have many sensors going different depths and areas
    - Possible to use data loggers or remotely
    - Easy to install
  
  • **Cons:**
    - Can have problems contacting soil in course textures
    - Can be affected by salinity
    - Need to periodically replace them (3-4 years)

Soil Monitoring: soil tension

• **Reading Soil Tension**

  Use the following readings as a general guideline:

  - 0-10 Centibars = Saturated soil
  - 10-30 Centibars = Soil is adequately wet (except coarse sands, which are beginning to lose water)
  - 30-60 Centibars = Usual range for irrigation (most soils)
  - 60-100 Centibars = Usual range for irrigation in heavy clay
  - 100-200 Centibars = Soil is becoming dangerously dry for maximum production. Proceed with caution!

  [http://www.irrometer.com](http://www.irrometer.com)
Soil Monitoring: neutron probe

- Neutron probe
  - Pros:
    - Adapts to many soil types
    - Reads actual water content
    - Only need to install access tubes
    - Reads multiple depths in one tube
    - Largest sample "volume" to estimate moisture
  - Cons:
    - Need radiation license to use
    - Needs to be calibrated to soil type
    - Reading includes water that is not free for plant use
    - Not possible to automate
    - Dependent on consultant

Soil Monitoring: soil moisture

- Dielectric sensors: Measure the ability of a material to establish an electrical field
  - Air dielectric constant of 1
  - Dry soil dielectric constant of 3 to 5
  - Water dielectric constant of about 80
  - More moisture increases the dielectric constant

- Pros:
  - Increased accuracy with calibration to soil type
  - Reads actual water content
  - Able to automate readings
- Cons:
  - Complicated electronics
  - Requires power
  - Some may be affected by salts or heavy soils
  - Errors can occur with loss of soil contact with sensor

Plant monitoring

- Integrates soil and atmosphere
Plant monitoring: pressure chamber

- Sealed chamber
- Pressure gauge
- Valve
- Pressurized gas tank

Plant monitoring: water potential

- Below balance point
- Above balance point
- Magnifying glass
- Plastic bag
- Pressure gauge
- Pressure chamber

Plant monitoring: stem or leaf water potential

- Bagged healthy shaded leaf representative of canopy features
- Non-bearing branchlet inside the canopy close to the main branch

Enclose the leaf in light and moisture impervious bags to stop leaf transpiration and wait at least 15 minutes, to allow the leaf to equilibrate with the branch underneath.
Plant water potential

- Measurement made at midday
- The higher the values the higher the stress
- Resins (or latex) from resinous channels can make the reading difficult

Water from the xylem, it expands rapidly in the absorbing paper, it is more transparent and clear

Resin exudate from the phloem, dense and less transparent. It doesn’t move easily in the paper so it is limited to the area in contact to the petiole
Plant monitoring: water potential baseline

* baseline is about 1/10th of temperature
* SWP 2 bars below baseline before irrigating
* Mature trees also 4 bars
* -14/-16 bars is considered stress (stomatal closure)

Plant monitoring: dendrometers

Plant monitoring: dendrometers
Higher MDS and lower stem water potential in a stressed pistachio orchard (red lines) versus a non-stressed one (blue lines).

NOTE: All plant-based indicators of tree water status are affected by environmental conditions, so baseline need to be developed and used for a correct interpretation of the results.

Marino et al. in press.
Putting the tools to work

1. Track ET
2. Monitor soil
3. Monitor plant
4. Irrigate
5. Check results

Deficit irrigation

Planned water deficits at specific crop developmental stages that control vegetative growth or improve quality without negatively affecting production

Deficit irrigation

Regulated Deficit Irrigation Impacts on Yield (Goldhammer et al., Kettleman City 1988-92)

<table>
<thead>
<tr>
<th>Irrigation Treatment</th>
<th>Split Nuts (%)</th>
<th>Dry Split Yield (lb/ac)</th>
<th>Water Use Efficiency (lb splits/inch irrigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Stage 1</td>
<td>87.9 a</td>
<td>2828 e</td>
<td>51.7 bc</td>
</tr>
<tr>
<td>0% Stage 2</td>
<td>73.6 b</td>
<td>2239 bc</td>
<td>53.7 bc</td>
</tr>
<tr>
<td>0% Stage 3</td>
<td>43.6 a</td>
<td>1014 a</td>
<td>44.8 a</td>
</tr>
<tr>
<td>0% Postharvest</td>
<td>78.8 bc</td>
<td>2451 bc</td>
<td>77.6 ab</td>
</tr>
<tr>
<td>50% Stage 2; 25% PH</td>
<td>82.7 cd</td>
<td>2744 cd</td>
<td>106.1 c</td>
</tr>
<tr>
<td>Control</td>
<td>79.5 bc</td>
<td>2714 cd</td>
<td></td>
</tr>
</tbody>
</table>

* Values followed by the same letter are not statistically different at p=0.05.
Deficit irrigation

(Goldhamer et al.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>STAGE 1</th>
<th>STAGE 2</th>
<th>STAGE 3</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>-1.6 MPa</td>
<td>Full ETc</td>
<td>Full ETc</td>
<td>Full ETc</td>
</tr>
<tr>
<td>T2</td>
<td>-1.6 MPa</td>
<td>50% ETc</td>
<td>Full ETc</td>
<td>Full ETc</td>
</tr>
<tr>
<td>CONTROL</td>
<td>Full ETc</td>
<td>Full ETc</td>
<td>Full ETc</td>
<td>Full ETc</td>
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</table>
Irrigation under saline conditions

- Salinity reduces water use
- Apply canopy cover reduction
- Check soil moisture, since water uptake may be lower
- Stem water potential may be misleading
- Progressive reduction of ET from stage 2 due to ion accumulation in leaves

Pistachio is resistant to drought and salinity but very sensitive to overirrigation and saturated soil conditions

Take-home Messages

- Pistachio is a drought tolerant crop but it can use large amount of water (40 inches over the entire season)
- Calculate the ETc to quantify the water need of your orchard (you just need ETo from CIMIS website and Kc)
- ETc alone is not enough to manage irrigation properly
- Integrate ET estimates with soil and plant water status monitoring to decide when to irrigate
- If you have water shortage, Stage II (shell hardening) is the preferred window to irrigate in deficit
Thank you

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