Water Management Considerations for Tree Crops Under a Limited Water Supply

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Information and tools to manage limited water supplies in orchards?

Setting priorities?
Useful tools?
Will All Orchards Respond the Same to More Water? One Experience in Almond.


Figure 6. Comparison of the 2014-2016 average response of orchard yield (A) and PAR (B) to the sum of applied irrigation, rain, and soil water use (depletion), in each irrigation treatment (each point) of the 3 study sites. Dashed lines are the expected values of about 70 kernel pounds (A) and 1.4% PAR (B) per inch of water use, based on research of B. Lampinen.

- Despite wide range of 35 to 60 inches of seasonal water use, observed modest increases in yield at two of three orchards (about 35 kernel pounds of additional yield per acre for every additional inch of water). Expected increases of about 70 kernel pounds per inch. Third orchard did not respond to range in water use.

- Overall canopy growth (PAR), did not appear to limit yield at any of the three sites.

- Together, these results indicate that a factor/factors other than water stress may be preventing yields from reaching their potential at these sites.
Not all walnut orchards will reach maximum yield potential.

Source: Lampinen, et. al., 2016 Walnut Research Reports.

Fig. 8. Midday canopy PAR interception versus yield broken up into 4 categories (great, above average, average, below average and poor) based on the yield per unit PAR intercepted.
Some factors that can confound orchard growth and production responses to water

Horticultural variables:

- Underperforming rootstock/scion selections
- Canopy light management
  - Less than optimal tree spacing
  - Pruning practices – too much pruning or excess shading
- Poor conditions for pollination
- Foliar and root diseases
- Nutritional deficiencies
- Second generation orchards (plant back problems)
- Aging orchards
If tree crop production responses to total seasonal water are variable, then how should limited water supplies be used across a farm to maximize productivity and returns?

A couple of options*:

1. Proportional deficit irrigation (PDI)
   • Allocate water equally across all mature orchards on the farm independent of production histories
   • Simpler to implement

2. Prioritized allocation
   • Allocate “enough” water to the most productive orchards, implement cutbacks to the less responsive.
   • More work to implement

* Young, developing orchards are not good candidates for water cutbacks. It’s important to manage irrigation water to promote tree growth and rapidly develop fruit bearing tree canopy.
How to identify orchards where production is more responsive to water from those less responsive?

Helpful and attainable information:
• Orchard production history
• Applied water measurements
• Midday canopy light interception
• Familiarity with orchards and other known limitations
Assess Water Productivity

- Pounds production per acre foot applied water
- Revenue per acre-foot applied water

- Example (multi-year average yield)
  - Orchard #1: 4500 lbs/ac dry inshell walnut @ 3.3 ac-ft/ac water
  - Orchard #2: 6100 lbs dry inshell walnut @2.9 ac-ft/ac water
  - Orchard #1: 1364 lbs dry inshell walnut per ac-ft water
  - Orchard #2: 2103 lbs dry inshell walnut per ac-ft water

  - Orchard #2 has history of higher water productivity and might be given higher priority for water
Evaluate midday canopy light interception and productivity (lbs crop production for each percent light interception).\(^1\)

<table>
<thead>
<tr>
<th>Yield Categories</th>
<th>Walnuts (dry in-shell yield for each % light interception or % PAR)</th>
<th>Almonds (kernel meat yield for each % light interception or % PAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great</td>
<td>&gt; 88 lbs</td>
<td>&gt; 44 lbs</td>
</tr>
<tr>
<td>Above Average</td>
<td>75 - 88 lbs</td>
<td>37.5 - 44 lbs</td>
</tr>
<tr>
<td>Average</td>
<td>50 - 75 lbs</td>
<td>25 - 37.5 lbs</td>
</tr>
<tr>
<td>Below Average</td>
<td>25 – 50 lbs</td>
<td>12.5 – 25 lbs</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt; 25 lbs</td>
<td>&lt; 12.5 lbs</td>
</tr>
</tbody>
</table>

\(^1\) Table adapted from Lampinen et.al., 2016 Walnut Research Reports and recent Almond Research Reports.

Orchards with higher crop production per unit canopy light interception are likely to have higher water productivity.

Values calculated by dividing crop yield by measured canopy light interception.
Ground techniques to assess canopy shading

Estimate midday canopy shading yourself (DIY)

Approximate canopy shading = 18/44 = 41%

Use iPhone/iPad app
https://ucanr.edu/sites/LampinenLab/Canopy_Management/iPAR/
Aerial imagery to estimate canopy shading

UAV’s

Fixed Wing

Satellite

University of California
Agriculture and Natural Resources
Example canopy assessment using aerial imagery

$PAR = \text{Photosynthetic Active Radiation} = \text{Percent canopy light interception or shading}$
Monitoring groundwater pumping levels and having well design and construction information is useful.

Manual Measurement

Automated and measured remotely

University of California
Agriculture and Natural Resources
Discerning more from less reliable groundwater supplies and foreseeing potentially costly well improvements.

Useful Diagnostics:
- Pumping water table level versus depth of well perforations or screens
- Pumping water table level versus GSA management criteria
- Well(s) at risk of going dry or facing SGMA restrictions combined with orchard(s) of low water productivity represent more difficult circumstances to sustain through a severe or extreme drought

California DWR Well Completion Map Application

University of California
Agriculture and Natural Resources
GOOD INITIAL IRRIGATION SYSTEM DESIGN, STEADY MAINTENANCE, AND PERIODIC EVALUATION REMAIN IMPORTANT

• One data set in Sacramento Valley
• From about 2009 to present
• Over 1200 irrigation system evaluations
• Mostly micro irrigation systems in orchards
• Suggests about 1 in 4 or 5 systems have less than 70 percent distribution uniformity (DU)
Three technical approaches may be used for making scheduling decisions. They are based on: a) monitoring soil water status; b) monitoring plant water status; and c) computing a water budget of the tree root zone.

While soil-based instruments give information of soil moisture levels in the plant root zone, the plant itself is the best indicator of its water status.

It is not easy to define thresholds for practical use. Tree water status measurements need to be benchmarked against equivalent measurements representing fully irrigated plants in the same environment.
Conventional Measurement of Plant Water Status in Trees

*Pressure Chamber & midday SWP*

Refer to Sacramento Valley Orchard Blog “Stem Water Potential Series” for information.

https://www.sacvalleyorchards.com/manuals/
Advanced Ground-based, Direct and Indirect Tree Water Status Sensors

Water Potential Sensor

Dendrometer – measures trunk growth characteristics
Canopy Temperature Applications

Map of Tehama County Almond Irrigation Experiment

Aerial Image – Stomatal Conductance, 7/2/15
One experience from northern California in walnut demonstrating potential value of tree water status as a drought management tool.

- California Walnut Board funding
- Began testing in 2014 near Red Bluff, CA
- 9-year old commercial Chandler/Paradox orchard located within 0.5 mile of Sacramento River
- Planted at 18 x 28 ft (86 trees per acre)
- Deep, well-drained silt-loam/fine sandy-loam
- Testing continued through 2019

- Used tree water status determined with a pressure chamber and SWP to guide when to begin irrigation at the start of the season.

- Test treatments included:
  - grower’s typical starting date about 30 days after leafout and when tree water status was at or near the fully irrigated baseline.
  - Four other trigger levels allowing the trees to reach 1, 2, 3, or 4 bars drier than baseline SWP before starting irrigation.
  - Each treatment was replicated in five different, randomly placed plots in the orchard.
  - All total, the test consisted of 12.5 acres
Irrigation start dates, seasonal irrigation applied, and crop yield, for each of the irrigation treatments imposed in the first year of the study (2014).

2014 (ET – in-season rainfall = 38 inches)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Irrigation Start Date</th>
<th>Irrigation Applied</th>
<th>Percent of ET - Rain</th>
<th>Yield (lbs dry in-shell/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grower – at or above baseline</td>
<td>April 26</td>
<td>38”</td>
<td>100%</td>
<td>3690</td>
</tr>
<tr>
<td>1 bar drier</td>
<td>April 26</td>
<td>34”</td>
<td>89%</td>
<td>3700</td>
</tr>
<tr>
<td>2 bar drier</td>
<td>May 28 to June 18</td>
<td>30”</td>
<td>79%</td>
<td>3440</td>
</tr>
<tr>
<td>3 bar drier</td>
<td>June 2 to June 13</td>
<td>25”</td>
<td>66%</td>
<td>3420</td>
</tr>
<tr>
<td>4 bar drier</td>
<td>June 2 to June 13</td>
<td>25”</td>
<td>66%</td>
<td>3360</td>
</tr>
</tbody>
</table>
Average irrigation start date, seasonal irrigation applied, yield, percent edible yield, and crop relative value (2015-2018).

<table>
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<tr>
<th>SWP Trigger for the first irrigation</th>
<th>Average 2015-2018 (ET-rain: 38.6&quot;)</th>
<th>Irrigation start date (days after leafout)</th>
<th>inches (ET-R)</th>
<th>yield (pounds/acre dry inshell)</th>
<th>% edible yield</th>
<th>Relative crop value (% of control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At or near baseline (control)</td>
<td>Late April/Early May (25-35)</td>
<td>24.4 (63%)</td>
<td>5360</td>
<td>45.1</td>
<td>4840 (100%)</td>
<td></td>
</tr>
<tr>
<td>1 bar below baseline</td>
<td>Mid to late May (45-60)</td>
<td>22.5 (58%)</td>
<td>5230</td>
<td>45.5</td>
<td>4760 (98%)</td>
<td></td>
</tr>
<tr>
<td>2 bars below baseline</td>
<td>Early to mid June (60-75)</td>
<td>20.7 (54%)</td>
<td>5000</td>
<td>45.1</td>
<td>4540 (94%)</td>
<td></td>
</tr>
<tr>
<td>3 bars below baseline</td>
<td>Mid to late June (75-85)</td>
<td>16.9 (44%)</td>
<td>5080</td>
<td>45.9</td>
<td>4660 (96%)</td>
<td></td>
</tr>
<tr>
<td>4 bars below baseline</td>
<td>Late June to early July (85-95)</td>
<td>18.3 (47%)</td>
<td>4940</td>
<td>45.9</td>
<td>4530 (94%)</td>
<td></td>
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Orchard settings where tree water status is likely to be more effective at reducing irrigation and managing water shortages

• Medium to high rainfall regions
• Deep, uniform soils of fine sandy loam texture of finer
• Potential for capillary water movement into root zone
  – River or tributary influences
  – Orchards bordered by surface water canals or drains
  – Non-saline soils and water
Knowledge of crop phenology important to manage limited water supplies

Olive Example

## Summary of Suggested Strategic Deficit Irrigation Approaches for Selected California Tree Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Stages Where Water Stress is Likely to Have Less Impact on Production and Revenue</th>
<th>Percent of ETc Supplied at Targeted Growth Stage</th>
<th>Potential Seasonal Water Savings*</th>
</tr>
</thead>
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<tr>
<td>Almond</td>
<td>Potential to delay start of irrigation from bloom to full canopy (March-April) and save water. Two weeks prior to hull split on heavy, deep soils only (June 15 – July 1). Two weeks after onset of hull split (early July) Approaching leaf drop (late Oct/Nov)</td>
<td>50 %</td>
<td>10 to 15 % Maybe more</td>
</tr>
<tr>
<td>Pistachio</td>
<td>Shell hardening (mid May through entire month of June) Post-harvest period (Oct. 1 – Nov. 15) Also, consider alternate bearing seasons</td>
<td>50 %</td>
<td>25 % or more</td>
</tr>
<tr>
<td>Walnut</td>
<td>Potential to delay irrigation and save water from bloom to full canopy and during shoot, hull, and shell expansion (April 1 – June 15)</td>
<td>50 %</td>
<td>20 – 30 % or more</td>
</tr>
</tbody>
</table>

* Potential water savings expressed as a percent of seasonal evapotranspiration for non-stressed crops and represent reductions in applied water that minimize impacts to production and revenue. Employing more extreme RDI regimes to cope with greater water shortages may result in more extreme impacts on production. The greater the water shortage the larger the impacts on production and revenue.
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<tr>
<td>Table Olive</td>
<td>Early stages of fruit sizing and pit hardening (June – Aug 15). Under severe water shortages, may extend deficit irrigation into mid stages of fruit sizing (mid Aug – early Sept)</td>
<td>50 %</td>
<td>20 % Maybe more</td>
</tr>
<tr>
<td>Olive Oil</td>
<td>Olive fruit size is not as critical for oil production, so extended and steeper deficits can be tolerated targeting the same tolerant fruit and pit hardening stages (June – mid September). A proportional deficit across the whole season works well too.</td>
<td>40 – 50 %</td>
<td>40-60 %</td>
</tr>
<tr>
<td>Prune</td>
<td>Potential to delay irrigation to save water after pollination through canopy development (April-early May) to save water. End of fruit sizing (mid to late August) fosters sugar accumulation and fruit drying. Post harvest cutbacks.</td>
<td>50 %</td>
<td>20 – 50 %</td>
</tr>
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</table>

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Information Resources to Learn More about Strategic Deficit Irrigation

• FAO Paper 66. Yield response to water of fruit trees and vines: Guidelines (Sections 4.0 and 4.1). https://www.fao.org/3/i2800e/i2800e00.htm
• UC Drought Management Website https://ucmanageddrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/
• UC ANR Drought Tips https://ucanr.edu/sites/ucanr/News/Drought/Drought_tips/
Suggested Information and Tools to Consider for Your Drought Management Tool Box

- Real-time Crop ET Information
- Weekly and Seasonal Applied Water Measurements
- Measure of mid-summer canopy shading
- Orchard Yield History
- Well Sounding Capabilities and Well Completion Reports
- Good Irrigation System Design, Steady Maintenance, and Periodic Evaluation
- Capabilities of monitoring tree water status
- Understand stages of tree and crop development and sensitivity to water stress
THANK YOU!