Irrigation management in a drought year

What drought means to the tree, and how best to deal with it

Ken Shackel, Jan/Feb 2014
Saving water: some general recommendations

1) Control weeds.

2) Maintain irrigation system and try to improve uniformity.

3) Use a pressure chamber to identify areas of severe stress and adjust your irrigation approach before these areas become a problem.

Recommendations specific to almonds:

1) No evidence that heavy pruning or kaolin/whitewash sprays do any economic good to mitigate drought conditions.

2) Mild to moderate stress at the start of hull split is a good idea to speed up hull split and reduce hull rot.
An issue we don’t have much (any?) data on:
The need for **WINTER IRRIGATION**

**Winter Irrigation of Fruit Trees.**

“They require only so much moisture from the ground as may serve to keep their tissues in a normal healthy state, and prevent mischief or death by their younger parts transpiring more than they receive.”

(E.P., 1907).
Winter Irrigation During Drought  
Joseph H. Connell, UC Farm Advisor, Butte Co.

We know that during the winter months walnuts can be hurt by either too much or too little water. … Cutting back on water earlier in the fall slows down the trees growth and helps harden them off. However, drought conditions during winter can make winter kill worse if we get cold temperatures as discussed in Carolyn DeBuse’s article on winter freeze injury.

…The ultimate goal is to make sure the soil reservoir is completely refilled either by rain or winter irrigations by the time your walnut trees begin to wake up next March.
Pressure chamber method for measuring water stress

Like measuring the “blood pressure” of the plant
Stem Water Potential (SWP)
Resources to help with the pressure chamber

<table>
<thead>
<tr>
<th>Pressure Chamber Reading (in bars)</th>
<th>WALNUT</th>
<th>ALMOND</th>
<th>FRUENES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to -2.0</td>
<td>Not commonly observed</td>
<td>Not commonly observed</td>
<td>Not commonly observed</td>
</tr>
<tr>
<td>-2.0 to -4.0</td>
<td>Fully irrigated, low stress, commonly observed when orchards are irrigated according to estimates of real-time evapotranspiration (ETc), long term root and tree health may be a concern, especially on California Black rootstock.</td>
<td>Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Suggest maintaining these levels from leaf-out through mid June.</td>
<td>Low stress, common from March to mid April under fully irrigated conditions. Ideal for maximum shoot growth.</td>
</tr>
<tr>
<td>-4.0 to -6.0</td>
<td>Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed.</td>
<td>Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline. These levels do not appear to affect kernel development.</td>
<td>Suggested levels in late April through mid June. Low stress levels enabling shoot growth and fruit sizing.</td>
</tr>
<tr>
<td>-6.0 to -8.0</td>
<td>Mild to moderate stress, shoot growth in non-bearing and bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.</td>
<td>Moderate to high stress, shoot growth in non-bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.</td>
<td>Suggested mild levels of stress during late June and July. Shoot growth slowed but fruit sizing unaffected.</td>
</tr>
<tr>
<td>-8.0 to -10.0</td>
<td>Moderate to high stress, shoot growth in non-bearing and bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.</td>
<td>High stress, temporary wilting of leaves has been observed. New shoot growth may be sparse or absent and some defoliation may be evident. Nut size likely to be reduced.</td>
<td>Mild to moderate stress, these levels of stress may be appropriate during the phase of growth just before the onset of hull split (late June).</td>
</tr>
<tr>
<td>-10.0 to -12.0</td>
<td>Relative high levels of stress, moderate to severe defoliation, should be avoided.</td>
<td>Moderate stress in almond. Suggested stress level during hull split, help control diseases such as hull rot and alternaria, if diseases are present. Hull split occurs more rapidly.</td>
<td>Mild to moderate stress suggested for August to achieve desirable sugar content in fruit and to reduce “dry-away” (drying costs).</td>
</tr>
<tr>
<td>-12.0 to -14.0</td>
<td>Moderate stress in almond. Suggested stress level during hull split, help control diseases such as hull rot and alternaria, if diseases are present. Hull split occurs more rapidly.</td>
<td>High stress, wilting observed; some defoliation.</td>
<td>Moderate stress acceptable in September.</td>
</tr>
<tr>
<td>-14.0 to -18.0</td>
<td>Severe defoliation, trees are likely dying.</td>
<td>Extensive defoliation has been observed</td>
<td>Moderate to high stress levels. Most commonly observed after harvest. Generally undesirable during any stage of tree or fruit growth. Most appropriately managed with post-harvest irrigation.</td>
</tr>
<tr>
<td>-18.0 to -20.0</td>
<td>Crop stress levels in English walnut not observed at these levels.</td>
<td>Moderate to high stress levels. Extensive defoliation has been observed</td>
<td>High stress, extensive defoliation.</td>
</tr>
<tr>
<td>-20 to -30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These guidelines are tentative and subject to change as research and development with the pressure chamber and midday stem water potential progress. This table should not be duplicated without prior consent by the authors.
Almonds, one seasons growth:
Dry treatment (SWP about -15 bars)
Almonds, one seasons growth: Medium treatment (SWP about -12 bars)
Almonds, one seasons growth:
Wet treatment (SWP about -8 bars)
Walnut canopy development effects
Using water stress to set terminal buds in cherry

![Graph showing the effect of water stress on terminal bud set in cherry. The x-axis represents dates from April to September 1992. The y-axis represents stem water potential (SWP) and percent terminal bud set (% Set). The graph includes lines for control, early stress, and mid-stress treatments. The data shows that water stress affects the SWP and the percentage of terminal buds set.](image)
Resources to help with the pressure chamber

New ‘baseline’ website:
Resources to help with the pressure chamber

New ‘baseline’ website:

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature (F)</th>
<th>Relative humidity</th>
<th>Almond/Prune</th>
<th>Walnut</th>
<th>Grape(SWP)</th>
<th>Grape(LWP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 PM</td>
<td>60.1</td>
<td>33.0</td>
<td>-5.5</td>
<td>-3.5</td>
<td>-3.1</td>
<td>-5.8</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>63.5</td>
<td>27.0</td>
<td>-5.9</td>
<td>-3.7</td>
<td>-3.3</td>
<td>-6.1</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>65.7</td>
<td>25.0</td>
<td>-6.0</td>
<td>-3.8</td>
<td>-3.4</td>
<td>-6.2</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>67.7</td>
<td>24.0</td>
<td>-6.2</td>
<td>-3.9</td>
<td>-3.5</td>
<td>-6.3</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>68.6</td>
<td>25.0</td>
<td>-6.2</td>
<td>-3.9</td>
<td>-3.5</td>
<td>-6.3</td>
</tr>
</tbody>
</table>
The drought of 2007-2009
(source: DWR 2010 report)

Percent of statewide average runoff

- 2006: 173%
- 2007: 53%
- 2008: 60%
- 2009: 65%
In California, “drought” means low winter rains. We always have dry summers!

Almond “full” ETc (inches per month) for two locations in a wet year (2006) and a dry year (2007)

<table>
<thead>
<tr>
<th>Month</th>
<th>Tehama 2006 (Wet year)</th>
<th>Tehama 2007 (Dry year)</th>
<th>Kings 2006 (Wet year)</th>
<th>Kings 2007 (Dry year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb</td>
<td>1.0</td>
<td>0.7</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Mar</td>
<td>1.6</td>
<td>2.5</td>
<td>1.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Apr</td>
<td>3.2</td>
<td>4.0</td>
<td>3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>May</td>
<td>6.5</td>
<td>7.1</td>
<td>6.6</td>
<td>7.1</td>
</tr>
<tr>
<td>June</td>
<td>8.4</td>
<td>8.9</td>
<td>8.0</td>
<td>8.3</td>
</tr>
<tr>
<td>July</td>
<td>9.4</td>
<td>8.9</td>
<td>8.6</td>
<td>8.5</td>
</tr>
<tr>
<td>Aug</td>
<td>8.0</td>
<td>8.3</td>
<td>8.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Sep</td>
<td>6.1</td>
<td>5.5</td>
<td>5.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Oct</td>
<td>3.8</td>
<td>3.2</td>
<td>3.1</td>
<td>3.3</td>
</tr>
<tr>
<td>Nov</td>
<td>0.9</td>
<td>1.8</td>
<td>1.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Total</td>
<td>48.9</td>
<td>50.9</td>
<td>47.8</td>
<td>50.3</td>
</tr>
</tbody>
</table>
Start your plan using ‘average’ year values

Reference ET (ETo) map from DWR
http://wwwcimis.water.ca.gov

“BASIC IRRIGATION SCHEDULING (BIS)” excel file from
http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm
Apply the same % of full ET across the season to reach your target total

Zone 15:
full ET total = 53"

<table>
<thead>
<tr>
<th>Month</th>
<th>Full ET 70% ET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;/week</td>
</tr>
<tr>
<td>Feb</td>
<td>0.25</td>
</tr>
<tr>
<td>Mar</td>
<td>0.60</td>
</tr>
<tr>
<td>Apr</td>
<td>1.15</td>
</tr>
<tr>
<td>May</td>
<td>1.78</td>
</tr>
<tr>
<td>June</td>
<td>2.15</td>
</tr>
<tr>
<td>July</td>
<td>2.40</td>
</tr>
<tr>
<td>Aug</td>
<td>2.15</td>
</tr>
<tr>
<td>Sep</td>
<td>1.50</td>
</tr>
<tr>
<td>Oct</td>
<td>0.90</td>
</tr>
<tr>
<td>Nov</td>
<td>0.35</td>
</tr>
<tr>
<td>Dec</td>
<td>0.13</td>
</tr>
<tr>
<td>Season Total</td>
<td>53&quot;</td>
</tr>
</tbody>
</table>

* At 1”/24h
Simple approach to drought (i.e., a fixed level of deficit all season)

1) Frost protection? (might allow later start of irrigation in spring)
2) Lack of flexibility in water deliveries, run times, or run days? (may cause feast/famine problems)
3) Salinity management?

<table>
<thead>
<tr>
<th>Month</th>
<th>NORMAL</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hr/wk</td>
<td>Hr/wk</td>
</tr>
<tr>
<td>Feb</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Mar</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Apr</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>May</td>
<td>43</td>
<td>30</td>
</tr>
<tr>
<td>Jun</td>
<td>52</td>
<td>36</td>
</tr>
<tr>
<td>Jul</td>
<td>58</td>
<td>40</td>
</tr>
<tr>
<td>Aug</td>
<td>52</td>
<td>36</td>
</tr>
<tr>
<td>Sep</td>
<td>36</td>
<td>25</td>
</tr>
<tr>
<td>Oct</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Nov</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Dec</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Practical issues that may impact the simple approach
3 arguments against a ‘simple approach’

1) What about ‘stress sensitive’ stages?
   - bloom?
   - post harvest?

2) Am I ‘wasting water’ if I just give small amounts?

3) Don’t I need to maintain irrigation at 100% ET early on to avoid the depletion of deep soil water?

(Specific to cherry: the importance of fruit sizing coupled with a long postharvest period probably means that deficit irrigation should probably focus on the postharvest period)
1) Stress sensitive stages in Almond?

- 1993-1996 study (Goldhamer et al, 2006), Southern SJV, 18 year-old orchard
- 3’ root zone, 7.5” average rainfall during study (no pre-irrigation)
- Control (100% Etc = 42”)
- 3 levels of irrigation deficit (34”, 28”, 23”) (80%, 67%, 55%)
- 3 patterns of deficit  △  ◆  ▼
1) Stress sensitive stages in Almond?

“C” pattern: Equal irrigation deficit all season

(Control = 100% season long, about 42”)

(Target about 34”)

(Target about 28”)

(Target about 23”)

(Goldhamer et al., 2006)
1) Stress sensitive stages in Almond?

“B” pattern: Some deficit early, most deficit post-harvest

(Goldhamer et al., 2006)
1) Stress sensitive stages in Almond?

Mean Kernel Yield (lbs/ac) 1993-1996

An even deficit over the season always gave the best result

(100% ETc CONTROL)

Seasonal Applied Irrigation (inches)

(Goldhamer et al., 2006)
2 & 3) Wasting water & deep moisture?

1 year almond drought study, 2009

<table>
<thead>
<tr>
<th>Water from</th>
<th>Irrigation</th>
<th>Rain</th>
<th>Soil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0”</td>
<td>5.5”</td>
<td>2.1”</td>
<td>7.6”</td>
<td></td>
</tr>
<tr>
<td>3.6”</td>
<td>6.7”</td>
<td>2.1”</td>
<td>12.4”</td>
<td></td>
</tr>
<tr>
<td>7.2”</td>
<td>5.9”</td>
<td>2.1”</td>
<td>15.2”</td>
<td></td>
</tr>
<tr>
<td>30.8”</td>
<td>(?)</td>
<td>2.1”</td>
<td>(32.9”)</td>
<td></td>
</tr>
</tbody>
</table>

A small amount of irrigation (3.6”) spread evenly over the season resulted in more use of deep water than did no irrigation.
July 21, 2009

Control tree

- 9.8 bars

SWP
July 21, 2009
0” tree
- 39 bars
SWP
Yield: The biggest reduction occurred in the year following the stress (i.e. carryover effect)
Example of field variability in a hull rot deficit irrigation test

Irrigation causes moderate stress in these trees

But the same irrigation causes severe stress in these trees
Bottom line - conclusions

1) Control weeds, maintain irrigation system and irrigate at a proportion of ‘normal’ (best to use full ETc as ‘normal’) throughout the season.

2) Under deficit irrigation, expect to see differences due to soils.

3) Use the pressure chamber to determine when to start irrigating (tentative: wait for at or below baseline values before starting) and for ‘early warning’ from soils which will present a significant problem later on.

4) Expect a reduced nut/fruit size this year, and reduced bloom and set next year, depending on the degree of deficit.
Thanks for your attention, and thanks to funding and/or cooperation from:

Almond Board of California  
USDA-SCRI  
Nickels Estate

Colleagues: Bruce Lampinen, Larry Schwankl, Allan Fulton, Sebastian SaaSilva, Patrick Brown, Andres Olivos, Gerardo Spinelli, Hector Munoz, and anybody else I forgot!