Almond Irrigation, Water Stress and Productivity:

Where do Drought & Deficit Irrigation Research Fit In?

Ken Shackel, UCD Plant Sciences
January, 2008
Some drought irrigation history:

a) 1989 – 1991. Irrigation cutoff & drought recovery trials in Kern Co. on relatively shallow sandy soil (Dave Goldhamer)

b) 1990 – 1995. Irrigation cutoff/cutback & drought recovery trials in Manteca on moderate depth sandy loam soil (Terry Prichard)

c) 1993 – 1996. Drought irrigation management trials N. Kern Co. 3' sandy loam (Dave Goldhamer)
Goldhamer study, 1989 - 1991

Yields: 1,700#/ac

Full ET: 30" – 40" in-season

(3rd year yield penalty at < 90% ET?)
Goldhamer study, 1989 – 1991

Drought recovery

Drought with a 60% reduction – choices:
a) use it at full ET until it is gone (long cutoff)
b) spread it out for various levels of cutoff

Results: More even spread is best
<table>
<thead>
<tr>
<th>Deficit Treatment</th>
<th>% ET</th>
<th>Yield (% Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1990-1992</td>
</tr>
<tr>
<td>(5) Midseason</td>
<td>50</td>
<td>78</td>
</tr>
<tr>
<td>(4) Mid and Postharvest</td>
<td>52</td>
<td>85</td>
</tr>
<tr>
<td>(3) Midseason</td>
<td>66</td>
<td>77</td>
</tr>
<tr>
<td>(6) Plant-based</td>
<td>66</td>
<td>93</td>
</tr>
<tr>
<td>(2) Postharvest</td>
<td>72</td>
<td>82</td>
</tr>
<tr>
<td>(1) Control</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

No yield loss at 66% ET with season-long plant-based irrigation (predawn WP < -12 bars)
IRRIGATION OF FRUIT TREES AND VINES

David A. Goldhamer • Mario Viveros • Mario Salinas

Regulated deficit irrigation in almonds: effects of variations in applied water and stress timing on yield and yield components

- 1993 -1996 study, Southern SJV, 18 year-old orchard
- Control (100% ETc)
- 3 levels of irrigation deficit
- 3 patterns of deficit  △ ◇ □
“C” Seasonal pattern in water application (% of control)

Equal irrigation deficit all season

(Control = 100% season long, about 42”)
(Target about 34”)
(Target about 28”)
(Target about 23”)

Date

(March, April, May, June, July, August, September, October, November)

(Goldhamer et al., 2006)
“B” Seasonal pattern in water application (% of control)

Some deficit early, most deficit post-harvest

Date (Goldhamer et al., 2006)
“C” Seasonal pattern in water application (% of control)

More deficit early, less deficit postharvest

Date

(March, April, May, June, July, August, September, October, November)

(Goldhamer et al., 2006)
Mean Yield 1993-1996

Kernel Yield (lbs/ac)

Kernel Size (g/nut)

Seasonal Applied Irrigation (inches)

(100% ETc CONTROL)

(ONLY 2 TREATMENTS WITH A SUBSTANTIAL 3RD YEAR REDUCTION)

Goldhamer et al., 2006
Crop Load (Thousand nuts/acre)

Seasonal Applied Irrigation (inches)

(Goldhamer et al., 2006)
Question: is the amount and timing of irrigation all you need to know to describe the stress experienced by the tree?

(Goldhamer et al., 2006)
Answer: probably not, maybe better to ask the tree?
Below balance point

Above balance point

Magnifying glass

Seal

Pressure gauge

Air pressure

Pressure chamber

Plastic bag
Example of the daily pattern in stem water potential (SWP) in Almonds

(Magnum ranch, Lassen Land Co., August 4, 2005)
Midday SWP values in Almond

(Minimal stress) Expected range even under fully irrigated conditions

(Mild stress) Will reduce overall growth of young trees, and shoot growth of older trees, but may also have some beneficial effects on older trees

(Moderate stress) Interior leaf yellowing and drop usually apparent. Not unusual to find under almond production conditions, but probably reduces tree productivity, particularly if these levels occur regularly

(Severe stress) Leaf drop, flagging, wilting. Can occur under almond production conditions, particularly around harvest.
Goldhamer study, predawn water potential

Predawn leaf water potential (bars)

Goldhamer et al., 2006
Midday SWP values in Almond

- **Minimal stress**
  - SWP values between -5 to 0 bars.
  - Expected range even under fully irrigated conditions.

- **Mild stress**
  - SWP values between -10 to -5 bars.
  - Will reduce overall growth of young trees, and shoot growth of older trees, but may also have some beneficial effects on older trees.

- **Moderate stress**
  - SWP values between -15 to -10 bars.
  - Interior leaf yellowing and drop usually apparent. Not unusual to find under almond production conditions, but probably reduces tree productivity, particularly if these levels occur regularly.

- **Severe stress**
  - SWP values below -15 bars.
  - Leaf drop, flagging, wilting. Can occur under almond production conditions, particularly around harvest.
Example: **Midday** stem water potential (bars) in 2006,
Lampinen et al., Spur Dynamics

- **T1 (high water, high N)**, Seasonal mean = **-10.9 bars**
- **T2 (high water, mod. N)**, Seasonal mean = **-11.0 bars**
- **T3 (mod. water high N)**, Seasonal mean = **-13.6 bars**
- **T4 (mod. water mod. N)**, Seasonal mean = **-13.7 bars**
Lampinen study, canopy development (5th leaf – 11th leaf orchard)

Seasonal average midday light interception (%)
Conclusions:

- Canopy development determines yield potential
- Approximately 10% loss in rate of canopy development per bar of seasonal average midday stem water potential deficit

(Lampinen study)
• Canopy development determines yield potential

• Approximately 10% loss in rate of canopy development per bar of seasonal average midday stem water potential deficit

(Lampinen study)
Goldhamer study, predawn water potential

Predawn leaf water potential (bars)

-35  -30  -25  -20  -15  -10  -5  0

APR  MAY  JUN  JUL  AUG  SEP  OCT

Control


(Goldhamer et al., 2006)
Question: Is it possible that stress can be determined by factors other than irrigation amount and timing?

Answer: Yes – we have a good example of a non-uniform field that required substantial irrigation compensation to make it uniform.
% Hull Split, Carmel variety
(East/West difference similar in all varieties)

<table>
<thead>
<tr>
<th></th>
<th>Date, 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 Aug</td>
</tr>
<tr>
<td>East</td>
<td></td>
</tr>
<tr>
<td>(Average SWP = -8.4 bars)</td>
<td>0%</td>
</tr>
<tr>
<td>West</td>
<td></td>
</tr>
<tr>
<td>(Average SWP = -14.1 bars)</td>
<td>4%</td>
</tr>
</tbody>
</table>

Problems with uneven hull split timing:

- Uncertain timing for hull split spray
- Irrigation management problems
- Uneven/delayed harvest
NonPareil variety (Corning) – Hull Split (RDI treatment)

<table>
<thead>
<tr>
<th>Year</th>
<th>East (silt)</th>
<th>West (gravel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:</td>
<td>[Table]</td>
<td>[Table]</td>
</tr>
<tr>
<td>2003:</td>
<td>[Table]</td>
<td>[Table]</td>
</tr>
</tbody>
</table>

### 2001:

<table>
<thead>
<tr>
<th>Date</th>
<th>JUL 13</th>
<th>JUL 20</th>
<th>JUL 27</th>
<th>AUG 1</th>
<th>AUG 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>% HS</td>
<td>2</td>
<td>20</td>
<td>45</td>
<td>70</td>
<td>100</td>
</tr>
</tbody>
</table>

### 2003:

<table>
<thead>
<tr>
<th>Date</th>
<th>JUL 29</th>
<th>AUG 7</th>
<th>AUG 15</th>
<th>AUG 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>% HS</td>
<td>29</td>
<td>96</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
## Corning location – irrigation summary (RDI)

<table>
<thead>
<tr>
<th>Soil</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water applied</td>
<td>Cutoff date</td>
<td>Water applied</td>
</tr>
<tr>
<td>East (silt)</td>
<td>24”</td>
<td>10-Jul</td>
<td>14”</td>
</tr>
<tr>
<td>West (gravel)</td>
<td>40”</td>
<td>25-Aug</td>
<td>41”</td>
</tr>
<tr>
<td>ETC</td>
<td>43”</td>
<td>40”</td>
<td>42”</td>
</tr>
</tbody>
</table>

Very long cutoff/cutback OK on East (silt) soil
## 2001 - 2004 Almond RDI sites:

<table>
<thead>
<tr>
<th>County</th>
<th>Location</th>
<th>Soil type</th>
<th>Age (yr)</th>
<th>Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tehama</td>
<td>Corning(E)</td>
<td>Silt-Loam</td>
<td>9</td>
<td>Microsprinkler</td>
</tr>
<tr>
<td>Tehama</td>
<td>Corning (W)</td>
<td>Gravel-Loam</td>
<td>9</td>
<td>Microsprinkler</td>
</tr>
<tr>
<td>Butte</td>
<td>Chico</td>
<td>Vina-Loam</td>
<td>9</td>
<td>Solid-set Sprinkler</td>
</tr>
<tr>
<td>Colusa</td>
<td>Arbuckle</td>
<td>Gravel-Loam (II)</td>
<td>13</td>
<td>Single line drip</td>
</tr>
<tr>
<td>Solano</td>
<td>Dixon</td>
<td>Yolo-S/CLoam</td>
<td>8</td>
<td>Solid-set Sprinkler</td>
</tr>
<tr>
<td>Madera</td>
<td>Madera</td>
<td>Dinuba FSL</td>
<td>10</td>
<td>Microsprinkler</td>
</tr>
<tr>
<td>Kern</td>
<td>Shafter</td>
<td>Sandy Loam</td>
<td>15</td>
<td>Microsprinkler</td>
</tr>
</tbody>
</table>

**Question:** Can we use RDI in the same location(s) over many years without reducing yield?
## Four year yield summary

(lbs. nutmeats per acre)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2001 (2 sites)</th>
<th>2002 (7 sites)</th>
<th>2003 (7 sites)</th>
<th>2004 (7 sites)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grower</td>
<td>2,400</td>
<td>3,170</td>
<td>2,860</td>
<td>2,650</td>
</tr>
<tr>
<td>RDI</td>
<td>2,430</td>
<td>3,080</td>
<td>2,660</td>
<td>2,680</td>
</tr>
</tbody>
</table>
Selected sites where differences in stress only occurred during hull split (15 “paired” comparisons)

<table>
<thead>
<tr>
<th>(Measured Value)</th>
<th>Irrigation Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grower</td>
</tr>
<tr>
<td>SWP (bar)</td>
<td>-11.1 ± 1.7</td>
</tr>
<tr>
<td>Yield (lbs/ac)</td>
<td>2,812 ± 787</td>
</tr>
<tr>
<td>Nut Size (g)</td>
<td>1.22 ± 0.19</td>
</tr>
</tbody>
</table>
## Four year (2001 – 2004) harvest effects summary

<table>
<thead>
<tr>
<th>Location</th>
<th>Hull rot (strikes/tree)</th>
<th>Days RDI advance in HS</th>
<th>Other effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grower</td>
<td>RDI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corning (silt)</td>
<td>0.0</td>
<td>0.0</td>
<td>5</td>
</tr>
<tr>
<td>Corning (gravel)</td>
<td>0.0</td>
<td>0.0</td>
<td>6</td>
</tr>
<tr>
<td>Chico</td>
<td>1.1</td>
<td>2.2</td>
<td>0</td>
</tr>
<tr>
<td>Arbuckle</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Dixon</td>
<td>4.4</td>
<td>2.4</td>
<td>1</td>
</tr>
<tr>
<td>Madera</td>
<td>20.1</td>
<td>5.1</td>
<td>4</td>
</tr>
<tr>
<td>Kern</td>
<td>24.0</td>
<td>17.5</td>
<td>0</td>
</tr>
</tbody>
</table>

- 60% mummy reduction, '02
- Grower required 2 shakes, '02
- 50% sticktight reduction, '03, '04
Magnum Ranch, Lassen Land co. RDI study.

Nutmeat yields, 2004 - 2007

Lbs. nutmeats/acre

YEAR

CONTROL

RDI
Benefits of RDI (mild stress) for almonds during hull split:

1) Speed up Hull Split (use water as a management tool)
2) Reduce Hull rot
3) Reduce Sticktights (Improve Harvestability)
4) Save Water
5) No negative impact on yield