Innovations in Agricultural Water Management

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Topics

Systems

1) Management
2) Changing

Irrigation Scheduling

1) Soil monitoring; Water budget
2) Plant monitoring

Reducing Consumptive Use

Future
Traditional approaches for reducing agricultural water use: Systems.

1. Improving management.
2. Changing from gravity to pressurized.
Systems

1. Improve management.

2. Changing to pressurized.

Can improve application uniformity; i.e. reduce losses to deep percolation and runoff, but does this reduce the consumptive use of water?
Traditional Irrigation Scheduling Concepts

1) Soil monitoring.
2) Water budget.
EnviroSCAN Probe
Cut-away diagram to the 12 inch sensor. Sensors are available for depths of up to 216 inches.

Top Cap
Access Tube
Sensor Electrodes
Soil
Sensor at 4 inches
Sensor at 8 inches
Sensor at 12 inches
Cable to Logger
Depths to 216 inches
Shortcomings of Soil Monitoring

1) Accuracy of measurement.
2) Few measurements per acre.
3) Interpretation of data.
4) Costs.
Water Budget

\[ \text{ETc} = \text{Kc} \times \text{ETo} \]

Orchard Water Use = Crop Coefficient \times Reference Crop Water Use
Daily Report

Rendered in ENGLISH Units.
February 10, 2003 - February 16, 2003
Printed on February 17, 2003

Porterville - San Joaquin Valley - Station 169

<table>
<thead>
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<th>Date</th>
<th>CIMIS ETo (in)</th>
<th>Precip (in)</th>
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<th>Avg Vap (mBars)</th>
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<th>Min Air Temp (°F)</th>
<th>Avg Air Temp (°F)</th>
<th>Max Rel Hum (%)</th>
<th>Min Rel Hum (%)</th>
<th>Avg Rel Hum (%)</th>
<th>Dwd Pt (°F)</th>
<th>Avg wSpd (MPH)</th>
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</table>
Shortcomings of Water Budget

1) Accuracy of CIMIS ETo.
2) Accuracy of Kc.
3) Applicability of regional data to a specific farm.
4) Application efficiency estimates.
5) Usefulness for RDI limited.
Reducing Losses ≠ “Saving” Water

Evapotranspiration (ET)

Irrigation Water Supply Area 1

Irrigation Water Supply Area 2

Runoff

Deep Percolation

Irrigation Return Flows

Reducing Losses = “Saving” Water
To reduce consumptive use, only options are:

decrease

E and/or T
Can we reduce Transpiration?
6 CO₂ + 12 H₂O → C₆H₁₂O₆ + 6 O₂ + 6 H₂O
(Sugar)
Alfalfa Production Function; New Mexico

\[ y = 0.136x - 4.43 \]
\[ R^2 = 0.752 \]

Sammis (1981)
Sorghum Production Function; S. Great Plains

Grain Yield (kg/ha)

Seasonal ET (mm)

\[ y = 15.2x - 1844 \]  

Stewart (1985)
Cotton Production Function; S. J. Valley

Grimes and El-Zik (1982)

\[ y = -0.003x^2 + 5.27x - 943 \]

\[ y = 2.034x - 98.6 \]

\[ R^2 = 0.981 \]
Red Pepper Production Function; Turkey

\[ y = -0.0017x^2 + 3.49x - 488 \]

\[ y = 1.79x - 90.9 \]

\[ R^2 = 0.989 \]

Gencoglan et al. (2006)
Regulated Deficit Irrigation (RDI)

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

Goals: Solve horticultural problems; Reduce water use; Achieve higher farm profits.
## Mean (1991-92) Yield and Component Results

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Split Nut Weight (g/nut)</th>
<th>Blanks and Aborted Nuts (% nut load)</th>
<th>Shell Splitting (% filled nuts)</th>
<th>Total Nut Load (No./tree)</th>
<th>Mechanical Removal of Split Nuts (% splits)</th>
<th>Yield of Dry, Split Nuts at Harvest (lb/acre)</th>
<th>Irrigation Water Use Efficiency (gals H₂O/lb product)</th>
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</thead>
<tbody>
<tr>
<td>0% Stage 1</td>
<td>1.24 b*</td>
<td>21.5 ab</td>
<td>87.8 d</td>
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<td>22.0 ab</td>
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<td>0% Postharvest</td>
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<td>78.8 bc</td>
<td>11411</td>
<td>88.8 bc</td>
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<td>350 ab</td>
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<tr>
<td>50% Stage 2; 25% PH</td>
<td>1.30 bc</td>
<td>21.2 ab</td>
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<td>89.5 bc</td>
<td>2744 cd</td>
<td>256 c</td>
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<td>79.5 bc</td>
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<td>2714 cd</td>
<td>333 ab</td>
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</table>

NSD

* Values followed by the same letter are not statistically different at p=0.05.
Y = 1.26x – 12.9
R² = 0.77

Only Stage 2 and PH Stress

Evapotranspiration (% of Control)

Yield, Dry In-Shell (% of Control)

Kettleman City, Atl., ’89-’92
Madera, Atl., ’92-’95
Lost Hills, Atl., ’93-96
McFarland, Atl., ’93-’96
Madera, PG1, ’04-’07
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**Applied (mm)**: 646  602  708  667  591  685  706  590  673  663  685

**Deficit (mm)**: 156  200  94  135  211  117  96  212  129  139  117

**Water Saved (%)**: 15%  19%  9%  13%  20%  11%  9%  20%  12%  13%  11%
Mean 1998-2000, Navel Oranges, ‘Frost Nucellar’

- Gross Revenue ($/ha)
  - RDI Treatments; Revenue
  - Control; Revenue

- Harvested Fruit Tonnage (kg/ha)
  - RDI Treatments; Tonnage
  - Control; Tonnage

Linear Through Origin 1:1
2004-6 Mean Results; Late Harvest Navels

<table>
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<tr>
<th>Seasonal Stress Period</th>
<th>2003-5 Mean Applied Water (mm)</th>
<th>Single Fruit Wt. (g)</th>
<th>Harvest Fruit Load (No./tree)</th>
<th>Gross Fruit Yield (kg/ha)</th>
<th>Gross Revenue ($/ha)</th>
<th>Water Productivity (kg/m3)</th>
<th>Irrigation-Revenue Productivity ($/m3)</th>
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<td>138</td>
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<td>c</td>
<td>155</td>
<td>ab</td>
<td>34000</td>
<td>8924 a</td>
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* Values in each column not followed by the same letter are statistically different based on Fisher’s LSD at 5%.

** NSD; No significant differences.
Last Gasp

We live in what many now say is the nation's worst air basin. What are the challenges to improving the air in the coming years?
Can we exploit horticultural impacts of water stress to eliminate ground drying and thus, eliminate dust, kernel contamination with soil borne pathogens, AND better maintain tree water status during and after harvest?
Hull Splitting; Non Pareil; 2004

Hull Split Nuts (%)

- T2
- T4
- Control

Jun 12 Jun 22 Jul 2 Jul 12 Jul 22 Aug 1

Hull Split Nuts (%)
Kernel Hydration; Non Pareil; 2004

The diagram shows the kernel hydration percentage over time for three groups: T2, T4, and Control. The hydration percentage decreases over time from July 24 to August 9.
<table>
<thead>
<tr>
<th>Irrigation Regime</th>
<th>Applied Water (mm)</th>
<th>Kernel Dry Wt. (g)</th>
<th>Kernel (%)</th>
<th>Fruit Load (#/tree)</th>
<th>Yield 5% H2O (kg/ha)</th>
<th>Water Productivity (g/m3)</th>
<th>Sticktight Nuts (No./tree)</th>
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<td>T2</td>
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<td>6510</td>
<td>2319</td>
<td>207</td>
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NSD: Not Stated; ND: Not Determined; 2004; 2004
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<th>Hull Rot</th>
<th>Dead Wood</th>
<th>Kernel Wt.</th>
<th>Shell Wt.</th>
<th>Hull Wt.</th>
<th>Whole Unit Wt.</th>
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<tr>
<td><strong>Control</strong></td>
<td>297 (#/tree)</td>
<td>508 (inches/tree)</td>
<td>1.19 (gms)</td>
<td>0.93 (gms)</td>
<td>4.12 (gms)</td>
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<td><strong>RDI</strong></td>
<td>49</td>
<td>33</td>
<td>1.14</td>
<td>0.95</td>
<td>4.19</td>
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<td><strong>RDI % Di</strong></td>
<td><strong>-84.5</strong></td>
<td><strong>-93.5</strong></td>
<td><strong>-4.2</strong></td>
<td><strong>+2.2</strong></td>
<td><strong>+1.7</strong></td>
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<td><strong>NSD</strong></td>
<td><strong>NSD</strong></td>
<td><strong>NSD</strong></td>
<td><strong>NSD</strong></td>
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Hull Rot; Teviotdale et al.; 1997
RDI Management Options (Triggers)

1. Water Budget
2. Soil-based-instruments
3. Plant-based
   a. Leaf water potential.
   b. Fruit or other tissue growth.
   c. Canopy temperature
<table>
<thead>
<tr>
<th>Process affected</th>
<th>Sensitivity to stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very sensitive</td>
</tr>
<tr>
<td>Reduction in tissue $\Psi_w$ required to affect the process (MPa)</td>
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</table>

<table>
<thead>
<tr>
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<th>Sensitivity to stress</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Very sensitive</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Cell growth ($-$)</td>
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<td>Wall synthesis $^b$ ($-$)</td>
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<tr>
<td>Protein synthesis $^b$ ($-$)</td>
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<tr>
<td>Protochlorophyll formation $^c$ ($-$)</td>
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<tr>
<td>Nitrate reductase level ($-$)</td>
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<td>ABA synthesis (+)</td>
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<td>Stomatal opening $^c$ ($-$)</td>
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</tr>
<tr>
<td>mesophytes</td>
<td></td>
</tr>
<tr>
<td>some xerophytes</td>
<td></td>
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<tr>
<td>CO$_2$ assimilation $^c$ ($-$)</td>
<td></td>
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<tr>
<td>mesophytes</td>
<td></td>
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<tr>
<td>some xerophytes</td>
<td></td>
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<tr>
<td>Respiration ($-$)</td>
<td></td>
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<tr>
<td>Xylem conductance $^d$ ($-$)</td>
<td></td>
</tr>
<tr>
<td>Proline accumulation (+)</td>
<td></td>
</tr>
<tr>
<td>Sugar level (+)</td>
<td></td>
</tr>
</tbody>
</table>
Shortcomings of the Pressure Chamber

1) Manually taken; can’t be automated.
2) Requires trips to the field and operator.
3) Limited time period to take measurements; noon-2:30 pm.

Thus, can’t adequately characterize a field.
Mature Almond Trees; San Joaquin Valley

Trunk Diameter Fluctuations (mm)

- Stress
- Ranch
Citrus; San Joaquin Valley

Onset of 25% ETc: July 1

Graph showing the onset of 25% ETc in Citrus, San Joaquin Valley, with the timeline from June 24 to August 23.
$y = -1.6029x - 1.2796$

$R^2 = 0.7819$

**Max. Daily Trunk Shrinkage (mm)**

**Stem Water Potential (MPa)**
MDS Signal and Threshold Scheduling Approach

Applied Water Rates (mm/d)

MDS Signal

- T2.75
- Applied Water Rates

Applied Water Rates (mm/d)

MDS Threshold

Jul 22, Jul 27, Aug 1, Aug 6, Aug 11, Aug 16
Desirable Characteristics of LVDTs

1. Indicator related to tree water status.
2. Signal strength greater than SWP.
3. Continuously records.
4. Electronic, automated.
5. Can be incorporated into controller.
6. Minimal labor required.
Is it feasible to install sensors on install individual trees on enough trees to adequately characterize an orchard?

No.

Cost.

Data interpretation.

Repair and maintenance.
Are there other useful indicators of tree stress?
Canopy, Air Temperature; High Stress

Hour of the Day

Canopy Temperature (F)

- RDI
- Control
- Ta CIMIS

17-Jun
Crop Water Stress Index (CWSI)

- Control
- RDI
Satellites

Altitude: 200-300 miles
Orbit Time: 94 mins
Return Time: 16 days
Swath Width: 10 miles
Pixel Size: 8 ft
ImageAire Lite ii
Small UAV for Geothermal Observations
Geoff Bland/614.6, Ted Miles/569
Barriers to innovation adoption

1. Real/perceived risk of:
   a. production and/or profit losses.
   b. reallocation of water supply.

2. Grower resistance to change.

3. Unwillingness to have higher level of management.

4. Holes in knowledge and technology.

5. Insufficient incentives.