Research update: Planting pistachios in saline soils
This isn’t morning frost!
This doesn’t look too salty… or is it?
Just a little “black alkali”...
Some spots are just too hot!

Really?
Research update: Planting pistachios in saline soils

DON'T DO IT!!

Thank you.
Acknowledgements & thanks:

- Starrh & Starrh Farms (8 years of cooperation)
- Beau Antongiovanni
- Paramount Farming Company – harvest 2011
- Rain for Rent Irrigation
- Belridge Water District
Pistachio acreage has doubled in last 10 years

![Graph showing the increase in pistachio and cotton acreage from 1977 to 2009. The x-axis represents years from 1977 to 2009, and the y-axes represent acres for cotton and pistachio.]
More than ½ million more acres are free of “perched water” but have poor surface soils with excessive silt and sodicity, resulting in “sealing” and poor structure not conducive to optimal root development.
However, much of this land is less expensive than the I-99 corridor, has Panoche-type clay loam soils with high-yield potential and good canal water supplies.
...with large areas that can “drown out” and salinize under surface irrigation. Well managed micro-irrigation systems can reduce or eliminate much of the drainage problem, but when salts become this bad some leaching and reclamation is essential.
The results in some areas of the Westside have been spectacular.
But no orchard is perfect
Marginal burn on 0.7 dS/m UCB Rep 2 (9/16/02)

No marginal burn on 0.7 dS/m UCB Rep 1 (9/16/02)
Boron, chloride and sodium accumulation killing marginal leaf areas at end of season.
STUDY SITE – NW KERN COUNTY (Aerial 9/19/02)

40 acre pistachio orchard planted 1989

Soil: calcareous Twisselman silty clay

Spacing: 5.2 x 6.1m (17 x 20 feet)

Irrigation: One 55 lph (14.5 gph) microsprinkler/tree centered between trees with 12 static jets @ 360° and a wetted diameter of 4.3m (14 feet). Established with CA Aqueduct water.

Salinity trial initiated April 1994, terminated November 2002. (Trial size = 12 trees x 20 rows)
Plot Layout in Orchard
Precipitated salts on soil surface in 12 dS/m plot (10/13/00)

SALINITY TRIAL IRR. WATER @ 8 dS/m
Na: 60 meq/l  Cl: 40 meq/l  B: 1 ppm
1,380 ppm  1,400 ppm
# Cumulative Yields by Salinity

Cumulative and (Average Annual) Yield per tree; 1997 - 2002

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Irrigation Water / Root Zone Salinity*</th>
<th>12 dS/m yield as a % of control yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.75 / 4.7*</td>
<td>4.0 / 8.7*</td>
</tr>
<tr>
<td>Atlantica</td>
<td>46.3 (7.7)</td>
<td>47.3 (7.8)</td>
</tr>
<tr>
<td>PGI</td>
<td>57.3 (9.6)</td>
<td>52.1 (8.7)</td>
</tr>
<tr>
<td>PGII</td>
<td>50.3 (8.4)</td>
<td>51.8 (8.6)</td>
</tr>
<tr>
<td>UCB1</td>
<td>56.0 (9.3)</td>
<td>62.0 (10.3)</td>
</tr>
</tbody>
</table>

*Soil salinities are end of season 2002 values.

+12 dS/m irrigation was only applied for 1997 through 2002 seasons.

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**8th-13th Leaf Average Annual Yield for 0.75 to 8 dS/m water (lb/ac):**

<table>
<thead>
<tr>
<th></th>
<th>PG1</th>
<th>UCB1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>2,531</td>
<td>2,727</td>
</tr>
</tbody>
</table>
Westside Salinity Trial 2001/2002 Biennial Split Nut Yields for all Varieties as a Function of Rootzone Salinity

**UCB Splits**
- Possible Threshold?
- $y = -0.2029x + 7.3912$
- $R^2 = 0.5317$
- $y = 0.0105x^3 - 0.3629x^2 + 3.576x - 3.9869$
- $R^2 = 1$

**PG1 Splits**
- $y = -0.0108x^3 + 0.3181x^2 - 2.9417x + 13.495$
- $R^2 = 1$

**PG2 Splits**
- Possible Threshold?
- $y = -0.1152x + 6.8033$
- $R^2 = 0.3517$
- $y = -0.0568x + 0.9 + 2.8935$
- $R^2 = 0.8931$

**Atlantica Splits**
- Possible Threshold?
- $y = -0.7544x + 15.595$
- $R^2 = 0.9991$
- $y = -0.3555x + 9.2596$
- $R^2 = 0.9315$
Current salinity thresholds for pistachios

WHAT ABOUT DEVELOPING NEW PISTACHIO PLANTINGS USING SALINE WATER?
Plant stress can be high even with wet soil  
(Effective soil moisture tension for a silt loam soil)

![Graph showing soil moisture tension](image)

Silt Loam  
(Sand = 20%,  
Clay = 20%,  
OM = 2.5%)
Reduced water, deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing the uptake of carbon dioxide and reducing vegetative growth.
Salt increases osmotic potential, costing the plant energy and interferes with water uptake and limits critical processes like cell expansion for germination and shoot growth.

Pistachios in Iran
(irrigation EC 25 dS/m)
Belridge Salinity Trial

-- 2, 155 acre fields

-- 12, 19.5 acre testplots
• Tape: TSX 12-220 @ 0.875 in diameter
• Emitters: spaced @ 12 inches
• Depth: 9 to 10 inches below bed.
• Run: 1280 to 1300 feet
• Cotton rows: 38 inches
• Irrigation depth: 1.97 in/day

SDI tape system installed January 2004
Objectives

1. Assess the viability of large-scale cotton production and pistachio interplanting using saline groundwater (EC 5 dS/m and B @ 10 ppm) and optimal irrigation scheduling with SDI.

2. Determine crop ET as a function of salinity using simple water and chloride balance.

3. Maintain acceptable soil salinity levels for cotton stand establishment/production and maximum growth of young pistachios.

4. Compare total project profitability under SDI using 3 different levels of salinity: saline water, non-saline CA Aqueduct water and a 50/50 blend.
Establishing pistachios interplanted in Pima cotton using drip tape and saline water.

(1st leaf, 8/2/05)
Recommended irrigation schedules are provided to the grower on a weekly basis for both cotton and pistachios for all treatments. In practice, all treatments are irrigated to supply the ET demand for the 0.5 dS/m treatment.
Following stand establishment problems from a cool spring, the saline Well and Blend treatments showed reduced cotton plant height compared to the Aqueduct treatment.

(29 June, 2006)

Belridge Well
EC  5.4 dS/m

Aqueduct
EC  0.5 dS/m

Phytogen
810RR planted
4/12-14/06.
By mid August, vigor in all treatments appeared equal.

(17 August, 2006)
### 9-1: 8/14/06 NDVI

<table>
<thead>
<tr>
<th>Source</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aqueduct</strong></td>
<td>0.5 dS/m</td>
</tr>
<tr>
<td>Blend (50/50)</td>
<td>3.0 dS/m</td>
</tr>
<tr>
<td><strong>Belridge Well</strong></td>
<td>5.4 dS/m</td>
</tr>
<tr>
<td><strong>Aqueduct</strong></td>
<td>0.5 dS/m</td>
</tr>
<tr>
<td><strong>Belridge Well</strong></td>
<td>5.4 dS/m</td>
</tr>
</tbody>
</table>
Normalized Difference Vegetation Index

Indicates plant biomass and possibly vigor by the following ratio:

\[ \text{NDVI} = \frac{(\text{NIR} - \text{R})}{(\text{NIR} + \text{R})} \]

NIR = near infrared reflectance @ 800nm
IR = infrared reflectance @ 675nm

NDVI comparison after 3 seasons of irrigation treatments

*Differences not statistically significant

<table>
<thead>
<tr>
<th>Treatment</th>
<th>NDVI 7/29/04</th>
<th>NDVI 8/14/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aque 0.5 dS/m</td>
<td>0.751</td>
<td>0.734</td>
</tr>
<tr>
<td>Blend 3.0 dS/m</td>
<td>0.734</td>
<td>0.727</td>
</tr>
<tr>
<td>Well 5.3 dS/m</td>
<td>0.716</td>
<td>0.707</td>
</tr>
</tbody>
</table>
9-1 East
10/3/07  3rd Leaf

Photoshop pixel counts of pistachio foliage
9-1 WELL
5/15/09

Well (60% Well, 40% Aque)
EC 4.7 dS/m
2009 PROBLEMS:

1) NO WATER! Surplus water to Belridge WD $400-500/ac-ft. 2 ft fresh water cost for 80 acres = $80,000

2) Former well for WELL treatment too saline (8 dS/m). To maintain 5 dS/m irrigation treatment requires blending with new well (3.4 dS/m), boron levels maybe excessive. Grower unwilling to commit 80 acres to long-term damage.

3) Small plot AQUEDUCT control currently maintained. Grower maybe willing for small plot 5 dS/m irrigation, but replumbing system required.
WHAT HAPPENED IN 2010?
WHAT HAPPENED IN 2010?

FIELD LAYOUT: 9-1

**ORIGINAL PLOTS**

FIELD LAYOUT: 9-3

**2010 REDUCED PLOTS**

COLOR KEY FOR SET VALVES & IRRIGATION WATER:

**BLUE (Set 1) --**
- AQUEDUCT
  - EC 0.5 dS/m

**GREEN (Set 2) --**
- 50/50 BLEND (low well)
  - EC 3.2 dS/m

**RED (Set 3) --**
- BLEND (same as above but not part of test area)

**ORANGE (Set 4) --**
- WELL ONLY
  - EC 5.1 dS/m

Direction of water flow in drip tape

Each plot is about 19.4 acres and can accommodate 29 to 30 rows. Tree spacing will be 22 x 17 feet. Pollinators to be planted every 5th row and 7th tree.

New reduced plots are to minimize the amount of Aqueduct water required (@ $400/ac-ft) and reduce acreage exposed to high salinity (5.2 dS/m). The center two rows and first 15 trees of this isolated 4 row x 20 tree section is the area where we have always done tissue / soil sampling and tree measurements for the last 5 years. Plot area = 0.687 acres.
Installing isolation mainlines, valves, manifolds and meters for 4 row x 20 tree plots, late April

<table>
<thead>
<tr>
<th>SIZE</th>
<th>CLASS</th>
<th>QTY (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>200</td>
<td>1200</td>
</tr>
<tr>
<td>1.25&quot;</td>
<td>125</td>
<td>5560</td>
</tr>
<tr>
<td>1.5&quot;</td>
<td>125</td>
<td>2600</td>
</tr>
<tr>
<td>2&quot;</td>
<td>125</td>
<td>3720</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>13080</strong></td>
<td></td>
</tr>
</tbody>
</table>
A single drip hose with 4, 2 gph emitters per tree was plumbed into the row manifold to quickly apply sufficient water from 9 dS/m well to achieve an equivalent 5.2 dS/m irrigation EC to trees during irrigation.
10 PG1 trees          10 UCB trees

V2West WELL
treatment sample rows
Select soil first with “Magic Wand” (Tolerance 50) and delete then select green foliage (Tolerance 50) to get total foliage pixel count and “Average Green” (0 is total green, 256 total white)
(a) V6W Aque
2,626,465 pixels
77.42 grn mean

(b) V2W Well
2,850,344 pixels
75.25 grn mean

9-1 West
10/28/11
Marginal burn was seen on most leaves.

Aqueduct
EC 0.5 dS/m

Blend (30% Well, 70% Aque)
EC 3.2 dS/m

Well (60% Well, 40% Aque)
EC 5.2 dS/m

9-1 West Compare
AVERAGE LEAF PIXEL TOTALS

<table>
<thead>
<tr>
<th></th>
<th>Leaf Pixels</th>
<th>% of Aque</th>
<th>Mean Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQUEDUCT</td>
<td>2,951,458</td>
<td>100.0%</td>
<td>78.23</td>
</tr>
<tr>
<td>BLEND</td>
<td>2,539,943</td>
<td>86.1%</td>
<td>78.00</td>
</tr>
<tr>
<td>WELL</td>
<td>2,740,930</td>
<td>92.9%</td>
<td>72.11</td>
</tr>
</tbody>
</table>

Pistachio foliage pixel counts 10/28/11 (no statistically significant difference)
2009-11 rootstock growth decreased 7 to 9% from well water

<table>
<thead>
<tr>
<th>% of Aqueduct</th>
<th>PG1</th>
<th>UCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend EC = 3.3 dS/m</td>
<td>93.0%</td>
<td>91.4%</td>
</tr>
<tr>
<td>Well EC = 5.1 dS/m</td>
<td>90.6%</td>
<td>90.8%</td>
</tr>
</tbody>
</table>

Trees planted March 5-11, 2005. *Irrigation salinity impact statistically significant (P<0.05)
## Change in tissues and soil salinity

<table>
<thead>
<tr>
<th>Kerman Leaves 10/31/06 Pistachio 2006</th>
<th>Rootzone ECe to 5'</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N (%)</strong></td>
<td><strong>P (%)</strong></td>
</tr>
<tr>
<td>Aque</td>
<td>1.19</td>
</tr>
<tr>
<td>Blend</td>
<td>1.36</td>
</tr>
<tr>
<td>Well</td>
<td>*1.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kerman Leaves 7/21/10 (PG1) Pistachio 2010</th>
<th>7/21/10</th>
<th>11/11/10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aque</strong></td>
<td>2.30</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Blend</strong></td>
<td>2.34</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Well</strong></td>
<td>2.33</td>
<td>0.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kerman Leaves 7/21/10 (UCB1) Pistachio 2010</th>
<th>11/11/10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aque</strong></td>
<td>2.41</td>
</tr>
<tr>
<td><strong>Blend</strong></td>
<td>2.44</td>
</tr>
<tr>
<td><strong>Well</strong></td>
<td>2.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kerman Leaves 7/29/11 (PG1) Pistachio 2011</th>
<th>11/27/11</th>
<th>PG1 (lb/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aque</strong></td>
<td>2.41</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Blend</strong></td>
<td>2.54</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Well</strong></td>
<td>2.55</td>
<td>0.13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kerman Leaves 7/29/11 (UCB1) Pistachio 2011</th>
<th>11/27/11</th>
<th>UCB (lb/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aque</strong></td>
<td>2.51</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Blend</strong></td>
<td>2.52</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Well</strong></td>
<td>2.66</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*Significantly different from Aqueduct @ 0.05, **Significant @ 0.01

1Cotton height @ irrigation cuttoff.  
2Cotton cover = 12.7 feet/tree row

Pistachio drip subbin
## Salt added to crop rootzone from start of project

<table>
<thead>
<tr>
<th>Irrigation Treatment</th>
<th>2005 Irrig (in)</th>
<th>2005 Salt ¹(lb/ac)</th>
<th>2007 Irrig (in)</th>
<th>2007 Salt (lb/ac)</th>
<th>2009 Irrig (in)</th>
<th>2009 Salt (lb/ac)</th>
<th>2011 Irrig (in)</th>
<th>2011 Salt (lb/ac)</th>
<th>TOTAL</th>
<th>²EC+ Max (dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aque</td>
<td>10.4</td>
<td>1742</td>
<td>12.0</td>
<td>1390</td>
<td>17.5</td>
<td>7022</td>
<td>33.3</td>
<td>3387</td>
<td>115.9</td>
<td>18192</td>
</tr>
<tr>
<td>50/50</td>
<td>10.4</td>
<td>8570</td>
<td>10.8</td>
<td>7571</td>
<td>15.6</td>
<td>14399</td>
<td>41.0</td>
<td>40838</td>
<td>111.1</td>
<td>78900</td>
</tr>
<tr>
<td>Well</td>
<td>11.8</td>
<td>14782</td>
<td>10.7</td>
<td>13197</td>
<td>16.6</td>
<td>18444</td>
<td>35.3</td>
<td>48596</td>
<td>117.7</td>
<td>129915</td>
</tr>
</tbody>
</table>

¹Irrigation inches for total tree spacing, salt totals (lb/ac) calculated for a 9.5 foot wide subbing area centered on the tree row. Assumes 640 ppm soluble salt = 1 dS/m and a 5 ac-ft depth of soil = 20 million lbs.

²Maximum increase in soil saturated paste EC for a 5 foot rootzone with no precipitation of salts and no leaching past the 5 foot depth.
### Average change in soil salinity over 8 years

#### PISTACHIO AVERAGE SOIL SALINITY FROM PREPLANT TO 7/21/11

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>SP %</th>
<th>pH</th>
<th>EC dS/m</th>
<th>Ca (SP) meq/l</th>
<th>Mg (SP) meq/l</th>
<th>Na (SP) meq/l</th>
<th>Cl (SP) meq/l</th>
<th>HCO3 meq/l</th>
<th>B (SP) ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aque</td>
<td>44</td>
<td>7.8</td>
<td>2.07</td>
<td>11.7</td>
<td>2.1</td>
<td>9.1</td>
<td>5.7</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Blend</td>
<td>47</td>
<td>7.8</td>
<td>2.53</td>
<td>13.0</td>
<td>2.3</td>
<td>11.4</td>
<td>7.0</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Well</td>
<td>46</td>
<td>7.7</td>
<td>2.10</td>
<td>14.2</td>
<td>1.9</td>
<td>9.3</td>
<td>4.9</td>
<td>1.9</td>
<td>0.8</td>
</tr>
</tbody>
</table>

#### % Change over 8 years

- Aque: 336% 388% 471% 262% 617% 92% 158% 141%
- Blend: 502% 654% 809% 419% 1247% 93% 431%
- Well: 405% 359% 623% 390% 1081% 72% 754% 168%

---

Weighted averages to 5 feet, soil sampled 3/23/04:

- **Aque**: 41 7.8 6.96 45.5 10.0 23.9 35.2 1.7 1.7 24.8
- **Blend**: 42 7.6 12.68 85.3 18.4 47.6 86.7 1.7 4.7 32.3
- **Well**: 41 7.7 8.49 50.9 12.1 36.5 53.2 1.3 5.7 34.9

---

Weighted averages to 5 feet, soil sampled 7/21/11:

- **Aque**: 41 7.8 6.96 45.5 10.0 23.9 35.2 1.7 1.7 24.8
- **Blend**: 42 7.6 12.68 85.3 18.4 47.6 86.7 1.7 4.7 32.3
- **Well**: 41 7.7 8.49 50.9 12.1 36.5 53.2 1.3 5.7 34.9

---

Nitric Acid Total B (ppm)

- **Aque**: 17.6
- **Blend**: 20.7
- **Well**: 24.8
Contours of soil salinity (ECe, dS/m) in pistachio rows, 2007-2011
neutron probe soil moisture readings showed significant leaching for the WELL treatment
2011 Bi-weekly Stem Water Potential

Stem Water Potential (bars)


Low to no-stress threshold

Aque
Blend
Well
<table>
<thead>
<tr>
<th></th>
<th>Clean Splits</th>
<th>Closed Shell</th>
<th>Total Inshell</th>
<th>Blanks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PG1</strong></td>
<td>1891</td>
<td>157</td>
<td>2159</td>
<td>290</td>
</tr>
<tr>
<td><strong>UCB</strong></td>
<td>1575</td>
<td>303</td>
<td>1949</td>
<td>184</td>
</tr>
<tr>
<td><strong>0.5 dS/m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PG1</strong></td>
<td>1602</td>
<td>334</td>
<td>1983</td>
<td>367</td>
</tr>
<tr>
<td><strong>UCB</strong></td>
<td>1568</td>
<td>278</td>
<td>1901</td>
<td>238</td>
</tr>
<tr>
<td><strong>3.2 dS/m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PG1</strong></td>
<td>1702</td>
<td>121</td>
<td>1902</td>
<td>279</td>
</tr>
<tr>
<td><strong>UCB</strong></td>
<td>1520</td>
<td>212</td>
<td>1808</td>
<td>216</td>
</tr>
<tr>
<td><strong>5.2 dS/m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FINAL TURNOUTS** (with standard error bars) FOR VARIOUS PISTACHIO YIELD CATEGORIES -- NO STATISTICAL DIFFERENCE BETWEEN 0.5 dS/m and 5.2 dS/m treatments
Conclusions

• Without effective winter rainfall/fresh-water irrigation > 6 inches every couple years, excessive salt buildup will reduce young pistachio growth and eventually yield.

• High Na/Ca ratios can make this problem worse and even lead to frost susceptibility (topic for another talk)

• Presently adsorbed boron could have a time bomb affect

• Use of saline water could save $2,000 - 10,000/ac over 20 years if appropriate leaching can be maintained