Developing Pistachios Under Saline Conditions: *when applied research is too successful*....

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Pistacia vera
cv. ‘Kerman’
2010:
215,336 ac
3,806 lb/ac
$2.22/lb
$8,449.00/ac
“Salinity in soil and water is irrevocably associated with irrigated agriculture throughout the world.”

James E. Ayars, 2003
Specific Salts

Cations = +
- Na$^+$ = Sodium
- Ca$^{2+}$ = Calcium
- Mg$^{2+}$ = Magnesium
- K$^+$ = Potassium

Anions = -
- Cl$^-$ = Chloride
- SO$_4^{2-}$ = Sulfate
- HCO$_3^-$ = Bicarbonate
- CO$_3^{2-}$ = Carbonate

Boron = micronutrient

pH > 8
Salinity:

- Concentration of salts in solution: dS/m
  - Irrigation water: ECw
  - Soil water: ECe
Soil and water salinity cause …

• Salinization:
  – when the concentration of soluble salts in the root zone are high enough to impede optimum growth

• Osmotic effects

• Specific ion effects
Specific Ion Damage

Osmotic Effects
<table>
<thead>
<tr>
<th>Farmer</th>
<th>Eciw (ds/m)</th>
<th>Average Yield 2002 (Tones/ha)</th>
<th>Average ECe (ds/m)</th>
<th>Average Irrigation depth (cm)</th>
<th>Irrigation interval (day)</th>
<th>Applied water (m3/ha)</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vakili</td>
<td>14.5</td>
<td>1.5</td>
<td>13.14</td>
<td>31.7</td>
<td>50</td>
<td>22190</td>
<td>Si.</td>
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<tr>
<td>Masoomi</td>
<td>22</td>
<td>0</td>
<td>11.51</td>
<td>43</td>
<td>45</td>
<td>34400</td>
<td>L</td>
</tr>
<tr>
<td>Mohammadi</td>
<td>24</td>
<td>3.7</td>
<td>10.38</td>
<td>56.7</td>
<td>45</td>
<td>45360</td>
<td>L</td>
</tr>
<tr>
<td>Shakeri</td>
<td>11.9</td>
<td>2.2</td>
<td>12.8</td>
<td>24.0</td>
<td>53</td>
<td>17220</td>
<td>L</td>
</tr>
<tr>
<td>Barkhordari</td>
<td>8.11</td>
<td>1</td>
<td>15.5</td>
<td>25.75</td>
<td>46</td>
<td>20600</td>
<td>Si.</td>
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<tr>
<td>Shateri</td>
<td>13.57</td>
<td>1</td>
<td>15.12</td>
<td>51.5</td>
<td>51</td>
<td>36000</td>
<td>Si.</td>
</tr>
</tbody>
</table>

14.88 acre feet/acre
<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>CRITICAL VALUES</th>
<th>NORMAL RANGE</th>
<th>GREEN TISSUE</th>
<th>NECROTIC TISSUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>2.3</td>
<td>2.5–2.9%</td>
<td>2.3</td>
<td>2.4</td>
</tr>
<tr>
<td>P (%)</td>
<td>0.14</td>
<td>0.14–0.17%</td>
<td>0.09</td>
<td>0.09</td>
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<tr>
<td>K (%)</td>
<td>1.0</td>
<td>1.0–2.0%</td>
<td>1.10</td>
<td>0.68</td>
</tr>
<tr>
<td>B (ppm)</td>
<td>90</td>
<td>120–250</td>
<td>57</td>
<td>87</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>1.3 (?)</td>
<td>1.3–4.0</td>
<td>1.30</td>
<td>1.91</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>0.6 (?)</td>
<td>0.6–1.2 (?)</td>
<td>0.59</td>
<td>0.68</td>
</tr>
<tr>
<td>Na (ppm)</td>
<td>?</td>
<td>?</td>
<td>6200</td>
<td>12,230</td>
</tr>
<tr>
<td>Cl (%)</td>
<td>?</td>
<td>0.1–0.3 (?)</td>
<td>1.98</td>
<td>3.43</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>30</td>
<td>30–80</td>
<td>625,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>7</td>
<td>10–15</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>4</td>
<td>6–10</td>
<td>2.9</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Central Valley of California

- **WSFS 1989**
  - yield and cold tolerance
  - Verticillium tolerance

- **S & J Ranch 1989**
  - yield and cold tolerance

- **KAC 1989**
  - yield and cold tolerance

- **Paramount Ranch 1989**
  - yield and cold tolerance
  - salinity tolerance

6/6/2018
Cumulative ET: 2002*

- 0.7 dS/m: 58.6
- 4 dS/m: 52.7
- 8 dS/m: 43.7
- 12 dS/m: 30.9
Soil Total Water Content: 2002*

Total Water Content Over Season
(Field Capacity @ 3.7”/ft and Wilting Point @ 1.9”/ft)
Tree Water Status: 2002

Bagged Leaf Water Potential Measurements for 2002

- 0.7 dS/m
- 4 dS/m
- 8 dS/m
- 12 dS/m

NSD
Effect of Saline Irrigation on Average Annual Individual Tree Yield by Rootstock, 1997 - 2002

Individual Tree Yield (Kg/tree) (4 year average)

Averages
- PGI: 2.4
- UCB1: 8.7
- PGII: 13.4
- ATL: 14.3

Ranges
- Irrigation Water Salinity
  - .75
  - 4.0
  - 8.0
  - 12.0

Overall Percentages
- 10%
- 15%
- 18%
- 35%

*
• No consistent pattern to specific ion damage or boron "toxicity"

EC\textsubscript{w} = 0.75 dS/m
1995 – 2002 Field Trial Summary

- Elevated soil ECe
- Decreased Evapotranspiration
- Trees on all four rootstocks:
  - producing normally > 8.4 dS/m
  - insignificant decreases @ 12 dS/m
  - no stress
  - inconsistent visible specific ion damage

- Normal leaf macronutrient and Na, Cl, B analysis
Relative Yield of as a Function of Soil ECe

Cotton Relative Yield = 100 - 5.2(ECe - 7.7)

Pistachio Relative Yield (%) = 100 - 8.4(ECe-9.4)

Alfalfa
Almond
Cotton
Pistachio

Tree Salt Tolerance

Yield Potential, %

Average Rootzone Salinity (ECe)

Plum
Date Palm
Olive
Citrus
Almond
Pistachio
Trunk Diameter Increase of ‘Kerman’ Pistachio as a Function of Increasing Salinity

Ferguson, Poss, Grattan, Grieve, Wang, Wilson, Donavan, Chao. 2002 JASHS 127 (2): 194-199
Partitioning of Na⁺ between ‘Kerman’ Pistachio Scion and Rootstock Wood as Influenced by Increasing Salinity Sodium

Ferguson, Poss, Grattan, Grieve, Wang, Wilson, Donovan, Chao. JASHS 127 (2) 194-99 2002.
Partitioning of Cl\(^{-}\) Between ‘Kerman’ Pistachio Scion and Rootstock Wood as Influenced by Increasing Salinity Chloride

Ferguson, Poss, Grattan, Grieve, Wang, Wilson, Donovan, Chao. JASHS 127 (2) :194-99. 2002
Major Findings......

• Field Trial:
  – Established trees can be irrigated with saline water up to 8.4 dS/m

• Greenhouse Trial:
  – Osmotic effects > specific ion damage
  – Difference among rootstocks in how they partition Na, CL
Major Question……

• Can an orchard be established at these salinity levels?
Establishing Pistachios with Blended Aqueduct and Well Water

2005 – 2009 (cotton)

• 5.2 dS/m
• 100,000 lbs/ac
• 3.2
• 60,000 lbs/ac
• 0.5 dS/m
Salinity effect marginal:
- growth
- yield: 3,000 lb/ac

Aqueduct
EC 0.5 dS/m

Blend (30%:70%)
EC 2.8 dS/m

Well (60%:40%)
EC 4.7 dS/m
Kemal Ataturk Dam, Turkey: 1990
"Grower Mark Watte is seeing a major shift from cotton production to permanent crops like pistachios...."
Saline Sodic Soils

November, 2009

Na

Saline Sodic Soils
What do we know about salinity tolerance in pistachios…

• Evidence of osmotic adjustment via K+ ion uptake
• Evidence of osmotic adjustment via synthesis of organic acids
• Differences among rootstocks
What we don’t know about salinity tolerance in pistachios….

• How the salts get taken up
• How the salts are transported
• Where are the salts sequestered
  – cellular level
  – whole plant level
• Specific ion level damages growth/yield
More specifically….

- Do roots do most of the work?
  - Filtering out salts during at cortex during uptake
  - Apoplastic or symplastic flow across cortex
  - Xylem loading and unloading in plant
- Is there phloem loading?
- Are ions sequestered in vacuoles?
  - Delaying onset of specific ion damage
Objective I

- Investigate the three physiological processes influencing salt transport to the leaves: (in major rootstocks).
  - Selectivity of uptake from the soil solution at the root cortex.
  - Loading of the xylem.
  - Retrieval from the xylem in upper parts of the roots.
Objective II

- Determine if control in the shoot occurs by the exclusion of salt from the phloem sap flowing to meristematic regions of the shoot.
Objective III

– Determine how the relative growth rate of the Kerman scion on the major different rootstocks affects the salinity status of the scion.
Objective IV

- Determine if cellular compartmentalization of salts in the vacuoles of the pistachio scion leaf mesophyll cells is occurring.
Objective V

– Use this information to direct a plant improvement program.
Overview

Louise Ferguson & Blake Sanden

What We Know: The Short of It

We know that roots do most of the work in protecting the plant from excessive uptake of salts, and filter out most of the salt in the soil while taking up water. But frankly, the fundamental processes governing the relationship between water and ion flow through roots are complex. Na, Cl and other ions do not move passively with the transpiration stream, neither are their movements entirely independent of it.

In addition to these root processes, we recognize that salt sensitivity is related to mechanisms within the plant tissue which minimize the effects of toxic ions, leading to resistance to salt stress.

The Terminology of Salinity

Ions

Salinity is based on the presence of charged ions, which can have either a positive charge (cations) or a negative charge (anions). These ions can be toxic to plants, depending on the plant and the concentration. Milligrams per liter (mg/L) is the typical unit of measure for ions. Examples of common ions affecting salinity:

- **Cations:** calcium (Ca$$^{++}$$), sodium (Na$$^{+}$$), magnesium (Mg$$^{++}$$)
- **Anions:** chloride (Cl$$^{-}$$), bicarbonate (HCO$$^{3-}$$), etc.