Understanding the Effects of Salinity on Pistachios

Louise Ferguson, Blake Sanden and Steve Grattan
University of California
Salinity:

- Amount of salts dissolved in water
- Concentration of salts in solution
  - Irrigation water
  - Soil water
Origin of Salinity in Soil and Water

• **Chemical weathering of earth minerals**
  – rocks and soils
  – sedimentary marine geological formations

• **Dissolved over the millennia**

• **Transported by water**
  – terminates in oceans or closed basins
  – concentrated by evaporation
  – percolates into ground
Specific Salts in Irrigation Water

- **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
  » pH > 8

Boron = micronutrient
Specific Salts in Irrigation Water

- **Cations** = +
  - $\text{Na}^+ = \text{Sodium}$

- **Anions** = -
  - $\text{Cl}^- = \text{Chloride}$

Boron = micronutrient
Salinity Units of Concentration

- **Weight Basis**
  - 1 ppm
  - 1 mg/l
  - 1 mg/kg
  - 1% = 10,000 ppm

- **Volume Basis**
  - mg/l
  - meq/l
  - 1 mmol_c/l = 1 meq/l
    – Systeme International d'Unites (SI)

Total dissolved solids (TDS) in irrigation and soil water
Measuring TDS

- Electrical conductivity (EC)
- Salts dissolve in water (+ or - )
- Charged electrode in water
  - Anions and cations migrate = electricity
- Water conducts electricity
- Electrical conductivity meter measures it
Electrical Conductivity

Power Source

- Cation (+)
- Anion (-)
Units for Measuring TDS

- ECw (water) or ECe (soil water extract)
  - mmhos/cm = dS/m
  - dS/m x (conversion factor) = TDS
    - Ion, concentration, temperature (25°C)
    - Soil – distilled dilution water -> underestimate
Soil and water salinity cause ......

- Salinization:
  - when the concentration of soluble salts in the root zone are high enough to impede optimum growth.
“Salinity in soil and water is irrevocably associated with irrigated agriculture throughout the world.”

James E. Ayars, 2003
Where is Salinization a Problem?

- Arid and semi arid regions
- Evapotranspiration > precipitation
- Irrigation is necessary
- World: 12% irrigated land
- USA: 28% of irrigated land
  - sharply increased from 1950 - 2010
Where in California……

• Imperial and San Joaquin Valleys
  – Westside
    • Naturally saline soils
      – weathering of marine sediment coastal range origin
    • Lack of a subsurface drainage outlet
      – SJV Drainage program
  • Over irrigation
  • Drainage water
  • Saline irrigation water
  • Fertilization
How does salinity harm plants?

- Salinization is progressive:
  - Irrigation, fertilization, possible soil saturation
- Osmotic effects
  - more common
- Specific ion toxicities
  - visible
Osmotic Effects of Salinity

• [root cell solute] > soil water ECw
  – water moves freely into root
• As soil ECw increases > [root cell solute]
  – Roots must compete for water
Osmotic Effects of Salinity

• To restore ability to extract soil water
  – plants adjust osmotically:
  • Glycophytes – “sweet” water loving plants
    – synthesize sugars, organic acids to adjust osmotically
    – Uses plants reserves
    – Less reserves available for growth, cropping
    – A smaller plant with less crop
  • Halophytes – salt loving plants
    – accumulate salts to adjust osmotically
Differences in Osmotic Adjustment

Glycophyte

Halophyte

= Cl

= NA
Glycophytes and Halophytes

Relative Yield (%)

Salinity

Glycophytes (most crops)

Halophytes
Trunk Diameter Increase of ‘Kerman’ Pistachio as a Function of Increasing Salinity

Relative trunk diameter increase

Soil solution electrical conductivity (dS·m⁻¹)

P. Atlantica
UCB 1
P. integerrima
<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.L</td>
</tr>
<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>24.6</td>
<td>55</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.L</td>
</tr>
<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.L</td>
</tr>
</tbody>
</table>
Specific Ion Effects of Salinity

- Cl and Na
  - absorbed by roots
  - accumulate in leaves
  - produce “burn”
<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>2.33</td>
<td>2.44</td>
</tr>
<tr>
<td>P</td>
<td>0.14</td>
<td>0.14–0.17%</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<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</td>
<td>90 ppm</td>
<td>120–250 ppm</td>
<td>57 ppm</td>
<td>87 ppm</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</td>
<td>?</td>
<td>?</td>
<td>6200 ppm</td>
<td>12230 ppm</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</td>
<td>30 ppm</td>
<td>30–80 ppm</td>
<td>625000</td>
<td>60000</td>
</tr>
<tr>
<td>Zn</td>
<td>7 ppm</td>
<td>10–15 ppm</td>
<td>7 ppm</td>
<td>6 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>4 ppm</td>
<td>6–10 ppm</td>
<td>2.9 ppm</td>
<td>2.9 ppm</td>
</tr>
</tbody>
</table>
Partitioning of Na\(^+\) between ‘Kerman’ Pistachio Scion and Rootstock Wood as Influenced by Increasing Salinity Sodium

Wood Na\(^+\) (mmol\cdot kg\(^{-1}\) DW)

Soil solution electrical conductivity (dS\cdot m\(^{-1}\))

- Rootstock
- Scion
- *P. integerrima*
- UCB 1
- *P. Atlantica*
What do we know about mechanism salinity tolerance pistachios...

- Tolerant to ECe 8.4 dS/m
- Evidence of osmotic adjustment via ion uptake
- Evidence of osmotic adjustment via synthesis of new compounds
- Rootstock differences
- Is salt sensitivity different at different seasonal growth stages?
  - More sensitive early vegetative growth
  - More tolerant later in the season
Tree salt tolerance

Yield Potential, %

Average Rootzone Salinity (ECe)

Citrus

Almond

Olive

Date Palm

Pistachios

1/25/2010
How to avoid salinity problems

• Row crop and wheat examples: Ayers, 2003
  – Previously leached and drained
• Tried fallowing, rotation, more salt tolerant crops, and better irrigation systems with more control
  – Stopgap solutions
• Now manage root zone salinity
  • Need good quality water
  • Need good drainage
  • Drainage water can be used partially if not toxic
Pistachio Salinity Management Now

- UCB I rootstock
- Monitor soil and keep EC$_e$ < 8.4 dS/m
- Budget irrigate using evapotranspiration and pistachio K$_c$
- Calculate leaching fraction
- Avoid soil saturation
- Use good water during early vegetative growth, possibly nut fill
Calculating Leaching Fractions

• If want soil $EC_e = dS/m$ of irrigation water
  – 33% leaching fraction

• $EC_e = 2 \times (dS/m \text{ of Irrigation water})$
  – 10% leaching fraction

• $EC_e = 3 \times (dS/m \text{ of Irrigation water})$
  – 5% leaching fraction
Industry Plan for Salinity Management

• Investigate the mechanism
  – Dr. Eduardo Blumwald
• Obtain and evaluate accessions
  – International contacts
• Aim toward a plant improvement program
2010 annual Statewide Pistachio Day

University of California Cooperative Extension

fruit&nut

http://fruitsandnuts.ucdavis.edu/