Root-Zone Redox Dynamics: In Search for the Cause of Damage to Treated-Wastewater Irrigated Orchards in Clay Soils

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Background

Yield of Treated-wastewater irrigated orchards relative to fresh-water irrigated orchards

Assouline and Narkis, 2013
Background

Water consumption in Israel 2013 (total of 2076 Mm³)

- Industry: 461 Mm³
- Agriculture: 492 Mm³
- Urban: TW

Saline and flood water: 112 Mm³

www.water.gov.il
**Background**

Water quality in Akko avocado orchard (2012-14 average and stdev)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TW</th>
<th>FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC (ds/m)</td>
<td>1.62 ± 0.13</td>
<td>0.86 ± 0.06</td>
</tr>
<tr>
<td>Na (meq/l)</td>
<td>6.61 ± 1.14</td>
<td>0.96 ± 0.18</td>
</tr>
<tr>
<td>Cl (meq/l)</td>
<td>5.70 ± 1.11</td>
<td>1.65 ± 0.40</td>
</tr>
<tr>
<td>Sodium adsorption ratio (meq/l)(^{0.5})</td>
<td>3.26 ± 0.62</td>
<td>0.47 ± 0.07</td>
</tr>
<tr>
<td>Total suspended solids (mg/l)</td>
<td>30.5 ± 21.9</td>
<td>-</td>
</tr>
<tr>
<td>Biological oxygen demand (mg/l)</td>
<td>18.1 ± 16.2</td>
<td>-</td>
</tr>
</tbody>
</table>
Background

- The damage was especially prominent in clay soils
- Salinity damage did not appear:
  - No excess chloride in leaves
  - No excess sodium in leaves
- Measured soil salinity within tolerance range
Hypothesis

Treated wastewater
  • High SAR
  • Available carbon source

Clay soil

Oxygen depletion

Direct damage to trees

Shift in redox:
  • Fe dissolution
  • Mn dissolution
<table>
<thead>
<tr>
<th>pe+pH</th>
<th>14-20</th>
<th>Oxic</th>
<th>$\text{O}_2 \rightarrow \text{H}_2\text{O}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9-14</td>
<td>Suboxic</td>
<td>$\text{NO}_3^- \rightarrow \text{N}_2$</td>
</tr>
<tr>
<td></td>
<td>0-9</td>
<td>Anoxic</td>
<td>$\text{Mn}^{4+} \rightarrow \text{Mn}^{2+}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}$</td>
</tr>
</tbody>
</table>

Patrick and Jugsujinda, 1992; Sposito, 1989

Mn toxicity: Sweet potato
Fe toxicity: Rice
Mn toxicity: Mahogany

http://keys.lucidcentral.org
www.knowledgebank.irri.org
Research questions

1. Does TW irrigation lead to more reduced conditions in the root zone compared with FW irrigation?

If it does:

2. What are the mechanisms responsible for the more reduced conditions?

3. Are changes in redox-sensitive mineral nutrients the cause of damage?
Methods

www.maphill.com
www.google.co.il/maps

pH
pe
Solution sampler
Results

A typical week in the irrigation season, TW irrigated plot

- $\Psi$ 20 cm
- $O_2$ 20 cm
- pe+pH west
- pe+pH east
Results

TW vs FW average of weekly-minimum values, with p-values for the difference between treatments
Results

TW vs FW minimum pe+\(pH\) values per irrigation cycle by irrigation volume (2014 irrigation season)

\[
\begin{align*}
FW & : y = -0.022x + 18.1 \\
& \quad R^2 = 0.105 \\
TW & : y = -0.389x + 18.8 \\
& \quad R^2 = 0.858
\end{align*}
\]
Results

Soil classification following Sposito, 1989

TW vs FW pe minimum values by pH at the time of minimum pe (2014 irrigation season)
Results

Relative abundance of elements in the soil solution and in leaves of TW vs FW irrigated avocado indicate significant difference, p<0.05.
Conclusions

• TW induced more reduced conditions, especially during the irrigation season

• Greater irrigation volume leads to more reduced conditions in TW but not in FW irrigated plots

• Reduced conditions did not affect soil solution composition or plant nutrient composition in the expected ways
Thank you

• To the audience
• My dear family
• Moshe Shenker and Amnon Schwartz
• Jorge Tarchitzky, Shmuel Assouline, Kfir Narkis, and other research collaborators
• The Israel ministry of agriculture