MODIFICATION OF CITRUS IRRIGATION WATER

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• Water from deep aquifers often contains elevated levels of bicarbonates.
• Bicarbonates can accumulate in irrigated area.
• High levels of bicarbonates pull calcium out of solution, reducing the presence of calcium on soil exchange sites.
• Bicarbonate levels in irrigation water are:
  – 0-100 ppm (low)
  – 100-180 ppm (moderate)
  – 180-600 ppm (severe)
Alkalinity

- Primarily determined by presence of bicarbonates (HCO$_3^-$), Carbonates (CO$_3^{2-}$), and hydroxides (OH$^-$) in water.
- A measure of the capacity of water to neutralize acids.
- Alkaline compounds in water remove H$^+$ ions and lower the acidity of water (increase pH).
- Limits nutrient availability in soils
Bicarbonate Levels in Irrigation Water

- Dissolved CO₂ in water exists in two forms:
  - CO₂ + H₂O → H₂CO₃ (carbonic acid)
  - H₂CO₃ + OH⁻ → H₂O + HCO₃⁻ (bicarbonate)
- Carbonic acid (H₂CO₃) dominate in water below pH 6.
- Bicarbonates dominate in water between pH 6 and 10.

Bicarbonates in Water

• Water above pH 7.5 is usually associated with high bicarbonates.
• Recommend levels of 2 mg/l or less
• Forms bicarbonate salts with Ca, Mg, Na, and K.
• High Ca concentrations will react to form Calcium carbonate or line.
• Particulates can drop out of water and plug emitters or microsprinklers.
• Soils with excess Ca forms CaCO₃ (lime).
Bicarbonates in Soil

- Makes phosphorus more available by tying up calcium, increasing the solubility of calcium phosphates.
- Higher calcium carbonate in soils increases pH making many nutrients less available.
- Bicarbonates have a physiological affect on roots reducing nutrient absorption.
- Treatments:
  - calcium or gypsum (calcium sulfate) to increase calcium availability to plants and soil,
  - elemental sulfur can be used to reduce soil pH,
  - applications of acidified water or acidic fertilizer.
• Soil pH and bicarbonates affect nutrient availability and root uptake.

• Bicarbonate induced chlorosis is caused by transport of bicarbonate into the plant leading to reduced nutrient uptake.

• Lime-induced chlorosis affects many annual crops and perennial plants growing on calcareous soils.

• The reduction of plant biomass in susceptible plants is related to a reduced root growth leading to a lower photosynthesis rate which also depends on the reduced leaf area per plant and chlorophyll concentration encountered under iron stress conditions.
Conclusions from Literature

- Many commercial root stocks do not perform well in high-carbonate soils.
- Inability to sufficiently extract micronutrients, including Fe, Zn and Mn.
- Limitation greatest for Poncirus trifoliata and its hybrids (e.g. Troyer, Carrizo and Swingle).
- Best adapted rootstocks are Sour Orange and Rough Lemon that have Tristeza and blight issues.
Impact of Bicarbonates on Citrus Rootstocks

- Growth rate in soil amended with CaCO3
  - Cleo > sour orange > Volk. > Rangpur > Carrizo > Swingle

Table 8. Plant growth and changes in leaf greenness (n = 6) among rootstocks in the Summer 1999 iron nutrition trial conducted in soil amended with CaCO3.

<table>
<thead>
<tr>
<th>Selection</th>
<th>Fresh wt (FW) (g)</th>
<th>FW rel. growth rate (g·g⁻¹)</th>
<th>HT rel. growth rate (cm·cm⁻¹)</th>
<th>Leaf greenness ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleopatra mandarin</td>
<td>3.4 f</td>
<td>87.2 de</td>
<td>24.4 a</td>
<td>6.7 a</td>
</tr>
<tr>
<td>Sour orange</td>
<td>5.8 cd</td>
<td>122.5 a</td>
<td>20.6 b</td>
<td>4.5 b</td>
</tr>
<tr>
<td>Sour orange + Carrizo citrange</td>
<td>6.5 bc</td>
<td>111.5 ab</td>
<td>16.5 c</td>
<td>3.7 bcd</td>
</tr>
<tr>
<td>Kinkoji</td>
<td>7.3 a</td>
<td>120.5 a</td>
<td>15.7 cd</td>
<td>4.5 b</td>
</tr>
<tr>
<td>Volkmann lemon</td>
<td>6.5 bc</td>
<td>105.9 abc</td>
<td>15.7 cd</td>
<td>4.4 b</td>
</tr>
<tr>
<td>Rangpur</td>
<td>5.8 cd</td>
<td>92.2 cde</td>
<td>15.0 cd</td>
<td>2.6 e</td>
</tr>
<tr>
<td>Sunki × Benecke TF</td>
<td>5.1 d</td>
<td>78.4 e</td>
<td>14.5 cd</td>
<td>2.9 de</td>
</tr>
<tr>
<td>Carrizo citrange</td>
<td>5.3 d</td>
<td>78.4 e</td>
<td>14.1 cd</td>
<td>3.0 cde</td>
</tr>
<tr>
<td>Smooth Flat Seville</td>
<td>6.6 ab</td>
<td>95.5 bcd</td>
<td>13.8 ed</td>
<td>3.9 bc</td>
</tr>
<tr>
<td>Cleo × Trifoliate orange</td>
<td>4.2 e</td>
<td>56.6 f</td>
<td>12.5 ed</td>
<td>3.9 bc</td>
</tr>
<tr>
<td>Swingle citremelo</td>
<td>5.2 d</td>
<td>51.6 f</td>
<td>9.1 e</td>
<td>2.4 e</td>
</tr>
<tr>
<td>TF 50-7</td>
<td>5.6 d</td>
<td>33.8 g</td>
<td>5.1 f</td>
<td>1.1 f</td>
</tr>
<tr>
<td>CaCO₃ means</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>15.6 a</td>
<td>3.8 ab</td>
<td>1.4 c</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>16.0 a</td>
<td>3.9 a</td>
<td>1.8 b</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>15.0 ab</td>
<td>3.7 ab</td>
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<tr>
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<td>13.9 bc</td>
<td>3.4 b</td>
<td>2.3 a</td>
<td></td>
</tr>
</tbody>
</table>

Effect of Bicarbonate on Grape Production

- Conclusion, decreased photosynthesis, grape yield and total dry matter.

<p>| Table 3. Fruit (grape) yield and quality, at harvest time, in relation to the soil. |
|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>Low-carbonate soil</th>
<th>High-carbonate soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape cluster yield (kg plant⁻¹)</td>
<td>2.56 a</td>
</tr>
<tr>
<td>Grape clusters per plant⁻¹</td>
<td>8 a</td>
</tr>
<tr>
<td>Cluster weight (g cluster⁻¹)</td>
<td>320 a</td>
</tr>
<tr>
<td>Rachis length (cm)</td>
<td>13.4 a</td>
</tr>
<tr>
<td>Berries per cluster⁻¹</td>
<td>64 a</td>
</tr>
<tr>
<td>Berry weight (g berry⁻¹)</td>
<td>5.0 a</td>
</tr>
<tr>
<td>Juice soluble solids (°Brix)</td>
<td>14.7 a</td>
</tr>
<tr>
<td>Juice titratable acidity (g L⁻¹)</td>
<td>5.1 a</td>
</tr>
<tr>
<td>Juice pH</td>
<td>3.63 a</td>
</tr>
</tbody>
</table>

Note: Values followed by the same letter are not significantly different at 5% level by Tukey test.

Water Treatment

- Standard treatment is to lower the water’s pH by adding an acid. Lowering the pH to 6.5 neutralizes about half the bicarbonate in the water.
- Injection of acidified water instead of a dry material to a wide area will reduce bicarbonate accumulation in the irrigated area where irrigation may cause accumulation.
- Most common acids to inject are sulfuric acid, phosphoric acid,
N-pHuric (urea and sulfuric acid) all the acidity of sulfuric acid but much less corrosive.

N-pHuric or sulfuric acid acidification reacts with bicarbonates to form gypsum and $\text{H}_2\text{CO}_3$, which rapidly converts to $\text{H}_2\text{O}$ and $\text{CO}_2$.

Phosphoric acid and N-pHuric supplies fertilizers in addition to acidification.
INJECTION PUMP

- Direct injection of acid into irrigation water.
- Can be used to apply nutrients.

SULFUR BURNER

- Burns elemental sulfur to create $\text{SO}_2$ gas.
- Oxidized sulfur blends with irrigation water to create sulfurous acid ($\text{H}_2\text{SO}_3$).
- The solution is very mild compared to concentrated sulfuric acid.
• Water from deep wells in limestone aquifers contain bicarbonates.
• Forms bicarbonate salts with Ca, Mg, Na, and K.
• Higher calcium carbonate in soils increases pH making many nutrients less available.
• Bicarbonates have a physiological affect on roots reducing nutrient absorption.
• Limitation greatest for Poncirus trifoliata and its hybrids (e.g. Troyer, Carrizo and Swingle).
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