Understanding Bicarbonates and their Impact on Tree Health

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Root Density

- Improved transpiration rate
- Accumulation of nutrients in root zone
- Greater water uptake = Greater nutrient uptake
- Periodic flushing to prevent salt accumulation
- Potential for increased water stress if irrigation failure
Effect of Tree Health on Root Density

Weak Tree with Damaged Root System

Healthy Tree with Normal Root System
Water from deep aquifers often contains elevated levels of bicarbonates.

Bicarbonates can accumulate in irrigated areas.

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)
Bicarbonates in Soil

• Higher calcium carbonate in soils increases pH making many nutrients less available.
• Bicarbonates have a physiological effect on roots reducing nutrient absorption.
• Treatments:
  – elemental sulfur can be used to reduce soil pH,
  – applications of acidified water or acidic fertilizer,
  – calcium or gypsum (calcium sulfate) to increase calcium availability to plants and soil.
Effect of Soil pH on Nutrient Availability
Plant Uptake

- Bicarbonate induced chlorosis is caused by transport of bicarbonate into the plant leading to reduced nutrient uptake.
- Lime-induced chlorosis effects many annual crops and perennial plants growing on calcareous soils.

Impact of Bicarbonates on Citrus Rootstocks

- Growth rate in soil amended with CaCO₃

  ✓ Cleo > sour orange > Volk. > Rangpur > Carrizo > Swingle

Survey of groves on Swingle and Carrizo

Well water pH and bicarbonate levels are related in Central Florida citrus groves

J.H. Graham, 2014 survey of central Florida citrus groves for effect of bicarbonates
Lower Root Density is related to higher pH

J.H. Graham, 2014 survey of central Florida citrus groves for effect of bicarbonates
Soil pH rebounds after injection ended at the beginning of the rainy season indicating the effect of irrigation water on soil if irrigation water acidification is not continued.

Results of Field Experiment

- Project funded by CRDF to determine the effect of soil pH on tree health and productivity
- Selected irrigation water pH with acid injection with and without soil application of slow release sulfur on both young and mature trees

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Initial measurements (April 2014)</th>
<th>6 month measurements (December 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil pH (mm cm⁻³)</td>
<td>Root length Density (mm cm⁻³)</td>
</tr>
<tr>
<td>control - no acid, no sulfur</td>
<td>7.45 A</td>
<td>7.42 A</td>
</tr>
<tr>
<td>pH 6.0 without sulfur</td>
<td>7.36 A</td>
<td>7.06 A</td>
</tr>
<tr>
<td>pH 6.0 with sulfur</td>
<td>7.21 A</td>
<td>6.37 AB</td>
</tr>
<tr>
<td>pH 5.0 without sulfur</td>
<td>7.38 A</td>
<td>6.11 AB</td>
</tr>
<tr>
<td>pH 5.0 with sulfur</td>
<td>7.56 A</td>
<td>5.41B</td>
</tr>
<tr>
<td>pH 4.0 without sulfur</td>
<td>7.34 A</td>
<td>5.26 B</td>
</tr>
<tr>
<td>pH 4.0 with sulfur</td>
<td>7.58 A</td>
<td>4.78 B</td>
</tr>
</tbody>
</table>

A and B indicate significant differences among treatments at the 0.05 level.
Soil Calcium Content Tending to Decrease with Decrease in Soil pH

- Soil test results for groves irrigated with acidified well water tend to decrease in extractable calcium

Source: Davis Citrus Management
Impact on Roots and Nutrients

• More than a pH problem
• Recommendations: More attention to soil test results and fertilizer materials, and rates,
• Many commercial root stocks do not perform well in high-carbonate soils, greatest limitation for Poncirus trifoliata and its hybrids (e.g. Troyer, Carrizo and Swingle).
• Soil pH related to irrigation water source,
• Root density related to soil pH,
• Initial data indicate increased root density with reduced irrigation water pH,
• Once started, irrigation water or soil acidification must be maintained.
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 to 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.
Acidification of the soil and water reduces pH, increase nutrient uptake

Water conditioning, Faster, lower soil bicarbonate

Injection of N-furic acid or sulfuric acid (40%) to adjust irrigation water to pH 6.5

Soil conditioning, Slower, high soil bicarbonate

300 lbs/treated acre of Tiger 90 sulfur lowered soil pH in 9 months
Valencia/Swingle - 10 yr old

<table>
<thead>
<tr>
<th>Sulfur</th>
<th>pH</th>
<th>Root density (mg/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>6.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Yes</td>
<td>5.9*</td>
<td>1.4*</td>
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</tbody>
</table>

*Significant difference P < 0.05
Calculating Applications

Milliequivalents (me) of base = ppm Ca * 0.05 + ppm Mg * 0.083

<table>
<thead>
<tr>
<th>Water quality (me base/L)</th>
<th>Approximate pounds of pure CaCO₃ added per acre by 20 inches of water</th>
<th>Approximate amount of acid-producing materials per acre to neutralize 100% of the bases from the water</th>
<th>93% Sulfuric acid (gallons)</th>
<th>Elemental sulfur (pounds)</th>
<th>Ammonium sulfate (pounds)</th>
<th>Ammonium nitrate (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>225</td>
<td>15</td>
<td>75</td>
<td>200</td>
<td>375</td>
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<tr>
<td>2.0</td>
<td>450</td>
<td>30</td>
<td>150</td>
<td>400</td>
<td>750</td>
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<tr>
<td>3.0</td>
<td>675</td>
<td>46</td>
<td>225</td>
<td>600</td>
<td>1125</td>
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<td>4.0</td>
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<td>62</td>
<td>300</td>
<td>800</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
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<td>77</td>
<td>375</td>
<td>1000</td>
<td>1875</td>
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<td>92</td>
<td>450</td>
<td>1200</td>
<td>2250</td>
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<tr>
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<td>123</td>
<td>600</td>
<td>1600</td>
<td>3000</td>
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<tr>
<td>9.0</td>
<td>2025</td>
<td>138</td>
<td>675</td>
<td>1800</td>
<td>3375</td>
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<tr>
<td>10.0</td>
<td>2250</td>
<td>154</td>
<td>750</td>
<td>2000</td>
<td>3750</td>
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</tr>
</tbody>
</table>

Source: SL142 Neutralizing Excess Bicarbonates from Irrigation Water
Example of Bicarbonate Neutralization

• Determine milliequivalents of base from irrigation water test results
  – \((\text{ppm Ca} \times 0.05) + (\text{ppm Mg} \times 0.083) = \text{milieq of base per liter of water}\)
  – \(\text{Milieq/liter} \times 0.294\) (sulfuric acid) or \(0.230\) for phosphoric acid = ounces of acid per 100 gal of water

• Example – Assume 200 ppm Ca, 100 ppm Mg
  – \((200 \times 0.05) + (100 \times 0.083) = 18.3\) miliequivalents per liter of water
  – \(18.3 \times 0.294 = 5.3\) oz of sulfuric acid per 100 gal of water
  – \(18.3 \times 0.230 = 4.2\) oz of phosphoric acid per 100 gal of water
Acidifying Fertilizers

• Alternative Acidifying methods
  – Formulations with acidifying materials
    • When ammonium is converted into nitrate in the soil $3H^+$ are released increasing soil pH
    • Ammonium thiosulfate is also acidifying because it supplies both ammonium and sulfur
  – Replace any filler with slow release forms of sulfur (e.g. Tiger 90)
Conclusions

• Soil pH affects citrus tree ability to extract nutrients, including Fe, Zn and Mn,
• Water and soil bicarbonates should be addressed to allow for proper nutrient uptake. This appears to not have been a problem prior to HLB except in extreme cases,
• Irrigation water acidification or application of acidifying fertilizer materials should be used to reduce soil pH in the irrigated area.