Nutrition and Fertilization

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UF/IFAS Citrus Research and Education Center
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Outline

• Methods
• Nutrients
• HLB and nutrient interactions
• UF and Grower Collaboration Program
Methods

• Soil applied
  • Granular
  • CRF
  • Fertigation
• Foliar applied
Soil-Applied Nutrition Program

• The plant uptakes nutrients via the roots when they are in a solution (water/irrigation)
• During the water uptake by the plant, the dissolved mineral nutrients get taken up by the plant and distributed throughout the tree canopy

Credit: T.R. Weeks, UF/IFAS
Granular (Dry) Fertilizer

• Traditional soil applied fertilizer

• Advantages
  • Fertilizer is inexpensive
  • Readily available to plant

• Disadvantages
  • Subject to leaching
  • Multiple applications increase labor and costs
Controlled Release Fertilizer (CRF)

• Granules release small amounts of fertilizer over time
  • Advantages
    • Slowly released; therefore, a constant supply of nutrients
    • Fewer applications
  • Disadvantages
    • Expensive

Credit: T.R. Weeks, UF/IFAS
Fertigation

• Liquid fertilizer applied through irrigation system

• Advantages
  • Relatively inexpensive
  • Flexibility in application
  • Small doses and constant supply

• Disadvantages
  • High maintenance (have a cleaning/flushing plan)
  • Not suitable for all nutrients
Foliar Nutrition Program

• Yield can increase 10%-25% with supplemental foliar feeding versus conventional soil fertilization only
• Best used as a supplemental and not a substitute for soil-applied nutrition
• Best time to apply is morning or evening
  • Right temperature (temperatures above 80°F can cause burn)
  • Minimal wind to ensure full coverage
  • Leaf stomates are open to increase uptake
• Best to apply when crop demand is high and tree needs additional help (vegetative growth, flowering, fruit set, and fruit growth)
• Quickest method to correct a deficiency, although, if a deficiency is observed, potential yield lost has already occurred
Foliar Nutrition Program

• Advantages
  • Quickest method
  • Assist trees during times of high demand or other hindering conditions (wet or dry conditions, cold weather, etc.)

• Disadvantages
  • Cannot use a foliar nutrition program alone, must be coupled with a soil nutrition program
  • Causes leaf burn when not applied at the correct time
Which fertilizer application method is best for fruit quality?

The method has no effect on fruit quality.
Fertilizer Application Method

• It is not the method, but what you put into the tree
• Example:
  • Different brands of trucks have one purpose: get from point A to point B

• Application method gets the nutrients in the tree

Fruit Quality and Application Methods

• Different nutrients are absorbed differently
  • Example: Micronutrients are absorbed best by foliar application for “quick fixes”; whereas, applying by soil and foliar along with regular leaf/soil testing keeps the micronutrients in balance
• Fruit quality will improve with the nutrients you provide the tree, not how you apply it
• Depending on what needs (juice, fruit size, etc.) to improve will determine what fertilizer you need to apply
• It’s all about balance between fruit and tree growth

Credit: http://cliparts.co/cliparts/ki8/ndx/ki8ndxanAT.png
Fruit quality

• Previous research provides guidelines for fruit quality
• Examples:
  • **Juice content**: increases when nitrogen and phosphorus are applied but other nutrients do not change the juice content
  • **Fruit size**: size decreases with excessive nitrogen but size increases with potassium (K) and magnesium (Mg)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Macronutrient element</th>
<th>Micronutrient element</th>
<th>Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Juice quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble solids (SS)</td>
<td>+</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Acid (A)</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>SS/A ratio</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Juice color (red)</td>
<td>+</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Juice color (yellow)</td>
<td>+</td>
<td>o</td>
<td>-</td>
</tr>
<tr>
<td>Solids/box</td>
<td>+</td>
<td>o</td>
<td>-</td>
</tr>
<tr>
<td>Solids/acre</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

| External fruit quality    |   |   |   |    |    | o  | o  | o  | o  | o  | o  | +   |
| Size                      | - | o | + | o  | o  | o  | o  | o  | o  | o  | o  |     |
| Weight                    | - | o | + | o  | o  | o  | o  | o  | o  | o  | o  | +   |
| Green fruit               | + | + | + | o  | o  | o  | o  | o  | o  | o  | o  | +   |
| Peel thickness            | + | - | + | o  | o  | o  | o  | o  | o  | o  | o  | -   |

| Peel blemishes            |   |   |   |    |    | o  | o  | o  | o  | o  | o  | +   |
| Wind scar                 | - | + | o | o  | o  | o  | o  | o  | o  | o  | o  | +   |
| Rust spot                 | - | - | o | o  | o  | o  | o  | o  | o  | o  | o  | o   |
| Creasing                  | + | + | - | o  | o  | o  | o  | o  | o  | o  | o  |     |
| Plugging                  | - | o | o | o  | o  | o  | o  | o  | o  | o  | o  | -   |
| Scab                      | + | o | o | o  | o  | o  | o  | o  | o  | o  | o  | +   |

| Storage decay             |   |   |   |    |    | o  | o  | o  | o  | o  | o  | +   |
| Stem-end rot              | - | o | - | o  | o  | o  | o  | o  | o  | o  | o  | -   |
| Green mold                | - | o | o | o  | o  | o  | o  | o  | o  | o  | o  | +   |
| Sour rot                  | o | o | o | o  | o  | o  | o  | o  | o  | o  | o  | o   |

Plant Nutrition

- Seventeen elements are essential
- Carbon (C), Hydrogen (H), and Oxygen (O), make up 95% of tree biomass
Mineral Nutrients

- There are 14 essential mineral nutrients
- Each nutrient has a specific role in plant growth and function

<table>
<thead>
<tr>
<th>Macro</th>
<th>Micro</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Manganese (Mn)</td>
<td>Calcium (Ca)</td>
</tr>
<tr>
<td>Potassium (P)</td>
<td>Zinc (Zn)</td>
<td>Magnesium (Mg)</td>
</tr>
<tr>
<td>Phosphorous (K)</td>
<td>Copper (Cu)</td>
<td>Sulphur (S)</td>
</tr>
<tr>
<td></td>
<td>Iron (Fe)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boron (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Molybdenum (Mo)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chlorine (Cl)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nickel (Ni)</td>
<td></td>
</tr>
</tbody>
</table>

Liebig's law of the minimum
What are mobile nutrients?

Mobile and immobile nutrients have equal and uniform distribution to all parts of the plant with movement of water

• Mobile Nutrients
  • Will move to new growth areas
  • Move in all direction
  • These nutrients can be transported via xylem and phloem
  • The deficiency symptoms will first show up in older leaves
• Nutrients: **Nitrogen, Phosphorus, Potassium, Magnesium, Sulfur**
  • Soil-applied and foliar-applied both are adequate

Credit: T.R. Weeks, UF/IFAS
What are immobile nutrients?

• Do not move in the plant
• Transported only via xylem
• Immobile nutrients will not move to new growth areas
• The deficiency symptoms will first show up in the new growth because they cannot take nutrients from the old leaves

• Nutrients: Calcium, Iron, Zinc, Copper, Manganese, Boron, Molybdenum
• Soil applied nutrients are adequate
• Should be supplied whenever there is growth

Credit: T.R. Weeks, UF/IFAS
4R’s of Plant Nutrition

- **Right Source**
  - Nutrients

- **Right Rate**
  - Amount

- **Right Time**
  - High demand
  - Morning or evening

- **Right Place**
  - Soil or foliar
Soil pH

- A critical factor for nutrient uptake
- At high soil pH, most of the micronutrients bind to the soil and becomes unavailable
- At extremely low soil pH, most of the macro and secondary nutrients become unavailable
- The goal is to have right soil pH at the time when nutrient uptake is expected
- Recommended to keep soil pH between 6.0-6.5
Does nutrition play a role in managing HLB?
Goal

• Effect of controlled release form of mineral nutrient, elevated levels of individual micronutrients, and soil pH amendments (to lower pH)
  • Soil pH amendment
  • Micronutrients at higher rate
Soil pH of Healthy vs HLB Trees

• Evaluated different ranges of soil pH on healthy and HLB trees
• By day 60, significant leaf drop and tree death
Soil pH of HLB vs Healthy Trees

• HLB-affected trees decline more rapidly than healthy trees at high pH

<table>
<thead>
<tr>
<th>pH</th>
<th>Disease</th>
<th>Total no. of Plants</th>
<th>Dead</th>
<th>Leaf Drop (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8</td>
<td>Healthy</td>
<td>8</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>5.8</td>
<td>HLB</td>
<td>8</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Healthy</td>
<td>8</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>HLB</td>
<td>8</td>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>8</td>
<td>Healthy</td>
<td>8</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>HLB</td>
<td>8</td>
<td>3</td>
<td>83</td>
</tr>
</tbody>
</table>
Soil pH of HLB vs Healthy Trees

• Both HLB and healthy plants showed a tendency of bringing soil pH close to 7 in course of experiment
  • Soil has its own buffering capacity
• When pH is not in the optimum range, nutrients become bound and unavailable to plant
• Optimum ranges
  • HLB: 5.8-6.5
  • Healthy: 6.0-6.5
HLB-affected trees often have deficiency of nutrients

- Due to significant reduction in root mass/quantity
- Compromised physiological processes (photosynthesis, growth, etc.)
- Bacterial infection may result in higher metabolism (plant defense response)

- HLB-affected trees like a lower pH, higher micronutrients, and constant supply
Does nutrition play a role in managing HLB?

• Short answer, yes!
• How?
  • Optimum pH range for healthy trees, 6.0-6.5
  • HLB-affected trees prefer a more acidic (lower) pH than healthy trees, 5.8-6.5
• Healthy trees can withstand stress better, but HLB-affected trees decline faster with any stress
• HLB-affected trees benefit from spoon-feeding
• The fertilizer plan should be customized for each grove—No one size fits all
How are these new findings being used in the groves?
Citrus Nutrition Box Program

• Good fertilizer program can be effective in managing HLB-affected trees
• Provide a resource to commercial citrus growers
• Assist in developing a customized nutrition management program
How does the program work?

• Collaboration between growers and UF
• Program operates from October 2019- November 2020
• Lab services are provided at no charge to the grower
• Only cost for the grower is the shipping cost
How does the program work?

• Growers
  • Growers receive a nutrition box kit with a unique identifying number
  • Growers will collect samples and mail to lab
• UF
  • Will receive results from lab
  • Twice a month UF faculty and Extension agents will meet to make recommendations
  • Will send results and recommendation to grower for the next quarter
  • Will send collection sample reminders every 3 months
What’s in the box?

• Nutrient Testing Program Overview
• Sampling Calendar
• Resources

Credit: T. Weeks, UF/IFAS CREC
What’s in the box?

- Four brown paper bags for leaf sample (L1, L2, L3, L4)
- Four shipping envelopes for leaf samples
- Zip top bag for soil collection (S)
- Shipping box for soil sample
What’s in the box?

• Citrus Leaf Sampling for Nutrient Analysis
• Soil Sampling Procedures for Nutrient Analysis
Leaf Sampling Instructions

- Place leaves into brown paper bag
  - L1: November 2019
  - L2: March 2020
  - L3: July 2020
  - L4: November 2020
- Insert brown paper bag into pre-addressed padded envelope
- Mail package as soon as possible
Soil Sampling Instructions

• Place soil into clear zip top bag
  • S: November 2019
• Insert zip top bag into pre-addressed box
• Mail package as soon as possible
## Results

- Results will be sent via email
  - [citrusnutrition@ifas.ufl.edu](mailto:citrusnutrition@ifas.ufl.edu)

### LEAF ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>B</th>
<th>Zn</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>ppm</td>
<td>ppm</td>
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<tr>
<td>Lab Results</td>
<td>1.93</td>
<td>0.13</td>
<td>1.35</td>
<td>0.23</td>
<td>2.92</td>
<td>51.52</td>
<td>50.54</td>
<td>54.14</td>
<td>49.92</td>
<td>10.41</td>
</tr>
</tbody>
</table>

### SOIL ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>S</th>
<th>B</th>
<th>Zn</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
<th>CEC</th>
<th>pH</th>
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<tbody>
<tr>
<td></td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>lbs/A</td>
<td>meq/100g</td>
<td></td>
</tr>
<tr>
<td>Lab Results</td>
<td>83</td>
<td>72</td>
<td>423</td>
<td>1910</td>
<td>72</td>
<td>0.48</td>
<td>19.82</td>
<td>7</td>
<td>17</td>
<td>10.59</td>
<td>7.42</td>
<td>7</td>
</tr>
</tbody>
</table>

### Recommendation for next quarter per acre

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>B</th>
<th>Zn</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add</td>
<td>50lb/acre</td>
<td>no change</td>
<td>Add</td>
<td>50lb/acre</td>
<td>Add</td>
<td>10lb/acre</td>
<td>Add</td>
<td>20lb/acre</td>
<td>Add 1/3lb per acre</td>
<td>Add 3 lb/acre</td>
</tr>
</tbody>
</table>
Goal

• Goal is to have all nutrient levels within the suggested range

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit of Measure</th>
<th>Deficient</th>
<th>Low</th>
<th>Optimum</th>
<th>High</th>
<th>Excess</th>
<th>Suggested Range for HLB³</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>%</td>
<td>&lt;2.2</td>
<td>2.2 - 2.4</td>
<td>2.5 - 2.7</td>
<td>2.8 - 3.0</td>
<td>&gt;3.0</td>
<td>2.6-2.9</td>
</tr>
<tr>
<td>P</td>
<td>%</td>
<td>&lt;0.09</td>
<td>0.09 - 0.11</td>
<td>0.12 - 0.16</td>
<td>0.17 - 0.30</td>
<td>&gt;0.30</td>
<td>0.14-0.23</td>
</tr>
<tr>
<td>K</td>
<td>%</td>
<td>&lt;0.7</td>
<td>0.7 - 1.1</td>
<td>1.2 - 1.7</td>
<td>1.8 - 2.4</td>
<td>&gt;2.4</td>
<td>1.45 - 2.10</td>
</tr>
<tr>
<td>Ca</td>
<td>%</td>
<td>&lt;1.5</td>
<td>1.5 - 2.9</td>
<td>3.0 - 4.9</td>
<td>5.0 - 7.0</td>
<td>&gt;7.0</td>
<td>3.5 – 6.00</td>
</tr>
<tr>
<td>Mg</td>
<td>%</td>
<td>&lt;0.20</td>
<td>0.20 - 0.29</td>
<td>0.30 - 0.49</td>
<td>0.50 - 0.70</td>
<td>&gt;0.70</td>
<td>0.35 – 0.60</td>
</tr>
<tr>
<td>Mn</td>
<td>mg/kg or ppm</td>
<td>&lt;18</td>
<td>18 - 24</td>
<td>25 - 100</td>
<td>101 - 300</td>
<td>&gt;300</td>
<td>50– 150</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/kg or ppm</td>
<td>&lt;18</td>
<td>18 - 24</td>
<td>25 - 100</td>
<td>101 - 300</td>
<td>&gt;300</td>
<td>50 – 150</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/kg or ppm</td>
<td>&lt;3</td>
<td>3 - 4</td>
<td>5 - 16</td>
<td>17 - 20</td>
<td>&gt;20</td>
<td>10 – 18</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/kg or ppm</td>
<td>&lt;35</td>
<td>35 - 59</td>
<td>60 - 120</td>
<td>121 - 200</td>
<td>&gt;200</td>
<td>90 – 160</td>
</tr>
<tr>
<td>B</td>
<td>mg/kg or ppm</td>
<td>&lt;20</td>
<td>20 - 35</td>
<td>36 -100</td>
<td>101 - 200</td>
<td>&gt;200</td>
<td>68 – 150</td>
</tr>
</tbody>
</table>

These are suggestions for HLB-affected trees based on the field observations, these ranges have not been scientifically proven yet.

Value of the Program

- Personalized nutrition management plan for one year
- Demonstration of the effectiveness of regular leaf sampling and developing customized fertilizer program
- Intensive nutrient management should improve productivity
- Monetary value = 4 leaf nutrient test and 1 soil nutrient test > $120
Future of the Program

- Currently considering if the program will continue next year
- Announcements will be made through the All In for Citrus newsletter
  - citrusresearch.ifas.ufl.edu to view newsletters and sign up
Take Home Message

• The method used to fertilize does not determine fruit quality
• Good nutrition practices are a must whether the trees are healthy or HLB-affected
• Every grove will have its own plan—No one size fits all!
• HLB-affected trees respond to intensive (spoon feeding) fertilizer management
• Regular nutrient sampling helps in assessing trees' nutritional needs
• With regular sampling, the fertilizer program can be tweaked to ensure that trees' demands are being met
Resources

  https://edis.ifas.ufl.edu/pdffiles/CG/CG09200.pdf

• Citrus Nutrition Management Practices. 
  https://edis.ifas.ufl.edu/pdffiles/HS/HS129200.pdf

  https://edis.ifas.ufl.edu/pdffiles/SS/SS47800.pdf
Any questions?