Do we need to revise the nutrition guidelines for HLB-affected citrus in Florida

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University of Florida
Citrus Grower Survey

• June 2017

• Eight growers, spread throughout the state were surveyed-Growers who have claimed to be making profit

    Every grower agreed that their nutrition management programs are more intensive and better now than pre-HLB.

    Growers who had better nutrition management program pre-HLB and early on adopted good psyllid control did not see as much decline as some other growers.

    There is no fixed recipe for a management, programs are often site specific, requires good observation and analyses and then responding to tree needs.
So what are the growers doing?

- Constant supply of nutrients is critical
- Applying higher rates of micronutrient than pre-HLB
- Focus on soil-applied nutrition

Johnson et al., 2014
Recent Research

Published Study 1

Foliar Applications of Essential Nutrients on Growth and Yield of ‘Valencia’ Sweet Orange Infected with Huanglongbing

Kelly T. Morgan1, Robert E. Rouse2, and Robert C. Ebel1,4
Southwest Florida Research and Education Center, University of Florida, 2685 State Road 29 North, Immokalee, FL 34142

Intraplant transport occurs in the presence of HLB. Foliar KNO₃ application had a stronger effect on growth than yield. Yield was most strongly affected by application of MnSO₄ where yield of the 3×/year treatment was 45% higher than that of the unsprayed control, but yield declined by 25% for the 6×/year treatment. Yield within 95% of the maximum occurred with foliar Mn concentrations of 70–100 µg·g⁻¹ dry weight when Mn was applied as MnSO₄, which is at the high end of the traditionally recommended 25–100 µg·g⁻¹ dry weight range. The phosphite form of Mn [Mn₂(PO₄)₂] depressed yield by an
Recent Research

- Overdose-higher than recommended rate
- There are increasing number of evidence that HLB-affected trees benefits from higher rate of micronutrients
Current Research

Nutrient uptake in HLB-affected plants

Question: Are HLB-affected roots efficient in nutrient uptake and if there is preference for certain nutrients?

• Investigate qualitative and quantitative difference in nutrient uptake of HLB affected plants

• To evaluate efficiency of nutrient uptake in HLB affected plants verses healthy plants
Experimental Setup

• Same age ‘Midsweet’ grafted on Kuharske rootstock: Healthy (HLY) and HLB-affected
• Plants were deprived from fertilizer for 6 months before experiment
• Hydroponic system with Hoagland solution added at the beginning
• Two month study, sampling every 7 days
Results

HLB-affected plants were significantly low in root and shoot biomass.

Vashisth Lab, Shahzad et al., manuscript accepted
Chlorophyll content increases with nutrient availability in HLB-affected plants
HLB affected plants have higher nutrient uptake efficiency

Small root mass is the major limitation
HLB-affected plants metabolize nutrient at higher rate as well as may have higher requirement of certain nutrients!
Feeder roots undergo significant changes to increase nutrient uptake.

Published Study 3

Nutrient deficient conditions

Nutrient available conditions

HLB-affected

Healthy
Transcriptomic Analysis

RNAseq for global gene expression study
Day 0, 7, and 14

<table>
<thead>
<tr>
<th></th>
<th>Number of Differentially Expressed Genes</th>
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<tbody>
<tr>
<td>Day 0 HLB vs HLY</td>
<td>9</td>
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<tr>
<td>Day 7 HLB vs HLY</td>
<td>21</td>
</tr>
<tr>
<td>Day 14 HLB vs HLY</td>
<td>3246</td>
</tr>
</tbody>
</table>
Metabolic process, stress and stimulus response, growth and development, death, and transport were mostly enriched categories.
Summary

- Roots of HLB-affected plants are functional in nutrient uptake
- HLB-affected plants have high requirement/metabolism for certain secondary and micro
  nutrients (possibly in plant defense response)
- HLB-affected plants/roots are highly efficient in nutrient uptake
- Molecular regulation of transport related genes and changes in root anatomy contribute to
  high nutrient uptake
- Added stress of nutrient uptake to meet shoot requirement may result in rapid decline of
  roots
- Good fertilization improves plant defense response
Soil acidification

- In Florida, optimum soil pH range for citrus: 6 to 7
  - However, citrus was grown in soils that were close to 7 or above
  - Dolomite was an essential part of grove management
- No soil acidification in commercial citrus groves pre-HLB
- Irrigation water: Bicarbonates >100 ppm and pH > 7.5
- HLB-symptoms intensify under high soil pH
- Root density is related to bicarbonate stress, thus reducing yield at high pH
Current Research

Effect of irrigation water pH on HLB-affected plants

Question: Why soil pH is critical to maintain HLB-affected plants

1. To investigate the effects of irrigation water pH on the performance of healthy (HLY) and HLB-affected citrus

2. To study the molecular regulation of pH-HLB interaction
Experimental Details

- Planting material: ‘Midsweet’ on Kuharske
- Experimental design: CRD (n=8), Factors:
  - pH: 5.8, 7.0 and 8.0
  - Disease: HLY and HLB

The pH Scale

- pH 5.8
- pH 7.0
- pH 8.0
Experimental details

Grown in autoclaved *Candler* fine sand (pH 7.2)

↓

Acclimatized and nutrient deprived for 2 weeks

↓

Fertilized at Day 0

↓

Irrigated with phosphate buffer every 3 days

↓

Final data collection: 60 days
Results

HLB-affected plants under pH 8.0 treatment had the highest death rate.
At pH 5.8, HLB-affected plants performed similar to HLY...
pH 8.0 HLB treatment resulted in heavy leaf drop

Published Study 4

Vashisth Lab, Ghimire et al., manuscript accepted
Healthy trees are not affected by soil pH as much as HLB-affected trees
Shoot system at Day 60

HLY:

pH: 5.8  7.0  8.0

HLB:

Published Study 4

Vashisth Lab, Ghimire et al., manuscript accepted
Root system at Day 60

HLY:

pH: 5.8, 7.0, 8.0

HLB:

Vashisth Lab, Ghimire et al., manuscript accepted

Published Study 4
### Nutrient concentration in the soil

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>Ca</th>
<th>Zn</th>
<th>B</th>
<th>K</th>
<th>Mg</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8 HLY</td>
<td>555.13±23.87 B</td>
<td>289±21.16 B</td>
<td>29.91±0.97 A</td>
<td>0.15±0.02 b</td>
<td>158.75±8.27 a</td>
<td>47.13±3.15 b</td>
<td>10.25±0.15 b</td>
<td>55.88±1.87 a</td>
<td>2.38±0.08 b</td>
</tr>
<tr>
<td>5.8 HLB</td>
<td>698.25±50.87 AB</td>
<td>489.25±63.27 AB</td>
<td>27.02±2.12 A</td>
<td>0.25±0.05 b</td>
<td>162.75±7.40 b</td>
<td>72.5±7.94 b</td>
<td>9.13±0.59 b</td>
<td>69.13±7.45 a</td>
<td>3.22±0.1 b</td>
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<tr>
<td>7.0 HLY</td>
<td>697.63±47.78 AB</td>
<td>515±64.45 AB</td>
<td>27.65±0.78 A</td>
<td>0.22±0.03 b</td>
<td>103.5±1.66 b</td>
<td>92.88±17.79 ab</td>
<td>11.38±0.56 ab</td>
<td>52.88±5.61 ab</td>
<td>2.54±0.15 b</td>
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<tr>
<td>7.0 HLB</td>
<td>610.63±45.86 AB</td>
<td>329±10.02 AB</td>
<td>23.02±3.17 AB</td>
<td>0.2±0.04 b</td>
<td>96.63±1.55 b</td>
<td>47.84±2.32 ab</td>
<td>11±0.29 ab</td>
<td>43.63±5.35 ab</td>
<td>2.63±0.05 b</td>
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<td>8.0 HLY</td>
<td>631.5±68.78 AB</td>
<td>370±96.8 AB</td>
<td>28.46±3.42 A</td>
<td>0.38±0.10 a</td>
<td>43.67±5.24 c</td>
<td>98.67±18.62 a</td>
<td>12.75±1.30 a</td>
<td>41.01±5.34 b</td>
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<tr>
<td>8.0 HLB</td>
<td>786.63±10.96 A</td>
<td>583.13±39.81 A</td>
<td>12.47±1.58 B</td>
<td>0.34±0.05 a</td>
<td>50.25±4.03 b</td>
<td>119.75±16.72 a</td>
<td>12.63±0.66 a</td>
<td>44.63±2.67 b</td>
<td>3.63±0.13 a</td>
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### Nutrient concentration in the leaves

<table>
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<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>
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</thead>
<tbody>
<tr>
<td>5.8 HLY</td>
<td>28000</td>
<td>9800</td>
<td>33600</td>
<td>2700</td>
<td>18800</td>
<td>30.66</td>
<td>65.72</td>
<td>147.81</td>
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<tr>
<td>5.8 HLB</td>
<td>30900</td>
<td>10600</td>
<td>37700</td>
<td>2600</td>
<td>15800</td>
<td>80.26</td>
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<tr>
<td>7.0 HLY</td>
<td>27800</td>
<td>5000</td>
<td>27200</td>
<td>2800</td>
<td>15800</td>
<td>55.71</td>
<td>25.09</td>
<td>51.80</td>
<td>137.70</td>
<td>7.89</td>
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<tr>
<td>7.0 HLB</td>
<td>35300</td>
<td>5100</td>
<td>31500</td>
<td>3000</td>
<td>20200</td>
<td>90.82</td>
<td>33.32</td>
<td>110.24</td>
<td>170.15</td>
<td>9.33</td>
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<tr>
<td>8.0 HLY</td>
<td>26500</td>
<td>6200</td>
<td>26100</td>
<td>3400</td>
<td>15500</td>
<td>53.71</td>
<td>27.75</td>
<td>73.54</td>
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<td>8.0 HLB</td>
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<td>2200</td>
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<td>1700</td>
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<td>45.88</td>
<td>10.73</td>
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**Optimum range**

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<th>Zn</th>
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<td>25000-27000</td>
<td>1200-1600</td>
<td>12000-17000</td>
<td>3000-49000</td>
<td>30000-49000</td>
<td>36.0-100</td>
<td>25.0-100</td>
<td>25.0-100</td>
<td>60.0-120</td>
<td>5.00-16.0</td>
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</table>
Summary

• Healthy citrus can thrive at wide soil pH range: 5.8-7.0

• High soil pH exacerbates HLB symptoms, preferred soil pH range is narrow for HLB-affected 5.8-6.5

• Performance of HLB-affected and healthy plants are comparable at low pH

• The poor performance of HLB-affected plants at high pH cannot be solely attributed to nutrient availability

• At low pH, HLB-affected plants have enhanced plant defense
Field Trial

• Effect of controlled release form of mineral nutrients, elevated levels of individual micronutrients, and soil pH amendments (to lower pH) on performance of HLB trees.
  • Soil applied
  • Constant supply of nutrients
  • Micronutrients at higher rate
  • Soil pH amendment
Treatments

1. Conventional granular fertilizer + foliar
2. Conventional granular fertilizer + Tiger Micronutrient Mix
3. CRF + foliar
4. CRF + Tiger Micronutrient Mix
5. CRF + Tiger Micronutrient Mix + Tiger Mn elevated by 20%
6. CRF + Tiger Micronutrient Mix + Tiger Zn elevated by 20%
7. CRF + Tiger Micronutrient Mix + Tiger Fe elevated by 20%
8. CRF + Tiger Micronutrient Mix + Tiger B elevated by 20%
9. CRF + Tiger Micronutrient Mix + Tiger Mn and B elevated by 20%
10. CRF + Tiger Micronutrient Mix + Tiger Mn and B elevated by 50%
3 Year Cumulative Yield (Boxes per acre)

Fort Meade

Arcadia

Vashisth et al., Manuscript in preparation

Ongoing Study 5
## Ranking based on cumulative yield of 3 years

### Arcadia Site

<table>
<thead>
<tr>
<th>Treatment #</th>
<th>Treatment</th>
<th>Total 3 Yr Yield (boxes per acre)</th>
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<tbody>
<tr>
<td>7</td>
<td>CRF+Tiger MM + Fe 20%</td>
<td>1310</td>
</tr>
<tr>
<td>4</td>
<td>CRF+Tiger MM</td>
<td>1263</td>
</tr>
<tr>
<td>8</td>
<td>CRF+Tiger MM + B 20%</td>
<td>1259</td>
</tr>
<tr>
<td>10</td>
<td>CRF+Tiger MM + Mn+ B 50%</td>
<td>1233</td>
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<td>5</td>
<td>CRF+Tiger MM + Mn 20%</td>
<td>1136</td>
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<tr>
<td>6</td>
<td>CRF+Tiger MM + Zn 20%</td>
<td>1118</td>
</tr>
<tr>
<td>2</td>
<td>Conventional+ Tiger MM</td>
<td>1095</td>
</tr>
<tr>
<td>3</td>
<td>CRF+ foliar</td>
<td>1088</td>
</tr>
<tr>
<td>9</td>
<td>CRF+Tiger MM + Mn+B 20%</td>
<td>1048</td>
</tr>
<tr>
<td>1</td>
<td>Control</td>
<td>908</td>
</tr>
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</table>

### Fort Meade Site

<table>
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<th>Treatment #</th>
<th>Treatment</th>
<th>Total 3 Yr Yield (boxes per acre)</th>
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<tbody>
<tr>
<td>9</td>
<td>CRF+Tiger MM + Mn+B 20%</td>
<td>1130</td>
</tr>
<tr>
<td>4</td>
<td>CRF+Tiger MM</td>
<td>1076</td>
</tr>
<tr>
<td>2</td>
<td>Conventional+ Tiger MM</td>
<td>1063</td>
</tr>
<tr>
<td>3</td>
<td>CRF+ foliar</td>
<td>1047</td>
</tr>
<tr>
<td>5</td>
<td>CRF+Tiger MM + Mn 20%</td>
<td>1039</td>
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<tr>
<td>10</td>
<td>CRF+Tiger MM + Mn+ B 50%</td>
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<tr>
<td>6</td>
<td>CRF+Tiger MM + Zn 20%</td>
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<td>1</td>
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Fertilizer Program Needs to Customized for the Site

Vashisth et al., Manuscript in preparation

Ongoing Study 5
Summary

- HLB-affected trees do benefit from micronutrients at higher than recommended rate
- Constant supply of nutrients and soil acidification is beneficial
- Fertilizer program should be site specific
  - to address specific tree needs
- 20% higher than recommended rate of micronutrients can improve productivity of HLB-affected trees
- Soil applied nutrient are better than foliar micronutrients
Take Home Message-For HLB-affected trees

• Good nutrition program and soil acidification is beneficial

• Micronutrients and secondary nutrients are needed at approximately 20% higher than recommended rate

• Preferred soil pH range for current Florida citrus is 5.8-6.5

• Due to small root system the fertilizer supply should be constant to the tree
  • small and frequent doses of fertilization

• Soil-applied nutrients are better than foliar

• Focus on leaf nutrient analysis rather than the rate of fertilizer applied, trees perform better when are in the high end of optimum range