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

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Citrus Grower Survey

- June 2017
- Eight growers, spread throughout the state were surveyed-Growers who have claimed to be making profit

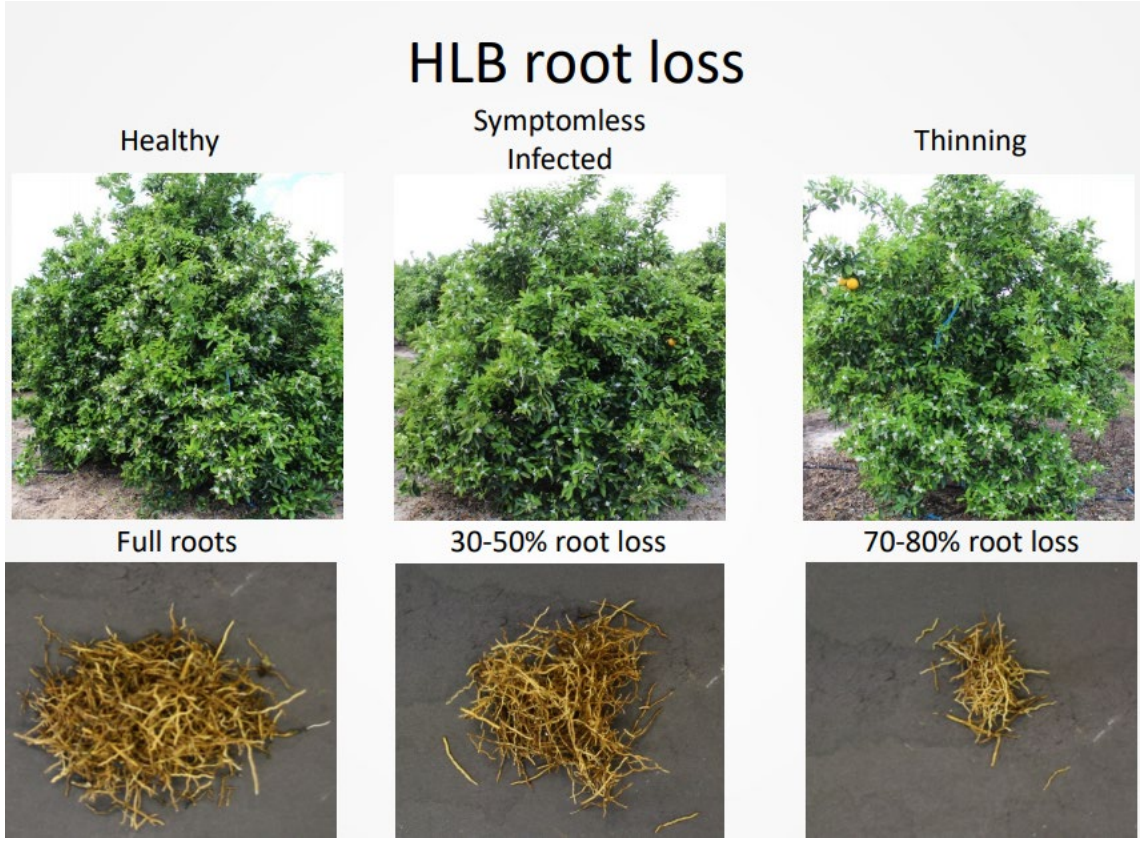
Every grower agreed that their nutrition management programs are more intensive and better now than pre-HLB.

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

Published Study 1

Recent Research

HortScience 51(12):1482–1493. 2016. doi: 10.21273/HORTSCI11026-16

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

Kelly T. Morgan[1], Robert E. Rouse[2], and Robert C. Ebel[3,4]
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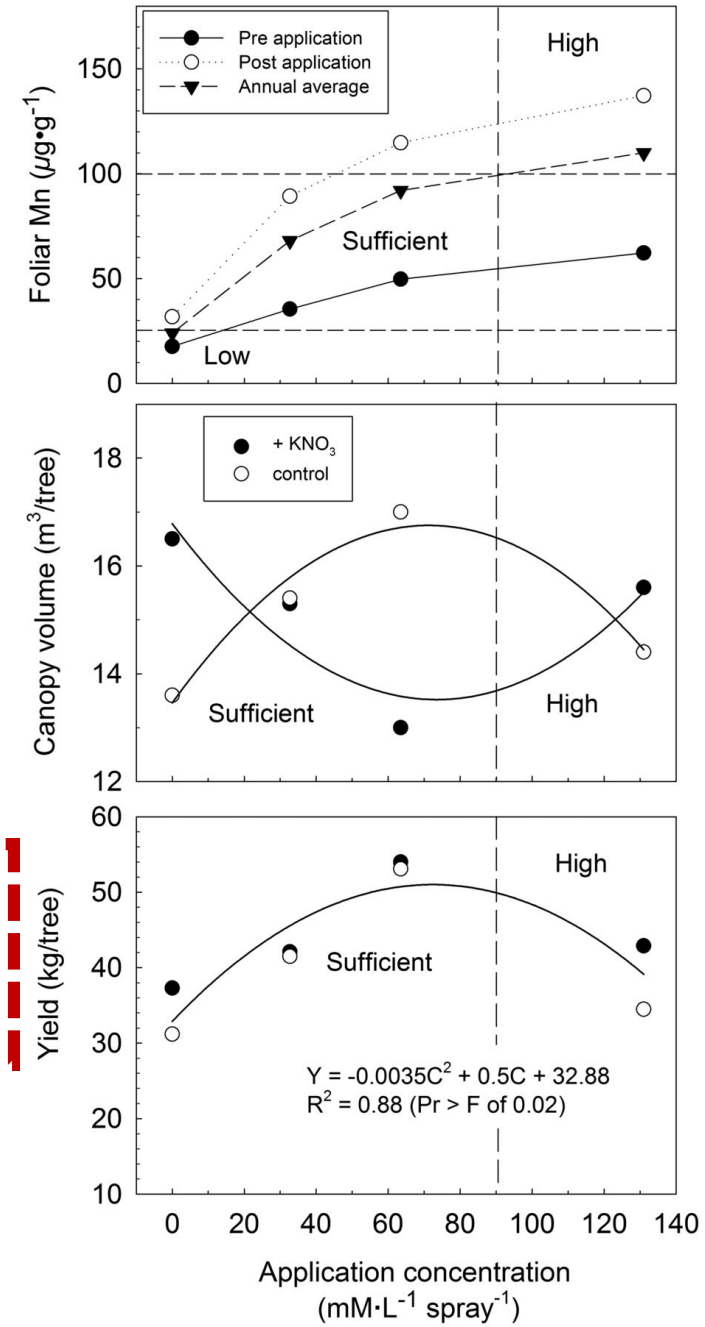
intraplant transport occurs in the presence of HLB. Foliar KNO_3 application had a stronger effect on growth than yield. Yield was most strongly affected by application of $MnSO_4$ where yield of the 3×/year treatment was 45% higher than that of the unsprayed control, but yield declined by 25% for the 6×/year treatment. Yield within 95% of the maximum occurred with foliar Mn concentrations of 70–100 $\mu g \cdot g^{-1}$ dry weight when Mn was applied as $MnSO_4$, which is at the high end of the traditionally recommended 25–100 $\mu g \cdot g^{-1}$ dry weight range. The phosphite form of Mn [$Mn_3(PO_3)_2$] depressed yield by an



Recent Research

Published Study 2

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

HortScience 54(6):1077–1086. 2019. https://doi.org/10.21273/HORTSCI13635-18

Ground Application of Overdoses of Manganese Have a Therapeutic Effect on Sweet Orange Trees Infected with *Candidatus* Liberibacter asiaticus

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Fig. 5. CLas-infected Valencia/UFR-3 typical root systems: control standard Harrell's CRF fertilizer (left) and Harrell's CRF plus triple TigerSul® manganese (right).

Published Study 3

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

Vashisth Lab, Shahzad et al., manuscript accepted

Published Study 3

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

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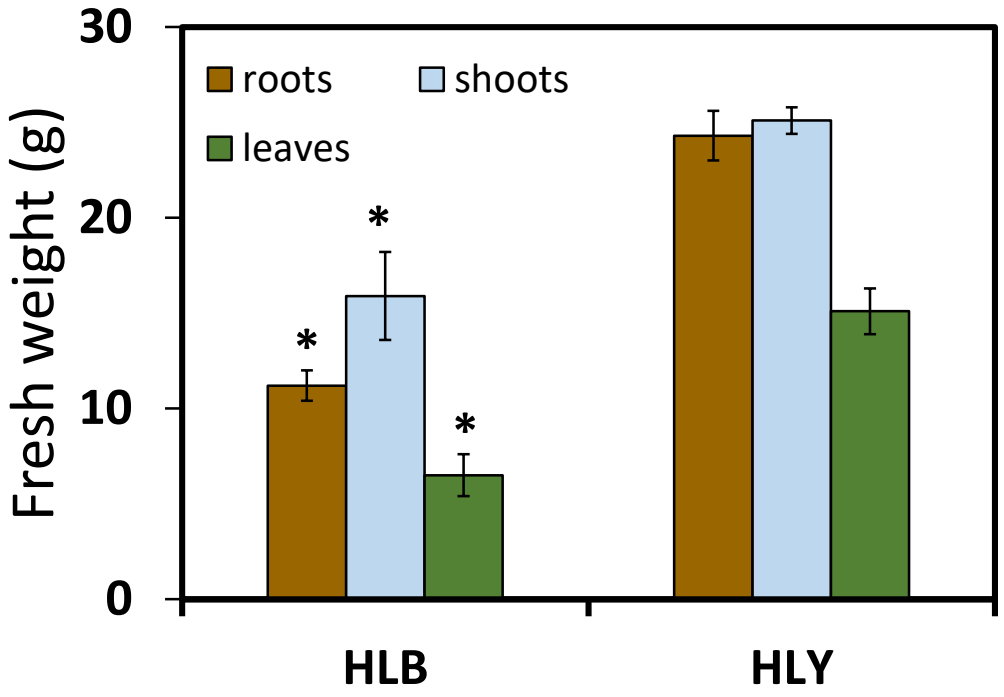
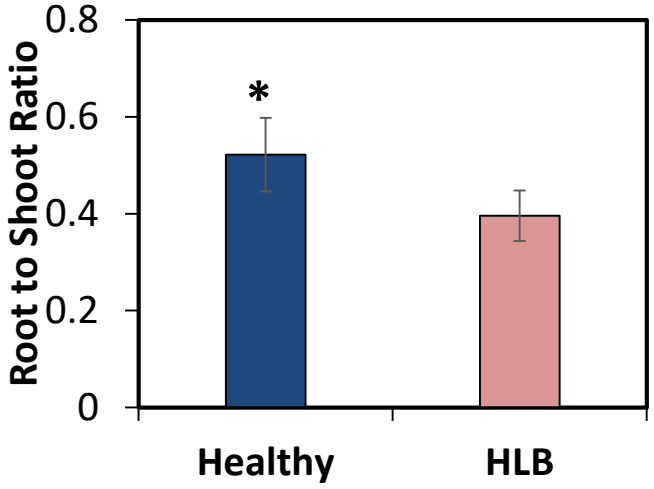
Results



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



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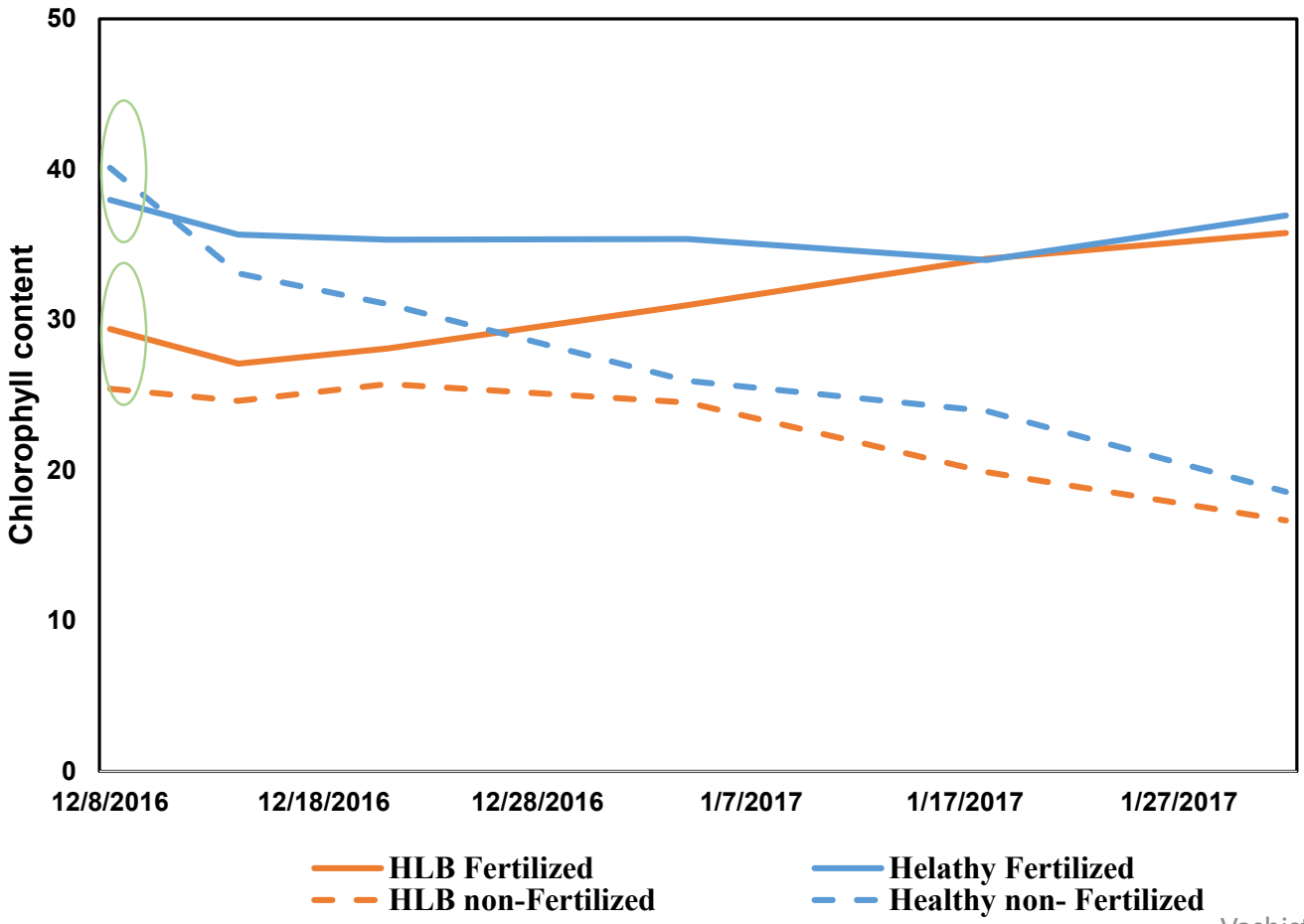
Chlorophyll content increases with nutrient availability in HLB-affected plants



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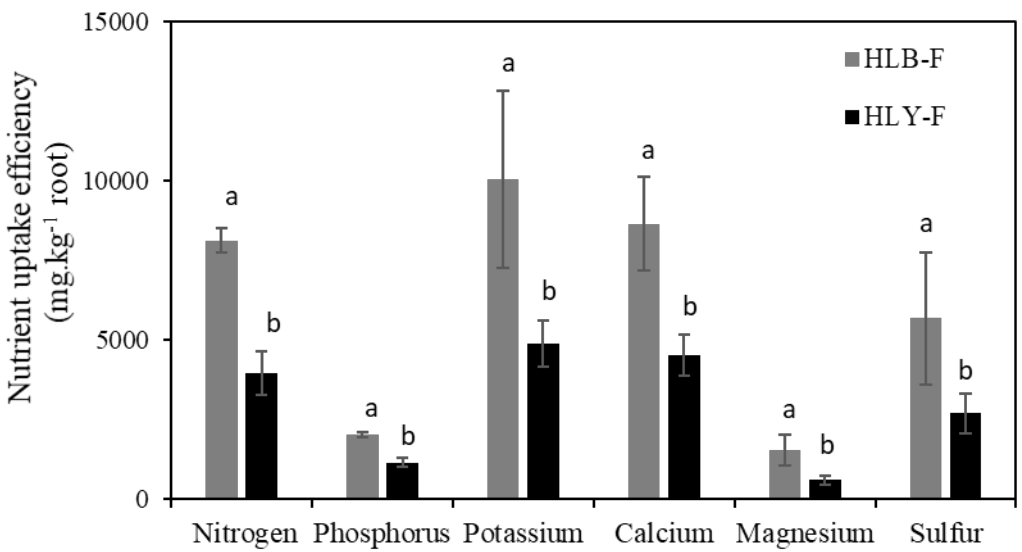
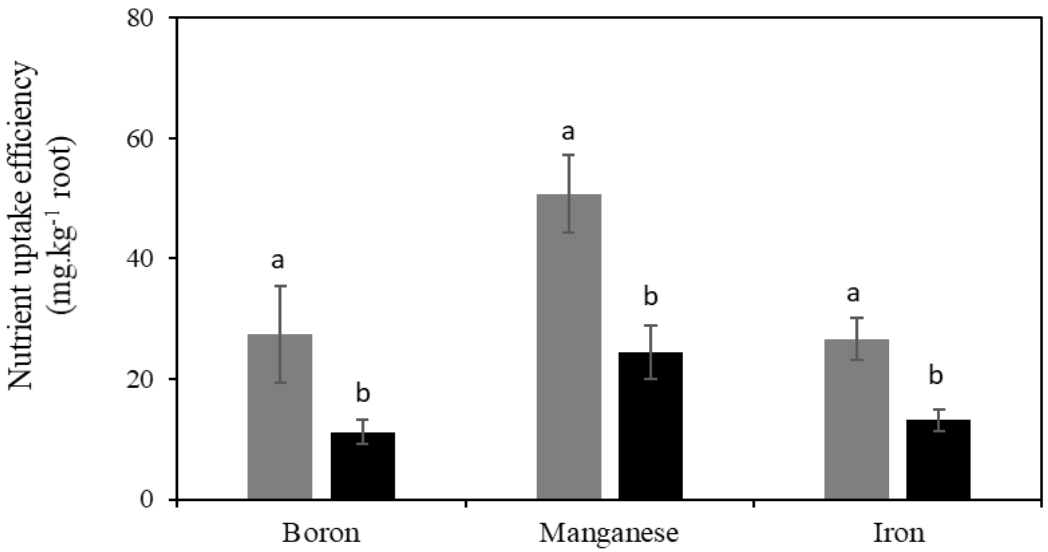
HLB affected plants have higher nutrient uptake efficiency





Small root mass is the major limitation

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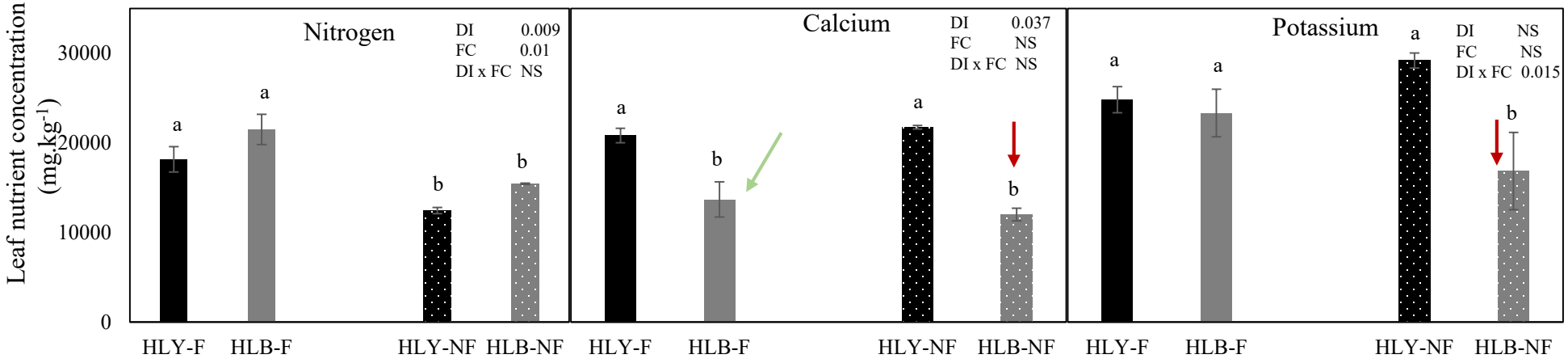
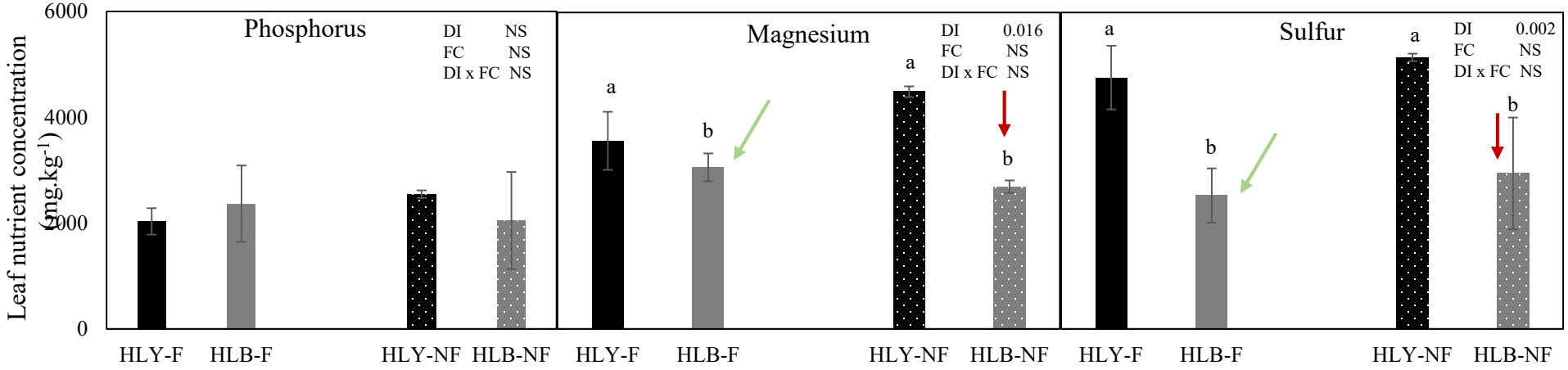
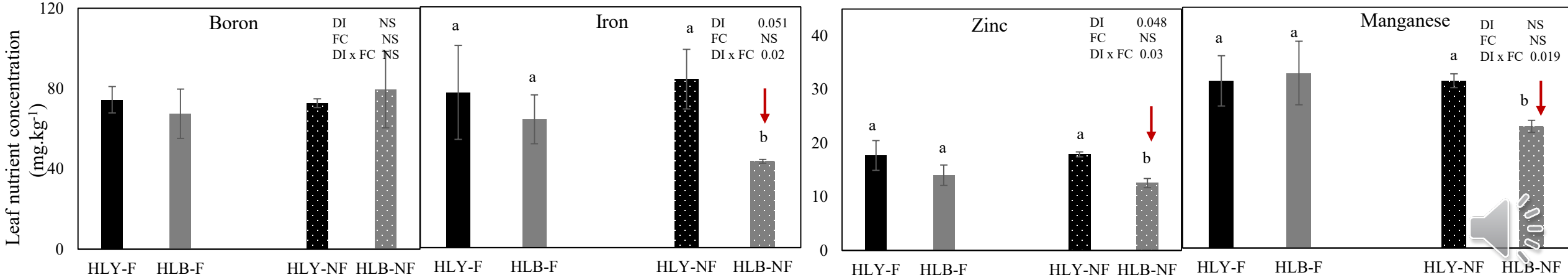
Published Study 3



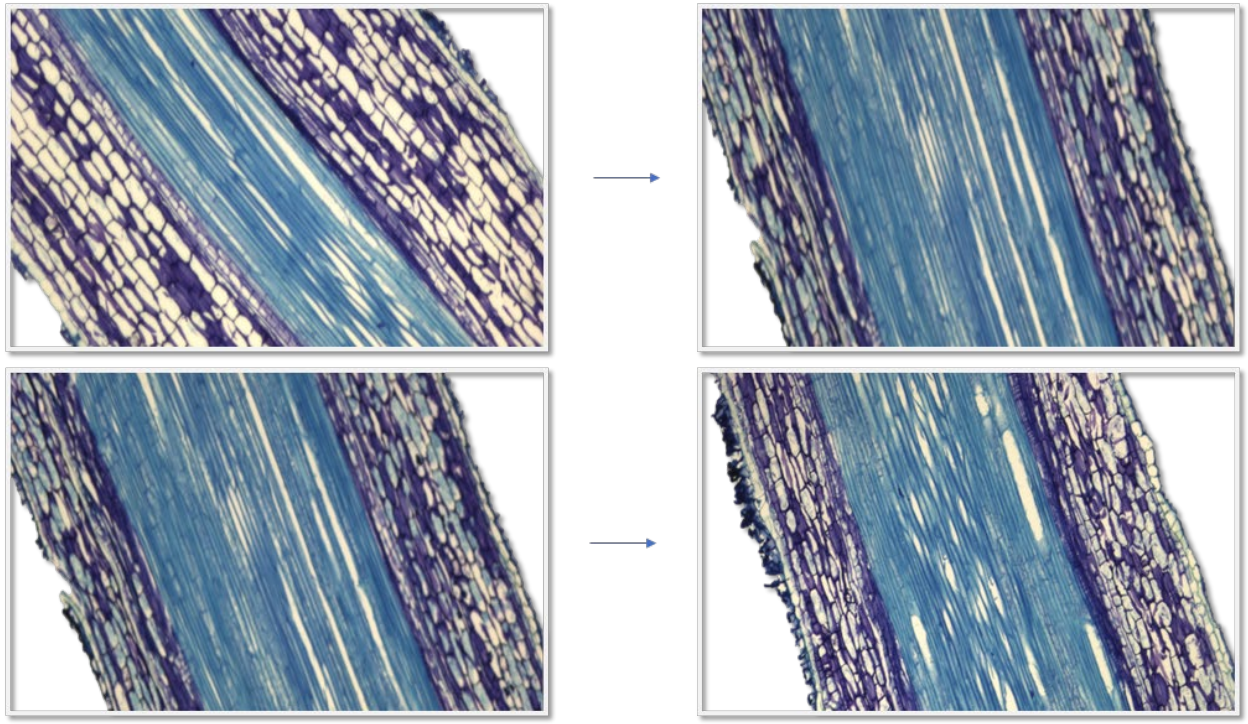




HLB-affected plants metabolize nutrient at higher rate as well as may have higher requirement of certain nutrients!

Published Study 3

Feeder roots undergo significant changes to increase nutrient uptake



HLB-affected

Healthy

Nutrient deficient conditions

Nutrient available conditions

Transcriptomic Analysis

RNAseq for global gene expression study

Day 0, 7, and 14

	Number of Differentially Expressed Genes
Day 0 HLB vs HLY	9
Day 7 HLB vs HLY	21
Day 14 HLB vs HLY	3246

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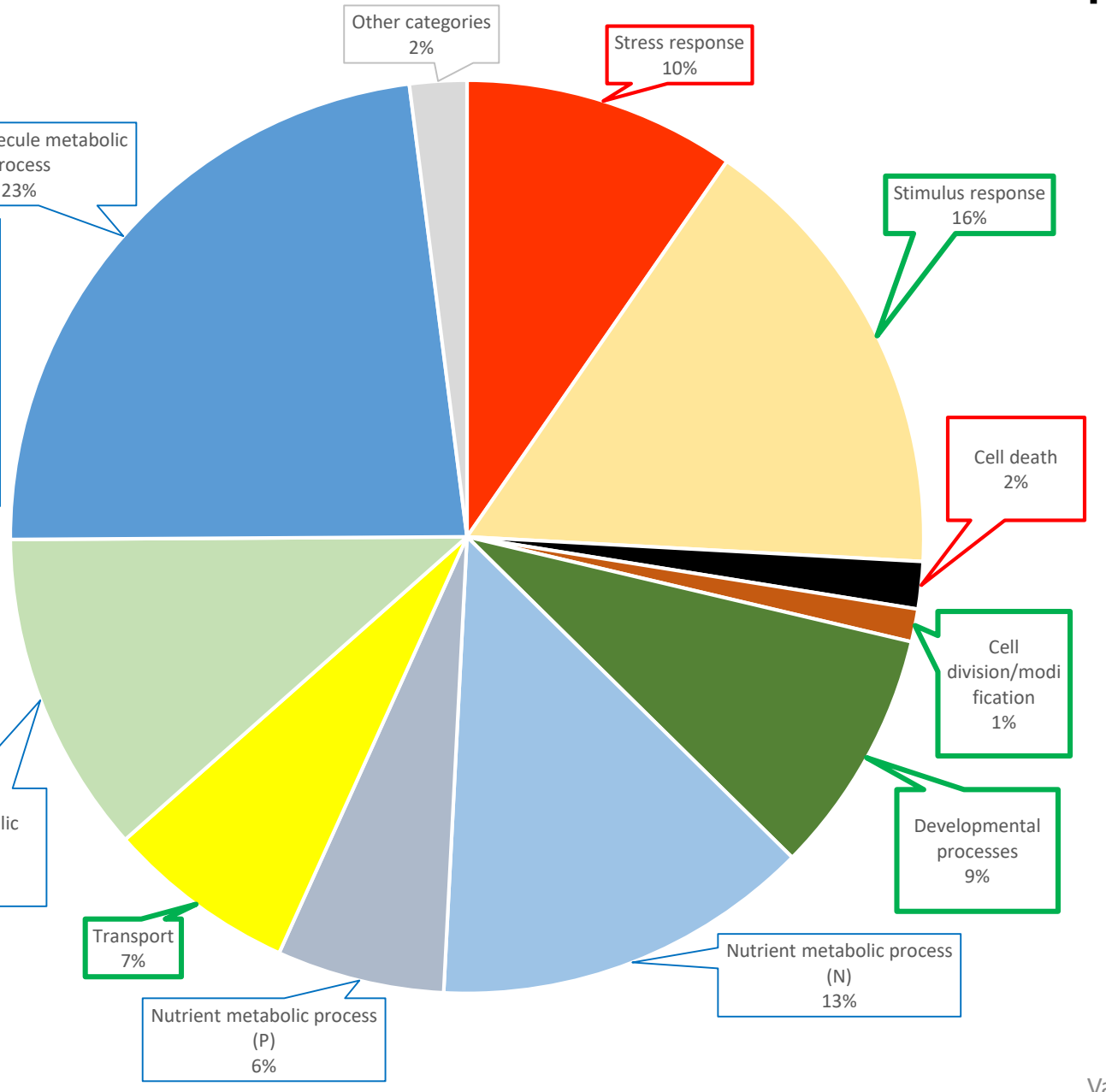
HLB vs. HLY D14 Enriched Categories

Published Study 3



Metabolic process, stress and stimulus response, growth and development, death, and transport were mostly enriched categories.

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Published Study 3

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

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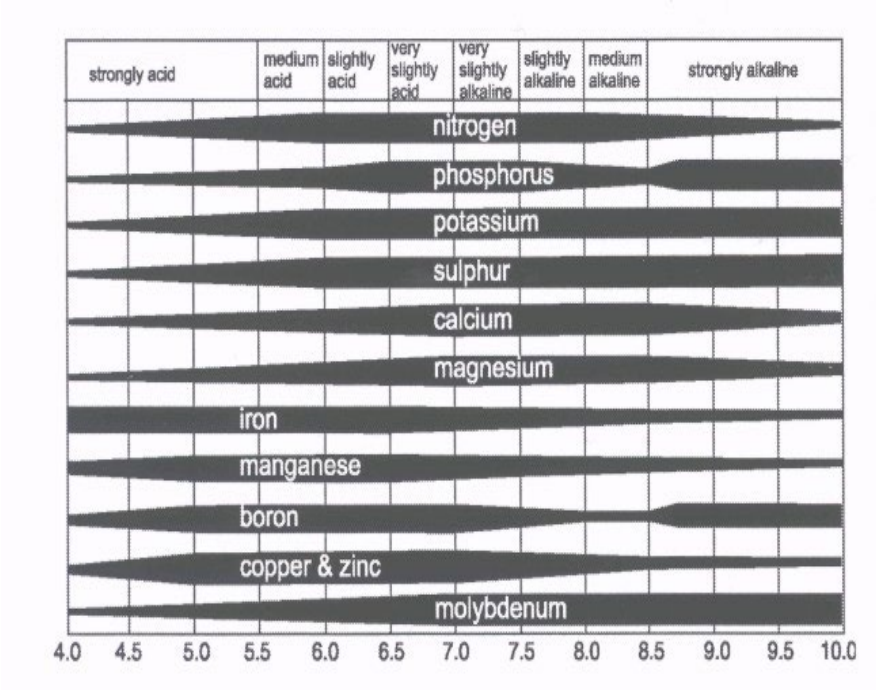
Soil acidification

- 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 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



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Current Research

<u>Effect of irrigation water pH on HLB-affected plants</u>

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

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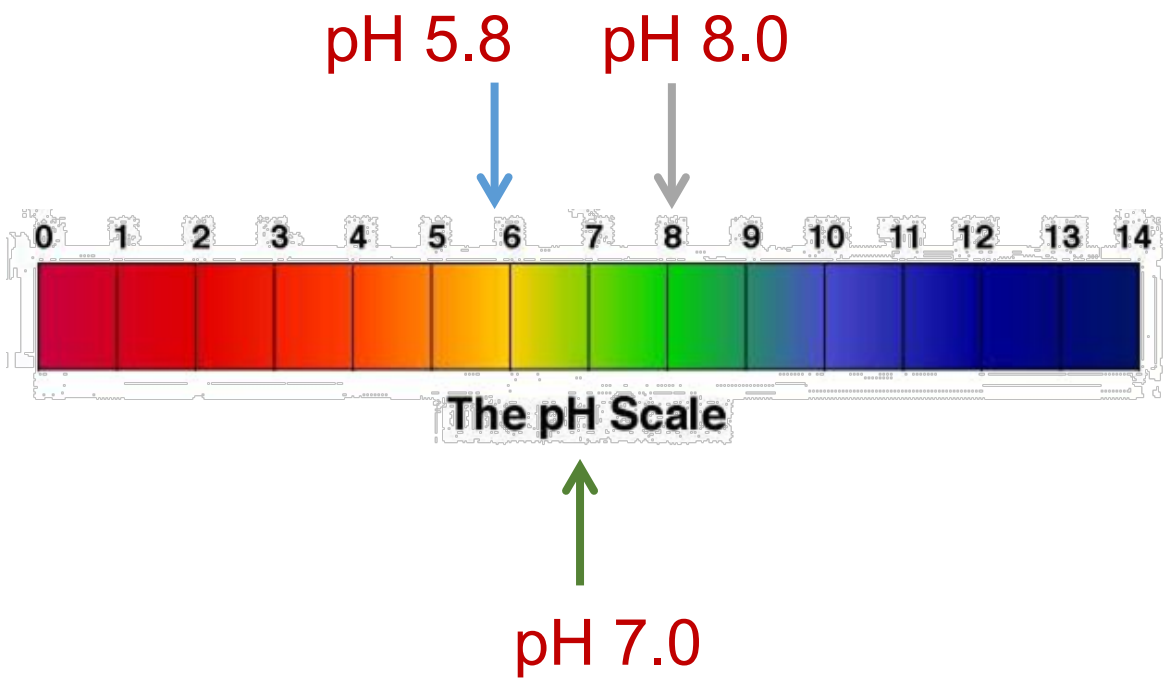
Experimental Details

Published Study 4

- Planting material: ‘Midsweet’ on Kuharske
- Experimental design: CRD (n=8), Factors:

➢ pH : 5.8, 7.0 and 8.0



➢ Disease: HLY and HLB

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Experimental details

Published Study 4

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

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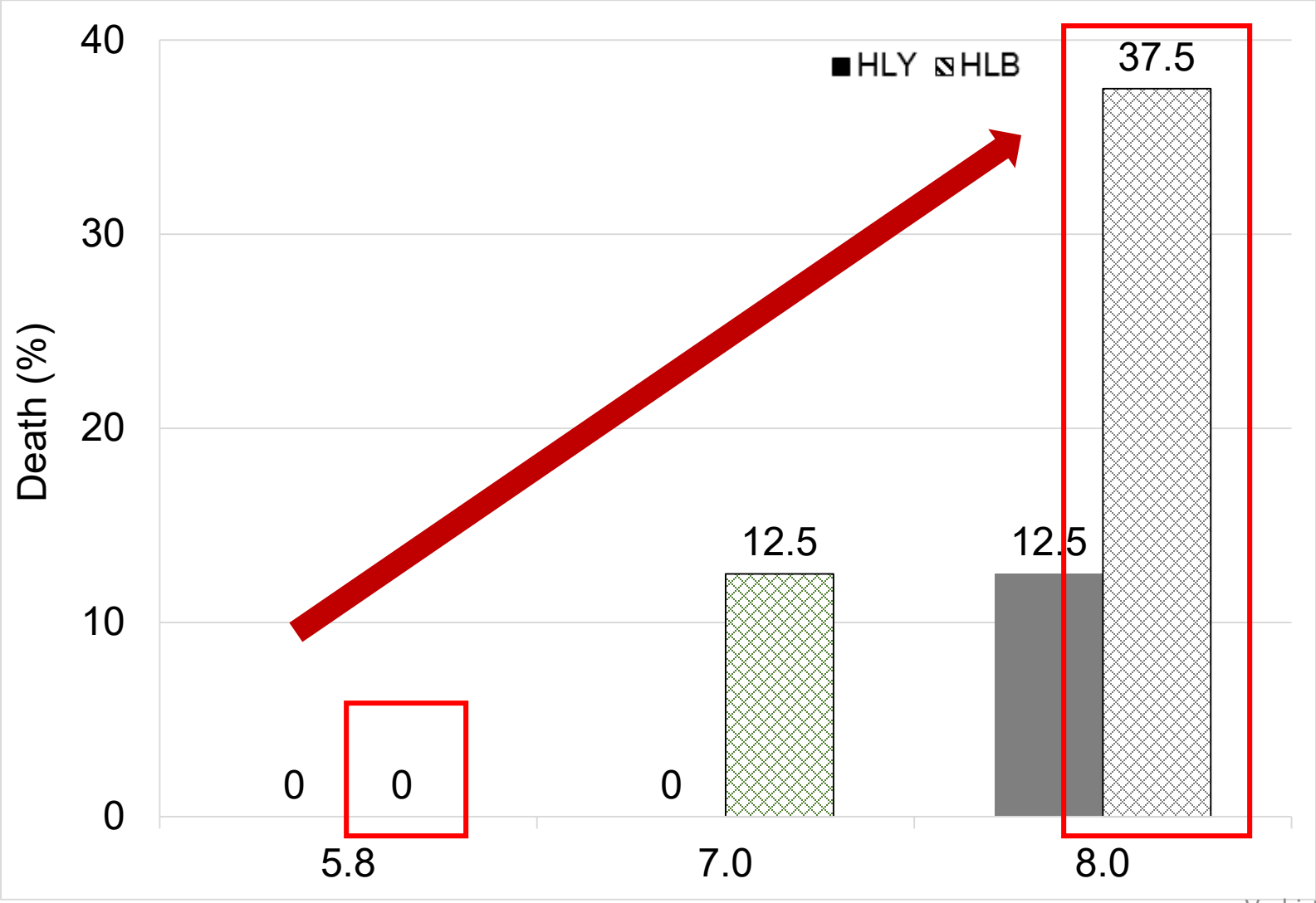
Results

Published Study 4

HLB-affected plants under pH 8.0 treatment had the highest death rate



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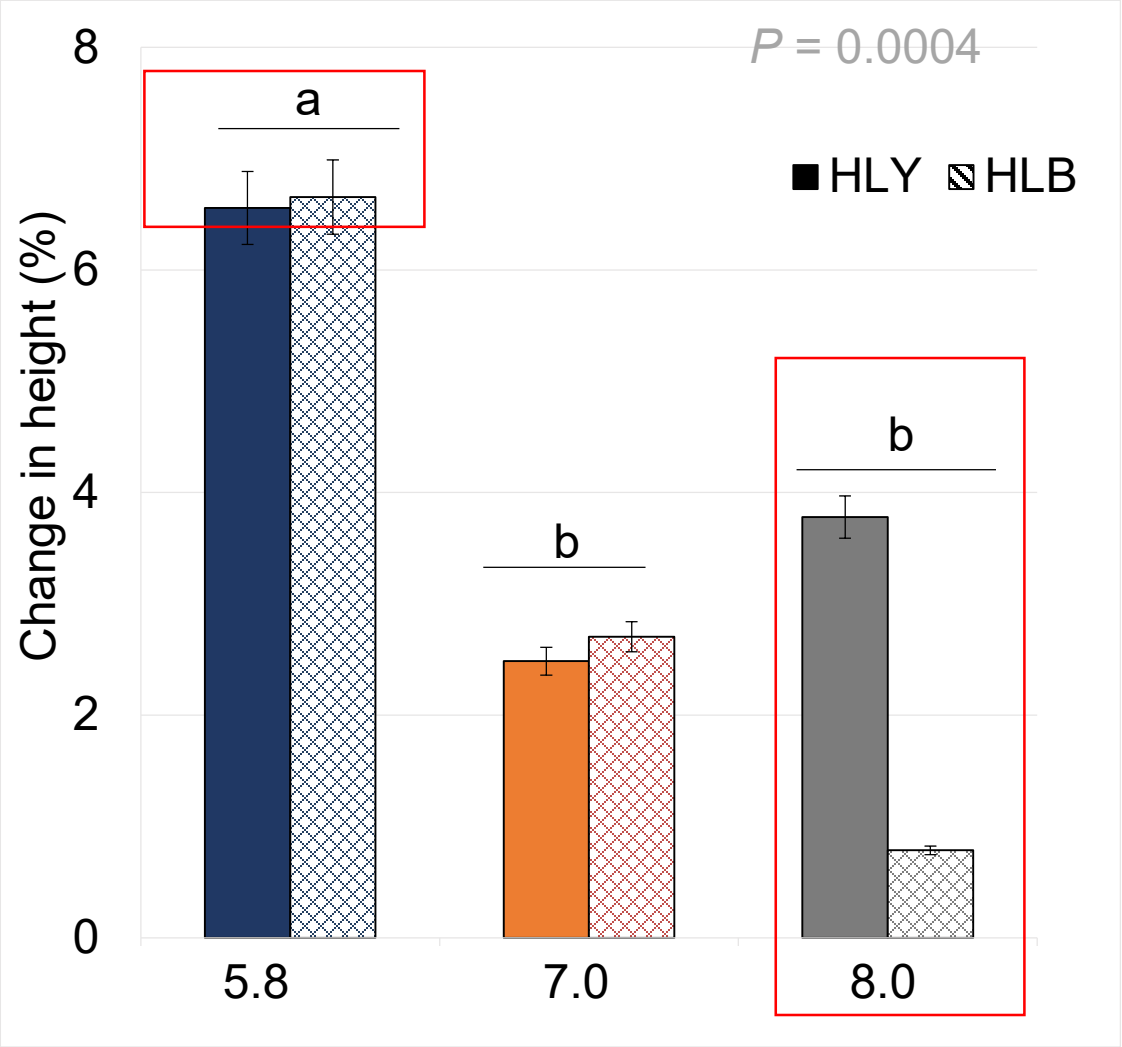
At pH 5.8, HLB-affected plants performed similar to HLY



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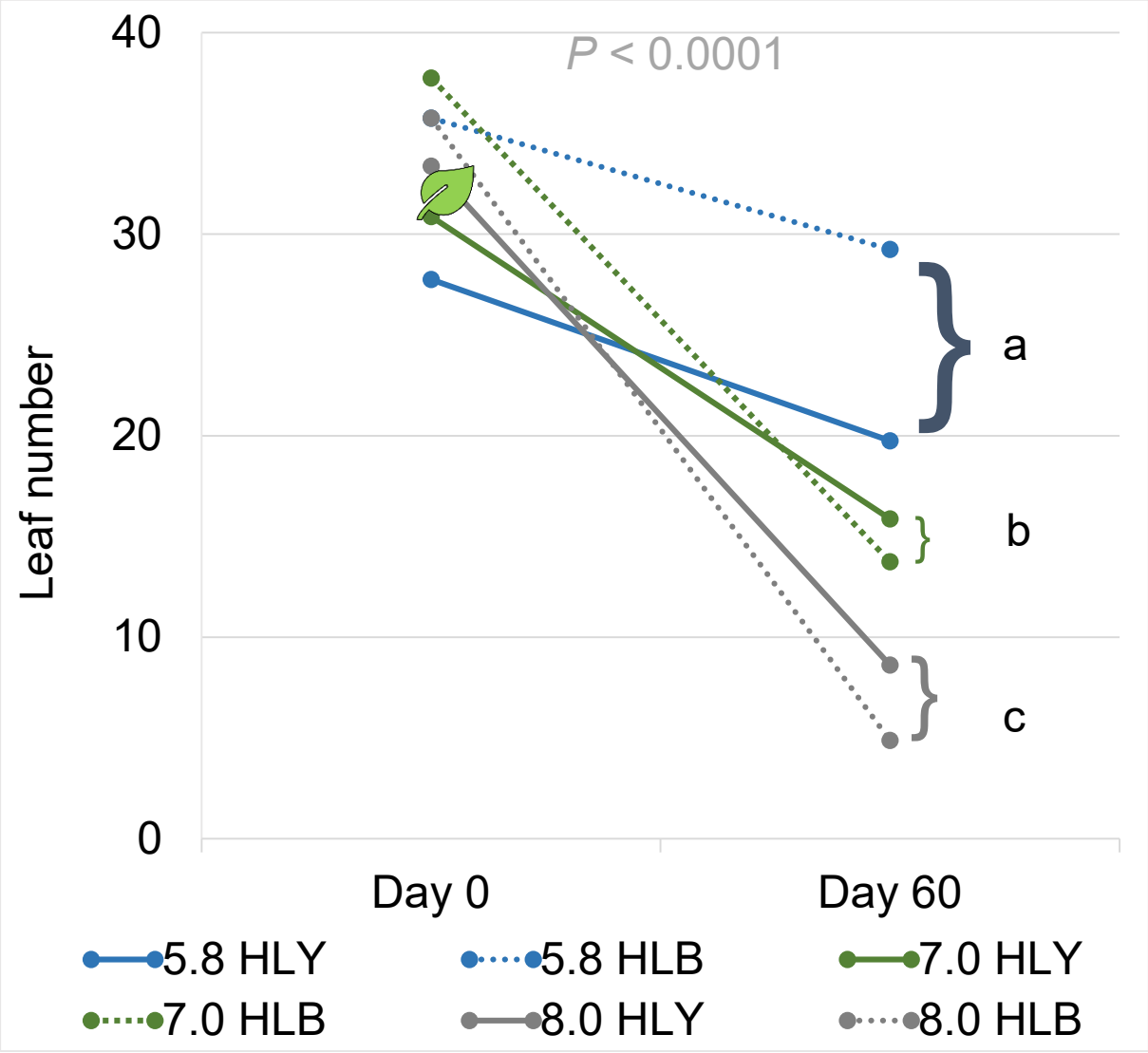
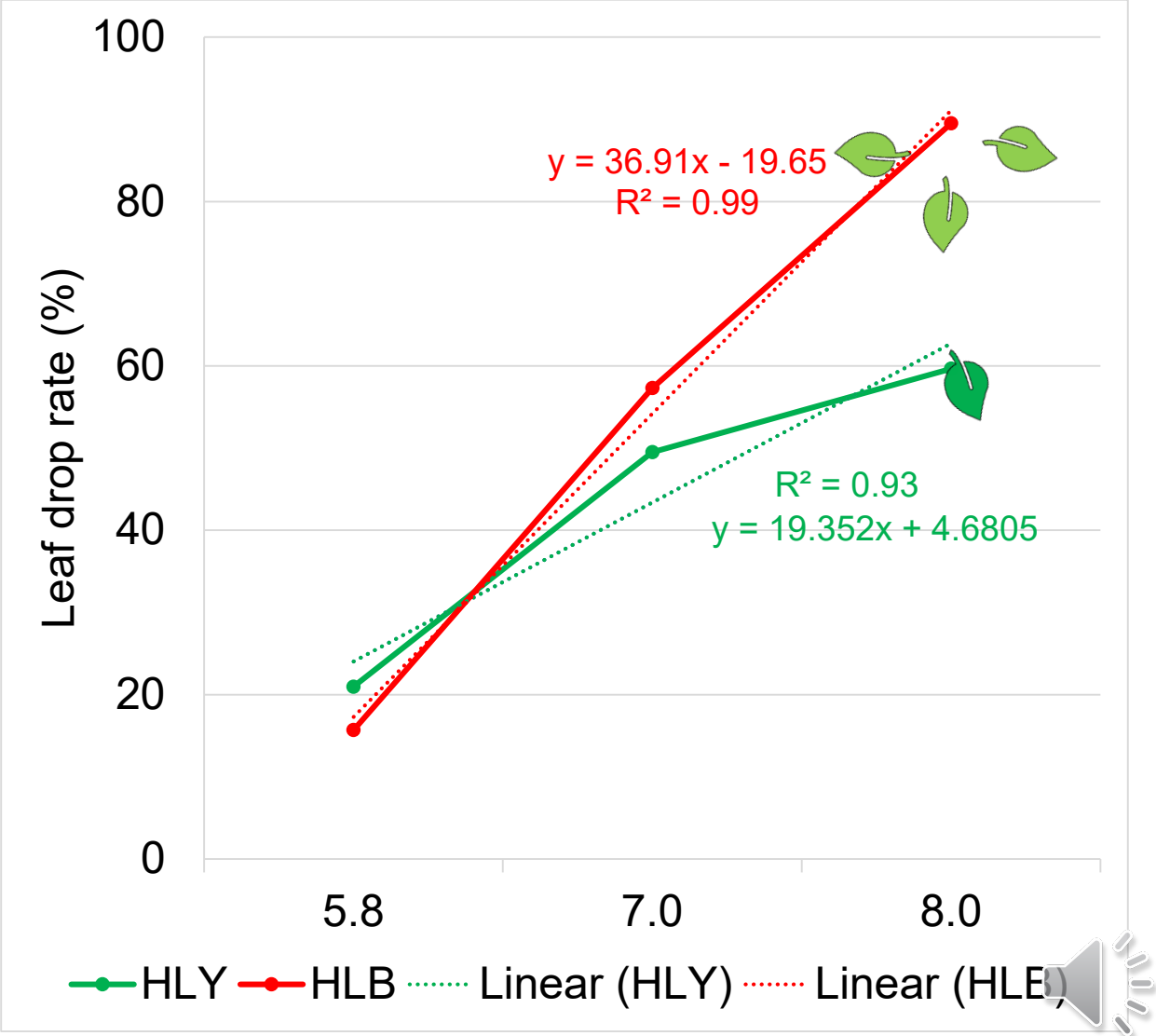
pH 8.0 HLB treatment resulted in heavy leaf drop





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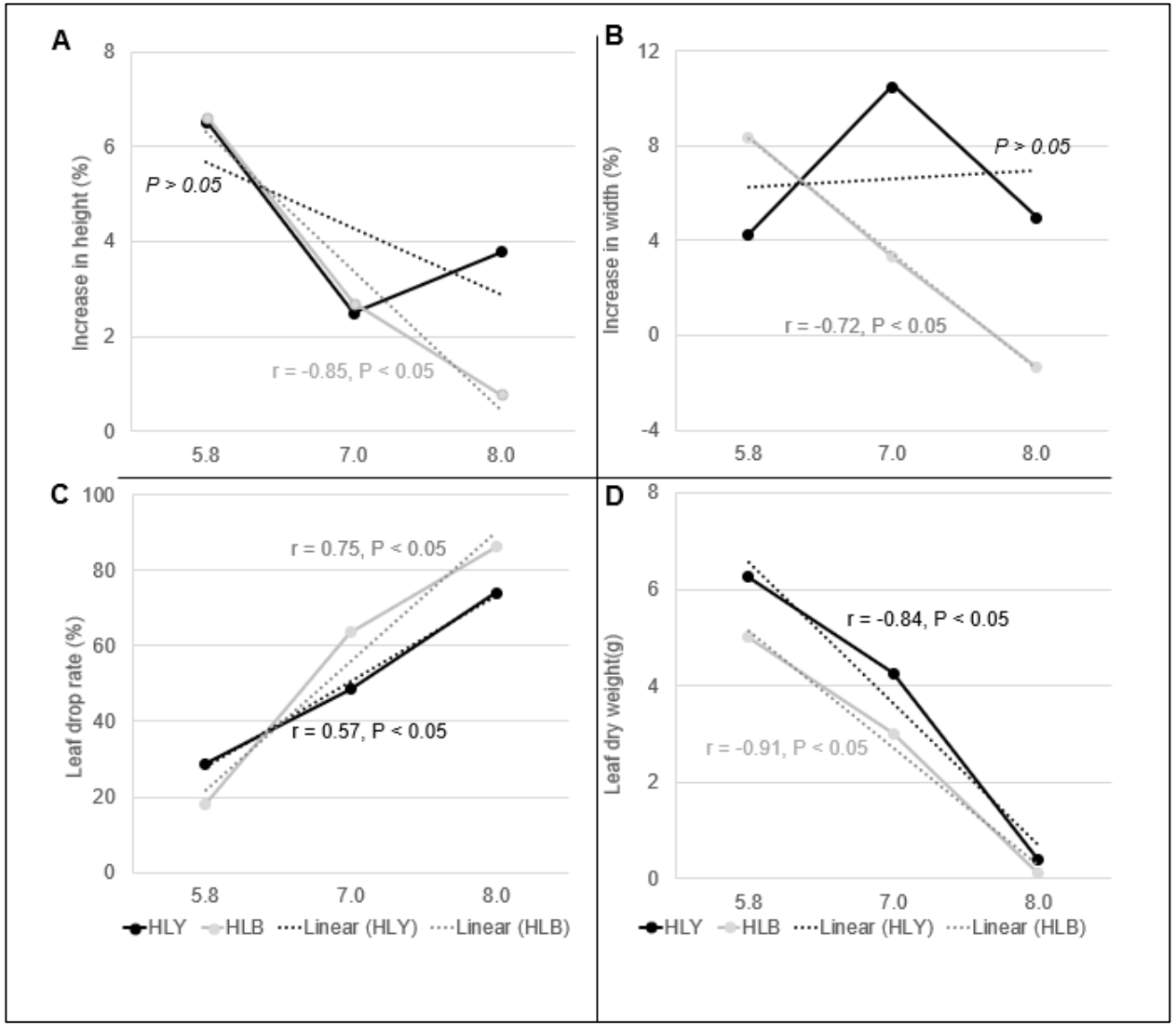
Healthy trees are not affected by soil pH as much as HLB-affected trees



Shoot system at Day 60

Published Study 4

HLY:

pH: 5.8 7.0 8.0

HLB:

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Published Study 4

Root system at Day 60

HLY:

pH: 5.8 7.0 8.0

HLB:

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Nutrient concentration in the soil

	P	Ca	Zn	B	K	Mg	Mn	Fe	Cu
5.8 HLY	555.13± 23.87 B	289 ± 21.16 B	29.91 ± 0.97 A	0.15 ± 0.02 b	158.75 ± 8.27 a	47.13 ± 3.15 b	10.25 ± 0.15 b	55.88 ± 1.87 a	2.38 ± 0.08 b
5.8 HLB	698.25± 50.87 AB	489.25± 63.27 AB	27.02 ± 2.12 A	0.25 ± 0.05 b	162.75 ± 7.40	72.5 ± 7.94 b	9.13 ± 0.59 b	69.13 ± 7.45 a	3.22 ± 0.1 b
7.0 HLY	697.63± 47.78 AB	515 ± 64.45 AB	27.65 ± 0.78 A	0.22 ± 0.03 b	103.5 ± 1.66 b	92.88 ± 17.79 ab	11.38 ± 0.56 ab	52.88 ± 5.61 ab	2.54 ± 0.15 b
7.0 HLB	610.63± 45.86 AB	329 ± 10.02 AB	23.02 ± 3.17 AB	0.2 ± 0.04 b	96.63 ± 1.55	47.84 ± 2.32 ab	11 ± 0.29 ab	43.63 ± 5.35 ab	2.63 ± 0.05 b
8.0 HLY	631.5± 68.78 AB	370 ± 96.8 AB	28.46 ± 3.42 A	0.38 ± 0.10 a	43.67 ± 5.24 c	98.67± 18.62 a	12.75 ± 1.30 a	41.01 ± 5.34 b	3.28 ± 0.26 a
8.0 HLB	786.63± 10.96 A	583.13 ± 39.81 A	12.47 ± 1.58 B	0.34 ± 0.05 a	50.25 ± 4.03	119.75 ± 16.72 a	12.63 ± 0.66 a	44.63 ± 2.67 b	3.63 ± 0.13 a

Nutrient concentration in the leaves

	N	P	K	Mg	Ca	B	Zn	Mn	Fe	Cu
5.8 HLY	28000	9800	33600	2700	18800	66.40	30.66	65.72	147.81	8.92
5.8 HLB	30900	10600	37700	2600	15800	80.26	35.84	98.27	146.60	8.49
7.0 HLY	27800	5000	27200	2800	15800	55.71	25.09	51.80	137.70	7.89
7.0 HLB	35300	5100	31500	3000	20200	90.82	33.32	110.24	170.15	9.33
8.0 HLY	26500	6200	26100	3400	15500	53.71	27.75	73.54	105.90	7.92
8.0 HLB	31600	2200	20300	1700	9100	45.88	10.73	84.85	98.73	4.08
Optimum range	25000-27000	1200-1600	12000-17000	3000-4900	30000-49000	36.0-100	25.0-100	25.0-100	60.0-120	5.00-16.0

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

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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%

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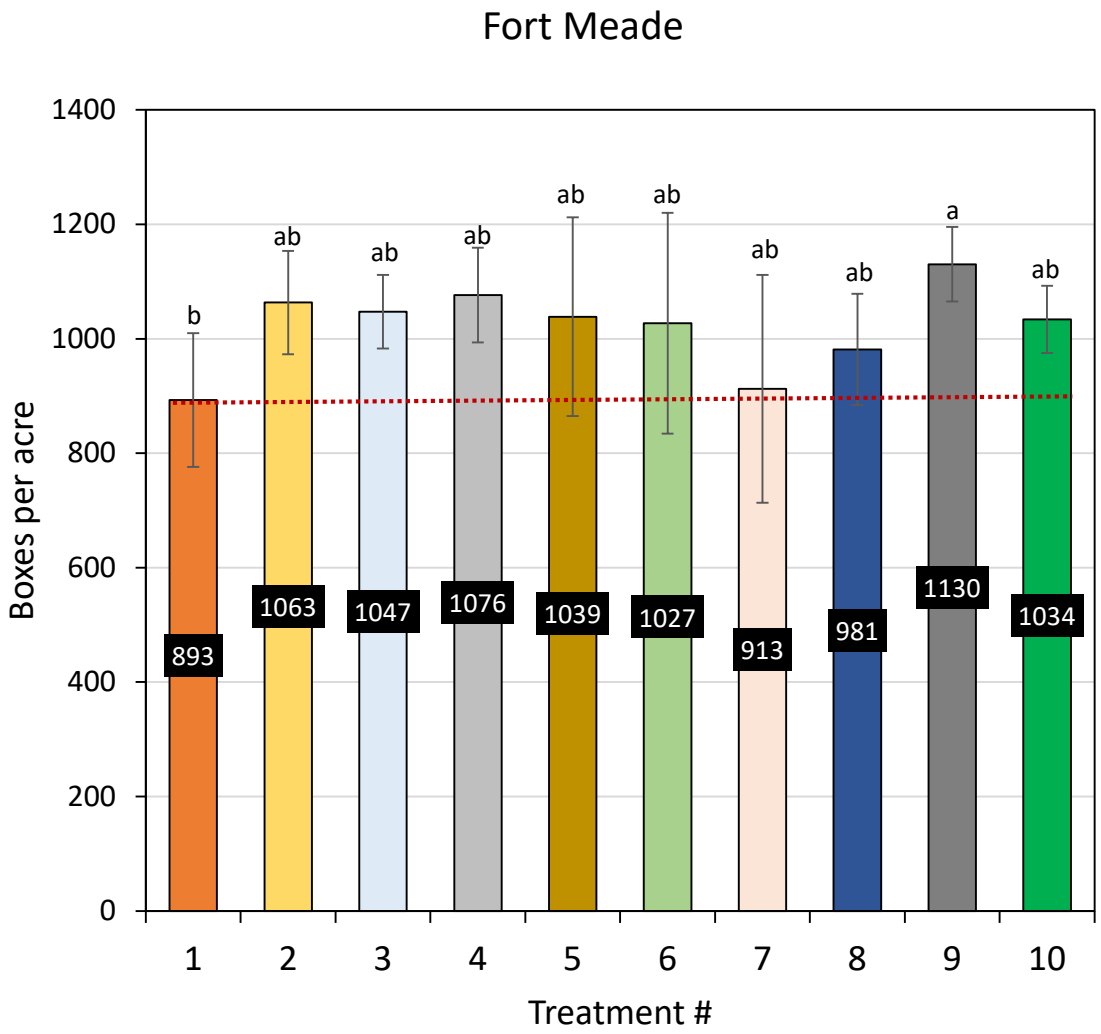
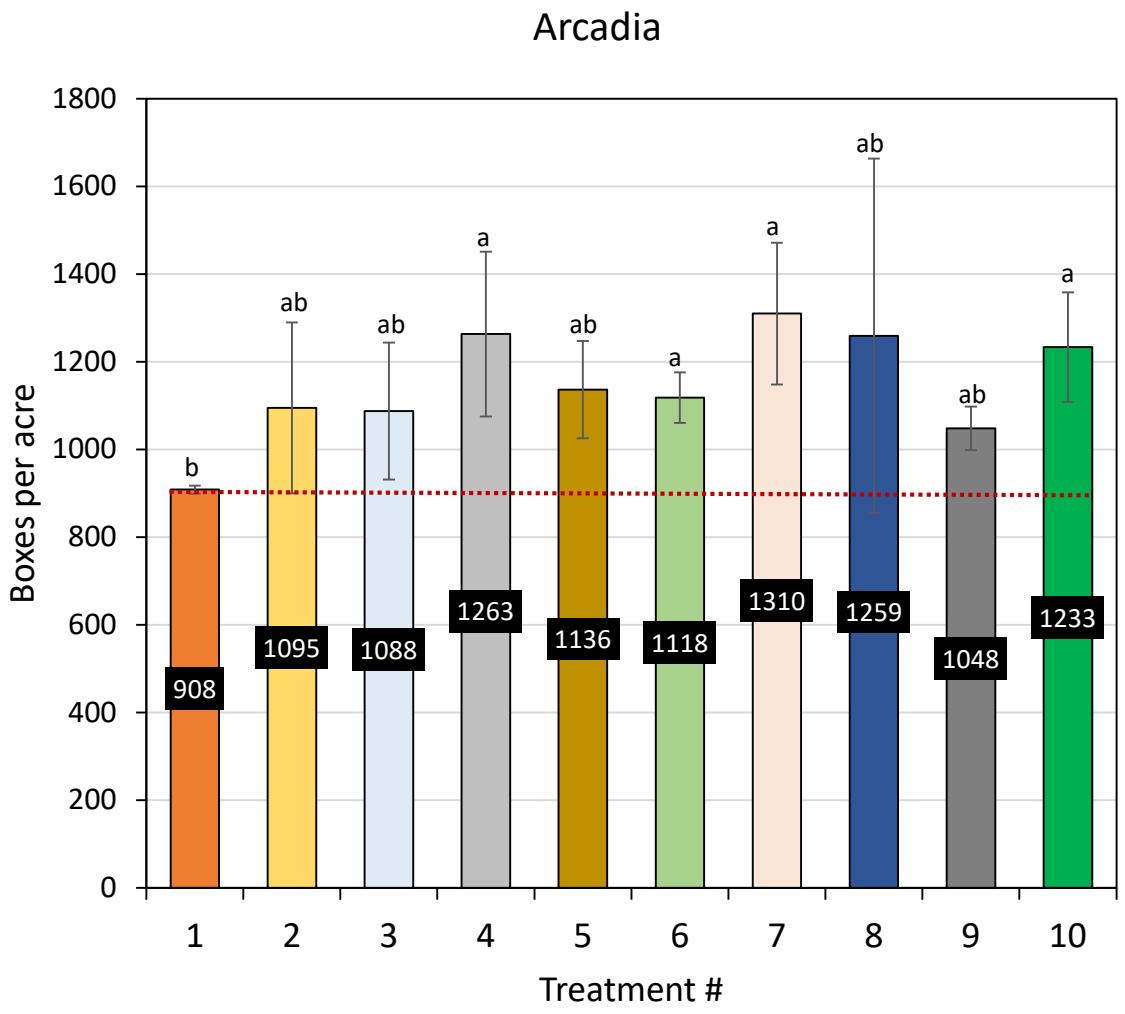
Ongoing Study 5

3 Year Cumulative Yield (Boxes per acre)





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Ranking based on cumulative yield of 3 years

Ongoing Study 5

Arcadia Site			Fort Meade Site		
Treatment #	Treatment	Total 3 Yr Yield (boxes per acre)	Treatment #	Treatment	Total 3 Yr Yield (boxes per acre)
7	CRF+Tiger MM + Fe 20%	1310	9	CRF+Tiger MM + Mn+B 20%	1130
4	CRF+Tiger MM	1263	4	CRF+Tiger MM	1076
8	CRF+Tiger MM +B 20%	1259	2	Conventional+ Tiger MM	1063
10	CRF+Tiger MM + Mn+ B 50%	1233	3	CRF+ foliar	1047
5	CRF+Tiger MM + Mn 20%	1136	5	CRF+Tiger MM + Mn 20%	1039
6	CRF+Tiger MM + Zn 20%	1118	10	CRF+Tiger MM + Mn+ B 50%	1034
2	Conventional+ Tiger MM	1095	6	CRF+Tiger MM + Zn 20%	1027
3	CRF+ foliar	1088	8	CRF+Tiger MM +B 20%	981
9	CRF+Tiger MM + Mn+B 20%	1048	7	CRF+Tiger MM + Fe 20%	913
1	Control	908	1	Control	893

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Fertilizer Program Needs to Customized for the Site

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