Critical leaf nutrient thresholds to diagnose deficiencies in HLB trees

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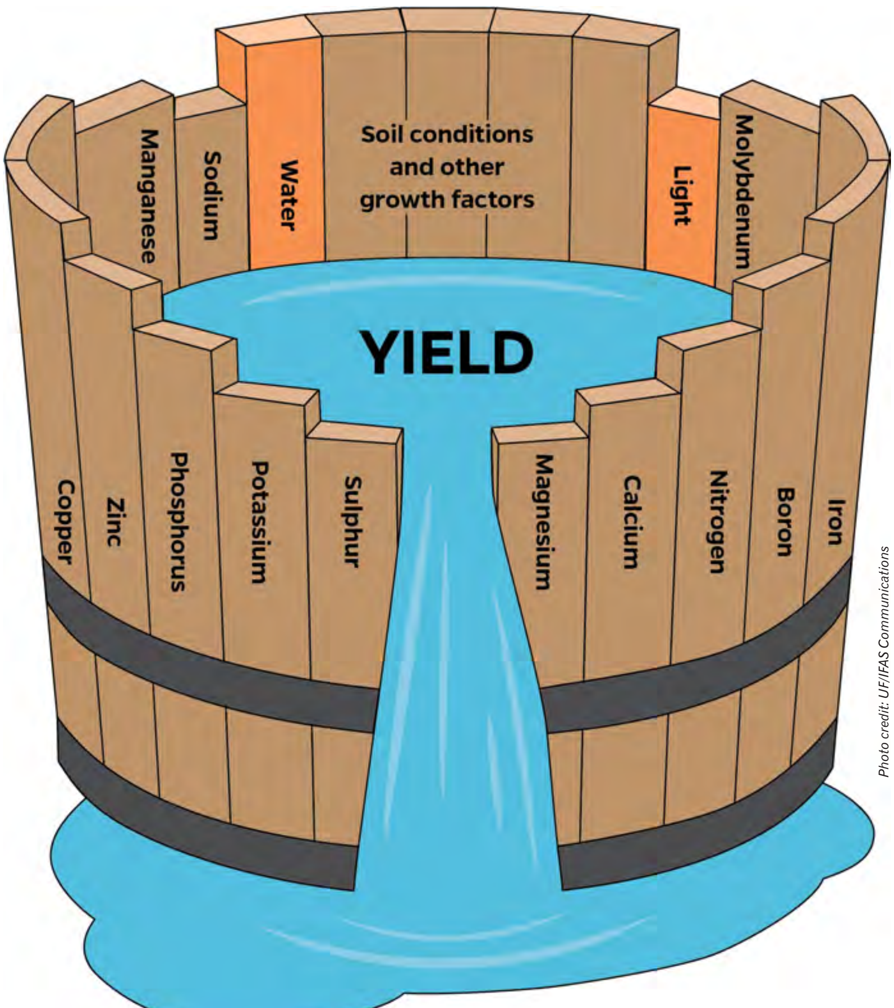

Figure 1. Liebig's law of the minimum is illustrated for plant growth and nutrition with a leaking barrel.

Efficient diagnosis of nutrient imbalances in HLB-affected trees (both deficiencies and excesses) is necessary to make fertilizer remedies cost-effective and productive.

Huanglongbing (HLB) disease severely impacts the nutrient status of citrus trees, particularly by stunting the feeder roots and causing measurable deficiencies of nutrients in the roots and canopies. Visible symptoms of nutrient deficiencies on citrus foliage are characteristic but not diagnostic of HLB disease.

Recent HLB research efforts have focused on manipulating nutrient deficiencies with fertilizer applications to mitigate HLB symptoms and help keep affected trees alive and productive.

Efficient diagnosis of nutrient imbalances in HLB-affected trees (both deficiencies and excesses) is necessary to make fertilizer remedies cost-effective and productive. Published thresholds defining deficient, low, optimal, high and excess ranges of nutrient concentrations in citrus leaves were derived long before HLB spread in Florida. Therefore, we conducted a series of survey studies to verify and improve those existing thresholds in HLB-endemic Florida citrus groves.

Traditionally, nutrient thresholds were obtained empirically from long-term replicated fertilization trials conducted decades ago, most notably where "missing nutrient" experiments would, over many years, cause those nutrients to become deficient in trees not receiving certain fertilizers. By comparing treatment plots to fully fertilized control plots, the fruit yield reduction and other symptoms caused by the nutrient deficiency could be quantified.

Critical threshold concentrations (CTCs) derived for each nutrient from those studies were then published and used as thresholds to diagnose leaf tissue samples collected from commercial groves. In the current study, we used a sample survey method and the Diagnosis and Recommendation Integrated System (DRIS) instead of "missing nutrient" experiments in order to save considerable time.

STUDY SETUP

Leaf tissue samples were collected quarterly from 2016 to 2018 in three citrus-growing regions of Florida (11 locations from the Central Ridge, five from the east coast Indian River and six from the southwest Flatwoods). Soil samples were collected annually, and tree canopy measurements, leaf size, starch content, quantitative polymerase

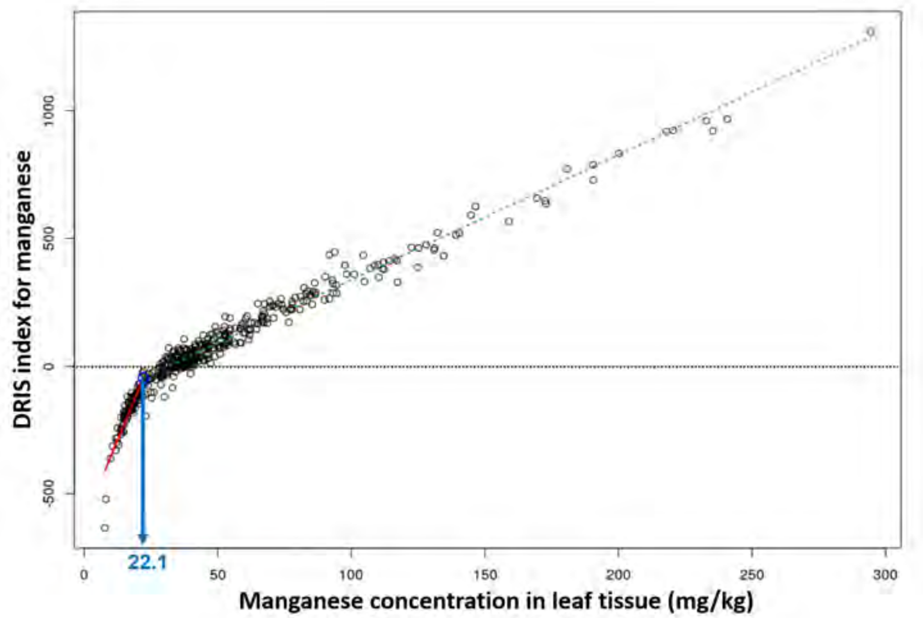

Figure 2. Scatter plot of leaf manganese Diagnosis and Recommendation Integrated System (DRIS) indices versus manganese concentrations in HLB-affected citrus. The breakpoint between red and green regression lines indicates the location of the critical threshold concentration (CTC = 22.1 mg/kg).

chain reaction (qPCR) assay and other measurements were conducted periodically for the same sites. In this article, we will focus only on the leaf tissue nutrients of sweet orange trees and assume that most of the sampled trees were HLB-positive, based on the qPCR analyses.

ABOUT DRIS

In an April 2009 Citrus Industry article, DRIS was introduced as a promising method for interpreting nutrient levels in plant tissues. See "Potential use of DRIS for leaf nutrient diagnosis in Florida citrus" (www.crec.ifas.ufl.edu/extension/trade_journals/trade_journals2009.shtml).

The DRIS method produces an index for each plant nutrient calculated from a series of leaf concentration ratios of that nutrient with all other measured nutrients, relative to a set of nutrient norms (standards) that were previously calculated from a high-yielding grove. We obtained the DRIS norms from leaf samples collected in the summer of 2003, from a 22-year-old block of Hamlin orange trees on Cleopatra mandarin rootstock near Fort Meade, Florida, spaced 20 by 25 feet and with an average fruit yield over four years of 770 boxes per acre. The leaf sampling for DRIS norm development coincided with a peak yield of 970 boxes per acre in the 2003–04 season, prior to Hurricane Charlie and the appearance of HLB in Florida.

The critical threshold concentrations are the thresholds for each nutrient that determine whether a given tree or grove would be responsive to fertilizer supplying that nutrient.

DETERMINING DEFICIENCIES

The application of DRIS to diagnose nutrient deficiencies in leaf tissue from HLB-affected trees is best done in conjunction with the CTCs. The CTCs are the thresholds for each nutrient that determine whether a given tree or grove would be responsive to fertilizer supplying that nutrient. Traditionally the CTCs occupy a spot on the plant response curve for each nutrient concentration of about 90 percent maximum yield or growth.

When multiple deficiencies occur, as is often the case with HLB-affected trees, the DRIS indices provide

Table 1. Leaf tissue analysis of HLB-affected orange trees shows the interpretation of multiple nutrient deficiencies with Diagnosis and Recommendation Integrated System (DRIS) indices in conjunction with nutrient concentrations and critical concentration thresholds.

N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
percentage of leaf dry weight (%)						(mg/kg, or ppm)				
2.47	0.16	1.27	0.20	3.15	0.19	55.4	13.5	16.2	46.9	12.1
DRIS indices						DRIS indices				
51	209	-26	-157	53	-55	-35	-82	-119	-3	56
Interpretation:						Mg<Mn<Zn<S				

information about the relative severity and ranking of the deficiencies, which the CTCs do not accomplish. Dealing with multiple nutrient deficiencies efficiently is important because of the biological stoichiometry that determines the ideal proportions of nutrients in a plant, just as, for example, a water molecule consists of exactly two atoms of hydrogen and one of oxygen.

Liebig's law of the minimum applied to plant growth, and often visualized as a leaking barrel, (Figure 1, page 20) demonstrates that it is the most limiting nutrient that limits growth and yield, regardless of the amounts or types of other nutrients available. Another analogy is that a gasoline engine will not run faster if only the gasoline flow is increased without proportionately increasing the air (oxygen) supply, such as if the choke control is active. The engine may flood and stall if too much gasoline is supplied without increasing the most limiting ingredient for combustion at that time (oxygen).

For example, consider the results in Table 1 of leaf tissue analysis from an HLB-affected tree.

DRIS indices have a theoretical optimum at zero, with more negative values indicating possible nutrient deficiency, and increasing positive values indicating possible nutrient excess. In the Table 1 example, Mg<Mn<Zn indicates that Mg was the most limiting nutrient, followed by Mn and Zn. All three nutrients were determined deficient according to the published CTCs and were therefore highlighted blue. Sulfur (S) was the third nutrient in the DRIS sequence but was in the low range (highlighted green) and not deficient according to the CTC. A similar procedure could be followed for any nutrient excesses, if they exist.

CALCULATING CTCs

To examine the validity of currently available CTCs for nutrient diagnosis in HLB-endemic Florida citrus, we used scatter diagrams of the

Table 2. Critical nutrient concentration thresholds for deficiency and optimal nutrient concentrations for Florida citrus leaf tissue samples. Values highlighted in yellow are existing published norms developed before HLB spread in Florida. The blue highlighted values were calculated with Diagnosis and Recommendation Integrated System (DRIS) indices from a 2016–2018 survey, when most of the trees were affected by HLB. The survey thresholds (blue) should be considered preliminary information and not a University of Florida Institute of Food and Agricultural Sciences recommendation.

Nutrient	Critical Threshold Concentration		Optimal Nutrient Concentration	
	Published* (pre-HLB)	From this survey (HLB-positive trees)	Published* (pre-HLB)	From this survey (HLB-positive trees)
K (%)	<0.7	<1.1	1.2-1.7	1.9
Mg (%)	<0.2	<0.23	0.3-0.49	0.43
Mn (ppm)	<18	<22	25-100	31
Zn (ppm)	<18	<20	25-100	24
Fe (ppm)	<35	<33	60-120	73
Cu (ppm)	<3	<8.7	5-16	11
B (ppm)	<20	<38	36-100	117

* Nutrition of Florida Citrus Trees, 2nd Edition (SL253), UF/IFAS Extension 2008

DRIS indices for each nutrient plotted against the nutrient concentrations. This technique has been used before in other crops to determine CTCs from nutrient survey data, including loblolly pine, cotton and signalgrass. Figure 2 (page 22) shows that the scatter plot for manganese in our survey of HLB-affected groves follows two data trends of different slopes, with the breakpoint indicating the CTC for that nutrient on the x-axis. We used segmented linear regression to determine the correct breakpoint.

The process was repeated for each nutrient in order to determine the preliminary CTCs listed in Table 2. The optimal nutrient ranges in Table 2 were estimated from the intercept of the regression line with zero on the y-axis (DRIS). By comparing our new CTCs with published CTCs, it appears that deficiency diagnoses for copper, boron, potassium, manganese and zinc could be underestimated by currently available CTCs when used for HLB-affected trees.

The optimal nutrient concentrations calculated from this study are mostly in agreement with ranges

CITRUS EXPO℠ Snapshot

GROWING STRONGER

The Citrus Expo seminar planning committee met in Sebring in February to discuss issues of importance to citrus growers. Those present at the meeting included (from left, around the table): Ray Royce, Highlands County Citrus Growers Association; LeAnna Himrod, Florida Department of Citrus; Tacy Callies, AgNet Media; Rick Dantzler, Citrus Research and Development Foundation; Josh McGill, Abbey Taylor and Ernie Neff, AgNet Media; Laurie Hurner, Highlands County Extension; Kait Shaw, Peace River Valley Citrus Growers Association; Robin Loftin, AgNet Media; Tripti Vashisth and Michael Rogers, University of Florida. Not pictured are Gary Cooper, AgNet Media, and Mary Hartney, Florida Fertilizer & Agrichemical Association.

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Citrus Expo 2019 is August 14–15.

previously published by the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), except that boron and potassium optimal levels were estimated slightly higher in the survey than those previously published. These results are preliminary, and in this study, CTCs could only be calculated for those nutrients where deficiencies occurred in the survey data. We plan to augment this survey with more leaf nutrition data to better define and expand CTC estimates to be used for diagnosing HLB-affected citrus for all nutrients.

Please contact us if you have leaf nutrient data from your groves that you are willing to share in this study, or if you would like to use the DRIS program which will be published online to a UF/IFAS web page.

SUMMARY

In this article we provided updates on research efforts to improve the nutrition of HLB-affected Florida citrus by revising the diagnostic CTC of nutrients in leaf tissue. We also revisited the DRIS method for improving diagnosis of multiple nutrient deficiencies that are common in HLB-affected groves, including potassium, magnesium, manganese, zinc, iron, boron and copper. Additional leaf nutrient data will be obtained for an expanded survey, to be analyzed and corroborated with results of recently completed micronutrient fertilization experiments.

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