Balancing resources for management of root health in HLB-affected groves

By Jim Graham, Tim Gottwald and Mike Irey

When huanglongbing (HLB) disease — caused by the systemic bacterium *Candidatus* Liberibacter asiaticus (LAS) — was first found in Florida, the overarching concern was the direct losses associated with tree decline. Initial HLB control efforts focused on inoculum management that starts with planting of disease-free trees from enclosed nurseries, survey for and removal of infected trees, and aggressive psyllid vector control. Now, more than six years since the discovery of HLB, the majority of the citrus industry has moved to use of enhanced nutritional programs (ENPs) that do not involve removal of HLB-infected trees, but rely heavily on area-wide management of psyllids to limit disease spread.

As a major consequence of rising incidence of HLB-infected trees and their treatment with ENPs, inoculum levels continue to rise, and incidence of HLB will approach 100 percent in a short number of years. The most current estimate of HLB disease incidence is 20 percent cumulative for 2010, 40 percent for 2011, and is likely even higher at present (Figure 1).

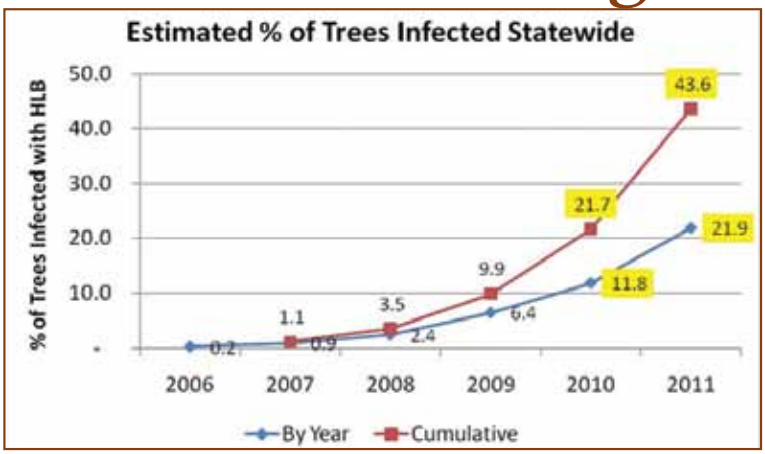

Figure 1. *Progress of HLB incidence from 2006 to 2011 (estimates from the US Sugar, Southern Gardens Diagnostic Lab and UF-IFAS survey databases)*

Typical of plant diseases and their interaction with the environment, crop loss is more complex than just the direct losses experienced as a result of symptoms, and therefore must also account for interactions with soils, water and fertilization/nutrition, interactions with abiotic stresses such as drought and temperature extremes, and interactions with other diseases and pests attacking the plant. Specific to systemic diseases, all parts of the plant may become infected and exhibit symptoms unique to that plant part.

It has been well-documented for HLB that the bacterium infects the structural and fibrous roots, but detailed studies of the infection process and progress of root symptoms have not been reported. Our greenhouse studies of bud-inoculated nursery size trees indicate that the bacterium may initially move to the roots before infecting the shoots, and that this infection may cause rapid decline of fibrous roots. Nutritional spray treatments of these nursery trees modify the root infection process, but do not mitigate symptom development. The implication from these observations for field trees is that even if HLB foliar symptoms appear to be reduced by ENPs, damage to fibrous roots still may occur and have effects on tree stress tolerance in the early stages of above-ground symptoms expression. Hence, root health must be considered as an integral part of an HLB management program.

SUSTAINING ROOT HEALTH OF HLB TREES IS COMPLICATED

Because of the bacterium-vector-host interaction, HLB is the most complex disease to manage that the Florida citrus industry has ever faced. Root-health interactions for HLB trees appear to be just as challenging. Surveys and observations statewide are mounting that management of HLB with ENPs is more complicated than initially thought and may have unanticipated consequences. In a previous *Citrus Industry* report (J. Graham, J. Taylor and M. Irey, May 2011), we drew attention to research that indicated that LAS infects fibrous roots, predisposing them to infection by *Phytophthora* spp., and that the interaction of LAS and

Phytophthora increases the damage caused by either one alone. This interaction is analogous to what we discovered 15 years ago between root damage caused by *Diaprepes abbrevatus* larval feeding and Phytophthora damage of structural roots. Diaprepes feeding broke resistance of roots to Phytophthora infection. Consequently, phosphites, which induce resistance of citrus tissues to Phytophthora, were no longer useful for root rot control, whereas mefenoxam, which has a direct fungicidal effect on the pathogen, was effective for control of Phytophthora root damage.

In the previous *Citrus Industry* report, we also drew attention to recent trends in the Phytophthora survey by Syngenta as a grower service in support of Phytophthora detection and management over the last 25 years. For this statewide survey of groves, root-soil samples are collected to determine which *Phytophthora* spp. is present, and to enumerate Phytophthora propagules per cm^3 of soil. Based on thousands of samples, groves with propagule counts exceeding the threshold of 10 to 20 should be considered for fungicide treatment. Since the 2010 survey was completed, 2011 trends indicate even higher levels of propagules and another sharp rise in the number of samples that exceed the threshold irrespective of grove location, rootstock or management practices (Figure 2).

What has changed in Florida citrus groves statewide to drive these numbers even higher than last year? Previously, we suggested the sharply rising incidence of HLB-infected trees promotes greater Phytophthora infection and root damage, but another major change in grove conditions has been the wide-scale adoption of ENPs as the incidence of HLB has rapidly increased (Figure 1).

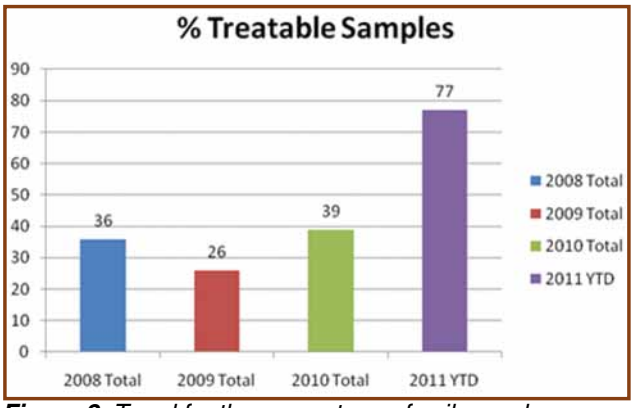

Figure 2. *Trend for the percentage of soil samples exceeding threshold of the 10 to 20 Phytophthora propagules/cm^3 which should be considered for fungicide treatment (data from Syngenta Crop Protection, Soil Bioassay Program). YTD = year-to-date*

WHAT DOES THE HLB-ROOT HEALTH SURVEY REVEAL?

To confirm the unprecedented rise in the Phytophthora populations statewide, our lab conducted a smaller scale survey to establish whether differences in Phytophthora populations between HLB affected (+) and unaffected trees (-) occurred, and whether Phytophthora-resistant/tolerant rootstocks, Swingle citrumelo and Carrizo citrange, support damaging populations in areas where they were previously uncommon. In 2011, three citrus operations were chosen that were treating with ENPs and also still scouting and removing trees in the central, south-central and southern areas of the citrus belt. This approach provided the opportunity to survey recently flagged HLB+ trees with symptoms for only three to six months, and to compare them with nearby HLB- trees. Ten soil-core samples from each of three pairs of trees per block were taken in the microjet wetted area — the zone where roots are most concentrated. For each soil sample, we measured fibrous root weight as well as propagules so that the amount of Phytophthora could be expressed based on the root mass available to support the pathogen. The survey results in Table 1 (page 10) are highly instructive in several respects:

- Phytophthora populations are trending higher irrespective of grove location, i.e., ridge versus flatwoods.
- Phytophthora populations are high to very high on Swingle rootstock, which does not normally support populations as high as those on Carrizo.
- Phytophthora populations are as high on HLB- trees as on HLB+ trees.
- Root mass on recently symptomatic HLB+ trees is significantly lower (33 percent to 49 percent) than HLB- trees, irrespective of ENP management.
- Phytophthora populations per root weight for HLB+ trees are generally higher, suggesting an interaction between HLB and Phytophthora damage is contributing to the root loss.
- All grove locations sampled are treated with ENPs (including phosphites), which may be affecting root mass production in the same way as ENPs stimulate shoot canopy vigor.

Our previous research indicated that Phytophthora populations are higher in growing seasons in which trees produce more roots and higher quality roots (i.e., higher carbohydrate concentration) that the fungus feeds upon. This biennial behavior is the same as that for fruit production and occurs on the off-year for fruit production. Previous research on fungicide and nematicide control of root parasites (Phytophthora and citrus nematode) also established a direct relationship between fibrous root loss and reduction in tree yield. Based on our past knowledge of root production, Phytophthora and yield responses of trees, preliminary conclusions from the survey are:

- Substantial root loss on HLB+ trees (33 percent to 49 percent) has occurred by the time of the appearance of above-ground symptoms, and is similar in magnitude to losses in fruit

Table 1. ***Phytophthora nicotiane*** **(P.n.) populations, root weight and P.n. propagules per gram of root in the central ridge (Highlands County), south central flatwoods (DeSoto/Hardee counties) and the southwest flatwoods (Hendry County) for pairs of HLB-affected and non-affected Valencia orange trees on Swingle or Carrizo rootstock**

Location	Scion/Rootstock	Month	P.n. propagules /cm^3 soil		Root dry weight (g)		P.n. propagules /g root	
			HLB-	HLB+	HLB-	HLB+	HLB-	HLB+
Hardee County	Val/Swingle	Sept.	52.7	44.2	0.37	0.20*	150.6	333.4
Highlands County	Val/Swingle	April	63.1	38.9	0.44	0.28*	144.4	147.5
DeSoto County	Val/Carrizo	May	92.0	65.5	1.47	0.96*	66.3	74.2
DeSoto County	Val/Carrizo	June	40.8	33.1	0.81	0.51*	40.6	73.9
Hendry County	Val/Swingle	May	58.1	49.0	1.58	1.00*	42.2	50.4
Hendry County	Val/Swingle	Oct.	63.7	55.1	0.81	0.54*	83.8	119.4*
Highlands County	Val/Swingle	Oct.	63.1	38.9	0.41	0.28*	144.4	147.7

** HLB +/- – significantly different according to paired t test at P ≤ 0.05*

t test is the name of the statistical test; P refers to the probability level at which the test is significant

production in the early stages of canopy decline for HLB trees in Brazilian groves (30 percent) and in Florida groves treated with ENPs for multiple seasons (20 percent to 40 percent).

• Phosphites commonly included in ENPs may not be contributing to protection of roots against Phytophthora, especially after pathogen infection, because the HLB appears to break host resistance.

• More intentional control of Phytophthora with a fungicide that directly controls infection and reproduction (e.g. mefenoxam) should be considered when populations exceed the damage threshold of 10 to 20 propagules/cm^3 soil.

IMPLICATIONS FOR INITIATING ROOT-HEALTH MANAGEMENT

The HLB syndrome appears to include an interaction with Phytophthora infection. HLB causes vascular decline and death of both above- and below-ground portions of the tree. Below ground, dysfunction of fibrous roots due to HLB provides an opportunity for *Phytophthora* spp. to infect the root system, thereby accelerating HLB tree decline. The evidence from the Syngenta survey and results from our survey confirm that under prevailing HLB incidence and management with ENPs, Phytophthora damage to roots may need to be managed with fungicides in groves where the soil assay indicates that propagules exceed the threshold indicated above. This fungicide treatment program must be sustained, aggressive and principally utilize mefenoxam, the only registered fungicide for citrus with direct fungicidal activity. Fosetyl-Al, which has a different active ingredient than phosphites (fosetyl-Al vs. PO^3), has proven effectiveness for management of Phytophthora and should be rotated with mefenoxam.

Grove trials are now under way to demonstrate whether this formulation of phosphite fungicide will be effective for HLB+ trees. Mefenoxam use rates are based on propagule counts. Treatment is not currently recommended when propagule counts are below 10 propagules/cm^3. When propagule counts are in the range of 10 to 20 propagules/cm^3, lower rates of mefenoxam are recommended. When propagule counts exceed 20 propagules/cm^3, higher rates of mefenoxam are recommended.

Due to differences in mefenoxam formulations, growers should refer to the individual product labels for proper rate recommendations. Application by irrigation injection or other methods should be timed when root flushes occur after spring and fall shoot flushes. Fosetyl-Al is foliar applied three to four times per season. For the rate and timing of fosetyl-Al applications, consult the Florida Citrus Pest Management Guide (http://www.crec.ifas.ufl.edu/extension/pest/). The fungicide program costs are on par with Temik before its use was suspended; hence the treatment program is a major expense. For operations that used Temik, this expense can shift to root heath management. If Temik was not a part of the production program, ongoing treatments with soil fungicides will be yet another unanticipated investment for a comprehensive HLB management program.

BALANCING RESOURCES TO INCLUDE ROOT HEALTH COSTS

Recently, our research on ENPs was published in the journal *Crop Protection*. A portion of the data reported in this publication was kindly shared with the authors by Cooperative Producers Inc. (CPI), which has conducted a multi-year trial at Ranch One grove in Immokalee. In Ranch One, the standard nutritional program (SNP) was compared with an ENP in three matched blocks per treatment (two sets of Valencia/Carrizo blocks, and one set of Valencia/sour orange blocks, all 8 years old). HLB disease incidence was recorded during 24 visual assessments from December 2006 through March 2011. Yield data were collected from each block for the five-year period from 2007 to 2011. From 2007 to 2008, trees did not have the advantage of micronutrient treatments and the production data were used to establish baseline yields per tree for each block.

When yields were adjusted for the pre-existing differences between the sets of blocks, yearly harvests from 2009-2011 treatments showed no effect of the ENP, compared to the SNP. Rates of HLB disease increase between these sets of trees were nearly identical for the ENP and SNP blocks. The cost of this ENP is approximately $611 per acre, about three times the cost of the SNP at $184 per acre.

Based on the comparison of these particular ENP and SNP programs, nutritional inputs may be adjusted to provide the level of nutrition needed to support production of HLB-affected groves while accommodating the need for additional root health management. To match nutritional supply with tree demand, leaf testing of the nutrient status of both HLB+ and HLB- trees should be conducted and compared. Non-nutritional components in ENPs such as SAR inducers have not been demonstrated to provide value for HLB tree health (J. Graham and G. Vallad, *Citrus Industry* May 2011).

We are not advocating a complete move away from the ENPs developed to manage HLB over the last five years, but instead recommend a reprioritization and integration of the management program based on the relationship between root decline due the HLB/Phytophthora interaction and yield losses, and from research experience with ENPs. Our learning curve for management of HLB has been steep and undoubtedly will continue to be steep (but hopefully less so) into the foreseeable future. What is certain is that much more remains to be learned about factors affecting HLB tree health, and that this process requires a strong partnership between researchers and the Florida citrus industry.

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