Phytophthora damage to roots

A potential contributor to decline of HLB-affected trees

By Jim Graham, Mike Irey and John Taylor

Huanglongbing (HLB, yellow dragon disease or citrus greening) was first found in Florida in late 2005 and is now widely distributed throughout the commercial citrus-growing regions. Survey data for 2009 indicated that the cumulative incidence of infected trees was in the range of 8 percent to 10 percent statewide, and in 2010 had climbed to 18 percent, which is probably an underestimate. The highest infection levels occur in south and east coast groves, where HLB incidence within individual groves is nearly 100 percent. In the northern and western areas of the state, infection levels in individual groves remain low.

When HLB was first discovered, the citrus industry adopted the recommended practices including control of the insect vector, use of disease-free planting material and the removal of infected trees to lower the inoculum load. However, as HLB infection increased in groves, many growers began moving to alternative treatments. Currently, a large portion of the industry has chosen to stop removing trees and, as an alternative practice, has adopted nutritional programs. This management scenario has heightened grower awareness of "good horticultural practices" to sustain tree health.

Unfortunately, the management of HLB with such practices is more complex than simply increasing the frequency and intensity of nutritional spray programs. This is because the HLB pathogen, *Candidatus* Liberibacter asiaticus (*Las*), infects all parts of the citrus tree, including the roots, and may cause unseen decline in the health of fibrous roots below ground, as well as leaves, fruit and branches above ground.

Phytophthora nicotianae and *P. palmivora* are soilborne fungus-like organisms that to some degree affect root health in most every Florida citrus grove. These *Phytophthora* spp. cause fibrous root rot as well as foot rot on susceptible rootstocks, and occasionally, brown rot of fruit on early-season citrus varieties. While foot rot of the trunk and brown rot are easily detected above ground, *Phytophthora* damage to fibrous roots below ground is difficult to assess directly. Therefore, soil samples are collected from the root zone of trees to measure the populations of the pathogen in the rhizosphere by a quantitative assay in the laboratory. This assay estimates the density of *P. nicotianae* and *P. palmivora* per volume of rhizosphere soil. Based on assays from thousands of samples in relation to the health of trees in Florida groves and fruit-yield response to *Phytophthora* root rot control with fungicides, populations of *P. nicotianae/palmivora* are considered damaging when counts exceed 10

propagules per cubic centimeter (cm^3) of rhizosphere soil.

In fine-textured soils, water-holding capacity greatly affects *Phytophthora* populations. Central Florida Ridge groves with predominantly sandy soils low in organic matter, natural fertility and water-holding capacity occasionally support damaging populations of *Phytophthora*. South Florida flatwoods groves are mostly located on soils that reduce rooting depth of citrus. Compared to the Ridge, flatwoods soils have more water-holding capacity and higher water tables depending on depth of restrictive organic and clay sub-soil layers. These soil conditions have the potential to promote high populations of *Phytophthora* spp. due to infection of fibrous roots and rot within four to six weeks.

Citrus rootstocks vary widely in resistance and/or tolerance to *P. nicotianae* based on the populations they support in the rhizosphere. For example, when growing in soils amenable for optimal horticultural performance, Swingle citrumelo is considered to be resistant because it does not sustain high populations of *P. nicotianae* and is able to regenerate fibrous roots after infection. However, in recent decades, Swingle in the east coast and southwest regions has been found to be unsuitable for adverse soils, e.g. high pH, calcareous, poorly or excessively drained. Under these soil conditions, and especially in the presence of *Diaprepes abbreviatus* root weevil (DRW), Swingle is highly susceptible to *P. nicotianae* and *P. palmivora*.

Phytophthora is most destructive when DRW larvae damage the fibrous and structural roots first and a *Phytophthora-Diaprepes* (PD) complex develops. Normally tolerant rootstocks are rendered highly susceptible because larval feeding breaks resistance to infection by *Phytophthora* spp., especially *P. palmivora*. This resistance-breaking activity negates the control achieved with systemic phosphite fungicides that act to induce host resistance of roots to *Phytophthora* infection. In contrast, fungicides containing the active ingredient mefenoxam (i.e. Ridomil Gold®) directly control the fungal population at a level sufficient to reduce fibrous root damage by both *Phytophthora* spp. and to promote recovery of fibrous root health.

Therefore, to achieve conditions that are not conducive for PD complex, the recommendation is to practice an aggressive weevil control program in

CRDF Takes Balanced Approach

By Tom Turpen

The mission of the Citrus Research and Development Foundation is to convert research into solutions to protect citrus production from threats of infectious disease. Our process is as rigorous, objective, transparent and as fast as we can achieve. The projects are selected by scientific merit and the likelihood of yielding an impact. Here we will provide a snapshot of 135 open and currently approved research contracts. It should come as no surprise that 92% of our funding is provided for Greening research while the other 8% mainly supports Canker research. The Foundation supports one project each in Black Spot and Leprosis, examples of two emerging diseases where some foresight now may be prudent. Behind the scenes we do what we can to recruit other sponsors to pay attention to issues like Blight and other diseases. We are well aware that infectious disease problems are inseparable from other aspects of the agricultural system including cultivar breeding, advanced citrus production systems, and customized nutritional support to provide relief to infected groves.

We continue to organize research by the categories published in the NRC planning study (full report can be found at http://www.nap.edu/catalog.php?record_id=12880) published in 2010:

2%	Consequences of HLB infection/Unclassified
14%	CLas culture, genomics, molecular biology, and Koch's postulates
10%	Citrus response to infection: symptoms, defense, CLas spread in the plant, SAR
9%	HLB pathogen and disease detection
10%	HLB epidemiology and mitigation of HLB by cultural practices
8%	ACP monitoring and behavior, cultivation and relationship to CLas
18%	ACP chemical, biological or biochemical management chemical attractants and repellants, and trapping and repelling plants
11%	Citrus genomics and transcriptomics, and Conventional citrus breeding for resistance
15%	Transgenic and viral/bacterial vector mediation of citrus resistance to HLB
3%	Model systems, including chemical screening

The above percentages are based on the amount of funding on currently open and pending-approved contracts. Overall, these categories have not fluctuated by more than 3% or so for three fiscal cycles. For example, we have reduced emphasis on diagnostics while increasing investments designed to prolong the harvest of marketable fruit from infected trees. The Foundation was a major one-time contributor to the citrus genome project, greatly accelerating the recent release of the current draft sequence but this contribution is non-recurring.

How do we know this portfolio of projects is correctly balanced? There are a few clues. First of all, it should please no one. Growers and the industry at large should always push for faster results. Teams of researchers with specific expertise should make the case that their projects have merit and impact and deserve to be funded. Secondly, we should fail often and fail fast. This is the nature of research. All projects should generate useful information but overall we are looking for both breakthrough products and incremental management tools that when brought together make a difference. No one can predict the results of these projects in advance. So, the industry and grower oversight on our Foundation board and research management committees have an eye on a return on investment, the only rule that matters. A balanced portfolio will manage the risk of infectious disease, keep and expand citrus markets and reduce production costs. This is occurring now and will span a horizon extending from immediate applications to very long-term new products for the future. The challenge for us all now is the same as for any value investment, to stay the course.

Dr. Turpen is the Interim COO and Program Manager of the Citrus Research and Development Foundation. The foundation is charged with funding citrus research and getting the results of that research to use in the grove.

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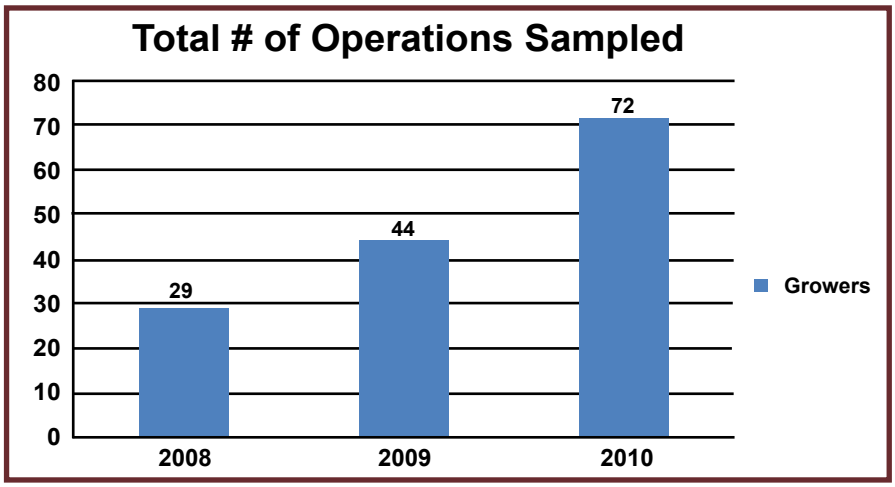

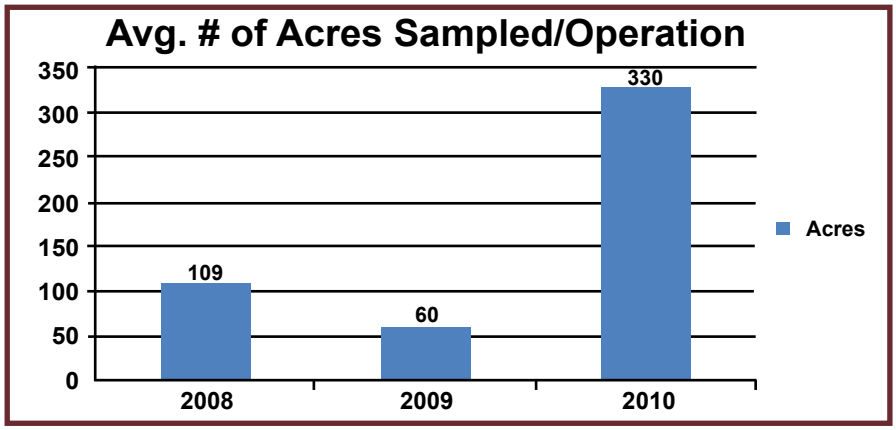

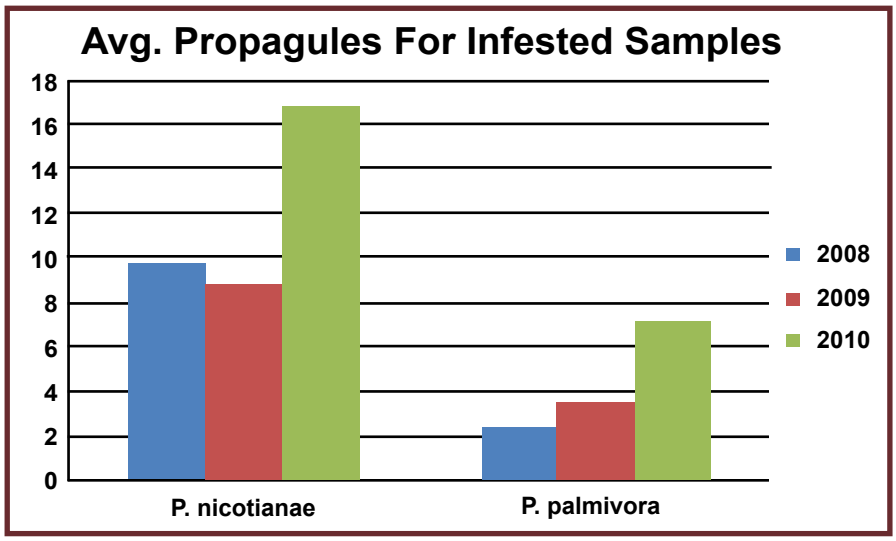

Figure 1. *Statewide survey for the occurrence of damaging populations of Phytophthora nicotianae and P. palmivora in soil samples collected in Florida groves between the months of May and September 2008 to 2010. (Data from J. Taylor, Syngenta Crop Protection, Soil Bioassay Program)*

conjunction with planting rootstocks resistant to *Phytophthora* spp., and to provide adequate soil moisture for the root system with proper soil drainage and irrigation management. If tolerance to PD complex is maintained, use of fungicides in the IPM program is only necessary under the most adverse soil and pest conditions. However, sustaining root health of HLB trees with *Las* infection of the root system may present an even greater challenge than the PD complex.

Recent evidence from an Asian study indicates that increasing incidence of HLB in citrus groves in the presence of *P. nicotianae* may have a greater impact on fibrous root health than that caused by the *Las* pathogen alone. Researchers in Taiwan discovered that prior infection of roots by *Las* accelerates *Phytophthora* infection and damage to the fibrous roots of potted seedlings and trees. The *Las*-induced predisposition of roots to *P. nicotianae* is apparently caused by a greater attraction of swimming zoospores to roots and/or less resistance to root invasion. The *Las-Phytophthora* interaction promotes higher levels of root damage than *Las* or *P. nicotianae*.

When *Phytophthora*-susceptible scions are grafted onto tolerant rootstocks, susceptibility of rootstocks to *P. nicotianae* greatly increases. These results suggested to the researchers that the seriousness of *Phytophthora* root rot in Taiwan is due not only to co-infection by *Las,* but also to grafting of rootstocks with susceptible scions (most scions in Florida are moderately to highly susceptible to foot rot). Researchers also unexpectedly discovered that co-infection of roots with *P. nicotianae* enhances HLB-induced symptoms in citrus plants. The mechanism for increased susceptibility of citrus to HLB in plants affected by *P. nicotianae* remains to be investigated.

Preliminary *Phytophthora* data from Florida groves suggests there is a resistance-breaking interaction of *Las* with *Phytophthora* spp. Every season for the last 24 years, Syngenta has conducted a statewide soil-

sampling program in support of Ridomil Gold® fungicide which provides the growers with soil propagule counts to estimate the damage that *Phytophthora* spp. are causing to fibrous roots. Because this program spans two decades, covers all production areas and is largely driven by grower requests, the results may serve as an indicator of emerging disease trends. Comparison of the survey data for the most recent three seasons, which have been relatively dry, shows a strong trend toward higher incidence of damaging *Phytophthora* populations coincident with the rise of HLB incidence in Florida citrus groves (Figure 1, see page 22). The survey found an increase in *Phytophthora* activity not only in the south and the east coast where HLB incidence is high, but also more activity in the central Ridge where high populations of *Phytophthora* spp. are historically less prevalent. Finally, the survey indicates heightened concern for tree health as is reflected by the increased number of grove operations sampled and the average number of acres sampled per operation.

Past research experiences and current *Phytophthora* data trends may indicate a need for more comprehensive management of HLB-affected trees. Healthy fibrous roots are necessary for water and nutrient uptake and tolerance of marginal soils, fluctuations in soil moisture, and root pests such as *Diaprepes abbreviatus*. This winter season, HLB trees have been more affected by the extremes of temperature and moisture than healthy trees. Symptoms of stress intolerance are excessive leaf and fruit drop of HLB-affected trees, even when trees have been under an intensive nutritional spray program, including phosphites, for several years (Figure 2). Thus, phosphite induction of *Phytophthora* resistance may be providing little protection for roots whose resistance has been degraded by *Las* infection. Henceforth, more direct, intentional control of *Phytophthora* with mefenoxan-based fungicides (i.e. Ridomil Gold®) appears to be warranted, not only where populations exceed the damage threshold, but should also be considered as a preventive program in groves with a high prevalence of HLB.

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Figure 2. *A Valencia orange tree with HLB (left side) after three years on an HLB nutritional program and two freezes in December 2010 showing excessive leaf and fruit drop, compared to a healthy tree (right side) in March 2011.*