Figure 1. Ray Ruby grapefruit trees grow in the ground inside the protective screen houses at the Indian River Research and Education Center. Trees shown are approximately 2.5 years old.

Research update: citrus undercover production systems and whole tree thermotherapy

By Arnold Schumann, Laura Waldo and Alan Wright

Research for producing huanglongbing (HLB)-free fresh Florida citrus with covered production systems began at the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) Indian River Research and Education Center in 2013 and at the Citrus Research and Education Center (CREC) in 2014. These citrus undercover production systems (CUPS) evolved from the already proven psyllid-proof, screen-covered citrus nurseries that were introduced in Florida more than a decade ago to allow the propagation of disease-free transplants for the citrus industry. The protected citrus experiments in both locations are approximately 1 acre each and consist of 14-foot-high pole and cable frame architecture, covered with 50-mesh, anti-insect screen.

Since the profitable long-term production of citrus fruit under screen was still untested in Florida and required a major shift in technology from growing short-term vegetative nursery transplants, these CUPS research projects were installed to be proof of concept demonstrations and to provide research platforms for developing rapid solutions. The learning curve was steep, but after two years, the project at the CREC is on target, where the blocks of tangerine and grapefruit are now in full production with viable crops of HLB-free fresh fruit.

Whole tree thermotherapy (WTT) was added to the CREC fresh fruit research program to explore less costly methods for growing high-quality, HLB-free fruit without the protective screen houses. The WTT technology relies on growing trees in containers, which allows 1) more effective application of systemic neonicotinoid insecticides, 2) the comprehensive elimination of the *Candidatus* Liberibacter asiaticus (*C*Las) pathogen from the citrus trees and 3) essential tree size control or dwarfing of trees that must be grown at high densities. Unexpected challenges were encountered in the WTT project, and new research was initiated to find rapid solutions. After two years, the WTT trees grown outdoors are also on target, producing high yields of HLB-free fresh fruit.

Figure 2. Ray Ruby grapefruit trees grow in 10-gallon pots in the Citrus Research and Education Center screen house. Average fruit yields were 150 to 192 boxes/acre in the first year. Grapefruits sampled in October 2015 were passing both fresh and processed fruit-quality standards, and the sizes were on average 36 for both sour orange and US-897 rootstocks.

Figure 3. Honey Murcott trees grow outdoors with hydroponics in 10-gallon pots. HLB-affected trees are treated with WTT to eliminate *C*Las. Yields in year two are estimated to be 600 boxes/acre, and the heavy trees must be supported by sturdy trellises.

This article provides updates on CUPS and WTT research at the two UF/IFAS locations. A more comprehensive field day and workshop discussion of these topics are planned for the CREC in early December this year.

FORT PIERCE CUPS PROJECT

Spring 2016 was the first time that yield was measured for the CUPS project, even though trees were only 2.5 years old. Fruit was not of sufficient quality to sell commercially at that time.

Grapefruit yield was higher inside screen houses (0.35 boxes/tree; 305 boxes/acre) than outside (0.27 boxes/tree; 235 boxes/acre), probably due to the absence of HLB inside. Yield did not differ between in-ground trees and potted trees inside the screen houses or outside. This was quite a surprising result since vegetative canopy growth was significantly greater for the in-ground trees.

Tree height, trunk diameter and canopy were all higher for in-ground trees than potted trees, both inside and outside the screen houses. There were no significant differences in yield between the US897 and sour orange rootstocks for grapefruit grown inside the screen houses, but the outside treatments showed higher yield for US897 (0.33 boxes/tree) than sour orange (0.23 boxes/tree).

Psyllids were monitored using sticky trap cards both inside and outside of the screen houses multiple times per year. No psyllids were identified on the sticky cards deployed inside the screen houses, indicating that the screens were effectively eliminating psyllids from entering.

Leaf samples were collected for HLB testing by the Southwest Florida Research and Education Center once per year, most recently in April 2016. No trees inside screen houses tested positive for HLB, as all tree cycle threshold (Ct) values were at the undetected level. Outside of the screen houses, the Ct values averaged 25 for the trees deemed positive for HLB, with an infection rate of approximately 50 percent. This result helps to support our objective of demonstrating the effectiveness of screen houses for excluding psyllids and growing HLB-free citrus. It is hoped that with another year's growth, the harvest in late 2016 will be of commercial quality.

LAKE ALFRED CUPS AND WTT PROJECTS

The tree-growing system used in the CREC project is an open (non-recirculating nutrient solution) hydroponic container method, using seven different fertilizer stock solutions that are custom-blended by computer and drip-fertigated to the trees multiple times each day.

The screen house successfully excluded most psyllids and prevented HLB from affecting the protected trees for two years so far. We recorded only one psyllid adult caught on a yellow sticky trap near the main vehicle door of the screen house.

Daytime temperatures in the screen house are on average 7 to 10 degrees Fahrenheit higher than outside, but at night, the temperature differential disappears. Higher temperatures and humidity in the screen house contributed to a periodic high pest pressure from mites and thrips, which are able to penetrate the 50-mesh screen. Citrus leafminer was completely excluded from the screen house so far. The mite and thrip pests, as well as greasy spot fungal disease, were best controlled by spraying pesticides and fungicides with an ultra-low volume (ULV) greenhouse sprayer that also electrostatically charges the spray droplets. The conversion from a regular high-volume, air-assisted

Citrus Researchers from Around the World Converge to Share Results

By Harold Browning

Research efforts to find solutions to huanglongbing (HLB) and other challenges to citrus production are alive and well, as evidenced by the International Citrus Congress (ICC) held in Brazil last month. Some 1,070 delegates attended the five-day meeting in Foz Do Iguaçu. This meeting, held every four years in citrus regions around the world, is a showcase for experts and rising stars alike, who attend to re-establish communication with their colleagues and to present their latest results. While not reserved for scientists alone, they make up the majority of participants at this meeting. Brazil, the host country, turned out in large numbers, including scientists, growers, nurserymen and allied business representatives who support the citrus industry.

The program — a composite of keynote speakers, short oral presentations, and 350 posters depicting a wide range of topics — was bracketed with pre- and post-congress tours to citrus-production areas in the region. Delegates were encouraged to mingle and share ideas and results at formal sessions, informal poster sessions and during meals at the very nice Mabu Convention Center.

HLB was clearly a major topic of the discussions and presentations, but a wide range of topics were presented by delegates from close to 50 countries, according to the organizers. Citrus plant genetics and plant improvement were recurrent themes. Local experts and their international colleagues updated attendees on citrus leprosis, citrus variegated chlorosis, citrus black spot and other diseases. Integrated pest management topics included fruit flies, mites and many of the insect pests familiar to Florida citrus growers. Horticultural practices were often presented in the program.

Brazil clearly had the largest participation, as is often the case at these meetings, but many U.S. scientists and fewer industry representatives traveled to the meeting. Florida was represented by 10 University of Florida (UF) scientists, three citrus Extension agents, five Agricultural Research Service scientists, three Citrus Research and Development Foundation (CRDF) representatives, nurserymen, a packer and two growers, both who serve on CRDF committees. California and Texas were represented by scientists, growers and allied industry members — all there to absorb information and new findings in the fight to keep citrus profitable across the globe.

The research community from Florida brought home new information to incorporate into its programs and, hopefully, new connections with cooperators it will work with. Notable presentations on topics of interest to the Florida industry were many, but a few warrant mention. UF Professor of Horticulture Fred Gmitter presented an outstanding keynote address on the global community effort to sequence the citrus genome. He walked the audience through the rapid changes that advances in technology mean to this effort. Bryce Falk's (University of California, Davis) keynote address covered the background and potential of RNA interference. Finally, a keynote by Leandro Peña, currently working in Brazil, summarized efforts to develop psyllid-repellent host plants through engineering.

The book of abstracts from the meeting can be accessed by going to the ICC website (www.icc2016.com/abstract/book-of-abstracts).

Harold Browning is Chief Operations Officer of CRDF. The foundation is charged with funding citrus research and getting the results of that research to use in the grove.

CRDF Grower Dollars at work for you

Column sponsored by the Citrus Research and Development Foundation

Figure 4. 1) Hamlin orange tree on September 24, 2014, before whole tree thermotherapy (WTT), showing HLB-symptomatic leaves and fruit. 2) The tree after pruning and WTT on September 27, 2014. 3) New leaf flush emerged by October 15, 2014. 4) Six months later (March 17, 2015), the tree blooms and sets fruit. 5) Two years after WTT (September 19, 2016), the tree is thriving, bearing healthy fruit and is PCR negative; the photo inset illustrates the large trunk diameter.

sprayer to the new ULV sprayer in early 2016 allowed us to dramatically improve the level of small pest (mite and thrip) control and prevent damage to flowers, fruit and foliage.

Yield and quality of the screen-house grapefruits were excellent in the first year, with an average yield per tree of 0.17 to 0.22 boxes (150 to 192 boxes/acre), shown in Figure 2 on page 10. The Honey Murcott trees are late-blooming, and fruit set in the first year was adversely affected by flower thrips and lack of self-pollination due to windless conditions in the screen house. In spring of the second year (2016), we effectively controlled the thrips with the new greenhouse sprayer and used a small airblast sprayer to shake the tree canopies for assisting self-pollination. As a result, fruit set of Honey Murcott trees was excellent in year two (2016–17), with yields estimated at about 500 boxes/acre. Second-year yields of 400 boxes/acre are estimated for the grapefruit trees, based on observed fruit set.

In WTT, the potted root systems as well as canopies of HLB-affected trees are heat-treated for sufficient time at a high enough temperature to kill the systemic causal pathogen, *C*Las. This is an alternative approach being investigated in this project for sustainable citrus production in HLB-endemic environments.

The severe mite and thrip infestations that were encountered in the closed screen-house environment did not occur in the 1 acre of outdoor citrus used for WTT research. Currently, the main insecticide

Fruit set of Honey Murcott trees was excellent in year two (2016–17), with yields estimated at about 500 boxes/acre.

protecting the WTT trees from psyllids and high HLB incidence is Admire Pro (imidacloprid), applied at labeled rates of 3 milliliters per tree per year for container-grown trees. Foliar pesticide sprays of different modes of action than imidacloprid are also periodically applied by airblast sprayer with a narrow (48-inch) cab tractor. The main purpose of the sprays is to prevent psyllids from developing resistance to imidacloprid, to knock down invading psyllid adults and to control other important citrus pests like mites.

The WTT project has so far succeeded, with higher Honey Murcott fruit set than in the screen house, estimated at 600 boxes/acre (see Figure 3 on page 10). The incidence of HLB was low for the first 18 months (<3 percent), and affected trees were periodically identified, heat-treated and then replaced in the grove to recover. At best, the WTT-treated trees fully recover in as little as six months, flower and set a normal crop of healthy fruit again, and the PCR Ct values increase until they become "undetected" at >40, indicating absence of *C*Las (see Figure 4). We encountered some tree recovery problems after WTT during hot summer weather, possibly due to sunburn of the bark on mostly defoliated trees.

We discovered that the best fit for WTT is for early-maturing fresh fruit varieties, because the fruit of trees with early HLB infection can still be economically harvested in the fall. Then the trees can be WTT-treated and should recover and set fruit normally the following season. With late-maturing varieties like Honey Murcott, the HLB-affected tree will unavoidably lose a year's yield due to fruit destruction during WTT if applied in the fall, or lack of fruit set if applied in the spring.

The WTT alternative for growing profitable fresh citrus in HLB-endemic environments has demonstrated very promising early results, and so far the problems encountered have been solved with new applied research. However, an increasing trend of HLB incidence was discovered recently after the second summer season, mainly in the grapefruits, and is now being thoroughly investigated to develop solutions. In order for WTT to succeed, the incidence of new HLB infections must remain low for the thermotherapy treatment of affected trees to keep up with demand and to limit the detrimental impacts on annual fruit production. Continuing research is required to develop more solutions for new problems that may be encountered in both CUPS and WTT systems.

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