Figure 1. Honey Murcott mandarin trees grow in 7-gallon pots at 1,361 trees per acre in the Citrus Research and Education Center screen house.

Update on citrus undercover production systems research

By Arnold Schumann, Laura Waldo, Alan Wright and Rhuanito Ferrarezi

Authors' note: This article was written before Hurricane Irma passed through Florida. We are still assessing the full impact and implications of storm damage to both University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) citrus undercover production systems (CUPS) facilities and will provide updates in future articles.

Citrus greening or huanglongbing (HLB) disease makes it difficult to profitably grow citrus with conventional methods once it becomes endemic. Proof of concept studies started by UF/IFAS in 2013–14 showed that high-yielding citrus trees can be grown under protective screen structures for fresh fruit production by completely excluding the Asian citrus psyllid (ACP, *Diaphorina citri*) and, therefore, HLB disease.

In this article, we update research on CUPS (also known as citrus under protective screen) at the UF/IFAS Indian River Research and Education Center (IRREC) in Fort Pierce and the Citrus Research and Education Center (CREC) in Lake Alfred. The protected citrus experiments in both locations are about 1 acre each. Screen houses consist of 14-foot-high pole and cable frame architecture, covered with 50-mesh, anti-insect screen. In 2016–17, about 50 acres of commercial CUPS were established in Florida, with at least 150 more acres planned. There is now also strong interest for CUPS to be evaluated in California (see page 38).

FORT PIERCE CUPS PROJECT

Spring 2017 was the second year that yield was measured for the Fort Pierce CUPS project, even though trees were only 3.5 years old at that time. Fruit produced were of sufficient quality to sell commercially, albeit with low boxes per acre. Grapefruit yield was higher inside the screen houses (0.29 boxes per tree; 228 boxes per acre) than outside (0.04 boxes per tree; 30 boxes per acre), 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.

Psyllids were monitored using sticky trap cards both inside and outside of the screen houses multiple times per year. One psyllid was identified inside one screen house, indicating that the screens were effectively eliminating psyllids from entering, but not psyllid-free.

> ***Tree height, trunk diameter and canopy were all higher for in-ground trees than potted trees, both inside and outside the screen houses.***

Leaf samples were collected for HLB testing by the Southwest Florida Research and Education Center once per year, most recently in March 2017. No trees inside screen houses tested positive for HLB, as all tree Ct values were at the undetected level. Outside of the screen houses, 100 percent of the trees tested positive for HLB. This result helps to support our objective of demonstrating the effectiveness of screen houses for excluding psyllids, which allow for the growing of HLB-free citrus.

It is hoped that with another year's growth, the harvest in 2017–2018 will generate more boxes per acre with improved Brix and acidity.

After this harvest season, some components of the production system will be changed to address issues related to the original design. Since this was the first CUPS designed for experimental use at UF, several parameters were selected without prior experience, such as pot size, growing media, irrigation, fertigation and spraying scheduling. We are replacing the sandy media with potting mix, increasing the number of varieties tested by including high-value mandarins, modifying the irrigation and fertigation system and evaluating advanced horticultural techniques to increase tree yield. Our goal is to develop and test an unmanned sprayer to free up labor for other operations inside the screen houses.

LAKE ALFRED CUPS AND WTT PROJECTS

A 1-acre pilot project investigating the use of whole-tree thermotherapy (WTT) was installed at the CREC in 2014 to evaluate a less costly alternative to CUPS. The results after one and a half years of growing the trees outdoors in containers were initially promising (see our report in Citrus Industry, November 2016). The experiment showed that if annual

HLB incidence is low (<5 percent), then WTT can effectively eliminate HLB from treated trees, allowing production of normal yields of healthy fruit to resume within six months. Unfortunately, during the second and third years of the experiment, ACP infestation and, therefore, new HLB incidence was exceptionally high (>80 percent of trees were HLB symptomatic). Consequently, the WTT method was determined unsustainable in 2017.

Fortunately, after three years, HLB is still absent from screen house-protected trees in the 1-acre CREC CUPS facility. The large contiguous blocks of Ray Ruby grapefruit and Honey Murcott mandarin in the CUPS were harvested by commercial pickers for the first time in February 2017, two and a half years after planting. The larger citrus blocks in the CUPS are important to demonstrate the commercial feasibility of managing the intensive container-hydroponics, high-density production system.

Smaller plots of replicated experiments were also harvested in February to evaluate various treatment combinations. Honey Murcott trees (Figure 1, page 16) planted in 7-gallon containers at 4 feet by 8 feet (1,361 trees per acre) yielded 47.5 pounds per tree (680 boxes per acre) versus trees planted in 10-gallon containers at 5 feet by 10 feet (871 trees per acre), yielding 40.2 pounds per tree (369 boxes per acre). The packout from the commercial harvest reported by the packing house was 99 percent.

Fruit size and quality were excellent. They were the same for both planting densities, except that the ratio was 21.6 for the 871 trees-per-acre block, and 20.4 for the 1,361 trees-per-acre block. Honey Murcott yield and fruit size from trees grown in the ground were the same as those grown in 10-gallon pots. However, for trees in pots, °Brix (15.3), acid (0.743 percent) and ratio (20.6) were significantly different from trees grown in the ground (°Brix = 14.1, acid = 0.647 percent, ratio = 21.9).

Grapefruit yields were highest from trees grown in the smallest pots.

For the Ray Ruby grapefruit harvest, fruit size and quality were also excellent, with no significant treatment differences. Grapefruit yields were highest from trees grown in the smallest pots (34, 31 and 30 pounds per tree for the 5-, 7- and 10-gallon pot sizes, respectively). Average grapefruit size was in the #32 class (10.8 centimeters diameter). Average yields at

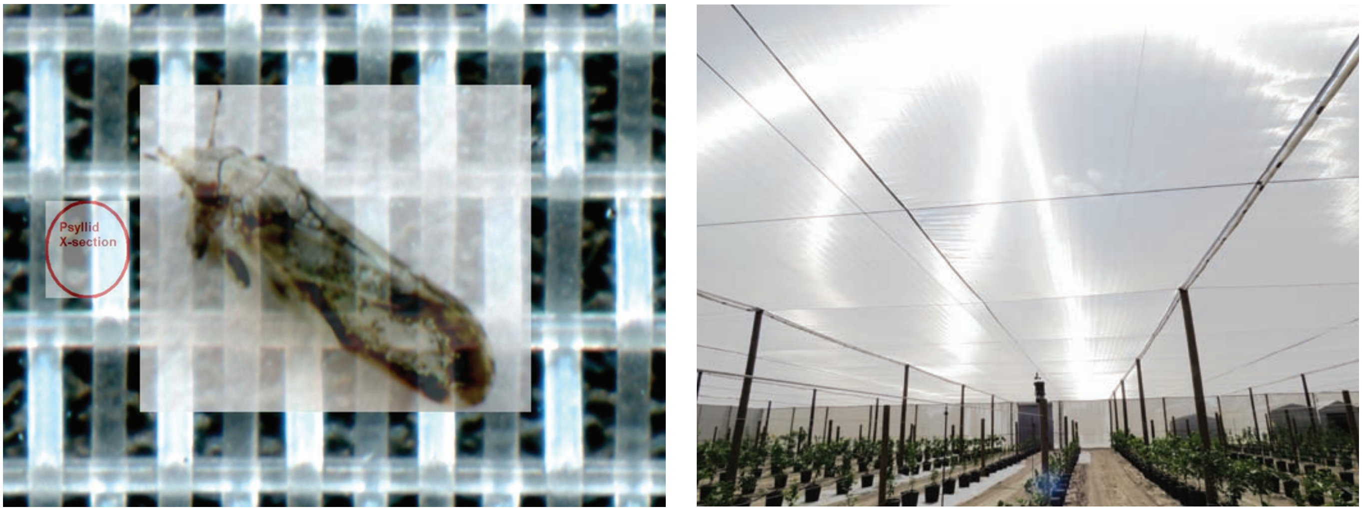

Figure 2. Left: Magnified view of 50-mesh, high-density polyethylene (HDPE) screen with adult Asian citrus psyllid to scale. Right: Enhanced sunlight dispersion through a CUPS roof caused by refraction of light through translucent HDPE fibers, and diffraction through apertures between fibers.

a density of 871 trees per acre ranged from 307 to 346 boxes per acre for the largest to smallest pot sizes, respectively.

LOOKING AT LIGHT

The protective CUPS screen house has proved to be a critical component for successful production of healthy, fresh fruit in HLB-endemic Florida. It appears that additional benefits of CUPS — such as the very early, high yields — can also be attributed in part to the screen house-growing environment.

Recently, we examined the screen and the lighting inside our CREC CUPS more closely. We had already observed that the sunlight transmission through the screen roof was about 80 percent in the visible and photosynthetically active region of the electromagnetic spectrum, and about 40 percent for ultraviolet (UV) light. Since UV light is blocked by the high-density polyethylene (HDPE) fibers of the 50-mesh screen roof, it can only enter through the apertures, which constitute about 40 percent of the surface area (Figure 2). The translucent fibers transmit visible light by refraction, which is why the visible sunlight is widely dispersed as it enters the CUPS.

We compared measurements of direct solar radiation and sky radiation components at solar noon on a cloudless day, both inside and outside the CUPS. The direct solar radiation is the light that passes directly to the earth's surface. Sky radiation is the diffuse light that has been scattered out of the direct beam by air molecules, water vapor, aerosols and clouds. The sky radiation outside was only 123 W/m^2 (watts per square meter). But in the CUPS, it amounted to a substantial 404 W/m^2, representing a 329 percent increase.

Total light transmission through the roof was 81 percent, similar to previously reported numbers. The large increase in dispersed light can be seen on the CUPS roof in Figure 2. The significance is that the dispersed light can enter the tree canopies from many angles, potentially improving canopy lighting and photosynthetic efficiency of leaves. It also may enhance other physiological processes like fruit color break and quality.

Normally, outdoors, the angular diameter of the sun, viewed from earth, is about 5 degrees. It varies somewhat according to hourly atmospheric changes, but is very small in comparison to the wide illumination angles achieved by light dispersed through the HDPE fibers of the CUPS roof. In addition to dispersion by refraction, diffraction can also scatter the light as it passes through the small apertures in the screen.

We expect that an important result of improved canopy lighting will be the ability to grow trees at higher densities in CUPS than is possible with natural lighting outside.

We expect that an important result of improved canopy lighting will be the ability to grow trees at higher densities in CUPS than is possible with natural lighting outside. Higher planting densities are essential to the successful implementation of a profitable CUPS enterprise. In ongoing experiments, we will explore these options with respect to planting density, canopy management and alternate bearing. We will also investigate the additional potential benefits of manipulating the spectral quality of transmitted light with colored screen.

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