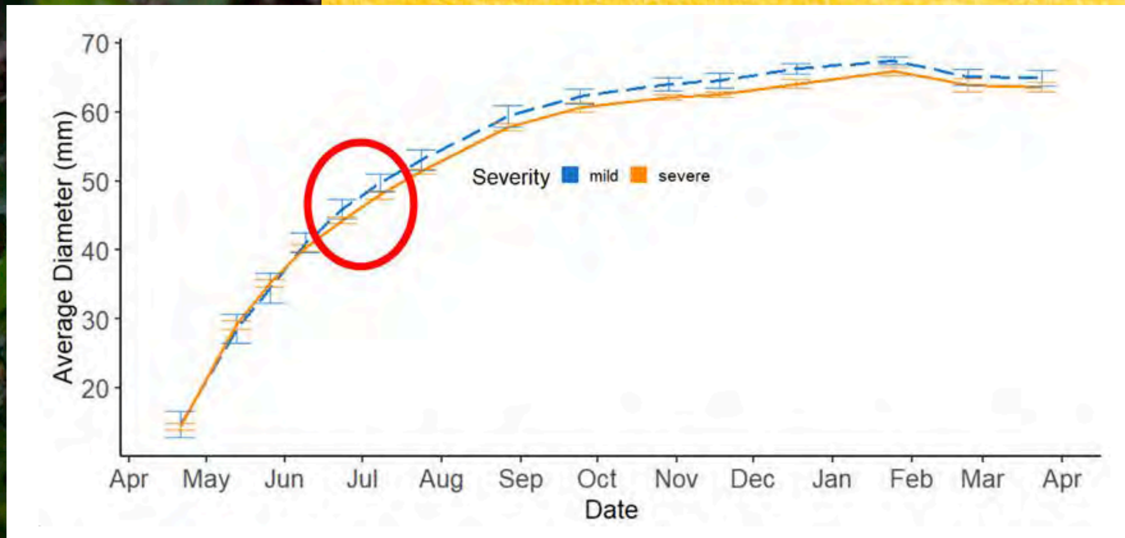

Figure 1. Average fruit diameter in mild and severe HLB symptomatic trees from April 2020 to April 2021. The red circle shows when the fruit size among mild and severe trees starts to differ.

Reducing HLB-associated preharvest fruit drop

By Tripti Vashisth and Christopher Vincent

This article summarizes current knowledge about HLB-associated preharvest fruit drop. Unfortunately, exactly how HLB induces preharvest fruit drop is still unknown. Nonetheless, this article links what we do know about HLB-associated fruit drop to fruit drop in HLB-free trees and how strategies, such as managing tree water status and use of gibberellic acid, can be useful in reducing drop.

HLB-associated fruit drop can be up to 60% of the total yield depending on the disease severity, cultivar and environmental factors. The severity of HLB or tree canopy density directly affects preharvest fruit drop. The greater the HLB symptoms, the higher the drop. In addition, fruit size is affected by HLB symptom severity. Trees with more HLB symptoms produce smaller fruit than trees with mild HLB symptoms. These scientific observations are evident from historical U.S. Department of Agriculture citrus crop data. As HLB became endemic in Florida, an obvious reduction in fruit size and increase in preharvest fruit drop were reported.

It was once suspected that the limited supply of carbohydrates from phloem blockage was the cause of HLB-associated preharvest fruit drop. Recently, three different experiments on Valencia and Hamlin concluded that the fruit likely to drop or that do drop have the same or higher amounts of sugars as the fruit that will likely remain attached to the tree. Therefore, fruit drop cannot be solely attributed to carbohydrate shortage.

FRUIT WEIGHT AND SIZE

In a study focused on characterizing attributes of dropped fruit versus retained fruit, only fruit weight and size were linked to a fruit's likeliness to drop out of many physical and compositional attributes such as seed number, leaf number, chlorophyll and soluble sugars. Fruit with a smaller diameter or less weight are more likely to drop than larger or heavier fruit in both Hamlin and Valencia, irrespective of overall tree HLB symptoms.

> *Fruit drop cannot be solely attributed to carbohydrate shortage.*

In citrus, fruit size increases rapidly because of water accumulation in cells at stage two of fruit development. Interestingly, differences in the size of developing fruit on mild or severe HLB trees can be observed as early as May (stage two of fruit development).

Figure 1 (page 10) shows the fruit size measurements in trees with mild and severe HLB symptoms throughout the season. A difference in fruit size between mild and severe HLB trees appears in May, but the actual impact of these subtle differences is not realized until late in the season.

ABA ACCUMULATION

February through June are usually dry months with limited rainfall in Florida. This is when stage one and early stage two of fruit development take place. HLB-symptomatic fruit have been found to have higher accumulation abscisic acid (ABA) than healthy and non-symptomatic fruit. ABA is a plant hormone that is correlated with drought stress, where low water supply and high transpirational demands result in ABA accumulation.

In studies focused on HLB-associated fruit drop, ABA- and

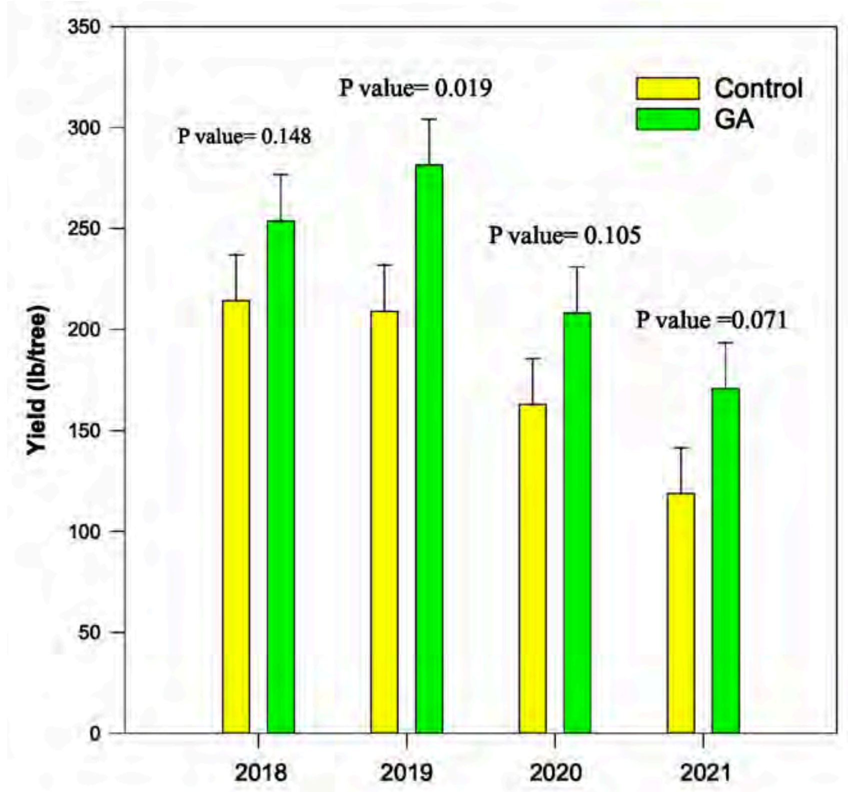

Figure 2. Valencia yield (pounds per tree) from 2018 to 2021 in gibberellic acid (GA)-treated and untreated control trees in Fort Meade, Florida. Each year, an increase in yield in GA-treated trees was observed. The four-year average yield of GA-treated trees was significantly higher than the control.

ethylene-related genes were upregulated in dropped fruit compared to retained fruit. In citrus, ABA indirectly increases the fruit abscission through promotion of ethylene. In fruit crops including citrus, during low-water availability conditions, ABA accumulation occurs in leaves. In a preliminary study, Valencia fruit that are ready to drop (mature as well as immature 'June drop' fruit) had higher ABA content in the peel than the fruit that were retained tightly on the tree.

WATER AVAILABILITY

HLB-affected trees undergo significant root dieback. Feeder root mass can decrease up to 80%, limiting water and nutrient uptake. Lower midday leaf water potential was observed for severe HLB trees in comparison with mild HLB trees of Valencia sweet orange in March. This suggests that water deficiency increases with more severe HLB symptoms, which may be exacerbated during low rainfall periods in Florida.

Remarkably, even in well-watered, healthy citrus, the lowest leaf water potential (highest water deficit) is found around noon. In parallel, mature Valencia fruit are easiest to detach (most likely to drop) and most susceptible to abscission agents around noon. This suggests that water availability to the fruit is linked with fruit drop.

MANAGEMENT STRATEGIES

Potential strategies to address fruit drop can be devised based on this background knowledge.

One strategy is to maintain a constant water supply through irrigation. Applying large volumes of water at once is not beneficial for HLB-affected trees as significant portions of water leach out of the root system before the tree can take up the water. Instead, trees should be provided with small amounts of frequent irrigation. The goal is to give trees enough water, so fruit growth and drop is not influenced.

A second strategy is to reduce transpiration. In HLB-free trees in Italy, reflective materials like kaolin and calcium carbonate improved water relations and photosynthesis. This resulted in at least 80 pounds per tree more fruit and reduction in preharvest fruit drop compared to untreated trees.

Plant growth regulators are a third strategy. Foliar applications of gibberellic acid (20 grams active ingredient per acre) on Valencia from September to January have shown promising results in HLB-affected sweet oranges. Generally, gibberellic acid (GA) is antagonistic to ABA and ethylene in plant tissues. GA increases fruit size, delays senescence and reduces fruit drop in healthy citrus.

Figure 2 (page 12) shows the four-year yield (pounds per tree) from GA-treated and control trees. Overall, with use of GA, the four-year average yield was significantly higher than untreated control trees. GA resulted in 228 pounds per tree compared to 176 pounds per tree in the control.

The GA positively influenced tree productivity in two ways, first by reducing the number of flowers and fruit set, which reduced the competition; and second, by increasing the vegetative growth in HLB-affected trees as compared to the control.

Practices to improve canopy density have the potential to reduce fruit drop.

In this trial, control trees experienced a significant decrease (-8.19%) in canopy density. No decrease in canopy density was found in GA-treated trees.

SUMMARY

To summarize, HLB-associated fruit drop is related to tree canopy density and limited water availability to the fruit. Practices to improve canopy density have the potential to reduce fruit drop. Use of frequent irrigation scheduling and GA may improve canopy growth and potentially improve yield. However, targeted research should test these hypotheses under field and HLB conditions in Florida.

Tripti Vashisth and Christopher Vincent are assistant professors at the University of Florida Institute of Food and Agricultural Sciences Citrus Research and Education Center in Lake Alfred.

Deliberating Over Funding Decisions

By Rick Dantzler, CRDF chief operating officer

It is the time of the year when the Citrus Research and Development Foundation (CRDF) is deciding which proposals to fund. The legislative appropriation we received this year was less than in the past, so we won't be able to fund as many projects. Nevertheless, we received many excellent proposals on the following topics:

1. Increasing fruit retention in HLB trees by manipulating hormonal balance
2. Relationship between root health and fruit drop
3. HLB management with plant growth regulators/protective tree covers
4. Control of sting nematode root damage to reduce young tree losses
5. Device/method for tree injection of therapeutics directly into the phloem
6. Assay for tree response to therapies for HLB control
7. Screening for potent peptides to prevent HLB infection or induce tree resistance
8. Tree size-controlling rootstocks in high-density planting to enable mechanical harvesting
9. Control of grapefruit rind blotch/potential causes of greasy spot/green symptoms
10. Plant breeding for HLB tolerance/resistance
11. Citrus nutrition to improve fruit production/quality
12. HLB therapeutics and their mode of action

These topics were chosen from our interaction with growers and our solicitation for research topics. The request for proposals was recommended by the CRDF Research Management Committee (RMC) and ratified by the board.

Pre-proposals were then accepted. A pre-proposal is a two-page summary of what the project would be.

The 63 pre-proposals were then sent to the members of our Scientific Advisory Board (SAB), eminent scientists from across the country who advise us on the scientific merit of the ideas. The RMC then reviewed the SAB remarks and the pre-proposals and made recommendations to the board about which projects should be "invited," meaning the idea was compelling enough to warrant a full proposal, which is a long document, often more than 50 pages. These recommendations went to the board for ratification, which included 27 invited projects.

When the researchers were notified that they had been invited to submit a full proposal, I provided them with comments that had been made to take into consideration when preparing the full proposal.

A total of 24 full proposals were submitted and sent to our several dozen *ad hoc* advisors, who are scientists from the United States, Brazil, Australia and Spain, for their input. Each proposal was assigned to two or three *ad hoc* advisors. Their comments, along with the full proposals, were sent to the SAB, which met for a day and a half to go over each project in detail.

CRDF staff pulled together all input into an analysis to assist the RMC and board in their deliberations regarding which projects to fund. The RMC will soon go over each proposal and recommend which ones to support. Heavy deference will be given to the RMC recommendations, but the board will balance the desire to fund projects with available funds.

As you can see, it is quite a process.