Update on insecticide resistance in the Asian citrus psyllid

A small bug, a big problem

By Monique R. Coy and Lukasz L. Stelinski

The Asian citrus psyllid (ACP) has spread widely throughout the United States since its initial introduction into Florida in 1998. Currently, ACP is firmly established throughout citrus groves across Florida and is gaining ground in other citrus-producing states in the United States. Psyllids are small insects — a bit larger than a grain of rice — and feed on the phloem of the tree. While ACP are not considered particularly harmful to citrus as direct pests, their presence can cause devastating yield losses due to the bacteria that they transmit. Once trees are infected with the bacterium, known as *"Candidatus"* Liberibacter asiaticus (CLas), they develop a disease called huanglongbing (HLB), which can cause progressive tree decline.

Currently, abatement of HLB relies heavily on insecticides to control psyllid populations in order to disrupt the transmission process until a cure or other means of control can be developed. Such a heavy reliance on insecticides necessitates careful management and monitoring due to the high propensity for insect populations to become resistant. Resistance can reduce the effectiveness of insecticides, thus causing loss of the precious few chemistries available for insect control.

Resistance can come in many different forms, from behavioral to biochemical, and elucidating the underlying mechanism(s) can be complex and time-consuming. In addition, resistance can be mediated by more than one mechanism, thus complicating the process to identify the underlying cause(s). Staying ahead of the game by understanding the behavior, molecular biology and biochemistry of the insect is a key component of the best management practice possible to keep the current insecticides labeled for ACP management in citrus effective and useful.

TURNING THE TABLE ON RESISTANCE

Insecticides are grouped into various classes depending on how they kill an insect, also known as modes of action. A main tenet of resistance management is rotating insecticides so that no one mode of action is used sequentially. For example, neonicotinoids, such as imidacloprid, target a type of receptor within the nerves of the insect called nicotinic acetylcholine receptors, whereas pyrethroids such as zeta-cypermethrin target a channel within the nerves called a voltage-gated sodium channel. These two chemicals are often recommended to be used in rotation with one another because they act to kill the insect in entirely different ways. However, it is possible for something called multiple-resistance to occur. With multiple-resistance, metabolic enzymes within the insect that break down the insecticides are able to metabolize more than one class of insecticide.

How resistance is mediated within the insect dictates what action needs to be taken. This is where an understanding of the insect, from the behavior to biochemistry, becomes vital, and the more we know in advance of detecting a problem, the better. Resistance management works best when it is approached proactively rather than reactively.

SURVEILLANCE AND WHAT IT TELLS US

Monitoring for insecticide resistance within insect field populations is another main tenet of resistance

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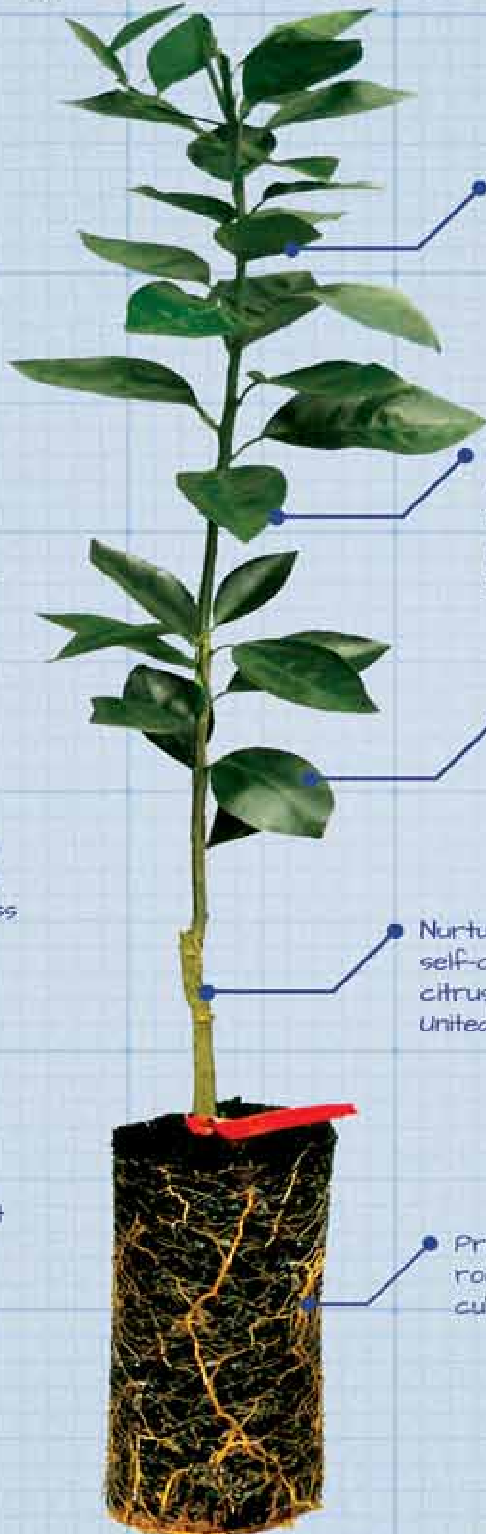

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management. We conduct an annual survey to determine the susceptibility of field ACP to a panel of insecticides as compared to a susceptible laboratory strain. This is determined with an LD_{50} estimate. LD_{50} is the dose of insecticide that is required to kill 50 percent of the test subjects. So, the higher the LD_{50}, the more insecticide it takes.

Between the years of 2009–12, an increase in LD_{50} estimates within ACP field populations was observed. However, in last year's survey, there was a drop to susceptibility levels similar to the lab susceptible standard culture in almost every field population tested, and this year's survey is holding the same trend. This tells us several things and raises important questions about ACP.

As would be expected, reduced susceptibility to insecticides can occur in this insect to all major insecticide classes currently available, and can do so rapidly. It also suggests that susceptibility levels are flexible, and at this point, can return to basal levels.

While that is good news, there was another finding. While most of the LD_{50} estimates for the field populations were not statistically different from the laboratory strain, the rates of response for some field populations were different, meaning the field insects remained alive over a wider dose-range than the susceptible laboratory strain. This suggests that insecticidal treatment has resulted in changes within the genetic background of some field populations. This parameter is being monitored carefully because it could mean that the genetics of these insects within these field populations is "primed" so that with further selection pressure from insecticides, a resistant phenotype could develop quickly in these populations. The finding also indicates the need to continue efforts to understand the behavior of these insects, including how far they migrate and how they survive the winter. On the surface, it may not seem that this would be important in terms of insecticide resistance, but movement and over-wintering are major factors in population dynamics, which directly impact gene flow.

Finally, we are trying to determine what factors are responsible for the return of insecticide response to basal levels. Many growing areas tested are members of the voluntary citrus health management area programs in which all growers in large geographic areas participate in the managed rotation of insecticides between different modes of action. One possible hypothesis is that the benefits from this program with respect to resistance management are now being manifested.

LESSONS FROM THE PAST

As stated above, figuring out how and why an insect is resistant to an insecticide is difficult and time-consuming. Therefore, no one is waiting for a stable, resistant field population to study in order to better understand insecticide response in the psyllid. Instead, work is being done proactively to characterize the molecular biology and biochemistry of the insecticidal response in ACP so that if and when it does happen, researchers are better prepared to act quickly on cases of insecticide resistance. To do that, scientists are using the information that has been gathered so far about the psyllid itself and information from other insect species, especially ones closely related to the psyllid, such as aphids and whiteflies, to anticipate how the psyllid would most likely become resistant and how to better preserve the arsenal of chemicals currently available.

There are a number of ways that an insect can become resistant to insecticides, but the two most common are: 1) enzymes within the insect become more efficient at breaking down chemicals into a less toxic form (increased metabolism), or 2) the target within the insect changes so that the insecticide does not affect the target as it should (target-site insensitivity).

Research is being done to investigate the three main chemical classes of neurotoxic insecticides used against psyllids: organophosphates, neonicotinoids and pyrethroids, in order to predict how ACP is most likely to become resistant to each and what potential there is for multiple or cross-resistance.

From past investigations, it is already known that metabolic enzymes play an important role in the reduced susceptibility of the psyllid to organophosphates and neonicotinoids; however, not much is known about pyrethroids. Pyrethroids can also be subject to increased metabolism, but, more than any other insecticide class, they are also subject to target-site insensitivity whereby mutations within the target make it insensitive to the action of the insecticide. Many cases of genetic variations that confer resistance to pyrethroids have been reported in a wide diversity of insects, including those closely related to psyllids.

Available genomic data is being used as a starting point to fully characterize the voltage-gated sodium channel from the psyllid, and researchers have found that it has the potential for population-level changes that can confer resistance through target-site mutations. A molecular assay is being designed to rapidly screen field populations for these expected mutations for cases of pyrethroid resistance in the field. This is a very important determination because if the mechanism is target-site insensitive, then typically only one insecticide class is affected. But if the mechanism is enzymatic, then as mentioned above, multiple-resistance becomes a potential issue, in which case care must be taken with regard to the choice of insecticide class used as a rotation alternative, so that further pressure is not placed on the population.

CONCLUSIONS

Insecticides will continue to be a very important part of the efforts to control HLB, and making sure that these chemicals remain useful as long as possible is top priority. While a rise in reduced susceptibility to insecticides between 2009 and 2012 was observed, in the past two growing seasons, there has been an overall return to basal levels of susceptibility in most field ACP populations. This is good news; however, there are indications that insecticide resistance could be a problem unless efforts continue to manage insecticides properly, especially rotation of insecticides with different modes of action.

Rather than wait for a problem to present itself in the field, scientists are taking the proactive approach to characterize the molecular and biochemical response of the psyllid to insecticide treatment to improve insecticide management schemes and to act rapidly in response if and when problems arise.

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Coming events

August 13–14 – Citrus Expo, Lee Civic Center, North Fort Myers (see pages 30–36 for details)

August 13 – Gulf Citrus Industry Celebration: An evening of fellowship, dining and dancing, Harborside Event Center, Fort Myers, RSVP to 239-690-0281