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Current Recommendations for Control of Laurel Wilt and Its Ambrosia Beetle Vectors In Florida's Commercial Avocado Groves

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Laurel wilt (LW) is a lethal vascular wilt disease of woody plants in the Lauraceae family, caused by the fungus *Raffaelea lauricola* (*Rl*). Introduced into the U.S. in 2002 and detected in Florida's avocado production area in 2012, LW has caused the death of more than half a billion redbay trees and 140,000 avocado trees worth an estimated $46.2 million. *Raffaelea lauricola* is dependent on ambrosia beetles (AB) for dispersal. In avocado groves *Rl* is associated with several native and exotic ambrosia beetles. These beetles occur in large numbers and usually colonize trees that are physiologically stressed. After trees are inoculated by AB, *Rl* can spread through root grafts. Long-distance spread of the disease is by movement of beetle infested wood products. To date, no avocado cultivars (scions or rootstocks) have shown tolerance to *Rl*. Symptoms of LW begin as green leaf wilting in one or more sections of the canopy, followed by leaf desiccation, stem and limb dieback, and ultimately tree death; frass tubes are a sign that AB have bored into the tree. The pathogen moves rapidly through the tree resulting, in obstruction of the water conducting tissue (xylem) caused by the host tree's attempts to contain the spread of the fungus by forming barriers/eliciting the formation of tyloses. To date there is no cure for the disease. Current recommendations to contain the disease include early detection, complete tree removal and destruction (chipping) of infected trees and then applying insecticides to the trunk of trees within one acre of the removed trees to reduce AB populations. Prophylactic fungicide injections, applying formulations of the biological mycoinsecticide *Beauveria bassiana* (entomopathogen) to the entire orchard in late winter/early spring, and pruning to improve light levels within the tree canopies, are also recommended. In the absence of cost-effective control measures for LW, the current strategy to maintain avocado production in South Florida is to replant trees that are lost to the disease and to keep investing in research to find a long-term and sustainable solutions.

The laurel wilt-ambrosia beetle complex continues to threaten Florida's avocado industry despite 14 years of research to find an entirely effective control program. To date the loss of over 140,000 commercial avocado trees can be attributed to LW worth an estimated $46.2 million (Evans and Crane, 2019). This is because little to nothing was known about the fungal phytopathogenic symbiont, *Raffaelea lauricola* (*Rl*; causal agent of the disease) when it was introduced into the United States in 2002 and the unexpected lateral transfer of *Rl* from the initial ambrosia beetle vector, *Xyleborus glabratus*, to at least nine other ambrosia beetle species that are the primary carriers of the pathogen in avocado systems (Carrillo et al., 2014; Ploetz et al., 2017). Large populations of these beetles commonly inhabit avocado groves and three species, *X. bispinatus*, *X. volvulus* and *Xyleborinus saxeseni* have been implicated in transmission of the pathogen to avocado trees (Carrillo et al., 2014). These beetles have a short flight period of ~1 h before sunset and usually colonize trees that are physiologically stressed (Menocal et al., 2018). The rapid movement of the pathogen within and among adjacent root-grafted avocado trees, the rapid rate of decline (4–8 weeks after symptoms onset) of avocado trees in response to the pathogen, and the ability of ABs to reproduce rapidly well protected inside the trees, have made development of economically feasible control tactics difficult (Inch et al., 2012; Inch and Ploetz et al., 2011a; Ploetz et al., 2011b; Ploetz et al., 2015). Additional challenges include the proximity of natural areas harboring LW susceptible hosts and back yard avocado trees serving as reservoirs for the pathogen and routes of dispersal among avocado groves.

This document updates previous recommendations for control strategies and mitigation of LW (Crane et al., 2008; Mayfield et al., 2008; Wasielewski et al., 2014; Crane et al., 2016; Wasielewski et al., 2016; Wasielewski and Crane, 2017; Ploetz et al., 2017) and expands on current recommendations (Crane et al., 2020a and Crane et al., 2020b).

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Current research findings related to control strategies

The LW pathogen is highly virulent and moves through the xylem rapidly within avocado trees and among mature root-grafted avocado trees. As few as 39 CFU (colony forming units) can induce symptoms of LW and the eventual death of mature avocado trees.

Prophylactic injection of propiconazole (Tilt®) every 12 to 24 months appears to be effective in protecting avocado trees from developing symptoms of LW. However, the time from injection to systemic coverage within a tree takes seven to eight months.

Ambrosia beetles implicated in *Rl* transmission are present year-round and their flight activity increases during late winter–early spring.

Groves with higher light levels have significantly reduced AB abundance compared to groves allowed to form dense canopy resulting in shaded conditions. Pruning (hedging, topping or selective pruning) to maintain higher canopy and grove light levels, re-establishing tree canopies (rejuvenating old non-productive trees) with severe pruning (e.g., hat-racking or stumping trees to four ft) and top-working large trees increase grove light levels and suppress AB activity.

Current control recommendations

Promote and maintain healthy trees through proper fertilizer, irrigation, and pest management. Poorly maintained and environmentally stressed trees (e.g., affected by drought, flood, drought, other diseases, wind/storm damage and/or freeze exposure) are attractive to AB and increase their chances of being colonized by AB carrying *Rl*.

Scout groves to detect trees with early LW symptoms such as green-leaf wilting. The earlier infected trees are removed and destroyed, the more likely the disease outbreak may be contained. When trees are showing symptoms associated to later stages of disease progress (i.e., large segments of the canopy with desiccated foliage), the LW pathogen has probably already moved through root grafts to adjacent health trees.

Rogue (uproot and chip/shred) LW-affected trees immediately upon detection. Severing the root system of adjacent trees is the most important step to limiting the spread of the pathogen to adjacent root grafted trees. In addition, rogueing helps to reduce AB populations by destroying the galleries where they reproduce. Spray the chipped or shredded wood twice with a contact insecticide. Insecticides registered for use on avocado include Malathion, Danitol®, Agri-Mek®SC, Talstar®S, Hero® (nonbearing trees only), Botanigard®, and Mycotrol® (*Beauveria bassiana*).

Two trunk and lower limb directed contact insecticide applications (fifteen days apart) should be made to protect healthy trees within a one-acre area of rogued LW-affected tree(s).

During late winter–early spring, when AB populations and activity increase, apply two grove-wide applications of the mycoinsecticides BotaniGard®ES or Mycotrol® (*Beauveria bassiana*) to suppress AB populations.

Productive groves with the lower canopy intact should be pruned annually to maintain canopy light levels and production. Groves with overgrown trees that have lost their lower canopy should be rejuvenated, i.e., cut back to four to eight feet to re-establish the lower canopy and then maintained at a height no higher than two-thirds the distance between rows. The re-established productive canopy of top-worked trees grafted to alternative cultivars should also be pruned to maintain the new productive lower canopy through regular pruning.

Consider, injecting non-LW affected groves prophylactically with propiconazole (Tilt®). If this is not possible, rogue LW-symptomatic trees and inject all remaining healthy appearing trees. Some loss of these trees may be expected due to the spread of the pathogen prior to injection. When additional avocado trees show LW symptoms, remove them as soon as possible. Injected trees will need to be reinjected on at 12 to 24-month interval depending upon pest pressure.

Current mitigation recommendations

Replant avocado trees lost to LW to establish future fruit production and maintain economic viability (Evans et al., 2010; Mosquera et al., 2015). Movement of the LW pathogen by tree-to-tree root grafting is not an issue in young trees because: it takes many years for root grafts to form; young trees are not a preferred host of AB; and the high light exposure of the area around these trees suppresses AB activity.

On-going and future research

The research into the biology and strategies to control and mitigate the LW epidemic continue. Control tactics that show promise include:

- Underlying biotic and abiotic factors that cause physiological stress on avocado trees making them attractive to ambrosia beetles,
- Push-pull (trap-kill) systems to repel, attract and kill AB,
- Understanding the microbiome of AB and how they may be manipulated to suppress AB populations,
- Cross protection of avocado trees with nonpathogenic species of *Rl* or other less virulent vascular fungi or non-viable *Rl*,
- Search for, document, and monitor healthy productive avocado trees that are positive to *Rl* to better understand how they are surviving the pathogen infection,
- Understanding the physiology scion-rootstock relationship and responses to *Rl*, and
- Understanding the molecular basis for disease development and how it may be manipulated to provide avocado trees tolerance to the pathogen.

Conclusion

The laurel wilt disease complex has posed the most significant challenge to avocado production in the western hemisphere. Understanding the biology of the pathogen and its vectors is in progress with the aim of providing new strategies for avocado producers to control and/or mitigate the effects of this devastating epidemic.

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