Current status and control recommendations for Laurel wilt and the ambrosia beetle vectors in commercial avocado (*Persea americana* L.) Orchards in South Florida

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Florida's US$100 million avocado industry is threatened by laurel wilt (LW), a lethal disease of trees and shrubs in the Lauraceae that is caused by *Raffaelea lauricola* (*Rf*). The primary ambrosia beetle vector of *Rf*, *Xyleborus glabratus* (Xg) was first detected in a natural area ca. 32 km north of Florida's commercial avocado production area in Miami-Dade County in March 2010. By February 2011 LW was confirmed in dying native swampbay (*P. palustris*) trees and by February 2012, LW had been confirmed in a commercial avocado orchard. Several other ambrosia beetle (AB) species, *X. volvulus* and *X. ferrugineus* are known to carry *Rf* and appear to be more important vectors of *Rf* under orchard conditions. Although AB are responsible for short and long distance movement of *Rf*, the most rapid spread occurs once LW is present in an orchard and spreads via root grafts among adjacent avocado trees. Recommendations for control of LW include: (1) early detection of *Rf* infected trees by frequent scouting of orchards; (2) sampling suspect trees for the pathogen; (3) tree uprooting, chipping of all wood possible and burning wood too large to chip and; (4) treatment of wood chips with insecticide. Additional recommendations include prophylactic infusion of propiconazole into avocado trees adjacent to infected trees or all trees in the orchard and periodic ground-based aerial insecticide applications to avocado trees adjacent to LW affected trees to reduce AB populations. More information on the AB vectors, the LW pathogen and control recommendations and costs of control will be discussed.

Key words: Scolytinae, Xyleborini, Curculionidae, Ascomycetes, Ophiostoma

INTRODUCTION

Laurel wilt caused by *Raffaelea lauricola* was first detected in Duval County, Florida in 2005 (Saeger, 2009). The primary vector of this lethal pathogen the redbay ambrosia beetle (*Xyleborus glabratus*) was first detected ca. 32 km north of Florida's commercial avocado industry in a natural area (Bird Road Basin) during March 2010 (Bronson and Gaskalla, 2010). By February 2011 laurel wilt was confirmed from in the native swampbay trees (*Persea palustris*) in this natural area (Ploetz *et al.,* 2011). Subsequently, in February 2012 laurel wilt was confirmed in a commercial avocado orchard in Homestead, Florida (Ploetz *et al.,* 2011; FDACS, 2012; A. Palmateer, 2012).

Based on the number of laurel wilt samples submitted since 2012 for pathogen analysis the number of confirmed diseased trees increased by 30% from 2012 to 2013 and 61% from 2013 to 2014 (A. Palmateer, personal communication). However, this does take into account instances where trees are symptomatic for laurel wilt but not sampled. GPS maps of trees suspect for LW went from five locations in the northeast quadrant of the industry in February 2012 to over 130 locations throughout the 323 square km commercial production area by 2015 (Don Pybas, personal communication). At total of 28 avocado cultivars have been documented as positive for Raf under orchard conditions; two of these 'Simmonds' and 'Donnie' (West Indian race), being the most common (Mayfield *et al.,* 2008; Peña *et al.,* 2012; Ploetz *et al.,* 2011; A. Palmateer and J. Crane, personal communication).

Laurel wilt spreads three ways, by ambrosia beetles vectors, human transport, and root-grafts among adjacent trees. Human transport of ambrosia beetle infested wood products is responsible for the rapid dissemination of LW among adjacent Counties and States. The initial laurel wilt vector *Xyleborus glabratus* (redbay ambrosia beetle) was thought to be the long distance vector of LW in the commercial avocado production area. However, current research confirms LW is vectored by several other ambrosia beetle species (e.g., *X. volvulus* and *X. ferrugineus*) (Carrillo *et al.,* 2014; Carrillo *et al.,* 2012). However, once a tree in a commercial orchard is affected by laurel wilt the pathogen moves to adjacent avocado trees through root grafts (Ploetz *et al.,* 2012; Hughes *et al.,* 2014). Currently, the death of ca. 8,500 avocado trees may be attributed to laurel wilt; this is about 1.2% of the estimated 740,000 commercial avocado trees in Florida (Don Pybas, personal communication).

Control recommendations

The Florida avocado industry has implemented an early detection and suppression program since November 2011 with the goal of removing and destroying LW affected trees and suppressing ambrosia beetle populations in commercial orchards. During 2012 the Florida Avocado Administrative Committee hired a Laurel Wilt Coordinator to oversee the aerial surveys. Surveys are conducted about every six to eight weeks by helicopter with the Coordinator taking GPS coordinates of LW symptomatic trees, creating a database (Excel) and Google map of the location of LW suspect trees and providing this data to the commercial industry. The coordinator may also ground-truth the LW suspect trees by xylem-wood samples for verification of Raf and contact orchard owners and/or operators in an effort to have LW affected trees promptly removed and destroyed.

Scouting and sampling for *Rf* for early detection

In addition to the aerial survey, producers should frequently scout their orchards to locate LW affected avocado trees at as early a stage of disease development as possible. Early symptoms of LW are green wilted canopies which are particularly suspect for LW if the symptomatic tree is located next to or near a completely desiccated, declining or dead tree. As the disease progresses leaves turn a blueish-green to brown color, desiccate (dead) and cling to the tree stems. Leaves may not drop for up to 12 to 18 months. Subsequent symptoms include stem and limb dieback and underneath the bark, the sapwood may have dark blueish-black streaks. Trunks and/or limbs may have numerous small diameter holes with sawdust tubes (toothpick-like protrusions from the bark), and/or sawdust clinging to the bark which is evidence of ambrosia beetles activity (i.e., boring into the tree).

Some visual symptoms of laurel wilt are similar to trees affected by Phytophthora root rot, flooding, lightning strike, and freeze damage. However, knowledge of some pre-existing or existing environmental factors (e.g., flooding, Phytophthora root rot history, and freezing events) may help separate the cause of the tree decline and provide growers/operators some guidance in ascertaining whether their tree or trees are infected with LW. If in doubt, take a sapwood sample for *Rf* verification.

In general after LW has been verified in one or more avocado trees in an orchard, further sampling of LW symptomatic trees may be unnecessary (i.e., it may be assumed they have LW). The removal and destruction of these LW symptomatic trees regardless of the cause is recommended in an attempt to quickly halt the spread of the LW pathogen to avocado trees and to prevent the reproduction of ambrosia beetles in the *Rf* affected wood.

In contrast in orchards in which LW has not been previously diagnosed or where a new suspect tree is many rows from a previously LW affected tree or area, a sample of the sapwood should be taken for laboratory analysis and disease confirmation. However, implementation of the following recommendations should not be delayed; a sample may be taken and submitted but these trees should be removed and destroyed as soon as possible.

Recent research and development suggest spectral (de Castro *et al.,* 2015) and canine detection of laurel wilt may have potential (D. Mills, personal communication).

Sanitation: rapid tree removal and destruction

The major component of LW control is to remove and destroy LW affected and ambrosia beetle infested trees as soon as it is apparent that they may have LW. Rapid tree removal including some type of root severing (via trenching or removal of the entire stump) is recommended because the LW pathogen is capable of moving quickly from an infected avocado tree to adjacent healthy avocado trees through root-grafts. Pushing trees over will uproot a major part of the root system and facilitate pulling the tree out of the ground. In addition the complete destruction of the tree by chipping and/or burning is recommended to eliminate ambrosia beetles residing and reproducing in the tree and because the wood and stumps of dead or declining avocado trees are attractive to ambrosia beetles (Spence *et al.,* 2013). This is especially important since *Rf* has been shown to survive in the trunks of swampbay (a close relative to avocado) up to 15 months; thus there is potential for reproduction of additional *Rf* contaminated ambrosia beetles. Large wood at the trunk-root system interface may be difficult to chip without heavy equipment and should be burned. Burning may have to be repeated because of its mass and high water content. Large wood left incompletely burned has been observed to attract and retain live ambrosia beetles.

Ambrosia beetle suppression

Ambrosia beetles are attracted to wood chips. Therefore two to three applications of insecticide should be made at about a 7 to 10 day interval. Efficacious contact chemical insecticides include Malathion 5EC, Danitol®2.4EC (fenpropathrin) and Hero® (zeta-cypermethrin plus bifenthrin) and the biopesticides BotaniGard®ES and Mycotrol®O which contain Beauveria bassiana Strain GHA. Addition of an adjuvant (e.g., NuFilm-17® or VaporGard®) may be of benefit. Healthy avocado trees surrounding the immediate LW affected area (~0.25 ha) may be sprayed twice at a 14-day interval with Malathion 5EC or Danitol®2.4EC plus adjuvant in an attempt to suppress ambrosia beetle populations on the surfaces of nearby trees. Currently the industry is sponsoring a cost-share program for producers who agree to make three applications of BotaniGard®ES or Mycotrol®O at a 21 to 40 day interval in an attempt to further reduce ambrosia beetle populations during the summer.

Prevention of *Rf* infection

Options for preventing the spread of *Rf* by root grafts among adjacent trees includes prophylactic systemic fungicide applications and/or trenching to sever the root system of adjacent trees. *Application of the systemic fungicide Tilt®*

At present there are no fungicides that cure LW affected trees. However, the systemic fungicide Tilt® (propiconazole) can be used to help prevent LW. In order for the fungicide to protect the tree, it must be inside the tree prior to inoculation with the *Rf* pathogen.

Infusion and injection are techniques used to place Tilt® inside trees (Ploetz *et al.,* 2011). Recent research indicates infusion to be a more effective method than injection (R. Ploetz, personal communication). However, injection of Tilt® is being used by some producers and investigations are underway to determine if this method is efficacious under some circumstances (e.g., frequent re-application).

There are two options for treating an orchard with Tilt®, treat the entire orchard prophylactically before a LW infests any trees in the orchard or use a spot treatment which is to infuse two to three or more healthy trees that are adjacent to diseased trees (Fig. 1). The key to the spot treatment is early detection of trees with symptoms of LW, the immediate treatment with Tilt® fungicide to the adjacent healthy trees and the immediate destruction of any diseased trees.

Currently there are two systems for infusing avocado trees with Tilt® fungicide: passive and pressurized. Both systems consist of chemically resistant polyethylene tubing attached to a reservoir containing a mixture of Tilt® and water and infusing the fungicide through ports inserted into flare roots and/or the base of the tree (Fig. 2). If trees are infused prior to *Rf* infection Tilt® has been shown to protect avocado trees from LW from 8 to 18 months (Crane *et al.,* 2015; R. Ploetz, personal communication).

Trenching to isolate LW affected trees

In some orchards where spot treatment with fungicides has not been entirely successful, trenching a perimeter between healthy and LW affected trees is recommended. However, like spot treatments with infusion, early detection of LW and implementation of sanitation procedures along with the trenching increase chances for limiting the spread of LW among adjacent trees.

To isolate the LW affected tree, dig a perimeter trench that surrounds 2 to 3 or more healthy trees in all directions from the LW affected tree (Fig. 1). In order to sever the roots among avocado trees, the trench must reach the limestone bedrock layer. Generally a trench 15 to 20 cm deep will sever tree roots among trees in-row and between-row areas but, the trench needs to be 46 to 61 cm deep where cross trenches correspond to the row and tree spacing (Fig. 3).

Constraints to controlling laurel wilt

Early detection of LW affected trees

Despite the periodic aerial survey for LW suspects and orchard scouting by producers, identifying trees affected by LW at the early wilt stage where leaves are green or greenish-blue has been problematic. This may be attributed to visible symptoms of wilting and canopy desiccation appearing much after significant and often lethal damage has already occurred to the water conducting tissue (xylem) (Inch and Ploetz, 2011; Inch *et al.,* 2012; Ploetz *et al.,* 2014). Trees that appeared healthy one day, quite suddenly without any discernable pre-symptoms wilt; thus unless trees are viewed daily a new LW affected tree may be missed for several days to weeks.

Cost considerations

The economics (cost-benefit) of preventing the spread of LW has been a major constraint to the full implementation of the current recommendations by the industry. Implementation among producers has been highly variable. This is due in large part to relatively low avocado prices during the past three years and the high cost of treating for LW that has resulted in reduced and in some cases negative (loss) profit margins for some producers. The cost of tree removal and destruction ranges from US$75 to US$125 per tree. The cost of injection (~US$7 per tree) and infusion (~US$13 per tree) makes treating entire orchards cost prohibitive (e.g., US$1729 to US$3211 per ha) especially when consideration is given to the fact that such treatments would likely have to be conducted on a yearly basis. The alternative, spot treatment of a limited number of trees with fungicide may be cost effective if implemented in a timely manner along with other recommendations (e.g., tree removal and destruction and ambrosia beetle control). However, the success of this approach hinges on intensive monitoring of fields and the will to act immediately. It also depends on the pest pressure in surrounding areas which in turn is reflective of the extent to which neighboring growers also take actions to control the disease. Preliminary analysis has shown that while 40 to 50 trees/ha can be lost from an orchard and still remains profitable, losses beyond this level result in seriously compromised profitability.

What is clearly emerging is that if prices were to remain more or less the same (i.e., low), many of the producers will not be able to adequately treat the disease and still remain profitable, unless efforts are made to increase yields considerably. We estimate, for instance, that in order to afford control of LW an avocado orchard may need to produce a marketable yield of about 18494 kg per ha. While many producers accomplish this level of production, many do not. This is partly due to differences cultivar productivity, planting density and management (cultural) practices.

CONCLUSIONS

Laurel wilt is a potentially devastating ambrosia beetle vectored disease that is adversely affecting Florida's avocado industry. While sanitation, prophylactic fungicide treatments and ambrosia beetle control tactics have been developed, the cost of implementing these may be cost prohibitive for producers whose orchards do not produce a sustainable economic return. Research and development of additional fungal and insect control tactics and earlier detection methods for LW affected trees may increase the cost effectiveness of current and/or new strategies to combat laurel wilt.

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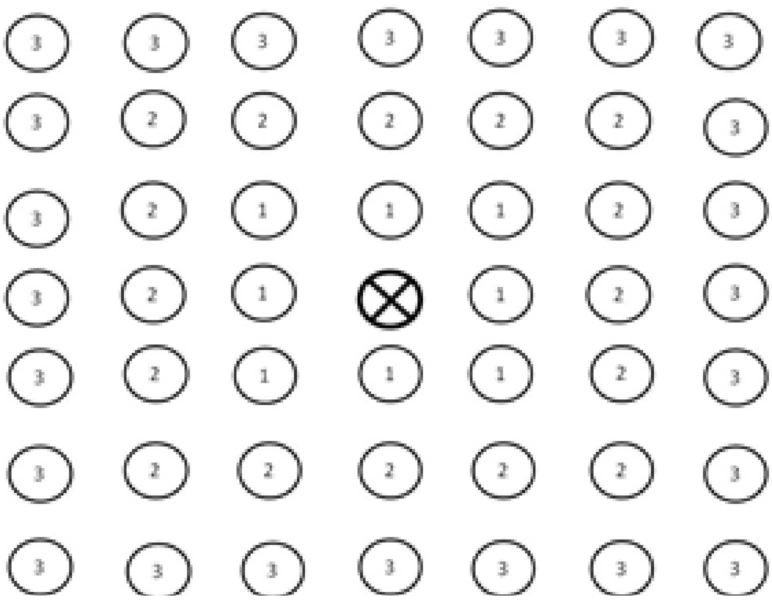

Fig. 1. Spot treatment by infusion or injection with fungicide of healthy avocado trees (◯) adjacent to a laurel wilt affected tree(⊗)

Fig. 2. Passive infusion of a mixture of Tilt® and water through ports inserted into flare roots and/or the base of the tree.

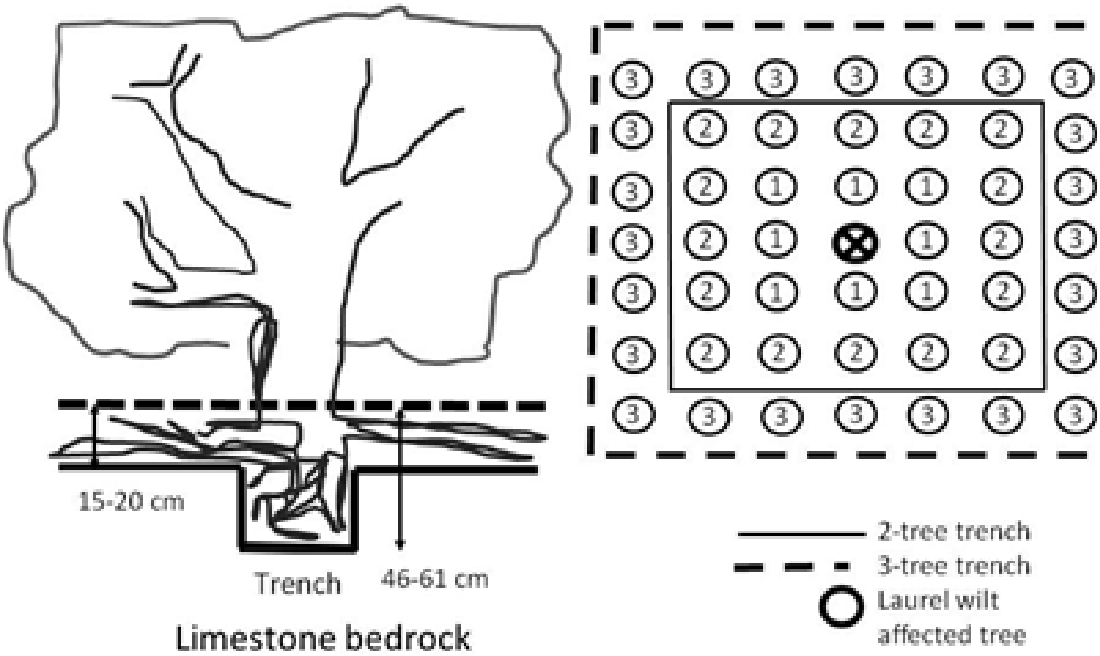

Fig. 3. Soil profile depicting limestone bedrock, plow layer and trench of avocado trees and 2 and 3 tree trench perimeters to sever tree roots among adjacent trees.

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