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CHEMICAL CONTROL OF THE REDBAY AMBROSIA BEETLE, *XYLEBORUS GLABRATUS,* AND OTHER SCOLYTINAE (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT

The redbay ambrosia beetle (RAB), *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae: Scolytinae), is an adventive pest of Lauraceae in the southeastern U.S. This wood-boring insect vectors a lethal fungus, *Raffaelea lauricola* T. C. Harr., Fraedrich & Aghayeva, the causal agent of laurel wilt (LW) disease. The vector-pathogen complex is responsible for extensive mortality of native *Persea* trees in South Carolina, Georgia, and northern Florida, and now poses an imminent threat to the avocado (*Persea americana* Mill.) industry in south Florida. While chemical control of the vector is not viewed as the primary solution, control tactics should be made available to Florida avocado growers. Field and laboratory tests were conducted using avocado bolts, potted avocado trees, and field grown swampbay trees (*Persea palustris* (Raf.) Sarg.) treated with contact and systemic insecticides. Zeta-cypermethrin + bifenthrin and lambda-cyhalothrin + thiamethoxam provided the most consistent control of Scolytinae as contact insecticides, while methomyl, malathion, bifenthrin, and endosulfan were more variable in effectiveness. Avocado trees treated with fenpropathrin, cryolite Na Al fluoride, and lambda-cyhalothrin+thiametoxam had similar numbers of beetle entrance holes on treated trees as on the untreated control trees. No statistical differences were observed in disease severity on treated versus non-treated avocados or swampbay. Linear regressions between the number of RAB entrance holes per tree (x) and LW disease severity (y_a) and between RAB entrance holes per tree (x) and recovery of *R. lauricola* (y_b) were both significant.

Key Words: Redbay ambrosia beetle, avocado, *Persea*, *Xyleborus*, *Xylosandrus*, *Hypothenemus*, chemical control

RESUMEN

El cucarroncito de ambrosia del laurel, *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae), es una plaga exótica de la familia Lauraceae que ha invadido el suroriente de los Estados Unidos. Este insecto barrenador es el vector del hongo, *Raffaelea lauricola* T.C. Harr., Fraedrich & Aghayeva, agente causal de la enfermedad del secamiento del laurel. El complejo vector-patógeno es responsable de una extensa mortalidad de arboles nativos del genero *Persea* en Carolina del Sur, Georgia y en el norte de Florida y representa una amenaza inminente para la industria del aguacate (*Persea americana* Mill.) de Florida. Aunque el control químico no es la única solución a este problema, se estima que este tipo de opción de tácticas se debe ofrecer a los productores de aguacate. Se condujeron experimentos tanto en campo como en laboratorio utilizando troncos de aguacate, arboles de aguacate y arboles del laurel de la ciénaga (*P. palustris* (Raf.) Sarg.), los cuales se trataron con insecticidas de contacto y sistémicos. En general, zetaciypermetrina + bifenthrina y lambda-cyalotrina + tiametoxam dieron un control consistente de los Scolytinae como insecticidas de contacto, mientras que metomíl, malatión y bifentrina y endosulfan dieron resultados variables. No hubo diferencias significativas en los orificios de entrada de los cucarroncitos cuando se trataron los arboles de aguacate con fenpropatrina, floruro de cryolita NA Al y lambda-cyalotrina-tiametoxam comparado con los arboles testigo. No se observaron diferencias estadísticas en cuanto a la severidad de la enfermedad entre árboles tratados y aquellos no tratados. Sin embargo, modelos de regresión lineal entre el número de orificios por árbol (x)

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y la severidad de la enfermedad (y_a) y entre número de orificios por ábol (x) y la recuperacion del patógeno (y_b), fueron significativas.

Translation provided by authos.

Redbay ambrosia beetle (RAB), *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae: Scolytinae), was first discovered in the U.S. at Port Wentworth near Savannah, Georgia in 2002 (Haack 2001, 2006; Rabaglia et al. 2006). *Xyleborus glabratus* is an effective vector of *Raffaelea lauricola* T.C. Harr., Fraedrich & Aghayeva (Harrington et al. 2008) that causes laurel wilt (LW) that affects plants of the Lauraceae (Crane et al. 2008; Mayfield et al. 2008). Laurel wilt, is responsible for high mortality of redbay [*Persea borbonia* (L.) Spreng.] and swampbay [*Persea palustris* (Raf.) Sarg.] trees in South Carolina, Georgia, and Florida (Fraedrich et al. 2008; Hanula et al. 2008). *Raffaelea lauricola* also affects avocado (*P. americana* Mill.), sassafras [*Sassafras albidum* (Nuttall) Nees], spicebush [*Lindera benzoin* (L.) Blume], and other woody Lauraceae in the southeastern U.S. (Fraedrich et al. 2008). The susceptibility of 18 avocado cultivars to attack by RAB and infection with *R. lauricola* was demonstrated by Mayfield et al. (2008) and by Peña et al. (to be submitted 2012) under greenhouse conditions. Additionally, in Oct 2008, LW and RAB infestations were found in 1.2 to 3-yr-old avocado trees in a Malabar neighborhood (Brevard County, Florida). Laurel wilt development and beetle infestation were monitored until Feb 2009, when all avocado cultivars at this study site were infested by both organisms (Peña et al., unpublished). Similar rapid progression of this disease was observed during 2010 by JEP & JHC (unpublished) in an abandoned commercial avocado grove located in Highlands County, Florida, demonstrating once more that beetle-vectored *R. lauricola* can be devastating when no vector management is implemented to reduce the impact of the disease.

According to Haack & Rabaglia (2012) although adults of all scolytine species bore into their host to lay eggs, they exhibit many different habits and utilize many different host tissues. True bark beetles bore through the outer bark to the phloem-cambial area where they construct characteristic galleries and lay eggs. Larval mines radiate out from the parental gallery as the larvae feed on the phloem (phloeophagy). Ambrosia beetle adults bore through the bark and into the xylem (wood) where they lay eggs. Ambrosia beetle adults and larvae propagate, cultivate and feed on symbiotic ambrosia fungi that grow in the galleries (xylomycetophagy). These ambrosia fungi are then, vectored by these scolytine species (Haack & Rabaglia 2012). *Xyleborus glabratus* completes its life cycle within 30 d, but only exits an avocado bolt after approximately 60 d. Both male and female *X. glabratus* adults emerge from avocado bolts, but males emerge in a lower (1:40) proportion to females (Gurpreet, pers. comm.; Duncan, pers. comm.).

Invasion of fruit orchards by disease vectors from external hosts presents a significant challenge to the timing of chemical controls. In addition to information on pest detection and monitoring to identify sources of infestations, data are needed on how much protection an orchard requires from ambrosia beetles, over what time periods, and which insecticides would be most effective at providing the required protection (Doerr et al. 2008). Successful control of disease vectors involves not only appropriate chemical control of the vector, but other IPM tactics, such as opportune sanitation (destruction of neglected and wild host trees) and effective monitoring techniques (Jones & Grand 2010). For RAB, a newly-established invasive pest, control will be particularly challenging, since much is still unknown regarding its basic biology, ecology, and population dynamics, and recent field studies indicate that the current monitoring system, Lindgren funnel traps baited with manuka oil lures, is suboptimal for detection of RAB in Florida (Kendra et al., unpublished).

Several insecticides have been evaluated previously for efficacy in control of ambrosia and bark beetles. For instance, pyrethroids suppressed emergence of scolytine beetles in oaks (Svira et al. 2004), elms (Pajares & Lanier 1989), and apple (Ciglar & Baric 2000), whereas other insecticides, such as endosulfan were effective against the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Damon 2000). The purpose of our research was to test the performance of registered and un-registered insecticides for control of pest Scolytinae, particularly *X. glabratus.*

Evaluations were conducted with cut avocado bolts, potted avocado trees, and field-grown swampbay trees to determine the efficacy of insecticides for reduction in beetle entry holes, beetle emergence, and LW transmission.

Materials and Methods

Contact Insecticides against Beetles Infesting Avocado Bolts

Four field experiments were conducted using avocado bolts. The major variables among experiments were the type and dose of insecticides, the use of adjuvants, the time of yr when application was made, and the sites in Florida where experiments were conducted. Doses evaluated were either suggested by the insecticide manufacturer or selected by the authors.

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Experiment 1. Infestation of Avocado Bolts in a Grove and Number of Beetles that Emerged

Avocado cv. 'Booth 7' bolts (30.0 ± 0.4 cm long × 9.0 ± 0.1 cm diam) were each dipped in 1 of 7 solutions of pesticides (Table 1) for approx. 2 min, allowed to dry for 24 h and then hung in partial shade throughout a 5-acre (2.02 ha) 8-yr old avocado grove at the University of Florida, Tropical Research and Education Center, Homestead, Florida (Miami-Dade County) (25° 30'26.58"N, 80° 30'14.93"W) on 30 Jul 2009. The avocado grove was bordered on the north by a natural hardwood hammock, on the west by a 10-acre (4.05 ha) pineland, on the east by a mango grove, and on the south by additional avocado groves. Ten bolts per treatment were hung randomly at 1.5 m above ground with an approx. distance of 10 m between adjacent treatments. Bolts remained in the field for approx. 30 d. Each bolt was then collected and transferred to the laboratory, where the number of entry holes was counted. Each bolt was placed in an emergence box (43 × 14 × 14 cm), sealed and stored at 26 °C and 75% RH for 60-70 d to allow for beetle emergence. Emerging beetles were counted and identified by MCT. At the time of this field test, Miami-Dade County was not reported to have LW disease or any breeding population of RAB.

Experiment 2. Comparative Efficacy of Lambda-Cyhalothrin + Thiamethoxam and Malathion

This experiment compared efficacy of two pesticides for control of the RAB and other Coleoptera attacking avocado bolts at 2 field sites, i.e., the same site in Homestead, Florida was used as for Experiment 1; and a second site at Hickory Hammock (Highlands County, Florida; 27° 25'35"N, 81° 9'42"W). Hickory Hammock consisted of a 4,000-acre (1,619 ha) natural preserve, bordered on the east by the Kissimmee River and on the south by the Istokpoga canal. The vegetation in the hammocks consisted predominantly of oaks (*Quercus* spp.) and swampbay; and each hammock was surrounded by upland pasture. Since 2009 this site was known to have LW and populations of RAB. Ten avocado bolts (cv. 'Booth 7', similar dimensions as above) were treated with either lambda-cyhalothrin + thiamethoxam (Endigo ZC, Syngenta, North Carolina) and amended with methylacetic acid (Nu Film) (Miller Chemical Fertilizer, Pennsylvania) or with malathion (Malathion 50, Gordon Corporation, Michigan) + Nu film, allowed to dry, hung in the 2 study sites on 27 Jan 2010, and kept exposed in the field for 30 d (Table 3). At Hickory Hammock, treated and untreated bolts were randomly placed around the trail of the Equestrian Center at an approximate distance of 10 m from each other and at the same height as in Experiment 1. At the time of collection, a 10 × hand lens was used to count the number of entrance holes of each bolt with frass, and then each bolt was placed individually inside an emergence box. Sixty d later, the number of emergence holes and emerged beetles were also counted. These beetles were identified by RED and MCT.

Experiment 3. Evaluation of Insecticides Registered for Avocado and Others with Known Promise

The insecticides selected for this study were those that either performed better during the initial tests, showed promise for bark beetle control (based on the literature), or had been registered for use with avocado (Table 5). Ten avocado bolts (cv. 'Booth 7', 21 ± 0.2 cm diam and 70 ± 0.3 cm long) were dipped for approximately 2 min in each pesticide solution, allowed to dry for 1 d, and then hung in the field in close proximity to avocado groves or in natural areas with native *Persea* spp. affected by LW. The first and second trials were deployed at the University of Florida, Homestead, initiated on 11 Feb 2010 and on 31 Mar 2010, respectively, in the periphery of a 10-acre (4.05 ha) pineland, bordered on the north by newly disked land, to the south by a commercial avocado grove, to the east by an experimental avocado grove, and to the west by a commercial longan (*Dimocarpus longan*), avocado and mamey sapote (*Pouteria sapota)* grove. Beetle entrance holes were recorded at 7, 15 and 21 d after treatment. Bolt storage and beetle collection followed the same methodology outlined above. The third trial was set up 31 Mar 2010 at Hickory Hammock in the same area described above and following the same methods explained on Experiment 2.

Experiment 4. Evaluation of Recently Developed Insecticides

Avocado bolts cv 'Booth' with similar dimensions to those used in Experiment 3 and the same numbers per treatment, were treated in the same manner as explained before with dinotefuran (Safari SG, Valent USA Corp., CA), thiamethoxam (Flagship 25 SG, Syngenta NC), tolfenpyrad (Hachi-Hachi 15EC, Nichimo America, IN), acetamiprid (TriStar 30 SG, Cleary Chemical Corp., NJ), chlorantraniliprole (Acelepryn 20 SC,) and cyantraniliprole (Cyaspyr, Dupont, De) (Table 7). The experiment was set up on 30 May 2010 at Hickory Hammock in the same area as described in Experiment 2 and following the same collection methods explained for Experiment 2.

Experiment 5. Evaluation of 2 Chitin Synthesis Inhibitors and a Pyrethroid in the Field and the Laboratory

This experiment had a field and a laboratory phase. For the field trial, 2 doses of diflubenzuron

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TABLE 1. INSECTICIDES TESTED FOR CONTACT ACTIVITY AGAINST BEETLES INFESTING AVOCADO BOLTS IN 2009 AND 2010. DATA ON THE NUMBERS OF ENTRANCE AND EMERGENCE HOLES AND AVERAGE NUMBERS OF SCOLYTINAE AND CERAMBYCIDAE THAT EMERGED PER INSECTICIDE-TREATED BOLT WERE COLLECTED FOLLOWING INFESTATION IN AN AVOCADO GROVE IN JULY 2009 AT HOMESTEAD, FLORIDA.

Chemical	Rate/100 gallons[1]	Adjuvant[2]	Rate/ 100 gallons	[3]Entrance + emergence holes/bolt Mean ± SE	Scolytinae/bolt Mean ± SE	Cerambycidae/bolt Mean ± SE
Hero® EW (zeta-cypermethrin+bifenthrin)	11.2 oz	LI-700	4 oz	1.00 ± 0.65 b	0.00 ± 0.00	1.00 ± 0.65 b
Hero® EW (zeta-cypermethrin+bifenthrin)	11.2 oz	Nu-Film-17®	8 oz	3.57 ± 1.57 b	0.57 ± 0.57	0.29 ± 0.29 b
Malathion® 5EC	24 oz	LI-700®	4 oz	31.77 ± 8.74 a	1.33 ± 0.83	1.11 ± 0.65 b
Permethrin® 3.2 AG (permethrin)	8 oz	LI-700®	4 oz	3.00 ± 1.23 b	1.00 ± 0.50	0.00 ± 0.00 b
Permethrin 3.2 AG (permethrin)	8 oz	Nu-Film-17®	8 oz	2.86 ± 1.52 b	0.57 ± 0.30	0.86 ± 0.46 b
Endigo® ZC (lambda-cyhalothrin+thiamethoxam)	5.5 oz	LI-700®	4 oz	0.50 ± 0.33 b	0.00 ± 0.00	0.75 ± 0.62 b
Endigo® ZC (lambda-cyhalothrin+thiamethoxam)	5.5 oz	Nu-Film-17®	8 oz	3.00 ± 1.09 b	0.44 ± 0.34	0.11 ± 0.11 b
Non-treated control		—	—	4.56 ± 1.03 b	0.67 ± 0.47	5.22 ± 1.31a
P value				0.007	0.51	0.0001

[1]Airblast sprayer was set to apply 100 gallons/acre (935 liters/ha).
[2]LI-700, phosphatidylcholine, methylacetic acid and alkyl polyoxyethlene ether; Nu-Film-17, di-1-p-menthene
Note: 1 ounce = 28.4 grams; 1 fluid ounce = 29.6 mL; 1 US pint = 0.473 liter; 1 US quart = 0.946 liter.
[3]Ambrosia enter and exit through the same holes, whereas bark beetles enter and exit through different holes.

(Micromite, Uniroyal Chemical, CT), 1 dose of novaluron (Rimon® 0.83 EC, Uniroyal Chemical, CT), and a mixture of novaluron + bifenthrin (Brigade® WSB, FMC, PA) (Table 9) were tested by treating ten avocado (cv. 'Booth 7') bolts with each material per treatment on 28 Jun 2010 as described above. Bolts were placed at Hickory Hammock on 29 Jun 2010 (as above) and collected one month later on 28 Jul 2010 and then stored for 2 mo until beetle emergence had ceased. The numbers of holes per bolt and numbers and species of Scolytinae and unidentified Cerambycidae were determined.

For the laboratory trial, avocado bolts (cv. 'Booth 7', 8 cm long and 3 cm diam.) were dipped for 2 min in the same 4 solutions of pesticides (Table 9), allowed to dry for approx. 8 h, and placed individually into mason jars (10 replications per treatment). Two newly emerged female RAB (obtained from UF colony, Gainesville, Florida) were placed onto each bolt, observed to bore into the bolt, and then the jars were capped. Every other d, water was added to the bottom of each jar to provide sufficient humidity for beetle development. Approx. 60 ds later, each bolt was removed from the jar and sliced into 4 quadrants using a miter saw. Once a gallery was observed in one of the quadrants, a flat-blade screw driver was used to carefully remove the wood close to the gallery in order to determine if eggs, larvae, pupae, or adults were present within the gallery. A gallery containing any of these stages was considered a successful gallery.

Experiment 6. Chemical Control of Redbay Ambrosia Beetles Infesting Avocado Trees

Ten pesticides (Table 10) were evaluated for control of RAB at the Indian River Research and Education Center (IRREC), Fort Pierce, Florida (27° 25'36.03"N, 80° 24'21.64"W). Individual experimental units placed in an open field consisted of 5 1.5-1.9 m tall cv. 'Brogdon' avocado trees, planted in 10-gallon(38 liter) pots. The trees were fertilized 3 wk before the insecticide treatment with Osmocote (14-14-14) and irrigated every other d, applying water to the soil. Treatments were applied on 14 Apr 2010 as either a drench or by using a manual sprayer, at approximately 25 psi (1,293 mm Hg), delivering approx. 100 gallons/acre (935 liters/ha). Drench doses were calculated based on the number of trees placed per acre. Each treatment had 5 repetitions with each repetition being an individual plant. The next d (15 Apr 2010), 3 newly emerged female RAB (from UF colony) were placed inside a 20 cm × 40 cm cotton bag that surrounded the basal portion of the stem of each tree. Each bag was sealed immediately afterwards to prevent beetle escape. Two wk later, the bags were opened, the number of entry holes per tree was recorded, and 3 new beetles were introduced. Infestation was repeated during the third week of the experiment. On 8 Jun 2010, 9 wk after treatment, total infestation was recorded as well as a LW disease severity index. The LW index was developed as follows: 0 = wilting symptoms; 1 = wilt, no necrosis on the leaves; 2 = wilt and necrosis on 10% of the foliage and partial defoliation; 3 = wilting and 30% of the canopy defoliated; 4 = 50% of the leaves necrosed; 5 = 75% of the leaves necrosed, defoliation; 6 = 100% necrosed leaves and/or 100% defoliation. Two wk later, starting at the base of the tree, portions of the stem were removed from each tree and placed individually in a plastic bag, numbered, and brought to the laboratory to isolate the fungus. Bark was removed from symptomatic sapwood, which was then cut into 5 mm^2 pieces and surface-disinfected for 15 seconds in 70% ethanol followed by a 2 min. in 10% household bleach. Tissue pieces were then rinsed in sterile water, blotted dry on sterile paper towels, and plated on a semi-selective medium that was developed by Harrington (1981) and amended by Ploetz et al. (2011). The results are expressed as the mean proportion of tissue pieces from which *R. lauricola* was recovered on this medium for a given treatment.

Experiment 7. Chemical Control of Redbay Ambrosia Beetles Infesting Swampbay Trees.

One hundred and five swampbay trees ca. 1.82 m tall were planted at the University of Florida, Plant Science Unit, Citra, Florida (29° 24'3540"N, 82° 09'28.59"W) on 11 Jun 2009. Distance between trees was 1.54 m and distance between rows was 3.66 m. All plants had drip irrigation. Almost 1 year after planting, on 21 Sep 2010, 8 chemical treatments (Table 11) were applied to the trees (5 replicate trees per treatment). Insecticides were applied either by drenching at the base of the trunk (based on trunk diam), or by using a broadcast application to the soil around the base of the trunk and then covering the pesticide with soil, or by foliar application using a manual sprayer calibrated at approximately 25 psi (1,293 mm Hg), (at an application rate of 100 gallons/acre (935 liters/ha). On 22 Sep 2010, two adult female RAB (from UF colony) were added to each tree for infestation following the same methodology as explained above. Trees were re-infested on 3 Oct 2010 with the same number of beetles per bag. Data collection on number of holes per tree and LW disease rating was performed as explained previously.

Statistical Analyses

Statistical differences for the number of entrance holes and species of beetles that emerged from treated bolts were determined by using PROC

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GLM and LSD (SAS Institute 2008). During the tests using potted avocado and swampbay trees, linear regression analysis was used to determine if there was a significant linear relationship between the number of entry holes made by RAB *(x)* and disease severity (y_a) and recovery of *R. lauricola* (y_b).

Results and Discussion

Effect of Contact Insecticides against Beetles Infesting Avocado Bolts

Experiment 1. Infestation of Avocado Bolts in a Grove and Number of Beetles that Emerged

With the exception of permethrin + Nufilm treated bolts, more beetle entrance holes were observed on the untreated control bolts compared to the insecticide treated bolts 1 after placing the bolts in the field. However, when the numbers of entrance/emergence holes were evaluated at the end of the experiment, more holes were recorded on bolts treated with malathion + Li-700 than either the untreated controls or the other treatments (Table 1). There were no differences in the number of emerged Scolytinae among treatments or the control bolts. *Xyleborus glabratus* had not been reported in Miami-Dade County while this study was conducted. The Scolytinae that emerged from avocado bolts were *Xylosandrus crassiusculus* (Motchulsky)*, Xyleborus volvulus* (F.)*, Xyleborus ferrugineus* (F.)*, Xyleborinus saxeseni* (Ratzerburg)*, Xyleborinus gracilis* (Eichhoff)*, Ambrosiodmus lecontei* Hopkins*,* and *Hypothenemus* sp. (Table 2). While *X. crassiusculus* and *Hypothenemus* sp. had already been known to attack avocado (Dixon et al. 2003; Peña 2003), this is the first report of *X. volvulus, X. ferrugineus, X. saxeseni,* and *X. gracilis* completing development within avocado. There were no statistically significant differences among the different species emerging from avocado bolts (df = 6,441; $F = 0.48$; $P < 0.82$). *Xyleborus volvulus, X. ferrugineus, Ambrosiodmus* spp., *Hypothenemus* spp., and several other scolytine beetles are attracted to host-based volatiles emitted from avocado wood, and these species may function as secondary colonizers of avocado trees subsequent to initial attack by *X. glabratus* (Kendra et al. 2011). No Scolytinae emerged from avocado bolts treated with Hero® + Li (zeta-cypermethrin+ bifenthrin + Li), or Endigo® + Li ((lambda-cyhalothrin+ thiamethoxam + Li) during this trial (Table 2). Bolt volume was not different statistically among treatments, therefore, bolt size likely did not influence beetle emergence.

Experiment 2. Comparative Efficacy of Lambda-Cyhalothrin + Thiamethoxam and Malathion

In the Homestead grove, the total number of entry holes did not differ between the untreated control and the treated bolts ($P = 0.34$) (Table 3). Emergence of Scolytinae was significantly lower on bolts treated with lambda-cyhalothrin + thiamethoxam than on bolts treated with malathion or left untreated (Table 3). At Hickory Hammock, an area infested with *X. glabratus,* the number of entrance holes on bolts treated with lambda-cyhalothrin+thiamethoxam was significantly lower than the number on the untreated bolts ($P = 0.003$). The number of emerging beetles was significantly higher on the untreated bolts than on bolts treated either with lambda-cyhalothrin+ theimethoxam or with malathion ($P = 0.01$). The Scolytinae that emerged from bolts in Homestead were *Hypothenemus* sp.*, X. saxeseni, X. volvulus,* and *X. crassiusculus* (Table 4). The most common species was *Hypothenemus* sp. (df = 3,116; $F = 6.86$; $P > 0.0003$), which is consistent with observations made by Kendra et al. (2011) using ambrosia beetle monitoring traps deployed in avocado groves. While other Scolytinae emerged from bolts hung at Hickory Hammock, only specimens of *X. glabratus* were recorded; significantly more *X. glabratus* emerged from untreated bolts than from treated ones (df = 2,27; $F = 8.00$; $P < 0.01$). Bolt volume was slightly higher on treated bolts compared to untreated bolts ($P = 0.04$). However, when the analysis was done comparing scolytid emergence by bolt volume, the results were similar to those those expressed on table 4 (df = 2,27; $F = 4.82$; $P < 0.02$).

Experiment 3. Evaluation of Insecticides Registered for Avocado and Others with Known Promise

The first replication of this experiment was conducted in Homestead. There were no statistical differences in number of entrance holes among treatments and the untreated control (Table 5). However, bolts treated with endosulfan, chlorpyrifos advanced, malathion, methomyl, and bifenthrin had significantly lower emergence of Scolytinae and total number of coleopterans than the untreated control. Only two species of Scolytinae were observed. *Xylosandrus crassiusculus* emerged only from chlorpyrifos treated bolts; and the dominant *Hypothenemus* spp. (df = 1,38; F = 6.69; p < 0.01) emerged from both treated and untreated bolts, but emergence was significantly lower with all of the insecticide treatments (Table 6).

In the second replication conducted in Homestead, there were no significant differences in the number of entrance holes or the number of Scolytinae emerging from the treated or untreated bolts (Table 5). However, highly significant differences were observed for total number of coleopterans (Scolytinae, Laemophloeidae, Cerambycidae, and Bostrichidae) emerging from untreated bolts as compared to the treated controls. No differences were observed among the different species of Scolytinae (*X. crassiusculus, Hypothenemus* sp.*, X.*

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TABLE 2. MEAN NUMBER ± SE OF SCOLYTINAE THAT EMERGED FROM AVOCADO BOLTS FOLLOWING INFESTATION IN AN AVOCADO GROVE IN JULY 2009 AT HOMESTEAD, FLORIDA (EXPERIMENT 1).

Treatment	*Xylosandrus crassiusculus*	*Xyleborus volvulus*	*Xyleborinus saxeseni*	Xyleborus ferrugineus	*Ambrosiodmus lecontei*	*Xyleborinus gracilis*	*Hypothenemus sp.*
Control	0	0	0	0.56 ± 0.38	0.11 ± 0.11	0	0
Hero+Li	0	0	0	0	0	0	0
Hero+Nu	0.43 ± 0.43	0.14 ± 0.14	0	0	0	0	0
Malathion+Li	0	0.44 ± 0.34	0.11 ± 0.11	0.11 ± 0.11	0.11 ± 0.11	0	0.33 ± 0.33
Permethrin+Li	0	0.25 ± 0.25	0.12 ±0.12	0.12 ± 0.12	0.12 ± 0.12	0.12 ± 0.12	0.25 ± 0.25
Permethrin+Nu	0.29 ± 0.18	0	0	0	0	0.14 ± 0.14	0.14 ± 0.14
Endigo+Li		0	0	0	0	0	0
Endigo+Nu	0	0.11 ± 0.11	0.11 ± 0.11	0	0	0.11 ± 0.11	0
P =	0.2754	0.5057	0.7347	0.1860	0.7347	0.6493	0.6723

TABLE 3. COMPARATIVE EFFICACY OF LAMBDA-CYHALOTHRIN + THIAMETHOXAM AND MALATHION AGAINST BEETLES INFESTING AVOCADO BOLTS AT TWO LOCATIONS IN FLORIDA, NUMBER OF BEETLE ENTRANCE HOLES AND AVERAGE NUMBERS OF SCOLYTINAE AND CERAMBYCIDAE THAT EMERGED PER INSECTICIDE-TREATED AVOCADO BOLT, 27 JAN 2010 (EXPERIMENT 2).

Treatment	Dose/100 gallons	No. of entrance holes/avocado bolt Mean ± SE	Scolytinae/avocado bolt Mean ± SE[1]	Cerambycidae/ Avocado bolt Mean ± SE
		Site and Date of Experiment: Homestead, Florida; 27 Jan to 25 Feb 2010		
Lambda-Cyhalothrin +Thiamethoxam	24 oz.	0.5 ± 0.3	0.10 ± 0.1 b	9
Malathion 5EC	5.5 oz.	1.1 ± 0.4	11.9 ± 4.3 a	0.5 ± 0.4
Untreated		1.2 ± 0.4	9.5 ± 2.3 a	1.8 ± 1.1
P =		0.3455	0.0156	0.1814
		Site and Date of Experiment: Hickory Hammock; 27 Jan to 25 Feb 2010		
Lambda-Cyhalothrin +Thiamethoxam	24 oz.	0.10 ± 0.10 b	0.20 ± 0.13 B	
Malathion 5EC	5.5 oz.	2.25 ± 0.92 ab	0.20 ± 0.20 b	
Untreated		4.60 ± 1.17 a	1.7 0 ± 0.47 a	
P =		0.0030	0.01	

[1]Means within a column with the same letter do not differ significantly.

TABLE 4. MEAN NUMBER ± SE OF SCOLYTINAE THAT EMERGED FROM AVOCADO BOLTS FOLLOWING INFESTATION IN AN AVOCAD GROVE AT HOMESTEAD, FLORIDA IN 27 JAN 2010 (EXPERIMENT 2).

Treatment	*Xylosandrus*[1] *crassiusculus*	*Xyleborinus saxeseni*	*Xyleborus volvulus*	*Hypothenemus* sp.
Endigo ZC (SC)	0.0 ± 0.0	0.1 ± 0.10	0.0 ± 0.0	0.0 ± 0.0 b
Malathion 5EC	3.2 ± 3.1	0.0 ± 0.0	0.0 ± 0.0	8.4 ± 3.7 a
Control	1.5 ± 1.5	0.1 ± 0.1	0.2 ± 0.1	7.8 ± 2.1 a
P =	0.5292	0.6120	0.1248	0.0419

[1]Means within a column with the same letter do not differ significantly.

volvulus, X. saxeseni, and *A. lecontei)* emerging from either treated or untreated bolts. However, the most common ambrosia beetle emerging from avocado bolts was *X. crassiusculus* (df = 4,345; F = 2.98; p > 0.02) in this replicate test (Table 6).

The third replication of this experiment was conducted at Hickory Hammock. A higher number of entrance holes was observed on bolts treated with methomyl and on the untreated control, compared to those treated with malathion, bifenthrin, chlorpyrifos or lambda cyhalothrin+thiametoxam (Table 5). More Scolytinae emerged from methomyl treated bolts than from bolts treated with other insecticides or left untreated. At Hickory Hammock, more *X. crassiusculus* and *X. glabratus* (df = 14,405; F = 3.96; P > 0.001) emerged from avocado bolts than *X. volvulus, X. saxeseni*, or *X. ferrugineus* (Table 6).

Experiment 4. Evaluation of Recently Developed Insecticides

No statistical differences were recorded in the number of entrance holes (df = 6,63; F = 0.67; P > 0.67) (Table 7), nor in the no. of scolytid beetles emerging from treated or untreated bolts (df = 6,63; F = 1.61; P > 0.16). However, there were significant differences among treatments when cerambycids (df = 6,63; F = 4.22; p > 0.001) and anobiids (df = 6,63; F = 2.75; P > 0.02) emerged from treated and untreated bolts. There were no significant differences from other coleopterans emerging from treated and untreated bolts (df = 6,63; F = 2; P > 0.08). Higher densities of *X. saxeseni* were obtained from bolts treated with acelepryn (df = 6,63; F = 2.97; P > 0.01) compared with other treatments and with the untreated control. Other species of Scolytinae emerged from treated and untreated bolts, including *X. glabratus, X. crassiusculus, X. volvulus, A. lecontei, X. ferrugineus, Hypothenemus* sp., and *X. andrewesi,* but their rates of emergence were not significant between treated and untreated bolts (Table 8).

Experiment 5. Evaluation of 2 Chitin Synthesis Inhibitors and a Pyrethroid in the Field and the Laboratory

No statistical differences were observed in the number of entrance holes, the number of *X. glabratus*, total Scolytinae, or Cerambycidae emerging from the treated or untreated bolts tested at Hickory Hammock. More *X. volvulus* emerged from bolts treated with novaluron compared to all other treatments, including untreated control bolts. Numbers of Scolytinae that emerged were higher during this experiment than during previous experiments (Table 9). In general, more *X. saxeseni* and *X. glabratus* emerged from all the bolts than the other species of Scolytinae (df = 7,552; F = 19.39; p > 0.0001).

Under laboratory conditions, there were no statistical differences in the number of successful galleries made by *X. glabratus* in treated versus untreated bolts. An average of 0.18 to 0.50 gallery was observed per avocado bolt, regardless of treatment. Thus the growth regulators and bifenthrin appeared to be ineffective.

Experiment 6. Chemical Control of Redbay Ambrosia Beetles Infesting Avocado Trees

Avocado trees treated with the insecticides fenpropathrin, clothianidin, cryolite-sodium aluminum fluoride, tolfenpyrad, zeta-cypermethrin, and the mixture of tolfenpyrad and HGW86 had significantly lower numbers of RAB entrance holes when checked at one d after treatment. However, there were no differences in entrance holes between the treated trees and the untreated controls when the avocados were re-infested 1 week later. At the end of the experiment, trees treated with bifenthrin actually had more beetle entrance holes compared to trees treated with any other product (Table 10). At the end of the experiment, trees that developed LW symptoms became infested by the false powder beetle, *Xylopsocus capucinus* (F.). The number of entrance holes made by *X. capucinus* were not significantly different among the various treatments and the untreated control (F = 0.85; P > F = 0.56, df = 10,14). No significant differences in disease rating and disease incidence were detected among treatments. However, some treatments, i.e., fenpropathrin and tolfenpyrad had a zero disease rating, while lambda-cyhalothrin + thiametoxam and cryolite followed each with a disease severity of 0.20 (Table 10). Linear regression models be-

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TABLE 5. EVALUATION OF INSECTICIDES REGISTERED FOR AVOCADO AND OTHERS WITH KNOWN PROMISE, I.E., EFFECT OF INSECTICIDE-TREATED AVOCADO BOLTS ON THE NUMBER OF BEETLE ENTRANCE HOLES, AND THE NUMBERS OF SCOLYTINAE AND TOTAL COLEOPTERANS THAT EMERGED POST-TREATMENT PER BOLT IN 2 FIELD TESTS AT HOMESTEAD, FLORIDA AND IN 1 FIELD TEST AT HICKORY HAMMOCKS, FLORIDA IN 2010 (EXPERIMENT 3).

Treatment	Dose	No. of Entrance Holes Mean ± SE	No. of emerged Scolytinae Mean ± SE	Total no. of emerged Coleoptera Mean ± SE
		Trial site and dates: Homestead; 11-II to 9-III-2010		
Endosulfan	1 qt	0.1 ± 0.1	0 b	0.2 ± 0.2 b
Chlorpyrifos 40.18%	5 pints	0.7 ± 0.4	0.7 ± 0.4 b	1.2 ± 0.6 b
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid	5.5 oz. + 4 oz	0.0± 0.0	0.1 ± 0.1 b	0.3 ± 0.2 b
Malathion	6 pints	0.1 ± 0.1	1.8 ± 0.9 b	3.0 ± 0.8 b
Methomyl 29%	3 pints	0.7 ± 0.4	0.1 ± 0.1 b	0.6 ± 0.3 b
Bifenthrin 25.1%	24 oz	0.6± 0.1	0.1 ± 0.1 b	0.1 ± 0.1 b
Untreated	—	0.3 ± 0.2	10.1 ± 3.9 a	10.5 ± 3.8 a
P =		0.1229	0.0005	0.0003
		Trial site and dates: Homestead; 31-III to 3-V-2010		
Endosulfan	1 qt	0.6 ± 0.4	0.1 ± 0.1	6.6 ± 1.0 bc
Chlorpyrifos 40.18%	5 pints	0.8 ± 0.2	0.2 ± 0.1	4.4 ± 1.6 bc
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid	5.5 oz. + 4 oz	0.3 ± 0.2	0.7 ± 0.6	2.7 ± 0.7 c
Malathion	6 pints	0.4 ± 0.4	2.0 ± 1.1	10.1 ± 1.6 b
Methomyl 29%	3 pints	0.4 ± 0.3	0.1 ± 0.1	5.3 ± 1.6 bc
Bifenthrin 25.1%	24 oz	0.7 ± 0.4	0.4 ± 0.2	4.4 ± 1.2 bc
Untreated		1.4 ± 0.6	4.2 ± 1.8	17.9 ± 4.1 a
P =		0.1375	0.1274	0.0011
		Trial site and dates: Hickory Hammock; 4-III to 6-V-2010		
Endosulfan	1 qt	1.1 ± 0.3 bc	3.8 ± 1.6 bc	0.0 ± 0.0
Chlorpyrifos 40.18%	5 pints	0.4 ± 0.3 c	1.0 ± 0.3 b	0.1 ± 0.1
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid	5.5 oz. + 4 oz	0.7 ± 0.4 c	2.5 ± 2.0 b	0.4 ± 0.3
Malathion	6 pints	0.3 ± 0.2 c	1.1 ± 0.8 b	0.4 ± 0.4
Methomyl 29%	3 pints	3.8 ± 1.0 a	11.9 ± 4.0 a	0.2 ± 0.2
Bifenthrin 25.1%	24 oz	0.4 ± 0.3 c	3.8 ± 1.8 b	0.2 ± 0.1
Untreated		2.6 ± 0.9 ab	5.0 ± 2.1 b	0.1 ± 0.1
P =		0.0001	0.0452	0.9126

Means within a column with the same letter do not differ significantly.
Note: 1 ounce = 28.4 grams; 1 fluid ounce = 29.6 mL; 1 US pint = 0.473 liter; 1 US quart = 0.946 liter.

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TABLE 6. MEAN NUMBER ± SE OF SCOLYTINAE THAT EMERGED FROM AVOCADO BOLTS FOLLOWING INFESTATION IN AN AVOCADO GROVE. THE AVOCADO BOLTS HAD BEEN TREATED WITH DIFFERENT INSECTICIDES PRIOR TO INFESTATION AT TWO FLORIDA LOCATIONS, 2010 (EXPERIMENT 3).

Treatment	Dose	*Xyleborus glabratus*	*Xyleborus volvulus*	*Xyleborus ferrugineus*	*Xyleborinus saxeseni*	*Xylosandrus crassiusculus*	*Hypothenemus* spp.	*Ambrosiodmus lecontei*
	Site and dates of experiment: Homestead, Florida; Feb-Mar 2010							
Endosulfan	1 qt	—	—	—	—	0.0 ± 0.0	0.0 ± 0.0	—
Chlorpyrifos 40.18%	5 pints	—	—	—	—	0.2 ± 0.13	0.5 ± 0.4 b	—
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid	5.5 oz. + 4 oz	—	—	—	—	0.0 ± 0.0	0.1 ± 0.1 b	—
Malathion	6 pints	—				0.0 ± 0.0	1.8 ± 0.9 b	
Methomyl 29%	3 pints	—				0.0 ± 0.0	0.1 ± 0.1 b	
Bifenthrin 25.1%	24 oz	—				0.0 ± 0.0	0.1 ± 0.1 b	
Untreated	—	—				0.0 ± 0.0	10.1 ± 3.9 a	
P =						0.1383	0.0006	
	Site and dates of experiment: Homestead, Florida; Mar-May 2010							
Endosulfan		—	0.0 ± 0.0	—	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1 ab	0.0 ± 0.0
Chlorpyrifos 40.18%		—	0.0 ± 0.0	—	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1 ab	0.0 ± 0.0
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid		—	0.0 ± 0.0	—	0.1 ± 0.1	0.6 ± 0.6 b	0.0 ± 0.0	0.0 ± 0.0
Malathion		—		—	0.0 ± 0.0	0.7 ± 0.7 b	1.2 ± 1.0 a	0.1 ± 0.1 a
Methomyl 29%		—	0.0 ± 0.0	—	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Bifenthrin 25.1%		—	0.1 ± 0.1	—	0.0 ± 0.0	0.2 ± 0.2 b	0.0 ± 0.0	0.1 ± 0.1 a
Untreated		—	0.6 ± 0.6	—	0.0 ± 0.0	3.0 ± 1.7 a	0.6 ± 0.3 ab	0.0 ± 0.0
P =			0.5167		0.6193	0.2084	0.5207	0.6193
	Site and dates of experiment: Hickory Hammock, Florida; Mar-May 2010							
Endosulfan	1 qt	1.5 ± 0.6	0.1 ± 0.1	0.0 ± 0.0	1.3 ±1.1	0.9 ± 0.7 b	0.0 ± 0.0	—
Chlorpyrifos 40.18%	5 pints	0.4 ± 0.2	0.3 ± 0.2	0.0 ± 0.0	0.1 ± 0.1	0.2 ± 0.1 b	0.0 ± 0.0	—
Lambda-Cyhalothrin 9.48% + Thiamethoxam 12.60% + Methylacetic acid	5.5 oz. + 4 oz	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.00	0.2 ± 0.2	2.2 ± 2.0 b	0.0 ± 0.0	—
Malathion	6 pints	0.1 ± 0.1	0.2 ± 0.2	0.0 ± 0.0	0.8 ± 0.8	0 b	0.0 ± 0.0	—
Methomyl 29%	3 pints	1.9 ± 0.9	0.2 ± 0.2	0.2 ± 0.2	0.5 ± 0.3	9.1 ± 3.3 a	0.0 ± 0.0	—
Bifenthrin 25.1%	24 oz	1.5 ± 1.1	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.4	1.4 ± 1.4 b	0.3 ± 0.3	—
Untreated	—	0.1 ±0.1	0.0 ± 0.0	0.1 ± 0.1	0.7 ± 0.33	4.1 ± 1.9 b	0.0 ± 0.0	—
P =		0.1569	0.5476	0.5888	0.6060	0.0281	0.4688	

Means within a column with the same letter do not differ significantly.
Note: 1 ounce = 28.4 grams; 1 fluid ounce = 29.6 mL; 1 US pint = 0.473 liter; 1 US quart = 0.946 liter.

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TABLE 7. EVALUATION OF RECENTLY DEVELOPED INSECTICIDES. EFFECT OF INSECTICIDE-TREATED AVOCADO BOLTS ON THE NUMBERS OF BEETLE ENTRANCE HOLES AND ON THE NUMBERS OF SCOLYTINAE AND TOTAL COLEOPTERA THAT EMERGED PER TREATED BOLT IN 3 FIELD TESTS CONDUCTED AT HICKORY HAMMOCK, FLORIDA, MAY 2010 (EXPERIMENT 4).

Treatment	Dose	Entrance Holes/bolt Mean ± SE	Scolytinae/bolt Mean ± SE	Cerambycidae/bolt Mean ± SE	Anobiidae/bolt Mean ± SE	Other Coleopterans/bolt Mean ± SE
Acelepyrin® 20 SC	0.25 fl oz/tree	5.40 ± 1.06	12.50 ± 3.69	0.00 ± 0.00c	0.10 ± 0.10b	0.00 ± 0.00
Cyazypyr®	0.25 fl oz/tree	3.90 ± 0.86	3.10 ± 0.89	0.00 ± 0.00c	0.00 ± 0.00b	0.00 ± 0.00
Flagship® 25 WG	0.17 oz/gallon	3.90 ± 1.02	10.60 ± 2.36	0.00 ± 0.00c	0.50 ± 0.22a	0.00 ± 0.00
Safari® 20 SG	12 g/gallon	4.10 ± 1.22	7.70 ± 3.10	1.90 ± 0.84ab	0.00 ± 0.00b	0.10 ± 0.10
Tolfenpyrad® 15EC	0.21 oz/gallon	4.00 ± 1.01	8.10 ± 1.32	3.30 ± 1.20a	0.10 ± 0.10b	0.00 ± 0.00
TriStar®30 SG	3 fl oz/gallon	2.60 ± 0.79	3.90 ± 1.46	0.00 ± 0.00c	0.10 ± 0.10b	0.30 ± 0.15
Untreated		3.40 ± 0.73	7.60 ± 3.90	1.10 ± 0.80bc	0.00 ± 0.00b	0.10 ± 0.10
P		0.16	0.16	0.001	0.02	0.07

Means within a column with the same letter do not differ significantly.
Note: 1 gallon equals 3.8 liters; 1 fluid ounce equals 29.6 mL.

TABLE 8. MEAN NUMBER ± SE OF SCOLYTINAE SPECIES THAT EMERGED FROM INSECTICIDE-TREATED AND UNTREATED AVOCADO BOLTS, HICKORY HAMMOCK, FLORIDA, MAY 2010 (EXPERIMENT 4).

Treatment	*Xyleborus glabratus*	*Xylosandrus crassiusculus*	*Xyleborus volvulus*	*Xyleborinus saxeseni*	*Ambrosiodmus lecontei*	*Xyleborus ferrugineus*	*Hypothenemus* sp.	*Xyleborinus andrewesi*
Acelepyrin 20 SC	1.80 ± 0.57	0.80 ± 0.33	0.90 ± 0.80	8.50 ± 207a	0.30 ± 0.21	0.20 ± 0.20	0.00 ± 0.00b	0.00 ± 0.00
Cyazypyr	0.30 ± 0.15	0.10 ± 0.10	0.10 ± 0.10	2.50 ± 0.98b	0.10 ± 0.10	0.00 ± 0.00	0.00 ± 0.00b	0.00 ± 0.00
Flagship 25 WG	3.80 ± 1.35	1.60 ± 0.67	0.40 ± 0.22	3.20 ± 1.07b	1.60 ± 1.49	0.00 ± 0.00	0.00 ± 0.00b	0.00 ± 0.00
Safari 20 SG	3.10 ± 2.12	1.00 ± 0.60	0.30 ± 0.21	2.80 ± 1.59b	0.20 ± 0.13	0.20 ± 0.13	0.00 ± 0.00b	0.10 ± 0.10
Tolfenpyrad 15EC	2.30 ± 0.70	1.50 ± 0.85	0.20 ± 0.13	3.80 ± 1.29b	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.13a	0.10 ± 0.10
TriSTar 30 SG	1.70 ± 1.04	0.20 ± 0.20	0.00 ± 0.00	0.80 ± 0.55b	0.90 ± 0.90	0.30 ± 0.30	0.00 ± 0.00b	0.00 ± 0.00
Untreated	2.70 ± 2.27	0.20 ± 0.20	0.40 ± 0.31	3.90 ± 1/57b	0.40 ± 0.31	0.00 ± 0.00	0.00 ± 0.00b	0.00 ± 0.00
P =	0.67	0.16	0.64	0.01	0.65	0.58	0.04	0.54

Means within a column with the same letter do not differ significantly.

TABLE 9. EVALUATION OF TWO CHITIN SYNTHESIS INHIBITORS AND ONE PYRETHROID IN THE FIELD. MEAN NUMBER± SE OF BEETLE ENTRANCE HOLES, AND NUMBERS OF SCOLYTINAE SPECIES THAT EMERGED FROM INSECTICIDE-TREATED AND UNTREATED AVOCADO BOLTS, HICKORY HAMMOCK, FLORIDA, MAY 2010. (EXPERIMENT 5).

Treatment	Dose	Holes	*Xyleborus glabratus*	*Xyleborus ferrugineus*	*Xyleborus volvulus*	*Xyleborinus saxeseni*	*Xylosandrus crassiusculus*	*Premnobius cavipennis*	Other Scolytids
Novaluron 9.3%	20 fl oz	19.4 ± 5.3	9.6 ± 2.6	1.1 ± 0.8	2.0 ± 0.7 a	1.2 ± 0.5	3.7 ± 2.2	0.1 ± 0.1	0.70 ± 0.3
diflubenzuron 80%	6.25 fl oz	18.7 ± 4.8	9.4 ± 5.13	0.1 ± 0.1	0.6 ± 0.3 b	0.8 ± 0.4	4.0 ± 1.9	0.0±0.0	0.40 ± 0.22
Micromite 80 WGS + MSO@1%	6.25 fl oz + 1%	15.1 ± 4.1	14.4 ± 4.6	0.1 ± 0.1	0.5 ± 0.2 b	1.0 ± 0.4	1.7 ± 0.6	0.0±0.0	1.00 ± 0.7
Novaluron 9.3% + Bifenthrin 10.0%	20 fl oz + 0.1 lb	13.8 ± 2.1	3.4 ± 1.8	0.0 ± 0.0	0.3 ± 0.2 b	0.5 ± 0.3	0.5 ± 0.5	0.0±0.0	0.20 ± 0.13
Untreated		14.2 ± 3.1	7.0 ± 1.4	0.1 ± 0.1	0.6 ± 0.2 b	0.9 ± 0.5	2.6 ± 1.6	0.0±0.0	0.44 ± 0.2
P =		0.7961	0.2769	0.1895	0.02	0.8186	0.4433	0.4321	0.6158

Means within a column with the same letter do not differ significantly.
Note: 1 fluid ounce equals 29.6 mL; 1 pound = 473.6 grams.

tween the number of RAB holes per tree (x) and LW disease severity (y_a) or recovery of *R. lauricola* (y_b) were both significant ($F = 20.70$; $P < 0.0001$; df = 53,54; $r^2 = 0.29$; $F = 29.14$; $P < 0.0001$; df = 53,54; $r^2 = 0.35$).

Experiment 7. Chemical Control of Redbay Ambrosia Beetles Infesting Swampbay Trees.

More RAB entrance holes were observed on swampbay trees treated with the insecticide cyantraniliprole (DPX HGW86) compared with trees treated with acetamyprid or a mixture of imidacloprid+cyfluthrin (Table 11). There were no statistical differences in the disease ratings among the various treatments. Linear regression between the number of entrance holes per swampbay tree (x) and disease severity (y) was significant ($F = 33.86$; df = 1,43; $P > 0.0001$; $r^2 = 0.44$). Recovery of *R. lauricola* was not conducted in this trial.

DISCUSSION

In general, pest Scolytinae are notoriously difficult to control, because they pass most of their lives hidden within galleries. Eggs are laid within the galleries and it is only when the adult female disperses to colonize a new host that the insect may be exposed to contact chemical control. Contact poisons tend not to penetrate the tree cortex and stomach poisons are ineffective due to limited (if any) ingestion of bark by a boring female. Our results indicate that pesticide treatments vary in their impact on the number of RAB entrance holes or on the number of emerging beetles. These data will help identify products for further evaluation for chemical control of Scolytinae in avocado. For instance, during the tests performed on avocado bolts, some insecticides, i.e., zeta-cypermethrin+bifenthrin, lambda-cyhalothrin+thiamethoxam, provided a more consistent reduction in the number of entrance holes or beetle emergence compared to bifenthrin, malathion, endosulfan, or chlorpyrifos. With malathion, a decrease in entrance holes and beetle emergence was observed during one test, but the insecticide proved to perform erratically during other tests in which a high number of entrance holes were observed. Methomyl, which is one of the pesticides currently registered for avocado (Crane & Mossler 2009), resulted in higher beetle emergence relative to the control in some tests. Since the avocado bolts were held at each site for approximately 30 d, the persistence of pesticide residues might have been influenced by the different amounts of rainfall at the different sites, exposure to sunlight, or susceptibility of some species of beetles. As explained in the materials and methods section, doses selected in this study were the commercial doses recommended for other bee-

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TABLE 10. EFFECTIVENESS OF INSECTICIDES ON *XYLEBORUS GLABRATUS*, I.E., FINAL NUMBERS OF ENTRANCE HOLES, LAUREL WILT SYMPTOMS AND DISEASE INCIDENCE ON POTTED AVOCADO TREES AT FORT PIERCE, FLORIDA, 2010.

Treatment	Dose	Entrance holes*	Disease Severity	Recovery of Raffaelea lauricola
Fenpropathrin	16 oz	40.00 ± 0.40 b	0.00 ± 0.00	0.00 ± 0.00
Clothianidin	6 oz	1.00 ± 0.31 b	1.50 ± 0.74	0.60 ± 0.24
Thiametoxam	4 oz	1.20 ± 0.73 b	1.40 ± 1.07	0.40 ± 0.24
Bifenthrin 10%	0.1 lb	2.40 ± 0.51 a	2.20 ± 1.10	0.60 ± 0.24
CryoliteNaAlfluoride 96%	10 lbs	0.40 ± 0.24 b	1.10 ± 1.10	0.20 ± 0.20
Lambda cyhalothrin & Thiametoxam	5.5 oz	0.60 ± 0.40 b	0.30 ± 0.30	0.20 ± 0.20
DPX HGW86-476	20.5 oz	0.80 ± 0.38 b	1.00 ± 1.00	0.60 ± 0.24
Tolfenpyrad 150g/l	24 oz	0.40 ± 0.24 b	0.00 ± 0.00	0.40 ± 0.24
DPX HGW86-476 + Tolfenpyrad 150g/l	20.5 oz + 24 oz	0.20 ± 0.20 b	0.40 ± 0.40	0.40 ± 0.24
Zetacypermethrin 9.6%	10.28 ml	1.00 ± 0.32 b	1.80 ± 0.97	0.80 ± 0.20
Untreated		0.80 ± 0.37 b	3.30 ± 1.11	0.80 ± 0.20
P =		0.0290	0.1720	0.2260

Means within a column with the same letter do not differ significantly.

Note: 1 pound = 473.6 grams; 1 ounce = 28.4 grams; 1 fluid ounce = 29.6 mL; 1 US pint = 0.473 liter; 1 US quart = 0.946 liter; 1 linear foot = 30.4 cm.

tle species. Obviously, laboratory bioassays are still needed on *X. glabratus* to determine to determine LD_{90} and LT_{90} doses of the products tested here.

Contact insecticides that confer repellency may be a more effective strategy for control of RAB. Repellency of contact insecticides against Scolytinae has been suggested as well as killing by fumigant actions (Damon 2000, Ruano et al. 2008, Rose et al. 2005; Doane 1962), particularly against the coffee berry borer, *H. hampei,* the bark beetle *Phloeotribus scarabaeioides* Bernard and the bark beetle *Scolytus multistriatus*. In the case of *H. hampei*, this type of control was observed after 6 applications of endosulfan. Multiple applications were not performed during the study presented here as they are not considered feasible in commercial avocado groves.

Peaks of activity of *X. glabratus* attacking *P. borbonia* occur throughout the year with peaks in Sep under Georgia conditions (Hanula et al. 2008), then, we would expect similar beetle activity when *X. glabratus* invades commercial avocado groves in southern Florida. Under these conditions, to effectively reduce the vector of laurel wilt, the use of insecticides for prophylactic protection would require more than a single treatment per year in avocado, and this might prove to be not cost competitive. In the case of *P. scarabaeioides*, a single application of deltamethrin reduced emergence (Damon 2000), suggesting that pyrethroids might have a repellent effect. Other authors, i.e, Pajares & Lanier (1989) reported that pyrethroids did not appear to be highly repellent to European elm bark beetle, but caused rapid knockdown. Therefore, beetle repellency by insecticides would merit further study for the vector of laurel wilt. On the other hand, use of knockdown pesticides might prove to be feasible if combined with effective trapping methods (Kendra *et al*., 2011).

Another interesting feature of our results was the lower number of entrance holes and the absence of laurel wilt development in avocado trees that were treated with fenpropathrin. However, when the same product was applied to swampbay trees infested with RAB, the number of entrance holes did not differ from the untreated control, but the disease did develop (Table 11). These conflicting findings suggest that further testing is necessary for fenpropathrin and for others, i.e., atranilic dianide (cyazypir) and cryolite, to determine their activity as repellents and/or toxicants for *X. glabratus*.

Results from experiments with avocado and swampbay trees that were infested with *X. glabratus* indicated a positive correlation between the numbers of entrance holes and disease severity. Further interdisciplinary work is needed to determine more accurately if entrance holes may serve as a pragmatic guide for future disease incidence. In addition a sensitive detection and rapid response strategy needs to be further developed to risks of incipient infestations of commercial avocado groves by the deadly duo, and the rapid elimination of such incipient infestations.

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TABLE 11. EFFECTIVENESS OF INSECTICIDES ON *X. GLABRATUS*, I.E., FINAL NUMBERS OF ENTRANCE HOLES, AND LAUREL WILT RATING ON POTTED SWAMP BAY, *PERSEA PALLUSTRIS* TREES, CITRA, FLORIDA, 2010.

Treatment	Dose	Entrance Holes ± SE	Disease Severity ± SE
Atranilic Dianide	0.25 fl oz/tree	1.20 ± 0.50 ab	0.40 ± 0.40
Cyantanilipole	0.25 fl oz/tree	2.80 ± 0.73 a	3.00 ± 0.45
Thiametoxam 25%	0.09 g /linear ft	1.40 ± 0.40 ab	1.60 ± 0.40
Dinotefuran 2%	105 g/tree	1.40 ± 0.25 ab	2.20 ± 1.00
Tolfenpyrad 150 g/l	24 fl oz/100 gal	1.00 ± 0.45 ab	0.00 ± 0.00
Acetamyprid 30% + Li 100	8 oz/100 gal +3 fl/gal	0.40 ± 0.25 b	1.40 ± 0.87
Imidacloprid 2.94%+Cyfluthrin 0.70%	44 ml/gal	0.40 ± 0.25 b	1.00 ± 0.55
Fenpropathrin 30.9%	473.6 ml/100 gal	1.00 ± 0.77 ab	1.20 ± 0.97
Untreated		1.20 ± 0.37 ab	1.60 ± 0.68
P =		0.05	0.10

Means within a column with the same letter do not differ significantly.

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