Proc. Fla. State Hort. Soc. 125:92–97. 2012.

Registered and Experimental Insecticides for Control of Asian Citrus Psyllid and Citrus Leafminer on Mature Orange Trees

JAWWAD A. QURESHI*, BARRY C. KOSTYK, AND PHILIP A. STANSLY

University of Florida/IFAS, Southwest Florida Research and Education Center, Immokalee, FL 34142

ADDITIONAL INDEX WORDS. chemical control, *Citrus sinensis*, citrus greening disease, *Chromobacterium substugae*, *Diaphorina citri*, huanglongbing, *Phyllocnistis citrella*

The Asian citrus psyllid (ACP) *Diaphorina citri* vectors *Candidatus* Liberibacter asiaticus, a bacterium which causes Asian form of "huanglongbing" (HLB) or citrus greening disease. Feeding damage by larvae of citrus leafminer (CLM) *Phyllocnistis citrella* predisposes foliage to *Xanthomonas axonopodis* pv. *citri*, a bacterium that causes citrus canker disease. Insecticides are critical component for developing integrated management strategies to reduce the incidence of ACP and CLM and associated diseases. Foliar sprays of registered and experimental insecticides with or without adjuvants were evaluated on 16-year-old *Citrus sinensis* (L.) Osbeck 'Valencia' orange trees pruned to produce new growth attractive to both ACP and CLM for oviposition and development of immatures. During June–July, experimental insecticides sulfoxaflor (Closer® 240 SC, 4.28 or 5.7 oz/acre) and flupyradifurone (Sivanto® 200 SL, 10.5, 12, or 14 oz/acre) and registered insecticides fenpropathrin (Danitol® 24 EC, 16 oz/acre) and spinetoram (Delegate® 25 WG, 4 oz/acre), all applied with 435 Oil (horticultural spray oil, 2–3%), reduced ACP compared to the untreated control for about 3 weeks after treatment. Effectiveness of Closer 240 SC was enhanced with the addition of 435 Oil and of Sivanto 200 SL with both 435 Oil and Induce. During August–September, treatments of fenpropathrin (Danitol® 24 EC, 16 oz/acre), thiamethoxam (Actara 25 WG, 5.5 oz/acre), abamectin + thiamethoxam (Agri-Flex® 8.5 oz/acre) and naled (Dibrom® 8 E, 16 oz/acre) all applied with 435 Oil (2%); thiamethoxam + chlorantraniliprole (Voliam Flexi®, 7.5 oz/ acre) and fenpyroximate (Portal® 0.4 EC, 32 oz/ acre) applied alone; Mpede + AdditTM (Soap 2% + Vegetable oil 0.50%); and treatments of the bioinsecticides *Chromobacterium substugae* applied with the adjuvant Hyper-Active (0.125%) reduced ACP compared to the untreated control for about 4 weeks after treatment. New insecticides effective against ACP will broaden the range of products available to control ACP. However, 3–4 week suppression of ACP observed here is still less than 6 months seen following foliar sprays of broad-spectrum insecticides made during dormant winter period when most mature trees are not producing new growth and beneficial insects are scarce. Therefore, growers are encouraged to suppress psyllids during the dormant winter period and rely on pest monitoring results and rotation of relatively selective chemistries to treat groves during the growing season. Only Agri-Flex® + 435 Oil, Voliam Flexi® and Delegate® 25 WG + 435 Oil reduced CLM compared to untreated control for 10–12 DAT, suggesting need of insecticides to target CLM for longer duration.

The Asian citrus psyllid (ACP) *Diaphorina citri* Kuwayama and citrus leafminer (CLM) *Phyllocnistis citrella* Stainton are economically important pests, mainly because they contribute to the spread of two serious diseases of citrus. ACP vector *Candidatus* Liberibacter asiaticus, a bacterium that causes Asian form of "huanglongbing" (HLB) or citrus greening disease (Halbert and Manjunath, 2004). Feeding damage by larvae of citrus leafminer (CLM) Phyllocnistis citrella predisposes foliage to *Xanthomonas axonopodis* pv. *citri*, the bacterium which causes citrus canker disease. Both pests and diseases are now well established in Florida and spreading (FDACS-DPI, 2008; Gottwald et al., 2002; Qureshi et al., 2009b; http://www.freshfromflorida.com/pi/chrp/ArcReader/ArcReader.html).

Suppression of ACP and CLM is warranted to reduce the incidence of citrus greening and canker diseases, respectively. Therefore, effective control measures are needed to develop integrated management strategies against these pests and associated diseases. Chemical pesticides are an important component of citrus pest management. However, the advent of "huanglongbing" (HLB) has greatly intensified insecticide use in Florida citrus (Rogers, 2008; Rogers et al., 2008). Few soil applied systemic insecticides are available and allowable rates are only sufficient for use on young citrus trees (Qureshi and Stansly, 2007; Qureshi et al., 2011). Therefore, insecticide sprays applied to the foliage are the primary control method for *D. citri* in mature Florida citrus, and these materials are continually being tested in the field (Qureshi and Stansly, 2009a; Qureshi et al., 2009a, 2010, 2011). Field tests under different conditions are necessary to evaluate effectiveness of new and already registered products against ACP and CLM, and provide growers with multiple modes of action for resistance management.

Both ACP and CLM require young shoots for oviposition and immature development. ACP adults can also survive and overwinter on hardened leaves. Most mature citrus trees in Florida

Acknowledgments. We are thankful to J. Mendez, M. Pinto, R. Riefer, and B. Pena for technical assistance. Funds were provided by Bayer CropScience, Syngenta Crop Protection, Nichino America, Dow Agrosciences, Marrone Bio Innovations, Amvac Chemical Corporation, Koppert Biological Systems, and the Citrus Research and Development Foundation (CRDF).

*Corresponding author; phone: (239) 658-3451; email: jawwadq@ufl.edu

produce the majority of new shoots in spring followed by sporadic growth in summer and fall (Hall and Albrigo, 2007; Qureshi et al., 2009b). Targeting overwintering ACP adults with so-called dormant sprays of broad-spectrum insecticides prior to spring growth flushes provides an effective tactic to protect these young shoots with minimal impact on many natural enemies (Qureshi and Stansly, 2010; Stansly et al., 2009a). Nevertheless, it may still be necessary to control both ACP and CLM during the growing season when all stages of both species are present. This would require products with multiple modes of action that can be used to control both pests and rotated to manage resistance. The objective of our experiments was to evaluate the efficacy of foliar applications of some experimental and registered insecticides, with or without adjuvants against ACP and CLM in mature citrus trees during growing season. We hypothesized that both registered and experimental insecticides will be effective in reducing psyllids and that adjuvants will enhance their performance.

Materials and Methods

Study location, trees and experimental design

The experimental block consisted of 16-year-old *Citrus sinensis* (L.) Osbeck 'Valencia' trees approximately 9–10 ft in height planted on double-row raised beds at a density of 326 trees/ha (132 trees/acre) at Southwest Florida Research and Education Center (SWFREC) in Immokalee, FL. Branches were pruned to induce new growth and encourage ACP and CLM infestation. Trees were irrigated by micro-sprinklers and subjected to conventional cultural practices (Jackson, 1999). Two separate experiments designed as randomized complete blocks were conducted.

First experiment

Eleven treatments and an untreated control were randomly distributed across 4 replicates in 3 rows, each separated by an untreated buffer row to minimize pesticide drift between treated trees. Each replicate contained 12 five-tree plots separated by an untreated buffer tree to avoid pesticide drift between plots within treated rows. Treatments included two experimental products, sulfoxaflor (Closer® 240 SC, Dow Agroscience, Indianapolis, IN, 2.85, 4.28, or 5.7 oz/acre) and flupyradifurone (Sivanto® 200 SL, Bayer CropScience Research, Triangle Park, NC, 10.5, 12 or 14 oz/acre), all applied with 435 Oil (horticultural spray oil, 2–3%). The 2.85 rate of Closer® 240 SC was also tested without adjuvant and the 14 oz/acre rate of Sivanto® 200 SL was also tested with Induce, a non-ionic surfactant. Fenpropathrin (Danitol® 2.4 EC, Valent USA, Walnut Creek, CA, 16 oz/acre), spinetoram (Delegate® 25 WG, Dow Agroscience, 4 oz/acre) and spirotetramat (Movento® MPC, Bayer CropScience, 16 oz/acre) were the registered products tested and all were applied with 435 Oil (2–3%). Treatments were applied on 16 June 2011 using a Durand Wayland AF100-32 air blast speed sprayer operating at 1.9 mph and 400 psi equipped with four John Beane Ceramics nozzles (#4, #4, #3 and #3) delivering 1122 L/ha (120 gal/acre). Evaluations were made at 5, 12, 19, 26, 33, and 40 days after treatment (DAT). Twelve randomly selected shoots per plot were collected and examined under a stereomicroscope in the laboratory to count ACP nymphs. Five of the 12 shoots were examined for CLM by checking three fully expanded leaves on each shoot under the microscope to count larvae. Density of ACP adults was estimated from three central trees in each five-tree plot by counting adults falling on a clipboard covered with a 22 × 28 cm (8½ × 11 inches) laminated white sheet held horizontally under randomly chosen branches, which were then struck three times with a length of PVC pipe to make a count for one "tap" sample (Qureshi and Stansly, 2007; Qureshi et al., 2009b). Four tap samples were conducted per tree. The first and last tree in the plot was avoided for sampling to further reduce any impact of pesticide drift.

Second experiment

Thirteen treatments and an untreated control were randomly distributed across 4 replicates in 4 rows separated by a buffer row. Measures taken to reduce impact of pesticide drift were similar to the first experiment. Each replicate contained 14 five-tree plots. Experimental treatments included *Chromobacterium substugae* (Marrone Bio Innovations, Davis, CA) MBI 203 DF1 (Grandevo™ dry formulation at 2, 3, or 4 lb/acre), MBI 203 F2 and F3 (flowable liquid formulation at 2 gal/acre), *Burkholderia* sp. (MBI 206 EP emulsified product at 2 gal/acre) all applied with the surfactant Hyper-Active (Helena Chemical Co., Collierville, TN, 0.125%) and insecticidal soap Mpede (Dow Agroscience, 2%) + vegetable oil Addit™ (Koppert Biological Systems, Berkel en Rodenrijs, The Netherlands, 0.5%). Registered products included fenpropathrin (Danitol® 2.4 EC, 16 oz/acre), thiamethoxam (Actara 25 WG Syngenta US Wilmington, DE, 5.5 oz/acre), abamectin + thiamethoxam (Agri-Flex® Syngenta US, 8.5 oz/acre) and naled (Dibrom® 8 E Amvac Chemical Corporation, Los Angeles, CA, 16 oz/acre) all applied with 435 Oil (2%); and thiamethoxam + chlorantraniliprole (Voliam Flexi®, Syngenta US, 7.5 oz/acre) and fenpyroximate (Portal®, 0.4 EC Nichino America Inc., Wilmington, DE, 32 oz/acre) applied alone. Treatments were applied on 22 Aug. 2011 using methods described for first experiment except that application volume of 2244 L/ha (240 gal/acre) was used for Mpede+Addit treatment and a second application of the MBI-203 DF1 and MBI-206 EP treatments made 14 d after first application on 5 Sept. Evaluations were made at 3, 10, 17, 24, and 31 DAT in reference to the first application using methods described for the first experiment except that 10 randomly selected shoots per plot were examined under a stereomicroscope in the laboratory to count ACP nymphs.

Statistical analysis

Data were log transformed to reduce heterogeneity of variances and subjected to ANOVA using the GLM procedure to evaluate treatment effects on ACP and CLM. Treatment means were separated using the Student–Newman–Keuls test, contingent on a significant treatment effect ($P = 0.05$) (SAS Institute, 2004). Actual means are presented.

Results

First experiment

All treatments reduced ACP nymphs compared to the untreated control through 33 DAT (Table 1). All treatments reduced adults compared to untreated control through 19 DAT except Movento MPC + 435 Oil at 12 DAT and Closer 240 SC applied at 2.85 oz without oil at 12 and 19 DAT and there was no significant difference among other treatments. At 19 DAT, no adults were observed in the samples from trees treated with the two higher rates of Closer 240 SC and Danitol 2.4 EC, all applied with 435 Oil (Table 1). No treatment was statistically different from the untreated control after 19 DAT although 13-fold fewer psyllids were observed in the trees treated with Danitol 2.4 EC 16 oz/acre + 435 Oil compared to untreated control at 40 DAT at which time

Table 1. Mean number of Asian citrus psyllid (ACP) nymphs per shoot and adults per tap sample in 16-year-old 'Valencia' orange trees that were untreated or treated with foliar sprays of insecticides on 16 June 2011 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment /formulation	Active ingredient	Rate (product per acre or % v/v)	ACP nymphs/shoot (days after treatment) 5	12	19	26	33	ACP adults/tap sample (days after treatment) 5	12	19	26	33	40
Control	Untreated		13.45 a	24.50 a	26.21 a	13.29 a	3.50 a	0.81 a	0.73 a	0.40 a	0.29 a	0.44 a	0.50 ab
Danitol 2.4 EC + 435 oil	Fenpropathrin + oil	16 oz + 2%	0.60 c	1.46 d	3.33 c	1.23 b	0.94 b	0.04 b	0.02 b	0.00 c	0.06 a	0.04 a	0.04 b
Delegate 25 WG + 435 oil	Spinetoram + oil	4 oz + 2%	1.06 c	2.33 cd	4.06 bc	5.56 b	1.25 b	0.04 b	0.06 b	0.08 bc	0.17 a	0.27 a	0.10 b
Closer 240 SC	Sulfoxaflor	2.85 oz	2.71 b	6.02 b	5.33 b	3.81 b	1.73 b	0.10 b	0.29 ab	0.42 ab	0.23 a	0.19 a	0.21 ab
Closer 240 SC + 435 oil	Sulfoxaflor + oil	2.85 oz + 2%	0.54 c	3.77 bcd	2.83 bc	4.13 b	0.75 b	0.00 b	0.23 b	0.02 c	0.21 a	0.31 a	0.25 ab
Closer 240 SC + 435 oil	Sulfoxaflor + oil	4.28 oz + 2%	0.02 c	2.35 d	1.08 c	0.90 b	0.48 b	0.13 b	0.10 b	0.00 c	0.13 a	0.06 a	0.08 b
Closer 240 SC + 435 oil	Sulfoxaflor + oil	5.7 oz + 2%	0.63 c	3.15 cd	3.98 bc	3.31 b	0.44 b	0.06 b	0.19 b	0.00 c	0.23 a	0.10 a	0.19 ab
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	10.5 oz + 3%	0.44 c	0.88 d	3.10 bc	1.92 b	0.60 b	0.04 b	0.04 b	0.02 c	0.02 a	0.08 a	0.10 b
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	12 oz + 3%	0.35 c	1.40 d	4.04 bc	2.60 b	1.02 b	0.17 b	0.19 b	0.04 c	0.06 a	0.10 a	0.10 b
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	14 oz + 3%	1.15 c	2.04 cd	4.71 bc	2.73 b	1.13 b	0.44 b	0.15 b	0.10 bc	0.21 a	0.48 a	0.15 ab
Sivanto 200 SL + Induce	Flupyradifurone + adjuvant	14 oz + 0.25%	0.52 c	0.81 d	3.83 bc	3.25 b	0.35 b	0.15 b	0.13 b	0.04 c	0.17 a	0.15 a	0.83 a
Movento MPC + 435 oil	Spirotetramat + oil	16.0 oz + 3%	1.52 c	6.92 bc	6.31 bc	5.46 b	0.56 b	0.29 b	0.29 ab	0.10 bc	0.17 a	0.08 a	0.21 ab

Means in a column followed by the same letter are not significantly different ($P > 0.05$).

reduction with other treatments averaged 6-fold or less (Table 1). Closer 240 SC at 2.85 oz/acre applied with 435 Oil provided more nymphal reduction compared to its application at the same rate without oil. Effects of Sivanto 200 SL 14 oz/acre applied with 435 Oil or Induce were similar. Significantly fewer CLM larvae compared to the control were observed at 5 DAT in treatments of Danitol 2.4 EC at 16 oz/acre, Delegate 25 WG at 4 oz/acre, Closer 240 SC at 2.85 or 4.28 oz/acre and Sivanto 200 SL at 12 oz/acre, all applied with 435 Oil and Sivanto 200 SL at 14 oz/acre applied with Induce, a non-ionic surfactant (Table 2). Only Delegate 25 WG + 435 Oil was still providing some control at 12 DAT although not statistically different from untreated control. No significant treatment effect was observed after 12 DAT and data are not presented.

Second experiment

All treatments reduced nymphs compared to the control through 24 DAT except MBI203 F3 2 gal/acre + Hyper-Active at 3 and 17 DAT and both Portal 0.4 EC 32 oz/acre and MBI203 F2 2 gal/acre + Hyper-Active at 24 DAT (Table 3). Most reduction was observed from Actara 25 WG 5.5 oz/acre + 435 Oil. MBI203 DF1 3 lbs/acre and MBI206 EP 2 gal/acre, both applied twice and with Hyper-Active provided more ACP suppression compared to all other MBI treatments and were equal in effectiveness to the other commonly used insecticides applied once. The MBI-203 DF and MBI-206 EP treatments applied twice provided more and longer protection compared to MBI203 F2 and F3 applied once (Table 3). Suppression of nymphs in response to Dibrom 8 E 16 oz/acre + 435 Oil and Mpede 2% + Addit 0.50% and other commonly used insecticides tested was similar. All treatments provided significant reduction in ACP adult numbers through 24 DAT (Table 3). No significant treatment effect was observed at 31 DAT. Significantly fewer CLM larvae compared to the untreated control were observed in all treatments at 3 DAT except Danitol 2.4 EC 16 oz/acre + 435 Oil and MBI applied with Hyper-Active (Table 4). Only Agri-Flex 8.5 oz/acre + 435 Oil and Voliam Flexi 7.5 oz/acre applied alone provided significant reduction in CLM larvae at 10 DAT (Table 4). No significant treatment effect was observed after 10 DAT and data not presented.

Discussion

The effectiveness of experimental products Closer 240 SC and Sivanto 200 SL against ACP was similar to registered and commonly used insecticides Danitol 2.4 EC, Delegate 25 WG and Movento, all applied with 435 Oil with suppression lasting for about 3 weeks. Only the 4.28 oz/acre rate of Closer 240 SC and the 10.5, 12 or 14 oz rates of Sivanto 200 SL were comparable to 16 oz/acre of Danitol 24 EC and 4 oz/acre of Delegate 25 WG. Sivanto 200 SL 14 oz/acre applied with 435 Oil or Induce provided similar effects. Sulfoxaflor (Closer 240 SC) belongs to class of sulfoximines reported to exhibit broad-spectrum efficacy against many sap-feeding insect pests, including aphids, whiteflies, hoppers, and lygus, with levels of activity that are comparable to

Table 2. Mean number of citrus leafminer (CLM) larvae per three leaves per shoot in 16-year-old 'Valencia' orange trees that were untreated or treated with foliar sprays of insecticides on 16 June 2011 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment /formulation	Active ingredient	Rate (product per acre or % v/v)	CLM larvae/3 leaves/shoot 5 DAT	CLM larvae/3 leaves/shoot 12 DAT
Control	Untreated		1.20 a[z]	1.60 ab
Danitol 2.4 EC + 435 oil	Fenpropathrin + oil	16 oz + 2%	0.00 c	0.95 ab
Delegate 25 WG + 435 oil	Spinetoram + oil	4 oz + 2%	0.00 c	0.20 b
Closer 240 SC	Sulfoxaflor	2.85 oz	0.45 abc	2.10 a
Closer 240 SC + 435 oil	Sulfoxaflor + oil	2.85 oz + 2%	0.20 bc	1.65 a
Closer 240 SC + 435 oil	Sulfoxaflor + oil	4.28 oz + 2%	0.20 bc	1.65 ab
Closer 240 SC + 435 oil	Sulfoxaflor + oil	5.7 oz + 2%	0.45 abc	1.35 ab
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	10.5 oz + 3%	0.55 abc	2.00 a
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	12 oz + 3%	0.05 c	1.45 ab
Sivanto 200 SL + 435 oil	Flupyradifurone + oil	14 oz + 3%	0.50 abc	1.30 ab
Sivanto 200 SL + Induce	Flupyradifurone + adjuvant	14 oz + 0.25%	0.25 bc	1.55 ab
Movento MPC + 435 oil	Spirotetramat + oil	16.0 oz + 3%	0.90 ab	0.95 ab

[z]Means in a column followed by the same letter are not significantly different ($P > 0.05$).

Table 3. Mean number of Asian citrus psyllid (ACP) nymphs per shoot and adults per tap sample in 16-year-old 'Valencia' orange trees that were untreated or treated with foliar sprays of insecticides on 22 Aug. 2011 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment /formulation	Active ingredient	Rate (product per acre or % v/v)	ACP nymphs/shoot (days after treatment) 3	10	17	24	ACP adults/tap sample (days after treatment) 3	10	17	24	31
Control	Untreated		7.88 a[z]	10.35 a	8.60 a	4.35 a	0.48 a	0.46 a	0.60 a	0.65 a	0.19 a
Danitol 2.4 EC + 435 oil	Fenpropathrin + oil	16 oz% + 2%	2.55 cd	0.70 ef	0.48 de	0.05 d	0.02 b	0.00 b	0.00 b	0.00 b	0.00 a
Actara 25 WG + 435 oil	Thiamethoxam + oil	5.5 oz + 2%	0.90 d	0.00 f	0.00 e	1.00 d	0.00 b	0.00 b	0.00 b	0.00 b	0.02 a
Agri-Flex + 435 oil	Abamectin + thiamethoxam + oil	8.5 oz + 2%	1.93 cd	0.00 f	0.35 e	1.34 bcd	0.00 b	0.00 b	0.00 b	0.00 b	0.00 a
Voliam Flexi	Thiamethoxam + chlorantraniliprole	7.5 oz	2.28 cd	0.00 f	0.13 e	0.28 d	0.00 b	0.00 b	0.00 b	0.00 b	0.00 a
Dibrom 8 E + 435 oil	Naled + oil	16 oz + 2%	1.33 cd	0.35 ef	1.80 cde	0.40 cd	0.00 b	0.02 b	0.20 b	0.00 b	0.00 a
Portal 0.4 EC	Fenpyroximate	32 oz	2.93 bc	1.75 cde	2.08 cde	2.80 abc	0.06 b	0.04 b	0.04 b	0.04 b	0.04 a
MBI203 DF1 + Hyper-Active	*Chromobacterium substugae*	2 lb + 0.125%	4.38 cd	7.30 bc	0.80 de	0.08 d	0.00 b	0.00 b	0.00 b	0.08 b	0.02 a
MBI203 DF1 + Hyper-Active	*C. substugae*	3 lb + 0.125%	1.55 cd	0.88 ef	1.05 de	0.72 cd	0.02 b	0.02 b	0.10 b	0.00 b	0.00 a
MBI203 DF1 + Hyper-Active	*C. substugae*	4 lb + 0.125%	1.70 cd	4.45 bcd	3.55 bc	0.90 bcd	0.25 b	0.21 b	0.04 b	0.10 b	0.00 a
MBI203 F2 + Hyper-Active	*C. substugae*	2 gal + 0.125%	2.64 cd	3.80 bc	2.28 cde	5.84 ab	0.21 b	0.25 b	0.27 b	0.15 b	0.33 a
MBI203 F3 + Hyper-Active	*C. substugae*	2 gal + 0.125%	5.18 ab	9.15 b	7.03 ab	1.43 bcd	0.17 b	0.04 b	0.06 b	0.04 b	0.02 a
MBI206 EP + Hyper-Active	*Burkholderia* sp.	2 gal + 0.125%	0.45 d	2.45 def	1.23 de	0.63 cd	0.02 b	0.00 b	0.00 b	0.00 b	0.00 a
Mpede + Addit	Soap + vegetable oil	2% + 0.50%	0.97 cd	1.23 def	0.95 de	0.23 d	0.02 b	0.02 b	0.02 b	0.00 b	0.00 a

[z]Means in a column followed by the same letter are not significantly different ($P > 0.05$).

Table 4. Mean number of citrus leafminer (CLM) larvae per three leaves per shoot in 16-year-old 'Valencia' orange trees that were untreated or treated with foliar sprays of insecticides on 22 Aug. 2011 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment /formulation	Active ingredient	Rate (product per acre or % v/v)	CLM larvae/3 leaves/shoot 3 DAT	10 DAT
Control	Untreated		2.14 b[z]	1.75 a
Danitol 2.4 EC + 435 oil	Fenpropathrin + oil	16 oz + 2%	2.00 b	2.05 a
Actara 25 WG + 435 oil	Thiamethoxam + oil	5.5 oz + 2%	0.16 c	2.05 a
Agri-Flex + 435 oil	Abamectin + thiamethoxam + oil	8.5 oz + 2%	0.00 c	0.05 b
Voliam Flexi	Thiamethoxam + chlorantraniliprole	7.5 oz	0.16 c	0.00 b
Dibrom 8 E + 435 oil	Naled + oil	16 oz + 2%	0.20 c	2.05 a
Portal 0.4 EC	Fenpyroximate	32 oz + 2%	0.20 c	1.95 a
MBI203 DF1 + Hyper-Active	*Chromobacterium substugae*	2 lbs + 0.125%	3.2 b	1.50 a
MBI203 DF1 + Hyper-Active	*C. substugae*	3 lbs + 0.125%	4.9 a	0.90 a
MBI203 DF1 + Hyper-Active	*C. substugae*	4 lbs + 0.125%	2.1 b	1.10 a
MBI203 F2 + Hyper-Active	*C. substugae*	2 gal + 0.125%	2.45 b	1.20 a
MBI203 F3 + Hyper-Active	*C. substugae*	2 gal + 0.125%	1.64 b	1.65 a
MBI206 EP + Hyper-Active	*Burkholderia* sp.	2 gal + 0.125%	2.40 b	1.70 a
Mpede + Addit	Soap + vegetable oil	2% + 0.50%	0.30 c	2.20 a

[z]Means in a column followed by the same letter are not significantly different ($P > 0.05$).

those of other classes of insecticides targeting sap-feeding insects, including the neonicotinoids (Zhu et al., 2011). Flupyradifurone (Sivanto 200 SL) represents a new chemical class of butenolide insecticides being developed to control a broad spectrum of sucking insects. Availability of these two products for use against ACP will extend the range of insecticides available to control this pest and opportunity to rotate with other products for resistance management.

Two applications of the bioinsecticide MBI 203 DF1 at 3lb/acre rate and MBI 206 EP at 2 gal/acre rate applied with Hyper-Active afforded protection from ACP similar to the single application of commonly used insecticides applied with or without 435 Oil with suppression lasting about 4 weeks. However, a single application of MBI 203 F2 or F3 was not comparable to two applications of MBI 203 DF1 or MBI 206 EP or single application of commonly used products applied with or without 435 Oil. This bioinsecticide might be useful to target psyllids particularly during growing season if proven to be less harmful to beneficial insects which colonize citrus trees when young shoots and citrus pests are common. It was also interesting to see that the Mpede + Addit, a combination of soap and vegetable oil was as effective as commonly used insecticides and two applications of MBI 203 DF1 and MBI 206 EP. It seems that increase in application volume to 2244 L/ha helped to enhance the effectiveness of this product compared to a volume of 608 L/ha tested in spring (Qureshi et al., 2011).

Addition of 435 Oil enhanced effectiveness of commonly used insecticides. This horticultural-spray oil by itself also affords protection from ACP and exerts less negative effects on beneficial insects compared to commonly used insecticides which provide long residual (Qureshi and Stansly, 2007; Qureshi et al., 2009a, 2010). Hall and Nguyen (2010) found 435 Oil, abamectin, fenpyroximate, and spirotetramat compatible with *Tamarixia radiata*, an ectoparasitoid of ACP, based on laboratory study of residual effects at 1–3 d after application. Frequent applications of oil during the growing season may be an option compatible with biological control to reduce both pests and insecticide use (McCoy, 1985; Qureshi and Stansly, 2009b).

Most treatments tested in these experiments provided only short duration suppression of CLM larvae lasting less than a week or a little longer with a few products such as Delegate, Agri-Flex and Voliam Flexi known to be more effective against CLM. Most contact insecticides do not impact CLM larvae which develop on growth that occurs after the application and not contacted by the insecticide solution. CLM is an important facilitator of citrus canker and its populations have increased in recent years, possibly in response to intensified use of insecticides to control ACP, which kill natural enemies of CLM and other citrus pests. Effective treatments in our experiments provided significant reduction in ACP lasting 3–4 weeks; however, magnitude and duration of control was much less than 6 months seen following foliar sprays of broad-spectrum insecticides directed at adults during dormant winter period when most mature trees are not producing new growth and beneficial insects are less common (Qureshi and Stansly, 2010; Stansly et al., 2009a). Therefore, growers are encouraged to suppress overwintering psyllids during the dormant winter period and rely on pest monitoring to treat groves (Stansly et al., 2009b) and relatively less harmful chemistries during the growing season. However, new chemistries with systemic action are required to enhance control of both ACP and CLM on young shoots.

Literature Cited

(FDACS–DPI) Florida Department of Agriculture and Consumer Services, Division of Plant Industries, 2008. Huanglongbing (HLB)/Citrus Greening Disease. Available from: http://www.doacs.state.fl.us/pi/chrp/greening/citrusgreening.html.

Gottwald, T.R., J.H. Graham, and T.S. Schubert. 2002. Citrus canker: The pathogen and its impact. Online. Plant Health Progress doi:10.1094/PHP-2002-0812-01-RV.

Halbert, S.E. and K.L. Manjunath. 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: A literature review

and assessment of risk in Florida. Florida Entomol. 87:330–353.
Hall, D.G. and L.G. Albrigo. 2007. Estimating the relative abundance of flush shoots in citrus with implications on monitoring insects associated with flush. HortScience. 42:364-368.
Hall, D.G. and Nguyen, R. 2010. Toxicity of pesticides to *Tamarixia radiata*, a parasitoid of the Asian citrus psyllid. BioControl 55:601-611.
Jackson, L.K., 1999. Citrus growing in Florida. Univ. Florida Press, Gainesville.
McCoy, C.W. 1985. Citrus: Current status of biological control in Florida. p. 481-499. In: M.A. Hoy, and D.C. Herzog (eds.). Biological control in agricultural IPM systems. Academic, Orlando, FL.
Qureshi, J.A. and P.A. Stansly. 2007. Integrated approaches for managing the Asian citrus psyllid *Diaphorina citri* (Homoptera: Psyllidae) in Florida. Proc. Fla. State Hort. Soc. 120:110–115.
Qureshi, J.A. and P.A. Stansly. 2009a. Insecticidal control of Asian citrus psyllid *Diaphorina citri* (Hemiptera: Psyllidae). Proc. Fla. State Hort. Soc. 122:172–175.
Qureshi, J.A. and P.A. Stansly. 2009b. Exclusion techniques reveal significant biotic mortality suffered by Asian citrus psyllid *Diaphorina citri* (Hemiptera: Psyllidae) populations in Florida citrus. Biol. Contr. 50:129–136.
Qureshi, J.A. and P.A. Stansly. 2010. Dormant season foliar sprays of broad-spectrum insecticides: An effective component of integrated management for *Diaphorina citri* (Hemiptera: Psyllidae) in citrus orchards. Crop Protection 29:860–866.
Qureshi, J.A., B. Kostyk, and P.A. Stansly. 2009a. Control of *Diaphorina citri* (Hemiptera: Psyllidae) with foliar and soil applied insecticides. Proc. Fla. State Hort. Soc. 122:189–193.
Qureshi, J.A., M.E. Rogers, D.G. Hall, and P.A. Stansly. 2009b. Incidence of invasive *Diaphorina citri* (Homoptera: Psyllidae) and its introduced parasitoid *Tamarixia radiata* (Hymenoptera: Eulophidae) in citrus groves of Florida. J. Econ. Entomol. 102:247–256.
Qureshi, J.A., B. Kostyk, and P.A. Stansly. 2010. Ground applications of foliar insecticides to 'Valencia' oranges for control of *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae). Proc. Fla. State Hort. Soc. 123:109–112.
Qureshi, J.A., B. Kostyk, and P.A. Stansly. 2011. Effectiveness of selective insecticides to control Asian citrus psyllid and citrus leafminer during leaf flushing. Proc. Fla. State Hort. Soc. 124:85–89.
Rogers, M.E. 2008. General pest management considerations. Citrus Ind. 89:12–17.
Rogers, M.E., P.A. Stansly, and L.L. Stelinski. 2008. Florida citrus pest management guide: Asian citrus psyllid and citrus leafminer. Entomol. Nematol. Dept., Fla. Coop. Ext. Serv., Inst. Food Agr. Sci., Univ. Fla., ENY-734. Available from: http://edis.ifas.ufl.edu/IN686.
SAS Institute. 2004. SAS for Windows, Version 9.1. SAS Inst., Cary, NC.
Stansly, P.A., H.A. Arevalo, M. Zekri, and R. Hamel. 2009a. Cooperative dormant spray program against Asian citrus psyllid in SW Florida. Citrus Ind. 90:14–15.
Stansly, P.A, J.A Qureshi, and H.A. Arevalo. 2009b. Why, when and how to monitor and manage Asian citrus psyllid. Citrus Ind. 90:24–26.
Zhu, Y., M.R. Loso, G.B. Watson, T.C. Sparks, R.B. Rogers, J.X. Huang, B.C. Gerwick, J.M. Babcock, D. Kelley, V.B. Hegde, B.M. Nugent, J.M. Renga, I. Denholm, K. Gorman, G.J. DeBoer, J. Hasler, T. Meade, and J.D. Thomas. 2011. Discovery and characterization of sulfoxaflor, a novel insecticide targeting sap-feeding pests. J. Agr. Food Chem. 59:2950–2957.