Control of *Diaphorina citri* (Hemiptera: Psyllidae) with Foliar and Soil-Applied Insecticides*

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The Asian citrus psyllid (ACP) *Diaphorina citri* damages new growth in citrus by feeding and vectors *Candidatus* Liberibacter asiaticus, a bacterium that causes "huanglongbing" or citrus greening disease. Therefore, reduction in psyllid populations is key to reducing spread of the disease. Several insecticides were evaluated for psyllid suppression in young and mature 'Valencia' orange trees. Drench applications of imidacloprid (Admire Pro and MANA AG 8412-094B at 14 and 16 oz per acre, respectively) and thiamethoxam (Platinum at 13.7 or 18.8 oz per acre) to 4-year-old trees in June significantly reduced psyllid population density for 3 months. Thiamethoxam tended to act more quickly compared with imidacloprid and the higher rate was more effective. Effects of foliar sprays with or without adjuvants targeted at new growth in mature trees were variable with products and rates and lasted from 2 to 4 weeks. The non-ionic surfactant Induce or "435 horticultural oil" were more effective adjuvants for spirotetramat (Movento) than methylated seed oil or the organo-silicone surfactant Kinetic. When present, more ladybeetles were seen on untreated trees compared to treated trees. Soil applied systemic insecticides provided much longer term ACP suppression than foliar applied materials during the growing season.

Diaphorina citri Kuwayama (Hemiptera: Psyllidae), the Asian citrus psyllid (ACP) vectors the bacterium *Candidatus* Liberibacter asiaticus, causal organism of "huanglongbing" (HLB) or citrus greening disease, a devastating disease of citrus worldwide. Therefore, it is an economically important insect pest of citrus in regions where this disease occurs (Halbert and Manjunath, 2004). ACP was detected in Florida in 1998 (Halbert, 1998) and HLB in 2005 (Halbert, 2005). Both pest and the disease are now established in Florida and have spread rapidly throughout the citrus growing region of the state (FDACS-DPI, 2008; Qureshi et al., 2009).

Chemical control is an important tool for suppressing psyllid populations. Only two systemic insecticides, imidacloprid and aldicarb, were allowed for use in Florida citrus when this study was conducted. Their application is subjected to rate and time restrictions. Imidacloprid is effective in small trees but can only be applied to a maximum of 0.56 $kg\cdot ha^{-1}$ per year. Aldicarb is allowed at the rate of 5.6 $kg\cdot ha^{-1}$ per year and may be effective in large trees, but is restricted for application only between 15 Nov. and 30 Apr. (Qureshi and Stansly, 2007, 2008; Rogers et al., 2008). Several broad spectrum insecticides are available for foliar applications during the dormant winter period, spring and summer (Rogers, 2008; Rogers et al., 2008; Stansly et al., 2009). However, if directed at new growth to target psyllid immatures these foliar sprays provide only short term protection and can negatively impact ladybeetles that in addition to psyllids, also attack several other insect pests in young shoots (Michaud, 2001, 2004; Qureshi and Stansly, 2007, 2009; Stansly and Qureshi, 2008). In this paper we present results from experiments conducted during the growing season to evaluate effectiveness of soil applied systemic insecticides in young trees and foliar applications in mature trees against *D. citri*. We also monitored populations of ladybeetles when present.

Materials and Methods

All experiments were conducted in the citrus orchard of the University of Florida Southwest Florida Research and Education Center (SWFREC) in Immokalee, FL and were designed as randomized complete blocks. Drench applications were evaluated in 4-year-old trees and foliar applications in 12-year-old trees, all sweet orange *Citrus sinensis* (L.) Osbeck 'Valencia' planted on double-row raised beds at a density of 132 trees per acre. Blocks containing experimental trees were irrigated by micro-sprinklers and otherwise subjected to conventional cultural practices (Jackson, 1999). The 4-year-old trees subjected to soil application were pruned approximately every 2 weeks with a hand-held trimmer to obtain a consistent supply of new growth for psyllid infestation and evaluation of systemic activity of the insecticides. The 12-year-old trees receiving foliar sprays were pruned approximately 2 weeks before treatment application with a tractor-mounted box blade mower to induce shoot growth and encourage psyllid infestation.

Drench applications

Four treatments and an untreated control (Table 1) were distributed across 4 replicates in 4 adjoining rows of 20 trees, each divided into 5 four-tree plots. Weeds, debris, and leaf litter were removed from beneath each tree prior to application. Treatments were applied on 13 June 2007 in 8 oz of solution as a drench to

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Table 1. Mean number of *Diaphorina citri* nymphs per shoot in 4-year-old 'Valencia' orange trees untreated or treated with a drench application of insecticides on 13 June 2007 at Southwest Florida Research and Education Center, Immokalee, FL.

	Rate amt	*Diaphorina citri* nymphs per shoot						
Treatment/formulation	form/acre	14 DAT	28 DAT	42 DAT	56 DAT	71 DAT	84 DAT	99 DAT
Untreated control	---	31.37 a[z]	15.65 a	67.25 a	87.75 a	26.51 a	17.06 a	32.00 a
Admire Pro 4.6 SC	14.0 oz	16.65 b	2.10 b	2.31 b	3.71 b	3.17 b	6.64 bc	12.44 b
Mana AG 8412-094B 4SC	16.0 oz	8.18 b	0.00 b	0.88 b	4.37 b	1.53 b	6.85 bc	10.74 b
Platinum 2EC	13.7 oz	0.01 c	0.05 b	1.64 b	10.37 b	2.08 b	14.26 ab	14.93 b
Platinum 2EC	18.8 oz	0.00 c	0.00 b	1.02 b	4.25 b	2.13 b	0.85 c	18.01 ab

[z]Means in a column followed by the same letter are not significantly different (*P* = 0.05, LSD).

bare soil within 18 inches of the trunk using an EZ-Dose® sprayer operating at a pressure of 45 PSI and a flow rate of 3.7 gpm. Evaluations were made every 13 to 15 d after treatment (DAT). Ten shoots on each of three trees per treatment were examined to record the number infested with psyllid eggs and nymphs. One infested shoot was collected and examined in the laboratory using a stereoscopic microscope to count eggs and nymphs. Adult psyllid density was estimated on each of the three trees by counting insects falling on a clipboard covered with an 8½ × 11 inch white paper sheet placed under randomly chosen branches which were then tapped 3 times with the hand (Qureshi and Stansly 2007).

Foliar applications

Experiment 1. Eleven treatments and an untreated control (Table 3) were randomly distributed across 4 replicates in 23 rows that included a buffer row after every treated row. Each replicate contained 3 treated rows of 20 trees divided into four 5-tree plots. Treatments were applied on 4 June 2007 to the bed side of the trees using a tractor mounted hydraulic sprayer operating at a pressure of 150 psi with an array of 12 ATR-80 ceramic hollow-cone nozzles directed at the tree on three 5-ft booms to deliver 54 gpa at a tractor speed of 1.5 mph. A pre-treatment sampling

Table 2. Mean number of *Diaphorina citri* adults per tap sample in 4-year-old 'Valencia' orange trees untreated or treated with a drench application of insecticides on 13 June 2007 at Southwest Florida Research and Education Center, Immokalee, FL.

	Rate amt	*Diaphorina citri* adults per tap sample						
Treatment/formulation	form/acre	14 DAT	28 DAT	42 DAT	56 DAT	71 DAT	84 DAT	99 DAT
Untreated control	---	0.80 a[z]	6.30 a	5.17 a	7.90 a	6.00 a	5.08 a	4.90 a
Admire Pro 4.6 SC	14.0 oz	0.80 a	0.17 b	0.17 b	0.50 bc	0.50 b	0.58 b	0.67 b
Mana AG 8412-094B 4SC	16.0 oz	0.00 b	0.00 b	0.42 b	1.16 b	1.17 b	0.42 b	0.75 b
Platinum 2EC	13.7 oz	0.00 b	0.00 b	0.08 b	0.92 bc	0.42 b	0.42 b	0.67 b
Platinum 2EC	18.8 oz	0.00 b	0.25 b	0.00 b	0.17 c	0.17 b	0.42 b	0.92 b

[z]Means in a column followed by the same letter are not significantly different (*P* = 0.05, LSD).

Table 3. Mean percentage of shoots infested with *Diaphorina citri* immatures, their density and rating per shoot, adults per tap sample, and lady-beetles per 1-min observation per tree in 12-year-old 'Valencia' orange trees untreated or treated with a foliar application of insecticides on 4 June 2007 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment/	Rate amt product/	Shoots infested with *D. citri* immature (%)		*D. citri* nymphs/ infested shoot			Infestation rating[z]	*D. citri* adults/ tap sample	Lady beetles (adults + larvae)/ 1 min observation/tree
formulation	acre or % v/v	7 DAT	49 DAT	3 DAT	14 DAT	24 DAT	7 DAT	14 DAT	49 DAT
Untreated control	---	92.5 a[y]	81.7 bc	16.9 a	28.5 a	2.3 bcd	3.9 a	1.4 a	0.6 a
Provado 1.6 F	10 fl oz	33.3 de	80.8 c	8.0 a	7.6 d	2.4 abcd	0.9 cd	0.5 bc	0.1 bc
Provado 1.6 F +Induce	5 fl oz + 0.25%	29.2 de	97.3 a	6.6 b	11.9 cd	2.6 abc	0.5 d	0.9 abc	0.1 bc
Provado 1.6 F + Induce	10 fl oz + 0.25%	21.7 e	91.7 abc	2.9 b	12.1 cd	2.7 ab	0.3 d	0.2 c	0.0 c
Movento 240SC + 435 Oil	10 fl oz + 2.5%	44.2 cd	79.8 c	2.5 b	10.2 cd	1.8 e	0.9 cd	0.9 abc	0.2 bc
Movento 240SC + MSO Seed Oil	10 fl oz + 0.25%	95.8 a	87.8 abc	5.3 b	25.9 ab	2.2 cd	1.9 bc	0.8 abc	0.3 ab
Movento 240SC + Induce	5 fl oz + 0.25%	87.0 a	89.8 abc	1.6 b	22.8 abc	2.1 de	1.4 cd	0.9 abc	0.1 bc
Movento 240SC + Induce	10 fl oz + 0.25%	76.2 ab	82.9 bc	6.8 b	12.5 cd	2.1 de	1.3 cd	1.1 ab	0.1 bc
Movento 240SC + Kinetic	10 fl oz + 0.10%	87.5 a	99.2 a	1.6 b	19.0 abcd	2.3 cd	2.8 ab	0.8 abc	0.0 c
Movento 240SC + Provado1.6F + Induce	5 fl oz + 5 fl oz + 0.25%	44.3 cd	90.8 abc	7.9 b	14.5 bcd	2.8 a	1.5 bcd	0.4 bc	0.2 bc
Movento 240SC + Provado 1.6F + Induce	10 fl oz + 5 fl oz + 0.25%	47.3 cd	82.8 bc	5.8 b	14.3 bcd	2.7 ab	0.8 cd	0.2 c	0.1 bc
Sevin XLR	48 fl oz	64.6 bc	94.8 ab	1.3 b	29.1 a	2.4 abcd	0.8 cd	0.3 c	0.2 bc

[z]ACP per shoot: 0 = none, 1 = eggs and first instars, 2 = second and third instars, 3 = fourth and fifth instars

[y]Means in a column followed by the same letter are not significantly different (*P* = 0.05, LSD).

Table 4. Mean percentage of shoots infested with *Diaphorina citri* immatures, their density and rating per shoot, adults per tap sample, and lady-beetles per 1-min observation per tree in 12-year-old 'Valencia' orange trees untreated or treated with a foliar application of insecticides on 22 June 2007 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment/	Rate amt	Shoots infested with *D. citri* immatures				*D. citri* nymphs/ infested shoot		Infestation rating/shoot[z]		
formulation	form/acre	3 DAT	10 DAT	17 DAT	24 DAT	3 DAT	10 DAT	10 DAT	17 DAT	24 DAT
Untreated control	---	81.7 abcd[y]	83.3 ab	46.7 abcd	86.1 a	57.5 ab	15.0 bcd	1.81 ab	0.63 abcd	1.32 abc
435 Oil	2 gal	93.3 ab	92.5 a	50.0 abc	85.8 a	64.3 a	23.0 abc	2.03 a	0.88 a	1.39 ab
Provado 1.6 F + 435 Oil	12 fl oz + 2 gal	31.7 g	59.2 cd	41.7 bcde	61.7 bcd	7.2 fg	16.7 bcd	0.83 ef	0.68 abc	0.87 cdef
Agri-Mek 0.15 EC + 435 Oil	10 fl oz + 2 gal	71.7 bcde	72.5 bcd	34.6 cde	61.3 bcd	34.5 bcd	22.2 abcd	1.26 cde	0.49 cde	0.83 def
Agri-Mek 0.15 EC + 435 Oil	20 fl oz + 2 gal	61.7 de	63.8 cd	57.6 ab	66.3 abcd	12.8 defg	19.3 abcd	1.01 def	0.88 a	1.08 abcd
MSR 2E	24 fl oz	65.8 cde	74.2 bc	34.8 cde	54.6 cd	27.3 def	13.9 bcd	1.28 cde	0.51 cde	0.73 def
MSR 2E	48 fl oz	54.2 ef	69.2 bcd	31.4 de	72.7 abc	23.6 defg	9.2 bcd	1.08 de	0.41 cde	0.92 cde
GF-1640 + 435 Oil	4 oz + 2 gal	50.8 efg	54.9 de	43.3 bcde	50.1 cd	7.8 fg	19.3 abcd	0.83 ef	0.64 abcd	0.58 ef
QRD 400 + 435 Oil	128 fl oz + 2 gal	86.9 abc	82.5 ab	60.8 a	65.9 abcd	37.1 bcd	21.6 abcd	1.39 bcd	0.83 ab	0.89 cdef
Actara 25WG	4 oz	62.5 de	68.3 bcd	41.7 bcde	68.0 abc	22.6 defg	34.7 a	0.98 def	0.58 bcde	0.93 bcde
Actara 25WG	5.5 oz	59.2 e	25.0 fg	28.3 e	43.4 d	0.7 g	6.5 cd	0.30 g	0.33 e	0.48 ef
Micromite 80WGS	6.25 oz	93.6 ab	84.2 ab	38.5 cde	81.7 ab	53.3 abc	25.4 ab	1.66 abc	0.54 cde	1.48 a
Portal 5 EC	64 fl oz	57.5 ef	73.3 bc	41.1 cde	80.0 ab	29.8 cdef	13.8 bcd	1.18 cde	0.57 bcde	0.93 bcde
Portal 5 EC + 435 Oil	64 fl oz + 2 gal	68.3 cde	39.2 ef	31.7 de	80.4 ab	32.8 bcde	6.2 d	0.54 fg	0.44 cde	1.14 abcd
MANA AG 8412-094B 4 SC	4.8 fl oz	36.1 fg	20.0 g	29.9 e	44.2 d	8.5 efg	5.9 d	0.27 g	0.38 de	0.44 f

Treatment/	Rate amt	*D. citri* adults/tap sample				Lady beetles/1-min
formulation	form/acre	3 DAT	10 DAT	17 DAT	24 DAT	observation/tree[x]
Untreated control	---	1.7 a	2.8 a	3.3 a	3.1 a	1.3 a
435 Oil	2 gal	1.8 a	2.2 a	3.1 a	2.6 abc	0.8 b
Provado 1.6 F + 435 Oil	12 fl oz + 2 gal	0.2 de	1.2 a	1.8 a	0.9 de	0.3 c
Agri-Mek 0.15 EC + 435 Oil	10 fl oz + 2 gal	1.3 ab	1.8 a	2.6 a	1.6 cde	0.4 bc
Agri-Mek 0.15 EC + 435 Oil	20 fl oz + 2 gal	0.5 cde	1.0 a	2.2 a	0.9 de	0.3 c
MSR 2E	24 fl oz	0.8 bcd	2.3 a	2.2 a	1.3 de	0.5 bc
MSR 2E	48 fl oz	0.8 bcd	0.7 a	1.1 a	1.8 bcde	0.2 c
GF-1640 + 435 Oil	4 oz + 2 gal	0.2 de	0.9 a	2.2 a	0.8 e	0.3 c
QRD 400 + 435 Oil	128 fl oz + 2 gal	1.3 ab	1.3 a	1.5 a	1.3 cde	0.6 bc
Actara 25WG	4 oz	0.4 cde	0.8 a	1.9 a	0.8 e	0.2 c
Actara 25WG	5.5 oz	0.0 e	1.2 a	1.0 a	2.2 abcd	0.3 c
Micromite 80WGS	6.25 oz	0.9 bc	2.3 a	1.3 a	2.9 ab	0.5 bc
Portal 5 EC	64 fl oz	0.3 cde	1.0 a	2.5 a	1.1 de	0.2 c
Portal 5 EC + 435 Oil	64 fl oz + 2 gal	0.3 cde	1.3 a	2.0 a	1.0 de	0.2 c
MANA AG 8412-094B 4 SC	4.8 fl oz	0.2 de	1.8 a	2.1 a	3.2 a	0.3 c

[z]ACP per shoot: 0 = none, 1 = eggs and first instars, 2 = second and third instars, 3 = fourth and fifth instars.
[y]Means in a column followed by the same letter are not significantly different ($P = 0.05$, LSD).
[x]Average of adults and larvae of all four species and sampling dates.

was conducted on 31 May and post-treatment evaluations were made 3, 7, 14, 24, and 49 DAT. One and three trees were observed per plot for pre and post-treatment samplings, respectively. Adult psyllid density was estimated on each tree using tap sample method described above. Ten randomly selected shoots were observed and the number infested with psyllid eggs or nymphs recorded. Infestation on each shoot was rated for the presence of psyllid stages on a 0 to 3 scale: 0 = none, 1 = eggs and first instars, 2 = second and third instars, 3 = fourth and fifth instars. One infested shoot of these was collected and examined in the laboratory under a stereoscopic microscope to count eggs and different instars of ACP. The number of larvae and adults of predatory coccinellids, *Curinus coeruleus* (Mulsant), *Olla v-nigrum* (Mulsant), *Harmonia axyridis* (Pallas) and *Cycloneda sanguinea* (L.) were recorded during 1-min observations of each tree.

Experiment 2. Fourteen treatments and an untreated control (Table 4) were randomly distributed across 4 replicates in 30 rows that included a buffer row between each treated row. Treated rows consisted of 20 trees divided into four plots of 5 trees each. Treatments were applied on 22 June 2007 to the bed side of the trees using a tractor mounted hydraulic sprayer operating at a pressure of 150 psi with an array of 15 ATR-80 ceramic hollow-cone nozzles directed at the tree on three 5-ft booms to deliver 66 gpa at a tractor speed of 1.5 mph. A pre-treatment sampling was conducted on 20 June and post-treatment evaluations were made 3, 10, 17, and 24 DAT. One and three trees were observed per plot for pre and post treatment samplings, respectively. Sampling for psyllids and ladybeetles was conducted according to the procedures described for experiment one.

Experiment 3. Eight treatments and an untreated control (Table 5) were randomly distributed across 4 replicates in 23 rows that included a buffer row after every treated row. Replicates contained 3 treated rows of 20 trees each divided into three plots of 6 trees. Treatments were applied on 25 Sept. 2007 to the swale side of the trees using a tractor mounted Durand Wayland 3P-10C-32 air blast speed sprayer with an array of five no. 5 T-Jet stainless steel

Table 5. Mean number of dead and live nymphs of *Diaphorina citri* per shoot, infestation rating, and adults per tap sample in 12-year-old 'Valencia' orange trees untreated or treated with a foliar application of insecticides on 25 Sept. 2007 at Southwest Florida Research and Education Center, Immokalee, FL.

Treatment/ formulation	Rate amt product/ acre or % v/v	Dead *D. citri* nymphs/shoot 3 DAT	Dead *D. citri* nymphs/shoot 7 DAT	Live *D. citri* nymphs/shoot 3 DAT	Live *D. citri* nymphs/shoot 7 DAT	Infestation rating[z]/shoot 3 DAT	Infestation rating[z]/shoot 7 DAT	Infestation rating[z]/shoot 14 DAT	*D. citri* adults/ tap sample 3 DAT	*D. citri* adults/ tap sample 7 DAT
Untreated control	---	0.0 c[y]	0.0 a	24.1 a	25.2 a	1.7 ab	2.1 bc	1.5 a	1.1 ab	1.4 a
Guava leaf extract	2%	0.0 c	0.0 a	19.6 ab	24.8 a	1.8 a	2.4 ab	1.6 a	1.4 a	1.1 ab
Danitol 2.4 EC + 435 Oil	21.3 fl oz + 3%	5.9 a	2.9 a	3.1 e	2.9 b	0.9 c	1.2 d	1.0 b	0.2 c	0.0 d
Vydate 2L	32 fl oz	5.6 a	0.8 a	10.1 cde	10.2 b	1.0 c	1.4 d	1.3 ab	0.4 bc	0.3 cd
Vydate 2L	64 fl oz	4.6 a	0.2 a	6.6 de	7.4 b	1.0 c	1.3 d	1.5 a	0.3 c	0.4 bcd
QRD 416	96 fl oz	0.0 c	0.3 a	12.3 bcd	20.7 a	1.6 ab	1.9 c	1.6 a	0.8 abc	0.6 bcd
QRD 416 + 435 Oil	96 fl oz + 3%	3.5 ab	1.0 a	10.6 cde	7.2 b	1.0 c	1.2 d	1.2 ab	0.4 bc	0.5 bcd
QRD 416	192 fl oz	0.7 bc	0.0 a	23.5 a	21.5 a	1.6 ab	2.5 a	1.6 a	0.1 ab	0.8 abc
QRD 400	192 fl oz	0.1 c	0.0 a	16.2 abc	28.9 a	1.4 b	2.1 c	1.5 a	0.8 abc	1.1 ab

[z]0 = none, 1 = eggs and first instars, 2 = second and third instars, 3 = fourth and fifth instars.
[y]Means within columns followed by the same letter are not significantly different ($P = 0.05$, LSD).

cone nozzles per side operating in low range first gear at 1500 rpm delivering 200 gpa. A pre-treatment sampling was conducted on 24 Sept. and post-treatment evaluations were made 3, 7, 14, and 21 DAT. Sampling for psyllids and ladybeetles was conducted according to the procedures described for experiment one except that both dead and live nymphs were counted on shoots observed under microscope.

Data analysis. Data were subjected to ANOVA to evaluate treatment effects on ACP, and lady beetles and means were separated using LSD contingent on a significant treatment effect ($P = 0.05$). Numbers of lady beetles were combined and transformed by log(x+1) prior to analysis. (SAS Institute, 2004).

Results

Drench applications

No ACP nymphs were seen on plants treated with the high rate of Platinum at 14 DAT, although not different from the plants treated with low rate of Platinum, and both rates performed better than the Admire Pro and Mana AG 8412-094B treatments (Table 1). ACP nymphs per shoot on the Mana AG 8412-094B treated trees was not significantly different from trees treated with Admire Pro. All treatments significantly reduced nymphs compared to the untreated control through 71 DAT with no differences among treatments. Significantly fewer nymphs compared to the untreated control were also seen at 84 DAT in all treatments except the low rate of Platinum. At 99 DAT, all treatments except the high rate of Platinum resulted in significantly fewer nymphs compared to untreated control with no differences among treatments. All treatments significantly reduced ACP adult numbers per tap sample compared to the untreated control through 99 DAT except for Admire Pro at 14 DAT (Table 2). There were no differences among treatments on all dates except at 56 DAT, when the high rate of Platinum was significantly better than Mana AG 8412-094B. In summary, Platinum tended to act more quickly particularly against nymphs, presumably due to its greater solubility. However, this greater solubility did not seem to compromise residual control at the rates tested.

Foliar applications

Experiment 1. A mean of 17% psyllid-infested shoots and 0.65 adult ACP per tap were seen at 3 DAT with no significant treatment effects. At 7 DAT, lowest % shoot infestation was seen with Provado alone or in combination with Induce, followed by Movento in combination with Provado and Induce (Table 3). No treatment effect on shoot infestation was seen at 49 DAT. Fewer ACP nymphs were seen on infested flush from treated trees at 3 DAT compared to the control except for the high rate of Provado alone (Table 3). Provado alone or in combination with Induce, and the high rate of Movento with 435 Oil or Induce reduced most nymphs compared to the control at 14 DAT. Nymphal density was low at 24 DAT, and only Movento with 435 Oil had significantly fewer than the control. Infestation rating in all treatments except Movento with Kinetic was significantly reduced compared to control at 7 DAT. Adult numbers were significantly reduced compared to the control by the high rate of Provado alone or with Induce, Movento with Provado and Induce, and Sevin. Induce and 435 Oil were more effective adjuvants for Movento than methylated seed oil (MSO) or Kinetic.

It is unlikely that predation from ladybeetles affected any of the results as no treatment effects on these predators were noted before 49 DAT when more were seen on untreated trees than all other treatments except Movento + MSO Oil (Table 3). No ladybeetles were seen in treatments with the high rate of Provado + Induce and the high rate of Movento + Kinetic.

Experiment 2. Greatest reduction in percentage shoots infested with ACP compared to the untreated control over the 3 to 24 DAT interval were provided by Provado + 435 Oil, MANA 8412-094B, GF-1640 + 435 Oil, and the high rate of Actara (Table 4). These treatments and the high rate of Agri-Mek with 435 Oil reduced nymphal densities during 3 to 10 DAT. The high rate of Actara and MANA 8412-094B reduced the infestation rating through 24 DAT, whereas Provado, Agri-Mek + 435 Oil, GF-1640 + 435 Oil, and Portal did so from 10 to 17 DAT. All treatments except 435 Oil and the low rate of Agri-Mek significantly reduced adult numbers compared to the untreated control at 3 DAT, although most reduction was seen with the high rate of Actara (no adults), followed by Provado + 435 Oil, GF-1640 + 435 Oil, MANA 8412-094B, Portal with or without 435 Oil, and the high rate of Agri-Mek + 435 Oil. There were no treatment effects at 10 and 17 DAT although significant reduction in adult numbers was seen at 24 DAT in treatments with Provado, Agri-Mek, MSR, GF-1640, QRD 400, low rate of Actara, and Portal.

All treatments reduced the number of lady beetles observed compared to the untreated control (Table 4). The activity of ladybeetles on untreated trees may explain the relatively low number of psyllids seen there and thus the lack of significant differences among many of the treatments later in the trial.

Experiment 3. Most nymphal ACP mortality (Table 5) was seen from Danitol + 435 Oil at 3 DAT, although not different from both rates of Vydate and the low rate of QRD 416 with 435 Oil. At 7 DAT, the number of dead nymphs was still high in the Danitol + 435 Oil treatment, although not significantly different from other treatments or the untreated control. Fewest live nymphs per shoot were seen with Danitol + 435 Oil at both 3 and 7 DAT, though not different from both rates of Vydate or the low rate of QTD 416 alone or with 435 Oil. Similar patterns were seen with infestation rating. Only the same treatments minus the low rate of Vydate showed significant effects on adults at 3 DAT although all but the two QRD treatments alone and guava leaf extract were significantly lower than the control at 7 DAT. No significant effects were seen with the guava leaf extract on any day by any criterion. There was no treatment effect on ACP after dates reported.

Discussion

The systemic neo-nicotinoid insecticides imidacloprid and thiamethoxam suppressed both adult and nymphal populations of ACP for 3 months after application. Thiamethoxam appeared to be taken up a little more quickly than imidacloprid, but provided the same length of control, even though the amount of active ingredient was less, 0.21 and 0.29 lb (a.i.)/acre compared to 0.5 lb (a.i.)/acre imidacloprid. While the rapid uptake of thiamethoxam may be attributed to its greater water solubility (4100 ppm) compared to imidacloprid (510 ppm), its activity is probably due to rapid metabolism in both plants and insects to the active moiety clothianidin, which is less soluble (300 ppm) than imidacloprid (Nauen et al., 2003).

Imidacloprid was much less effective when applied as a foliar treatment compared to a soil drench. Control was short-lived and similar to foliar applied thiamethoxam. The activity of imidacloprid sprays was not enhanced by non-ionic surfactants. The systemic lipid synthesis inhibitor spirotetramat provided control of ACP nymphs for up to 24 DAT and seemed to work better with the addition of horticultural mineral oil. However, it provided little control of adults. All foliar applications reduced numbers of ladybeetle species known to feed on ACP and suppress their populations.

Given limited effectiveness, short residual and negative impact on predaceous ladybeetles, there appeared to be little benefit to foliar applications of insecticides against ACP, at least as indicated by these small plot studies. In contrast, soil applications of neo-nicotinoids provided long term suppression of ACP. Unfortunately the use of these materials is limited by label restrictions to amounts that are insufficient to provide season-long control except in very small trees. Nevertheless, this use is critical to bring small trees into production. Given the limited effectiveness of these same materials when applied as sprays to the foliage, good resistance management practices would dictate they not be used in this manner.

While foliar applications on young growing shoots provided limited control at best, sprays of broad spectrum insecticides during the winter dormant season suppressed ACP populations for up to 6 months with no discernable impact on predaceous ladybeetles (Qureshi and Stansly, 2010). Therefore, it would seem plausible to utilize dormant sprays and soil applied systemic insecticides to their maximum advantage. Additional sprays that might be needed as indicated by monitoring of the adult psyllid population would probably be more effective if applied during times of minimum foliar flushing.

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