Control of the Asian Citrus Psyllid, *Diaphorina citri* Kuwayama, with Ground and Aerial Application of Selected Insecticides

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The Asian citrus psyllid, (ACP) *Diaphorina citri* Kuwayama, is subject to intense insecticidal control in Florida due to its role in the spread of greening disease or huanglongbing. Aerial application is a rapid and efficient way to deploy insecticides, although, effectiveness against ACP compared to ground application has not been sufficiently evaluated. Aerial and ground insecticide applications were made in designated plots covering 154 acres of 'Valencia' x 'Carrizo' oranges in southwest Florida. Ground applications were conducted with an airblast sprayer at 125 gal/acre and aerial applications were conducted with a fixed-wing aircraft at 10 gal/acre. We used tap samples to evaluate adult psyllid populations in the field. The broad-spectrum insecticides fenpropathrin (Danitol) and phosmet (Imidan) functioned well after application by air and their efficacy was not improved by adjuvants. In contrast, the more selective insecticides spinetoram (Delegate), and imidacloprid (Provado) provided little control when applied by air but performed satisfactorily by ground application. Control with spinetoram seemed to be improved by the addition of 435 oil.

Efficient management of the Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama, has become one of the major priorities of the citrus industry in Florida and elsewhere. The Asian citrus psyllid is associated with the transmission of huanglongbing (HLB), considered by most researchers and producers as the most important disease of citrus in the world (Bove, 2006; Halbert and Manjunath, 2004; Yasuda, 2006). As a result, the psyllid has been the subject of intense insecticidal control where the disease is present, including Brazil and Florida. In addition to soil applied systemic insecticides such as aldicarb or imidacloprid, the efficacy of foliar applications using broad spectrum and selective insecticides has been intensively studied (Mannion and Pena, 2007; Qureshi and Stansly, 2007a, 2007b, 2008; Stansly et al., 2007a, 2007b, 2008a, 2008b).

Despite the importance and the resources invested in the management of this insect vector, we cannot find published studies comparing aerial and standard ground applications. Contrasting the effectiveness of these application techniques could give citrus growers the data needed to make informed decisions balancing the cost-benefit of an application. Our objective was to compare two of the most common methods of application available to growers: low-volume aerial applications using a fixed-wing aircraft and conventional ground applications using an air-blast "speed" sprayer to manage ACP populations in the field.

Materials and Methods

Two contiguous 31.16-ha (77 acre) blocks of 'Valencia' orange on 'Carrizo' citrange rootstock planted on double-row raised beds at 4.5 × 6.7 m (15 × 22 ft) spacing for a total of 151 trees per acre located in Collier County, FL, were selected to conduct a trial to evaluate the effectiveness of a group of selected insecticides using air or ground applications (Table 1). Twenty randomly selected trees in each plot were sampled in two locations using a "tap" sample whereby adult psyllids were counted from a letter-size laminated white sheet of paper after a branch above the paper was hit three times using a PVC tube (Arevalo et al., 2009; Qureshi and Stansly, 2007b). Samples were taken on the bed side of center rows of each plot to reduce border effects. Pre-treatment samples were collected in all plots on 13 June 2008 and post-treatment evaluations were conducted on 19, 23, and 30 June; and on 7 and 15 July 2008.

Aerial treatments. Aerial applications were made on 16 June 2008 using an AirTractor AT802 (AirTractor, Oney, TX), flying at 257.5 $Km \cdot h^{-1}$ (160 mph), 3 m (10 ft) above the canopy producing a 24.4-m (80 ft) application swath. The airplane had 15 adjustable CT nozzles and was operating at 344 KPa (50 psi) pump pressure to apply 94.3 $L \cdot ha^{-1}$ (10 gal/acre). Plots were 4.8 ha (12 acre), each 10 beds wide. We sampled 10 trees, 20 samples per treatment in each plot, toward the center of the two middle beds (beds 5 and 6), to reduce border effects on either direction. Each randomly selected tree was tap-sampled in two locations and the total number of adult psyllids per tap was recorded. Details on rates and adjuvants are included in Table 1.

Ground treatments. Ground spray treatments were applied the same day to 1.5-ha (3.8 acre) plots. Applications were made using an Air-O-Fan air blast sprayer [Air-O-Fan, Reedley, CA], with 18 nozzles (nine on each side) operating at 1032 KPa (150 psi) at 3.2 $Km \cdot h^{-1}$ (2 mph) to apply 1182 $L \cdot ha^{-1}$ (125 gal/acre) using the swale and bed side of the row. Plots were three beds wide and samples from 20 trees were collected in the middle bed following the same procedures described above.

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Table 1. Treatment details for the insecticides used for the aerial or ground application comparison trial.

Insecticide	a.i.	Type of application	Rate (oz/acre)
Control	Untreated		
Danitol 4EC	Fenpropathrin	Aerial	16
Danitol 4EC + Joint Venture	Fenpropathrin + adjuvant	Aerial	16 + 8
Delegate WG	Spinetoram	Aerial and ground	4
Delegate WG + 435 Oil	Spinetoram + oil	Aerial and ground	4 + 1 gal/acre
Imidan 70W + 435 Oil	Phosmet	Aerial and ground	16 + 1 gal/acre
Imidan 70W + 435 Oil	Phosmet	Aerial and ground	24 + 1 gal/acre
Micromite 80WGS + Mustang Max	Diflubenzuron + zeta-cypermethrin	Aerial	6.25 + 4.3
Mustang Max	Zeta-cypermethrin	Aerial	4.3
Mustang Max + Joint Venture	Carboxilate + adjuvant	Aerial	4.3 + 8
Provado 1,6F + Joint Venture	Imidacloprid + adjuvant	Aerial and ground	16 + 8

Table 2. Mean number of adult Asian citrus psyllid per tap-sample for one pre-application evaluation (13 June 2008) and five post-application evaluations. The last column contains the mean adult ACP captured over the 5 weeks.

Type of application / treatment	Pre-application 13 June	19 June	23 June	30 June	7 July	15 July	Post-application mean
None							
Control	3.54 ± 0.22	21.7 ± 2.99	9.70 ± 1.2	3.40 ± 0.54	2.60 ± 0.44	2.10 ± 0.27	7.90 ± 3.71
Aerial							
Fenpropathrin	1.80 ± 0.38	0.90 ± 0.35	0.25 ± 0.12	0.50 ± 0.19	0.20 ± 0.09	0.25 ± 0.09	0.42 ± 0.13
Fenpropathrin + Joint Venture	0.75 ± 0.23	0.65 ± 0.16	0.10 ± 0.06	0.95 ± 0.43	1.05 ± 0.35	0.10 ± 0.10	0.57 ± 0.20
Spinetoram	6.25 ± 0.65	8.00 ± 1.41	5.05 ± 0.68	2.65 ± 0.50	4.80 ± 0.73	2.25 ± 0.31	4.55 ± 1.02
Spinetoram +435 Oil	9.05 ± 1.52	5.95 ± 1.38	3.30 ± 0.51	1.55 ± 0.34	1.15 ± 0.26	0.85 ± 0.18	2.56 ± 0.94
Phomet 16 oz/acre +435 Oil	1.75 ± 0.33	0.85 ± 0.23	0.50 ± 0.25	0.45 ± 0.17	0.70 ± 0.27	0.30 ± 0.12	0.56 ± 0.09
Phomet 24 oz/acre +435 Oil	1.10 ± 0.31	0.25 ± 0.12	0.65 ± 0.23	0.40 ± 0.18	0.50 ± 0.15	0.40 ± 0.16	0.44 ± 0.06
Diflubenzuron + zeta-cypermethrin	2.65 ± 0.95	3.05 ± 0.64	6.05 ± 1.50	0.95 ± 0.31	0.40 ± 0.15	0.50 ± 0.13	2.19 ± 1.07
Zeta-cypermethrin	3.75 ± 0.71	5.85 ± 0.64	6.95 ± 1.67	1.95 ± 0.46	1.00 ± 0.25	0.70 ± 0.20	3.29 ± 1.29
Zeta-cypermethrin + Joint Venture	3.00 ± 0.62	2.60 ± 0.44	2.25 ± 0.58	1.75 ± 0.45	0.80 ± 0.20	0.30 ± 0.16	1.54 ± 0.43
Imidacloprid + Joint Venture	1.50 ± 0.35	3.55 ± 0.77	2.85 ± 0.56	2.20 ± 0.59	2.55 ± 0.53	1.30 ± 0.30	2.49 ± 0.37
Ground							
Spinetoram	2.60 ± 0.54	0.30 ± 0.14	0.70 ± 0.21	1.30 ± 0.32	1.20 ± 0.25	1.00 ± 0.29	0.90 ± 0.18
Spinetoram +435 Oil	6.25 ±1.19	0.00 ± 0.00	0.25 ± 0.20	0.05 ± 0.05	0.05 ± 0.05	0.05 ± 0.05	0.08 ± 0.04
Phomet 1 oz/acre +435 Oil	2.55 ± 0.73	0.10 ± 0.10	0.10 ± 0.01	0.00 ± 0.00	0.05 ± 0.05	0.25 ± 0.09	0.16 ± 0.04
Phomet 1.5 oz/acre +435 Oil	9.50 ± 1.34	0.20 ± 0.15	0.20 ± 0.11	0.10 ± 0.06	0.00 ± 0.00	0.10 ± 0.06	0.06 ± 0.02
Imidacloprid + Joint Venture	2.35 ± 0.73	0.40 ± 0.13	0.60 ± 0.22	0.45 ± 0.18	0.30 ± 0.12	0.60 ± 0.22	0.47 ± 0.06

Results and Discussion

Good control was observed with all ground applications during the first month after the application (Table 2). Aerial applications of broad-spectrum insecticides such as phosmet and fenpropathrin were also effective at maintaining low populations following aerial application of insecticides. The addition of an adjuvant did not seem to improve the efficacy of these broad-spectrum insecticides when applied by air. ACP populations on trees treated with spinetoram, diflubenzuron, zeta-cypermetrin, and imidacloprid were similar to the untreated control, while zeta-cypermetrin, when mixed with Joint Venture (Helena Chemicals) as adjuvant, appeared to provide some suppression when compared with the untreated plot. Of the ground applications, phosmet, independent of rate, and spinetoram when combined with oil were the insecticides that maintained the lowest populations during the trial. Spinetoram and imidacloprid sprayed by ground maintained lower ACP populations than the untreated plots and than these same insecticides sprayed by air.

Cost and speed are factors that need to be considered when weighing advantages and disadvantages of different types of application. The cost of aerial applications varies depending on volume applied and distance to a landing strip for refilling. In the Immokalee area, typical cost for an application at 94.3 L·ha^{-1} (10 gal/acre) using a fixed wing aircraft is about $8.00 per acre and between 200 and 300 acres can be sprayed in 1 h. Costs of ground applications were estimated for southwestern Florida in 2007 at $32.50/acre (Muraro, 2008). At 1.5 mph and a typical 22-ft-wide swath (spraying both middles and swales), a ground spray machine will only spray about 4 acres per hour, 32 acres per day. Thus, a professional low-volume application by air is less than one-fourth the cost and 10 times faster than a conventional ground application.

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