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Spray Droplet Size Affects Efficacy of Fenpropathrin Against Asian Citrus Psyllid

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ABSTRACT: In a laboratory investigation, the effect of spray droplet size on the mortality of three life stages (eggs, nymphs, and adults) of the Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama, was determined. Six spray droplets of nearly uniform size (diameter) ($\bar{D}_{10} = 40.5$, 52.0, 101.5, 147.9, 174.0, and 264.7 μm) of fenpropathrin, a synthetic pyrethroid, were generated using a piezo-electric droplet generator. The formulation active ingredient (AI) was applied at spray delivery rates of 0.38 or 0.58 mg AI/min (168.9 and 253.4 g AI/ha), which were equivalent to 1/2 and 3/4 of the recommended field rates, respectively. The desired rates were achieved by moving the target plants across the spray stream at speeds of 7.2 or 27.2 cm/s. These operating parameters resulted in a high droplet density of 81.3 to 327.2 droplets/cm^2 and a low droplet density of 20.8 to 130.7 droplets/cm^2. The ACP populations were counted at 3 and 7 days after spray (DAS). In general, the percent mortality of ACP eggs, nymphs, and adults decreased at 3 and 7 DAS as the droplet size increased, regardless of the spray discharge rate or droplet density. Smaller droplet sizes (40.5 and 52.0 μm) resulted in significantly greater ACP mortality than the remaining droplet sizes, with few exceptions. The intermediate droplet sizes (101.5 and 147.9 μm) resulted in ACP mortalities ranging from 40 % to 92 %, and larger droplets (174.0 and

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264.7 μm) resulted in the lowest mortality at both droplet densities. These laboratory results suggest that field applications of fenpropathrin with smaller droplet sizes might be more effective against ACP than applications with larger droplets.

KEYWORDS: *Diaphorina citri*, droplet density, low volume spray, synthetic pyrethroid, uniform droplet generator

Introduction

The Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), is a vector of three bacterial species in the genus *Candidatus* Liberibacter that are the presumed causal agents of Huanglongbing disease in citrus [1–3]. Huanglongbing is the most destructive disease of citrus; infected citrus trees survive for only 5 to 10 years and bear fewer fruits, and those fruits are misshapen and bitter tasting [2]. Given the prevalence of the ACP throughout commercial citrus groves in Florida and its strong dispersal capabilities [4], the eradication of ACP is highly unlikely, and management efforts are focused on suppressing the insect's populations using six to eight foliar insecticide sprays per year [5,6]. Spray deposit characteristics such as droplet size, distribution, density, and concentration determine the effectiveness of insecticides against agricultural pests [7,8]. Spray droplet size is an important factor because it affects the amount of pesticide reaching the target and, in turn, the efficiency of spray applications [9,10]. Spray droplets that are too small might drift away from the target area, whereas droplets that are too large might run off the target surface. Therefore, pest control can be maximized with the optimal droplet size selection for a given pest and insecticide chemistry.

Omar et al. [11] reported that permethrin droplets sprayed onto brussels sprout leaves at a volume median diameter (VMD) of 36 μm resulted in greater mortality of second instar *Plutella xylostella* L. larvae than did 274 μm droplets. Furthermore, residues of permethrin sprayed as 80 μm droplets lasted longer and caused greater mortality of the larvae than did residues of 160 μm droplets [12]. They concluded that smaller droplets resulted in greater transfer of insecticide (in the form of deposited spray material) to the target pest. Similar findings were reported with deltamethrin and chlorpyrifos against *Myzus persicae* (Sulzer) and *Nebria brevicollis* [13] and with permethrin and lambda-cyhalothrin against *Trichoplusia ni* (Hübner) in topical bioassays [14]. In addition, the efficacy of abamectin against citrus rust mite (*Phyllocoptruta oleivora* (Ashmead)) decreased as the droplet size was decreased from 43.9 to 693.1 μm [15]. However, deposits made with smaller droplets were found to be more susceptible to rain washoff than deposits of larger droplets [16]. In some cases, for example, 337 μm VMD droplets of bifenthrin were more effective than 96 μm droplets against *H. virescens* [17]. These results suggest that droplet size effects are also target dependent.

The contradictory results obtained in the abovementioned studies suggest that the optimal spray droplet size varies with the insecticide, target, and method of application. Therefore, the relationship between the spray droplet size of an insecticide and the mortality of the target pest needs to be determined on a case-by-case basis. Furthermore, the influence of the insecticide dosage and other spray deposit characteristics such as droplet density, distribution, and concentration need to be determined in order to achieve optimal control of a target pest.

Currently, citrus growers in FL are showing keen interest in low volume applications of insecticides for ACP control because of the reduced cost of this application procedure [18]. Normally, low volume applicators generate smaller droplets than do conventional airblast sprayers. However, there is no information on the relationship between the droplet size and the efficacy of ACP control. Therefore, the present study was conducted using fenpropathrin in order to determine the effect of spray droplet size on the mortality of ACP life stages. In addition, the effects of the spray discharge rate and droplet density on the insecticide's efficacy against ACP were investigated.

Materials and Methods

Insect Culture and Insecticide

The ACP used in these experiments were from a greenhouse colony established by founders collected in 2005 from an orange grove near Lake Alfred, FL, and maintained since then without exposure to insecticides [19]. A synthetic pyrethroid, fenpropathrin (Danitol 2.4 EC, Valent USA Corporation, Walnut Creek, CA), recommended for ACP control in FL citrus and shown to be highly toxic to the adult insect [20], was selected for this study. The insecticide was tested at 168.9 and 253.4 g active ingredient (AI)/ha rates, which are equivalent to 1/2 and 3/4 of the label rates. It should be mentioned that the label rates specify the total amount of pesticide that can be discharged on a unit grove area, irrespective of the tree size or mode of application (one-sided or two-sided). In practice, the trees are normally sprayed from two sides to ensure thorough coverage. The reduced rates could minimize the chance of total pest knock-out and improve the sensitivity of the tests to the droplet size change. These application rates corresponded to spray discharges of 0.38 and 0.58 mg AI/min, respectively.

Droplet Generator

A modified vibrating orifice droplet generator (Model 3050, Thermo-Systems Inc., St. Paul, MN), described elsewhere [9], was used to generate spray streams made of six sizes of nearly uniform spray droplets. The procedure involved using six piezoelectric nozzles with orifice sizes of 10 to 150 μm at various combinations of the system operating parameters (Table 1). Insecticide solution was supplied from a pressurized tank to the nozzle head. A frequency generator (Model E

TABLE 1—*Details of parameters used in droplet generation.*

	Nozzle Orifice Size, μm					
Parameter	10	20	35	50	100	150
Jet break-up frequency, kHz	229.0	47.0	41.5	38.5	18.7	10.3
Spray flow rate, ml/min	0.057	0.153	0.509	0.97	2.42	5.45
Droplet charge, kV	4.0	4.4	3.6	1.4	2.1	2.5
Droplet size $\bar{D}_{10}$, μm[a]	40.5 ± 4.8	52.0 ± 5.2	101.5 ± 6.5	147.9 ± 11.1	174.0 ± 10.0	264.7 ± 9.1
Lower droplet density[b]	130.7 ± 9.3	118.6 ± 11.7	77.1 ± 9.3	69.2 ± 8.3	30.0 ± 3.7	20.8 ± 3.5
Higher droplet density[b]	327.2 ± 12.5	303.4 ± 10.9	209.9 ± 14.3	165.8 ± 11.7	123.1 ± 7.4	81.3 ± 10.8

[a]Length mean diameter (±SD).
[b]Mean number/cm^2 (±SD). Lower and higher droplet densities were achieved at target speeds of 27.2 and 7.2 cm/s, respectively.

310B, sine/square wave generator, B + K Precision Corp., Yorba Linda, CA) provided mechanical disturbances to the discharged liquid jet to break it up into uniform-sized droplets. For each orifice size, an appropriate combination of fluid flow rate and vibration frequency generated nearly uniform droplet sizes ranging from 40.5 ± 4.8 μm to 264.7 ± 9.1 μm in length mean diameter ($\bar{D}_{10}$) (Table 1). The optimum frequency was determined visually by trial and error using a strobe light (type 1531A Strobotac, Westbury, NY). The generated droplets were charged (up to 2000 V dc) in order to disperse them as a band in a controlled manner. A wind tunnel provided horizontal air transport of generated droplets toward the deposition targets (Fig. 1). The velocity of the wind carrying the droplets to the target (11.2 to 15.2 m/s) was adjusted for each orifice size. In addition, parameters such as nozzle head angle, distance of the target from the nozzle head, height of the nozzle head from the wind tunnel outlet, and height of the target with respect to the wind tunnel outlet were determined for each orifice size so as to obtain the optimal spray band width (to spray the plant foliage uniformly) for deposition onto the target.

Droplet Size and Density Measurement

In order to determine the size range of generated droplets, a sample of droplets was captured between two layers of high and low viscosity (60 000 and 100 mm^2/s) silicone oils (200 Fluid, Accumetric, Elizabethtown, KY), and the droplet diameter was measured under a stereomicroscope (Model XB 906, Bausch and Lomb Optical Co., Rochester, NY). For each orifice size, the mean diameter ($\bar{D}_{10}$) and standard deviation (SD) of ten droplets (in micrometers) were determined in three replications. Similarly, for each orifice and target

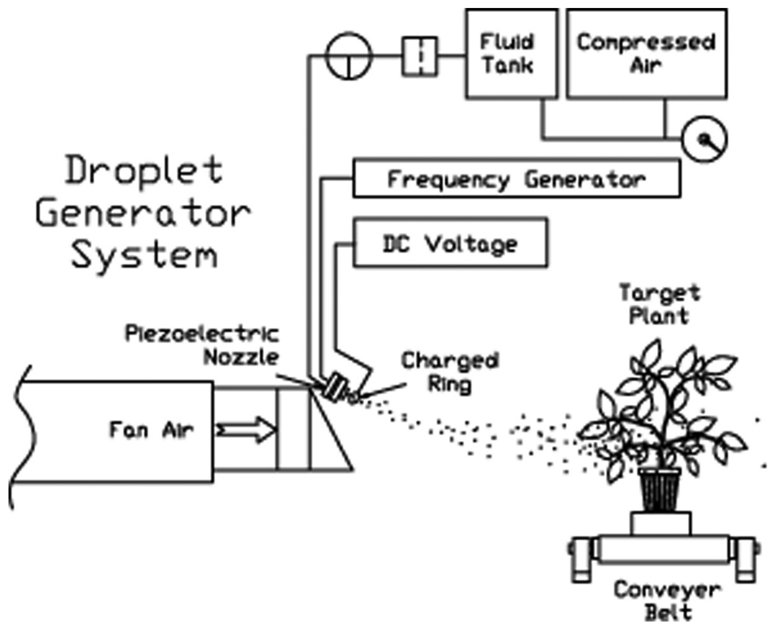

FIG. 1—*Schematic view of spray application onto a citrus tree target.*

speed, the mean (±SD) number of droplets within a 1 cm^2 area of sprayed water sensitive paper (WSP) targets (Spraying Systems Co., Wheaton, IL) was counted under the stereomicroscope. The generated droplet size and density data and their related information are listed in Table 1.

Spray Targets

Spray targets consisted of potted citrus plants (infested with ACP) and WSP. Citrus plants [Swingle variety, *Citrus aurantiifolia* (Christm.)] 15 to 20 cm in height were placed in a greenhouse that contained the ACP culture for infestation. After 10 to 15 days, plants containing eggs, nymphs, and adults were used in the experiments described below. This duration allowed the ACP present in the greenhouse to colonize the newly introduced potted citrus plants. WSP targets were used to check the droplet density and the uniformity of the droplet distribution during the experiment. A target holder was used to hold the WSP perpendicular to the droplet stream.

Experimental Design and Spray Procedure

In this study, four experiments were conducted at 1/2 (168.9 g AI/ha) or 3/4 (253.4 g AI/ha) of the recommended label rate of fenpropathrin (337.8 g AI/ha). Below label rates were tested in order to determine whether ACP mortality could be optimized by means of adjusting the droplet size.

In experiment 1, fenpropathrin was applied at a 168.9 g AI/ha rate to plants that were moving at 27.2 cm/s on a conveyer belt (Fig. 1). Starting with the 150 μm nozzle, 1 l of spray fluid was prepared by diluting 0.25 ml of fenpropathrin in tap water. Thereafter, the amount of insecticide in water was increased as the nozzle size decreased from 150 to 10 μm. This procedure allowed us to discharge the same amount (0.38 mg AI/min) of insecticide through different-sized nozzles. For this rate, droplet densities, corresponding to the largest to smallest droplet sizes, ranged from 20.8 to 130.7 droplets/cm^2 (Table 1).

In experiment 2, the target plants were moved at a speed of 7.2 cm/s (3.8 times slower than in experiment 1). Accordingly, the amount of insecticide in the solution was decreased 3.8-fold in order to deliver an amount of fenpropathrin onto target plants that was equivalent to that in experiment 1, but at a higher droplet density (81.3 to 327.2 droplets/cm^2) for each droplet size than in experiment 1 (Table 1).

Experiments 3 and 4 were conducted similarly by spraying fenpropathrin at a 253.4 g AI/ha rate, which was achieved by diluting 0.37 ml of fenpropathrin in 1 l of water for use with the 150 μm nozzle. Again, the target plants were moved through the spray on the conveyer belt at 7.2 or 27.2 cm/s, which resulted in the delivery of an equal amount of insecticide by different nozzle sizes per unit time, but at a higher rate (0.58 mg AI/min) than in experiments 1 and 2. Therefore, the above-described experimental design resulted in four combinations of spray discharge rate and droplet density:

(a) Lower rate at lower droplet density (0.38 mg AI/min and 20.8 to 130.7 droplets/cm^2)
(b) Lower rate at higher droplet density (0.38 mg AI/min and 81.3 to 327.2 droplets/cm^2)
(c) Higher rate at lower droplet density (0.58 mg AI/min and 20.8 to 130.7 droplets/cm^2)
(d) Higher rate at higher droplet density (0.58 mg AI/min and 81.3 to 327.2 droplets/cm^2).

Sprays were applied to both sides of plants in order to maximize coverage. Smaller orifice nozzles (10, 20, and 35 μm) produced a narrower band of spray (vertical); therefore, for these nozzle sizes, target plants were sprayed twice, aiming the spray at upper and then lower portions of each plant on both sides. WSP was placed vertically through the plant canopy to insure that there was no overlap between the upper and lower sprays. The insecticide concentration was reduced accordingly (halved) for 10, 20, and 35 μm orifice nozzles in order to maintain a constant amount of sprayed pesticide for all droplet sizes.

Four ACP-infested plants containing eggs, nymphs, and adults were sprayed for each treatment (nozzle size) in each experiment. Also, four unsprayed plants served as untreated controls. Sprayed WSP targets were transferred to plastic bags and sealed. Plant targets were covered individually with transparent plastic cage cylinders (made of plastic sheets with a cloth top for aeration) to prevent the escape of adult ACPs. Treated plants were placed in a greenhouse for 7 days at 27°C to 33°C and 60 % to 70 % relative humidity.

Observations and Statistical Analyses

The numbers of ACP eggs and nymphs present on three randomly selected newly expanded leaves were counted per plant using a 10× hand lens prior to treatment applications (pretreatment counts). Also, the total number of adult ACPs per plant was counted prior to spray application. Counts of all ACP life stages were taken identically at 3 and 7 days after spray (DAS) (i.e., post-treatment counts). Live eggs were differentiated from dead eggs by the paler color and collapsed appearance of non-viable eggs. Eclosed eggs were differentiated from non-viable/dead eggs based on color and the presence of an opening in the egg shell. Nymphs that emerged from eggs laid prior to treatment were included in subsequent nymphal counts. Likewise, any newly eclosed adult was counted as an adult. Although any post-treatment surviving adults or newly emerged adults could lay eggs, such potential subsequent egg deposition was not separated in day 3 and day 7 egg counts, nor were any nymphs that emerged from new oviposition separated in nymphal counts. Therefore, direct mortality was not measured for each stage; instead the counts reflect an overall reduction for each stage relative to the pre-treatment counts. A percent increase was calculated for control treatments. For treated plants, the data were converted to a percent reduction from pre-treatment counts for each life stage and arcsine transformed before being subjected to statistical analysis. A correlation analysis (PROC CORR) [21] was performed between the number of insects per target plant and the percent reduction in order to determine whether the reduction depended on the number of ACPs per target plant. Mean (±SEM; $n = 4$ to 8) percent reduction values were calculated for egg, nymph, and adult stages. Considering the spray discharge rate, droplet density, droplet size, and observation time as independent variables and the percent reduction as a dependent variable, a four-way analysis of variance (ANOVA) (PROC GLM) [21] was performed for significant interactions. The significant interactions of interest were further analyzed via one-way ANOVA, and treatment means were separated via Fisher's protected least significant difference (LSD) post hoc tests for means separation [22] at the $\alpha = 0.05$ significance level.

Results

Spray Droplet Distribution and Density

Visual assessment of the droplet density on WSP targets indicated that as the droplet size increased from 40.5 to 264.7 μm, the spacing among droplet specks increased, and larger droplets appeared to be more randomly distributed. At each target speed, larger droplets resulted in a lower droplet density than did the smaller droplets. The droplet density for different droplet sizes ranged from 81.3 to 327.2 droplets/cm^2 [high droplet density (HDD)] and from 20.8 to 130.7 droplets/cm^2 [low droplet density (LDD)] at target speeds of 7.2 cm/s and 27.2 cm/s, respectively (Table 1). Although there might have been some differences between spray droplet distributions on WSP targets and plant leaves, we assumed comparable distribution patterns on both surfaces. The mortality of eggs, nymphs, and adults on unsprayed plants (control) in different experiments ranged from 0 to 14.4 %. Correlation analysis of all treatments indicated a weak negative correlation (non-significant) between the number of insects per target plant and the percent reduction ($r = -0.11$; $P = 0.13$).

Effect of Spray Droplet Size

As the main objective of the study was to evaluate the effect of spray droplet size on the efficacy of ACP population reduction, significant interactions involving spray droplet size were chosen for further analysis. This was accomplished in such a way as to avoid repetition and maintain succinctness. Of the two significant three-factor interactions obtained, the interaction involving droplet density, droplet size, and observation time was considered the most relevant (Table 2). Given that there was no significant effect of the spray discharge rate in the three-way interaction, the reductions in the number of each life stage at each observation time and for each droplet size were combined for both spray discharge rates (0.38 and 0.58 mg AI/min), and significant differences due to droplet size were determined.

TABLE 2—*Details of the statistically significant interactions among the spray parameters tested.*

Variable	Level	
(A) Spray discharge rate, mg AI/min	0.38, 0.58	
(B) Spray droplet density, mean number of droplets/cm^2	20.8 to 130.7, 81.3 to 327.2	
(C) Spray droplet size $\bar{D}_{10}$, μm	40.5, 52.0, 101.5, 147.9, 174.0, 264.7	
(D) Post-treatment observation time (DAS)	3, 7	
Effect	Significance Level	
	$P < 0.0001$	$0.0001 < P < 0.05$
Main effects	(A), (B), (C), (D)	. . .
Two-factor interactions	(A × C), (B × D)	(B × C), (C × D)
Three-factor interactions	. . .	(A × B × D), (**B** × **C** × **D**)[a]

[a]The most relevant significant interaction is highlighted in bold.

Effect of Droplet Density

At LDDs (20.8 to 130.7 droplets/cm^2), the mortality of ACP eggs, nymphs, and adults generally decreased as the droplet size increased (Table 3). This was the case for both 3 and 7 DAS counts. Overall, the two smaller droplet sizes (40.5 and 52.0 μm) resulted in mortalities that were greater than those seen with the larger droplet sizes. At 7 DAS, we observed a greater percent reduction of all life stages than that seen at 3 DAS, and nearly complete mortality of egg and nymph stages for the two smaller droplet sizes.

When the plants were sprayed at HDDs (81.3 to 327.2 droplets/cm^2) (Table 4), there were generally higher egg, nymph, and adult ACP mortalities than observed with LDD sprays at 3 DAS (Table 3). Again, observed mortalities were negatively related to droplet size at both 3 and 7 DAS.

Discussion

The general trend of increased reduction of ACP life stages with decreased droplet size observed in the present study concurs with the findings of Salyani and McCoy [15], who reported that the mortality of citrus rust mite adults decreased as the spray droplet size of abamectin increased from 44 to 693 μm. Also, regardless of the droplet density and droplet size, the numerical reduction of ACP life stages was greater at 7 DAS than at 3 DAS (Tables 3 and 4).

TABLE 3—*Effect of fenpropathrin on ACP eggs, nymphs, and adults sprayed at densities of 20.8 to 130.7 droplets/cm^2.*[a]

	Mean Percent Reduction of ACP on Target Plants[b]					
		Eggs		Nymphs		Adults
Droplet Diameter $\bar{D}_{10}$, μm	3 DAS[c]	7 DAS	3 DAS	7 DAS	3 DAS	7 DAS
40.5	73.3 ± 7.0a	100.0 ± 0.0a	86.2 ± 5.8a	100.0 ± 0.0a	60.0 ± 4.1a	84.3 ± 5.2a
52.0	61.9 ± 7.2ab	98.3 ± 0.9ab	74.6 ± 5.4a	99.6 ± 0.4a	62.0 ± 6.1a	82.3 ± 4.4a
101.5	41.4 ± 7.3bc	90.0 ± 3.3bc	48.5 ± 10.4b	88.3 ± 5.5ab	49.6 ± 5.5ab	71.6 ± 6.2ab
147.9	49.3 ± 4.9abc	87.2 ± 3.6c	49.2 ± 6.4b	84.5 ± 7.2b	40.1 ± 6.6bc	64.1 ± 6.6bc
174.0	50.3 ± 8.4abc	77.9 ± 6.9cd	42.5 ± 8.8b	75.1 ± 9.2b	40.3 ± 6.3bc	53.7 ± 6.6c
264.7	37.7 ± 8.4c	63.9 ± 8.7d	33.2 ± 8.7b	78.1 ± 9.2b	32.7 ± 5.0c	49.8 ± 6.4c
F-statistic[d]	3.14	8.44	7.49	3.81	3.74	6.14
P value	0.017	<0.0001	<0.0001	0.006	0.007	0.0002

[a]Combined data for 0.38 and 0.58 mg AI/min spray discharge.
[b]Compared to pre-treatment counts.
[c]DAS = days after spray.
[d]Degrees of freedom = 5, 42. Means (±SEM; $n = 8$) not labeled by the same letter in a column are significantly different according to Fisher's protected LSD tests ($P < 0.05$).

TABLE 4—*Effect of fenpropathrin against ACP eggs, nymphs, and adults sprayed at a density of 81.3 to 327.2 droplets/cm^2.*[a]

	Mean Percent Reduction of ACP on Target Plants[b]					
	Eggs		Nymphs		Adults	
Droplet Diameter $\bar{D}_{10}$, μm	3 DAS[c]	7 DAS	3 DAS	7 DAS	3 DAS	7 DAS
40.5	99.1 ± 0.9a	99.3 ± 0.7a	98.1 ± 1.3a	98.6 ± 0.9a	72.8 ± 1.6a	88.6 ± 2.4ab
52.0	95.1 ± 1.9a	99.7 ± 0.3a	97.0 ± 1.5a	100.0 ± 0.0a	78.0 ± 2.4a	91.7 ± 4.1a
101.5	84.4 ± 5.0b	89.5 ± 4.3ab	85.2 ± 3.8b	92.2 ± 3.5ab	63.6 ± 4.2ab	79.6 ± 4.9abc
147.9	72.7 ± 5.6c	88.2 ± 3.5b	72.2 ± 6.3c	83.5 ± 6.7bc	48.9 ± 5.4bc	68.8 ± 7.2bcd
174.0	56.5 ± 5.8d	73.8 ± 9.2bc	53.4 ± 5.7d	76.5 ± 6.2bc	48.3 ± 7.8c	65.8 ± 7.8cd
264.7	29.6 ± 4.5e	58.6 ± 10.3c	33.7 ± 6.4e	68.1 ± 9.1c	36.1 ± 6.7c	54.2 ± 7.6d
F-statistic[d]	35.59	8.99	33.51	6.28	9.71	5.08
P value	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.001

[a]Combined data for 0.38 and 0.58 mg AI/min spray discharge rates.
[b]Compared to pre-treatment counts.
[c]DAS = days after spray.
[d]Degrees of freedom = 5, 42. Means (±SEM; $n = 8$) not labeled by the same letter in a column are significantly different according to Fisher's protected LSD tests ($P < 0.05$).

Increased contact with insecticide residues over time likely explains this observation. Our results indicate that only two three-factor interactions [(A × B × D) and (B × C × D)] had a significant effect on the survivorship of the ACPs (Table 2). At a given spray discharge rate, a significant increase in overall ACP mortality was observed as the droplet size decreased from 264.7 to 40.5 μm, due to an increase in droplet density at each droplet size. Similarly, at a given droplet size, an increase in droplet density resulted in a significant increase in ACP mortality. Although the same amount of fenpropathrin was deposited onto all plants at a given spray discharge rate, the concentration of insecticide per droplet increased as the droplet size decreased (there was a nearly 50-fold increase in concentration from largest to smallest droplet size tested). This might also have contributed to the greater mortality of ACPs encountering 40.5 and 52.0 μm droplets than of those with 174.0 and 264.7 μm droplets (Tables 3 and 4). Collectively, the factors that might be responsible for the above results are as follows: (1) There is a greater probability that smaller droplets with a higher droplet density and concentration will contact and transfer insecticide to the target pest. (2) More droplets of smaller size provide more even insecticide distribution. (3) Insects might be less able to detect, and hence avoid, smaller droplets [10,11]. The current results suggest that droplet size can be optimized for effective control of ACP.

Hoffmann et al. [23] characterized spray droplet spectra from five hand-held ultralow volume (ULV) sprayers. Those sprayers produced droplets ranging in size from 14.9 to 90.5 μm for water-based solutions and 11.7 to 92.4 μm for oil-based sprays. Therefore, the 40.5 and 52.0 μm droplet sizes generated in our study were in the size range measured for ULV applicators.

Low volume (17.3 to 19.7 l/ha) applications of insecticides for ACP control in FL, which are characterized by average droplet sizes of about 90 μm, are becoming increasingly popular [18]. A single low volume applicator can treat up to 100 ha of citrus crop per night, which results in six- to sevenfold cost savings relative to standard airblast applications, which deliver about 500 to 1000 l/ha [18]. Furthermore, low volume applicators are easier to transport to spray sites than standard high volume airblast sprayers. Currently, abamectin, carbaryl, diflubenzuron, fenpropathrin, zeta-cypermethrin, dimethoate, malathion, and spinetoram are approved for low volume spray applications on citrus in FL [24]. Label changes are in progress for this use pattern for several other insecticides that are effective for ACP control in citrus. Low volume applications characterized by droplet sizes ranging from 100 to 150 μm might have a lower potential for spray drift than applications with smaller droplet sizes. In addition, nighttime applications (with lower temperature and higher relative humidity) might improve droplet deposition [25]. Overall, our laboratory results suggest that the application of fenpropathrin with smaller droplet sizes might be more effective than application with larger droplets in killing ACP in commercial citrus. However, further validation of these laboratory results under field conditions is needed.

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