**Evaluation of Low-volume Sprayers Used in Asian Citrus Psyllid Control Applications**

Clint Hoffmann1,8, Brad Fritz1, Dan Martin1, Ryan Atwood2, Tim Hurner3, Mark Ledebuhr4, Matt Tandy5, John L. Jackson6, and Gail Wisler7

**ADDITIONAL INDEX WORDS.** technology, Diaphorina citri, greening

**SUMMARY.** The asian citrus psyllid [Diaphorina citri (Sternorrhyncha: Psyllidae)] is a detrimental pest to citrus (Citrus spp.) crops when it serves as a vector of the pathogen that causes greening (huanglongbing). Transmission of this disease causes mottling, chlorosis, dieback, and reductions in fruit size and quality. It is well established that the presence of asian citrus psyllids and the vectored pathogen necessitate chemical control in the form of pesticide applications (Tolley, 1990). Given the seriousness of the disease, it is important to protect even apparently disease-free trees (Aubert, 1990), especially with new growth flush (Aubert 1987). Recommended treatment intervals range from 10 to 13 treatments per year (Roistacher, 1996) to every 7 to 20 d (Gonzales and Viñas, 1981), with area-wide treatments being preferred (Aubert 1990). Supriyanto and Whittle (1991) recommend high-efficacy pesticides as essential to provide sufficient control to significantly delay a greening epidemic. It can be further conjectured that optimal application techniques also are critical to obtaining maximum biological control of asian citrus psyllids.

Stover et al. (2002), in a survey to indentify current spray application practices on citrus crops in Florida, identified three predominate sprayer types, including two airblast sprayers at mid- and high-volume application rates and a low-volume application rate air-assisted sprayer, with spray rates ranging from 25 to 750 gal/acre. Sprayer type is generally selected by the operator based on experience and/or perceived coverage and deposition of spray material within the citrus canopy. The selected sprayers can typically be modified to generate spray plumes that fit tree contours through changes in nozzle numbers, and orientation of and/or oscillation of airflow (Stover et al., 2003). With the need for numerous spray treatments for asian citrus psyllid control, applicators are looking to and adapting for use a number of spray application machines initially targeted for the mosquito vector control industry. Machines that apply agrochemical products at these low-volume rates allow applicators to respond to the need to treat large numbers of acres repeatedly in a timely manner. These machines can produce droplets with volume median diameters that range from 5 to 210 μm, depending on spray solution and equipment setup (Hoffmann et al., 2007a).

The list of pesticides approved for application to control asian citrus psyllids in Florida is limited. As a result of the urgent need for control, applicators in Florida have been granted Special Local Needs provisions on a number of insecticides, including spinetoram (Delegate® WG; Dow

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### Units

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T he asian citrus psyllid is a detrimental pest to citrus crops when it serves as a vector of the pathogen that causes greening (huanglongbing). Transmission of this disease causes mottling, chlorosis, dieback, and reductions in fruit size and quality (Halbert and Manjunath, 2004). Once a tree is infected, there is no cure, and trees may only live for another 5 to 8 years, potentially never bearing usable fruit. It is well established that the presence of asian citrus psyllids and the vectored pathogen necessitate chemical control in the form of pesticide applications (Tolley, 1990). Given the seriousness of the disease, it is important to protect even apparently disease-free trees (Aubert, 1990), especially with new growth flush (Aubert 1987). Recommended treatment intervals range from 10 to 13 treatments per year (Roistacher, 1996) to every 7 to 20 d (Gonzales and Viñas, 1981), with area-wide treatments being preferred (Aubert 1990). Supriyanto and Whittle (1991) identified three predominate sprayer practices on citrus crops in Florida, and the need to treat large numbers of acres repeatedly in a timely manner. These machines can produce droplets with volume median diameters that range from 5 to 210 μm, depending on spray solution and equipment setup (Hoffmann et al., 2007a).
AgroSciences, Indianapolis), difluuben-
zurom (Micromite® 80WGS; Chem-
tura, Middlebury, CT), fenpropatrin
(Danitol 2.4 EC; Valent, Walnut
Creek, CA), and zeta-cypermethrin
(Mustang; FMC, Philadelphia). All
of these Special Local Needs labels
require air-blast or air-assisted sprayers
with application rates of no less than
2 gal/acre and with volume median
droplet diameters of 90 μm or larger.
Most labels allow the addition of
adjuvants or other tank-mix partners
as long as the other restrictions are
maintained; however, fenpropatrin
does not allow use of additional ad-
juvants. No information is given re-
garding the reasoning behind the
90-μm lower limit, though it is likely
based on risk assessment analysis for
spray drift. The Special Local Needs
labels also do not specify an upper
limit on the droplet size. Given that
spray droplet size is dependent on and
changes with varying combinations of
spray equipment, equipment setup,
and spray product (Hoffmann et al.,
2007b), the objectives of this work
were: 1) evaluate three sprayers, un-
der laboratory conditions, for droplet
size produced from a.i. formulations
and the necessary equipment adjust-
ments needed to meet the Special
Local Needs label; 2) conduct “on-
site” evaluations of production appli-
cation equipment for droplet size
when operating under normal condi-
tions; 3) adjust the individual sprayer’s
operating parameters to produce a vol-
ume median diameter of 90 μm or
greater to ensure compliance with the
Special Local Needs labels; and 4) docu-
ment the general operational modifica-
tions required for machine type to
provide guidance for future spray cal-
ibrations.

Materials and methods

Sprayer droplet size testing was
completed in two stages: one looking
at three sprayers and five a.i. under
laboratory conditions and the second,
a field-based evaluation of production
sprayers brought to a central location
by local applicators. The first labora-
ory-based work was conducted at the
U.S. Department of Agriculture-
Agricultural Research Service (USDA-
ARS) Areawide Pest Management
Research Unit’s Riverside campus fa-
cilities in College Station, TX. The three
sprayers to be evaluated were provided
by the equipment manufacturers. The
field-based evaluations were con-
ducted at two locations in central
Florida. Both sets of trials followed
the same testing protocols with the
exception of the field-based trials not
using a.i. formulations. These proce-
dures, along with greater details on the
site-specific testing, are discussed fur-
ther in the following sections.

General testing procedures.

To evaluate the droplet size produced
by a particular sprayer and spray for-
mulation combination, the sprayer
was first operated under its normal
factory or user-established settings.
Basically, the sprayer was initially op-
erated as-is. A droplet measurement
system (Sympatec, Clausthal, Ger-
many) mounted on a custom-made
forklift mount was used to measure
droplet size at the sprayer nozzle
outlet. The unit was positioned such
that the location of measurement was
1 to 2 m from the outlet of the
sprayer (Fig. 1). This distance varied
somewhat from sprayer to sprayer
depending on the droplet density of
the resulting spray cloud and the
width of the spray plume. Wider spray
plumes required a closer distance to
avoid depositing spray material on the
lenses of the droplet measurement
unit. Denser sprays required further
distance to insure that the spray cloud
density did not prevent the diffracted
laser light from reaching the measure-
ment sensor. The spray cloud from
the sprayer was directed through the
laser beam for 10 to 20 s during
which time droplet size measure-
ments of the spray cloud were made.
The time that the spray cloud was
directed through the optical path of
the laser varied between sprayers
depending on the width of the spray
plume generated by the sprayer. The
element spray plume for each sprayer
was measured by traversing the laser
through the plume using the forklift
replicated measures were made for
each unique piece of equipment and
specific set of operational conditions.

Droplet sizing system. The
Helos laser diffraction droplet sizing
system (Sympatec), which uses a 623-
nm helium-neon laser, was fitted with
an R5 lens, resulting in a dynamic size
range from 0.5 to 875 μm in 32 sizing
bins. The authors found that when
using the laser system under adverse
conditions (outdoors and mounted
to a forklift), the last channel (i.e.,
sizing bins) of the Helos system
should be turned off such that it is
not factored into the droplet size
measurement results. This channel
represents the largest droplet size
and tends to pick up some “noise”
or random signals that typically result
from equipment vibration or scat-
tered ambient light. With this channel
turned off, the dynamic range of the
instrument was from 0.5 to 735 μm.
These channels were not turned off if
any droplets were measured within
two sizing bins of the nearest deacti-
vated channel.

The spray droplet size data were
determined and reported as a mean
and standard deviation correspond-
ting to the data measured during the
three replications for each combina-
tion of sprayer and pesticide. Means
and standard deviations of the volume
median diameter [VMD or D0.5
(ASTM International E1620-97,
2004)], D0.1, and D0.9 were
determined. The D0.5 is the droplet
diameter in micrometers where 50% of
the spray volume is contained in
droplets smaller than this value (ASTM

Fig. 1. Testing setup showing the droplet measurement system with the spray
plume from the citrus sprayer directed through the laser beam of the droplet
measurement system.
TECHNOLOGY AND PRODUCT REPORTS

permit.

The goal of the laboratory studies, five a.i. along with water plus a nonionic surfactant (NIS) were used. The use of a specially designed scrubbing system allowed for the use of these a.i. without adverse environmental impacts. Three liquid-based products were used: malathion (Malathion 5EC; Drexel Chemical, Memphis, TN), dimethoate (Dimethoate 4E; Arysta LifeScience North America, Cary, NC), and fenpropathrin. Two of the products were wettable powders: diflubenzuron and spinetoram. The rates at which these products were tested are shown in Table 1. For all a.i. tests, spray rates were maintained at 3 gal/acre. For each of the three sprayers tested, the first step was to run the sprayer at the factory settings using water to determine a benchmark for further modifications. Depending on the measured $D_{V0.5}$, engine speed was modified such that the 90-μm lower size requirement was met. The goal for each a.i. formulation tested was to determine the appropriate engine speed settings that resulted in compliance with the Special Local Needs permit.

**Citrus sprayer calibration rodeos.** The field evaluations were organized by the Florida Extension Service in Lake Placid, FL, and Haines City, FL. Growers and applicators in the region were invited to bring their equipment to these locations for droplet size measurements. Thirty-three machines were evaluated representing 16 different models of sprayers. Water with 0.25% volume/volume addition of a NIS (R-11; Wilbur-Ellis, Walnut Creek, CA) was used during these tests as there were a large number of spray trials conducted and a large number of people involved. This prevented any environmental contamination or adverse health effects. The water plus NIS solution simulates most water-based insecticide sprays well (Hoffmann et al., 2007a, 2007b). Each sprayer tested was initially run at the user settings. Based on the measured $D_{V0.5}$, engine speed and, in a few cases, spray pressure were adjusted until the 90-μm size requirement was met. Typically, engine speed was first reduced to its minimum level and if the resulting measured $D_{V0.5}$ was still less than 90 μm, spray pressure was increased.

An example of the data reports that were provided to each of the applicators is shown in the Appendix (Fig. 2).

**Results**

**Active ingredient tests with three sprayers.** Final equipment settings required to meet the $D_{V0.5}$ 90-μm size requirement for each a.i. are shown in Tables 2 through 4 for the three sprayers tested. Droplet size at the factory settings for water and water plus NIS are also included for reference. For the London Fog model 18–20 sprayer (London Fog, Long Lake, MN) (Table 2), initial testing with water and water plus NIS with the machine operating at 2810 and 1850 rpm, respectively, and a rate of 1.9 L·min⁻¹ produced $D_{V0.5}$ of 57.8 ± 13.2 and 85.9 ± 1.2 μm (mean ± SD of three replications), respectively. Two of the a.i. formulations, diflubenzuron and spinetoram, produced $D_{V0.5}$ values that were at or near the 90-μm requirement while operating the sprayer at 1500 rpm while two, fenpropathrin and malathion, required reducing the engine speed to 1350 rpm. The dimethoate formulation was such that even at the lowest engine speed setting (1350 rpm), the 90-μm size requirement could not be met.

For the Curtec sprayer (Curtec of Florida, Vero Beach, FL), water and water plus NIS resulted in $D_{V0.5}$ that were greater than 90 μm at factory settings. Dimethoate and diflubenzuron formulation also achieve the 90-μm requirement at the factory settings, while the malathion, spinetoram, and fenpropathrin formulation required engine speeds to be reduced to 4800, 4000, and 4000 rpm, respectively.

For the Proptec sprayer (Ledebuhr Industries, Williamston, MI), water and water plus NIS resulted in $D_{V0.5}$ values that met the 90-μm requirement. Spinetoram and diflubenzuron formulations also met the 90-μm requirement at the 5100-rpm factory setting, while malathion and fenpropathrin formulations required the engine speed to be reduced to 3500 rpm.

**Citrus sprayer calibration rodeos: single machine evaluations.** During the calibration rodeos, there were 17 unique models of machines evaluated. Fourteen of the models only had one machine of that type that was tested. Two, the Dyna-Fog Ag-Mister LV-8 (Curtis Dyna-Fog, Westfield, IN) and the London Fog model 18–20, had multiple machines of that type tested.

Of the individual machines tested, eight had a $D_{V0.5}$ of 90 μm or greater (Table 5). Three of the remaining sprayers were able to be adjusted via spray pressure or engine speed to achieve a $D_{V0.5}$ near or greater than 90 μm. One of the sprayers, MaxCharge ES100 (Electrostatic Spraying Systems, Watkinsville, GA), was designed to generate droplets with a $D_{V0.5}$ of between 30 and 40 μm to optimize the electrostatic charge that it imparts to the spray droplets.

There were 14 Dyna-Fog Ag-Mister LV-8 (LV-8) and six London Fog model 18–20 citrus sprayers evaluated in the calibration rodeos (Table 6). Each row of data presented in Table 6 represents a unique machine. These machines were all of different age, levels of maintenance, degree of user modification, and standard operating settings thus variation in spray droplet size among the machine was expected. Of the 14 LV-8 sprayers, four were version 1 (LV-8-V1), one was version 2 (LV-8-V2), and nine sprayers contained some modifications of pumps and spray lines that made it difficult to distinguish a specific version. Therefore, all data are presented by individual machine, with no attempt to characterize

### Table 1. Five a.i. (three liquid and two wettable powders) and the rates at which they were used in the sprayer calibration trials.

<table>
<thead>
<tr>
<th>Liquid formulation</th>
<th>Application rate (oz/acre a.i.)</th>
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<tr>
<td>Malathion</td>
<td>9.0</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>13.9</td>
</tr>
<tr>
<td>Fenpropathrin</td>
<td>6.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wettable powders</th>
<th>Application rate (oz/acre a.i.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diflubenzuron</td>
<td>5.0</td>
</tr>
<tr>
<td>Spinetoram</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1 oz/acre = 70.0532 g ha⁻¹.
The general sprayer model performance. For each machine tested, the droplet size under the initial operational settings is presented followed by the droplet size at the adjusted settings. Typically, for the LV-8 and LV-8-V2, decreasing the engine rpm resulted in increased droplet size such that the 90-μm size requirement was met. There were several of the LV-8 machines that, even with maximum reduction of the engine speed, the 90-μm level was not met. Each of the individual machines tested had unique lower engine speed, again due to variability in machine age, maintenance, and level of modification. For the LV-8-V1 machines tested, similar adjustments in engine speed did not result in sufficient increase in droplet size. The LV-8-V1 has a smaller pump and smaller diameter tubing leading to each of the spray nozzles, which limits flow output and thereby the ability to generate larger droplets.

The London Fog model 18–20 citrus sprayers followed similar trends

### Table 2. Effects of a.i. and engine speed on spray atomization for the London Fog model 18–20 sprayer (London Fog, Long Lake, MN).

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Engine speed (rpm)</th>
<th>Rate per atomizer (gal/min)</th>
<th>D_{0.1} (μm ± sd)</th>
<th>D_{0.5} (μm ± sd)</th>
<th>D_{0.9} (μm ± sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2810</td>
<td>0.6</td>
<td>22.3 ± 5.1</td>
<td>57.8 ± 13.2</td>
<td>110.6 ± 22.3</td>
</tr>
<tr>
<td>Water + 0.25% NIS</td>
<td>1850</td>
<td>0.6</td>
<td>30.2 ± 2.3</td>
<td>85.9 ± 1.2</td>
<td>214.7 ± 14.8</td>
</tr>
<tr>
<td>Diflubenzuron</td>
<td>1500</td>
<td>0.6</td>
<td>38.1 ± 0.4</td>
<td>94.0 ± 2.7</td>
<td>305.5 ± 6.5</td>
</tr>
<tr>
<td>Spinetoram</td>
<td>1500</td>
<td>0.6</td>
<td>35.1 ± 0.5</td>
<td>86.4 ± 0.6</td>
<td>260.7 ± 12.9</td>
</tr>
<tr>
<td>Fenpropathrin</td>
<td>1350</td>
<td>0.6</td>
<td>38.1 ± 0.7</td>
<td>91.4 ± 0.4</td>
<td>322.2 ± 10.5</td>
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<tr>
<td>Malathion</td>
<td>1350</td>
<td>0.6</td>
<td>37.1 ± 1.0</td>
<td>92.0 ± 0.9</td>
<td>279.2 ± 9.9</td>
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<tr>
<td>Dimethoate</td>
<td>1350</td>
<td>0.6</td>
<td>30.0 ± 2.7</td>
<td>79.6 ± 2.8</td>
<td>205.1 ± 52.7</td>
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</table>

1 gal = 3.7854 L.
^2 D_{0.1}, D_{0.5}, and D_{0.9} = the droplet diameter where 10%, 50%, and 90%, respectively, of the spray volume is contained in droplets smaller than this value. Values represent the mean of three replications; 1 μm = 1 micron.

### Table 3. Effects of a.i. and engine speed on spray atomization for the Curtec sprayer (Curtec of Florida, Vero Beach, FL).

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Engine speed (rpm)</th>
<th>Rate per atomizer (gal/min)</th>
<th>D_{0.1} (μm ± sd)</th>
<th>D_{0.5} (μm ± sd)</th>
<th>D_{0.9} (μm ± sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>5100</td>
<td>0.3</td>
<td>41.3 ± 9.4</td>
<td>111.8 ± 12.8</td>
<td>173.6 ± 17.9</td>
</tr>
<tr>
<td>Water + 0.25% NIS</td>
<td>5100</td>
<td>0.3</td>
<td>35.3 ± 5.2</td>
<td>94.9 ± 4.6</td>
<td>149.1 ± 4.2</td>
</tr>
<tr>
<td>Diflubenzuron</td>
<td>5100</td>
<td>0.3</td>
<td>37.9 ± 5.9</td>
<td>96.7 ± 11.0</td>
<td>167.3 ± 11.5</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>4800</td>
<td>0.3</td>
<td>31.2 ± 1.3</td>
<td>88.9 ± 0.6</td>
<td>168.7 ± 9.0</td>
</tr>
<tr>
<td>Malathion</td>
<td>4000</td>
<td>0.3</td>
<td>66.0 ± 23.1</td>
<td>126.4 ± 11.9</td>
<td>200.5 ± 13.1</td>
</tr>
<tr>
<td>Diflubenzuron</td>
<td>4000</td>
<td>0.3</td>
<td>39.9 ± 3.7</td>
<td>113.2 ± 2.9</td>
<td>185.5 ± 11.4</td>
</tr>
</tbody>
</table>

1 gal = 3.7854 L.
^2 D_{0.1}, D_{0.5}, and D_{0.9} = the droplet diameter where 10%, 50%, and 90%, respectively, of the spray volume is contained in droplets smaller than this value. Values represent the mean of three replications; 1 μm = 1 micron.

### Table 4. Effects of a.i. and engine speed on spray atomization for the Proptec sprayer (Ledebuhr Industries, Williamston, MI).

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Engine speed (rpm)</th>
<th>Rate per atomizer (gal/min)</th>
<th>D_{0.1} (μm ± sd)</th>
<th>D_{0.5} (μm ± sd)</th>
<th>D_{0.9} (μm ± sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>5100</td>
<td>0.36</td>
<td>29.4 ± 0.8</td>
<td>98.4 ± 5.7</td>
<td>161.2 ± 13.6</td>
</tr>
<tr>
<td>Water + 0.25% NIS</td>
<td>5100</td>
<td>0.36</td>
<td>33.0 ± 4.2</td>
<td>94.9 ± 15.8</td>
<td>193.0 ± 21.6</td>
</tr>
<tr>
<td>Malathion</td>
<td>3500</td>
<td>0.36</td>
<td>33.7 ± 1.6</td>
<td>91.6 ± 4.0</td>
<td>173.6 ± 3.8</td>
</tr>
<tr>
<td>Spinetoram</td>
<td>3500</td>
<td>0.36</td>
<td>32.6 ± 2.0</td>
<td>97.6 ± 5.9</td>
<td>165.8 ± 7.0</td>
</tr>
<tr>
<td>Diflubenzuron</td>
<td>3500</td>
<td>0.36</td>
<td>31.6 ± 1.1</td>
<td>93.8 ± 3.8</td>
<td>172.9 ± 4.1</td>
</tr>
<tr>
<td>Fenpropathrin</td>
<td>3500</td>
<td>0.36</td>
<td>34.5 ± 0.4</td>
<td>96.4 ± 2.1</td>
<td>209.5 ± 11.1</td>
</tr>
</tbody>
</table>

1 gal = 3.7854 L.
^2 D_{0.1}, D_{0.5}, and D_{0.9} = the droplet diameter where 10%, 50%, and 90%, respectively, of the spray volume is contained in droplets smaller than this value. Values represent the mean of three replications; 1 μm = 1 micron.

xNIS = nonionic surfactant (R-11; Wilbur-Ellis, Walnut Creek, CA).
Table 5. Spray droplet size measurements from sprayers in the citrus spray calibration rodeo with the original setting results followed by the adjusted setting results for a water plus nonionic surfactant solution. The sprayers were adjusted to comply with the droplet size requirements of the Special Local Needs permits granted to some insecticides in the State of Florida.

Sprayer*  Model no.  Nozzle*  Spray rate (gal/acre)*  Liquid pressure (psi)*  Air pressure (psi)  Engine speed (rpm)  Original settings  Droplet size in first testa  
| Sprayer  | Model no. | Nozzle | Spray rate (gal/acre) | Liquid pressure (psi) | Air pressure (psi) | Engine speed (rpm) | D_{\text{V0.1}} (\mu m \pm SD) | D_{\text{V0.5}} (\mu m \pm SD) | D_{\text{V0.9}} (\mu m \pm SD) |
|----------|-----------|--------|----------------------|----------------------|-------------------|-------------------|------------------|------------------|------------------|------------------|
| Adapco   | 190GS     | Standard | 2 | 3 | 2800 | 17.2 ± 1.5 | 51.1 ± 5.8 | 121.4 ± 13.8 |
| AirTec   | CAB1000   | Albuz | 25 | 70 | 540 · PTO  | 37.3 ± 0.9 | 99.1 ± 1.2 | 173.7 ± 4.5 |
| Curtec   | 648 D     | Curtec coarse | 10 | 15 | 2100 | 30.4 ± 0.4 | 75.5 ± 0.8 | 138.3 ± 2.3 |
| Curtec   | 648 D     | Curtec fine | 10 | 15 | 1500 | 31.6 ± 1.0 | 87.1 ± 3.7 | 159.7 ± 17.6 |
| Curtec   | G3000     | Curtec coarse | 21 | 15 | 540 · PTO  | 27 ± 0.4 | 70.9 ± 0.6 | 130.6 ± 4.2 |
| Curtec   | P400D     | Proptec coarse | 2 | 2 | 2100 | 63.2 ± 4.8 | 149.2 ± 12.2 | 335.8 ± 79.7 |
| London Fog | 2D MaxiPro Standard | 2 | 1 gal/min ³ | 4 | 2500 | 17.6 ± 0.2 | 38.4 ± 0.1 | 79.4 ± 6.2 |
| ESS      | MaxCharge | ESS100 | Standard | 15 | 20 | 30 | 440 · PTO | 14.3 ± 0.3 | 41.9 ± 0.3 | 102.9 ± 1.1 |
| Proptec  | Proptec coarse | 3 | 7 | 1700 | 31.5 ± 1.8 | 75.5 ± 6.7 | 147.3 ± 28.1 |
| Rears    | PulBlast Rotary | 5 | 50 | 2500 | 56.4 ± 0.8 | 131.4 ± 0.4 | 214.9 ± 1.0 |
| Sides    | Spectrum Ogee shear | 10 | 42 | 1700 | 38.6 ± 2.3 | 99.7 ± 8.2 | 184.8 ± 27.4 |

Sprayer*  Model no.  Nozzle*  Targeted rate (gal/acre)  Adjusted settings  Liquid pressure (psi)  Air pressure (psi)  Engine speed (rpm)  Droplet size after adjusting sprayera  
<table>
<thead>
<tr>
<th>Sprayer</th>
<th>Model no.</th>
<th>Nozzle</th>
<th>Targeted rate (gal/acre)</th>
<th>Adjusted settings</th>
<th>Liquid pressure (psi)</th>
<th>Air pressure (psi)</th>
<th>Engine speed (rpm)</th>
<th>D_{\text{V0.1}} (\mu m \pm SD)</th>
<th>D_{\text{V0.5}} (\mu m \pm SD)</th>
<th>D_{\text{V0.9}} (\mu m \pm SD)</th>
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</thead>
<tbody>
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<td>190GS</td>
<td>Standard</td>
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<td>0</td>
<td>1900</td>
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<td>107.6 ± 4.5</td>
<td>227.2 ± 14.8</td>
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<td>648 D</td>
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<td>1500</td>
<td>31.9 ± 0.8</td>
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<td>139.3 ± 4.5</td>
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<td>Curtec coarse</td>
<td>21</td>
<td>15</td>
<td>440 · PTO</td>
<td>33.3 ± 2.1</td>
<td>95.7 ± 2.7</td>
<td>180.2 ± 1.0</td>
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<tr>
<td>London Fog</td>
<td>2D MaxiPro Standard</td>
<td>2</td>
<td>1 gal/min ³</td>
<td>4</td>
<td>1640</td>
<td>29.4 ± 2.1</td>
<td>76.7 ± 5.6</td>
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<td>ESS</td>
<td>MaxCharge</td>
<td>ESS100</td>
<td>Standard</td>
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<td>30</td>
<td>25</td>
<td>450 · PTO</td>
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<td>0</td>
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<td>1300</td>
<td>31.3 ± 1.8</td>
<td>75.5 ± 6.7</td>
<td>147.3 ± 28.1</td>
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<tr>
<td>Proptec</td>
<td>Proptec fine</td>
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<td>0</td>
<td>7</td>
<td>1300</td>
<td>37.4 ± 2.0</td>
<td>88.7 ± 3.6</td>
<td>162.9 ± 13.1</td>
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<td></td>
</tr>
</tbody>
</table>

*Adapco (Sanford, FL); AirTec (AirTec Sprayers, Winter Haven, FL); Curtec (Curtec of Florida, Vero Beach, FL); ESS (Electrostatic Spraying Systems, Watkinsville, GA); Proptec (Ledebuhr Industries, Williamston, MI); Rears (Rears Manufacturing, Eugene, OR); Sides (Goldthwaite, TX); Albuz (Spirit River, AB, Canada); Ogee (Ogee Spectrum Electrostatic Sprayers, Houston).

1 gal/acre = 9.3540 L/ha, 1 psi = 6.8948 kPa, 1 gal = 3.7854 L.

DV_{0.1}, DV_{0.5}, and DV_{0.9} = the droplet diameter where 10%, 50%, and 90%, respectively, of the spray volume is contained in droplets smaller than this value. Values represent the mean of three replications; 1 μm = 1 micron.

Power take-off.

Conclusions

In response to the need for accurate droplet size assessments of field application equipment used in the control of the Asian citrus psyllid in Florida, a variety of field application sprayers were evaluated to determine if the applied sprays met the Special Local Needs labeling requirements of the State of Florida. As the LV-8s. With a single exception, reducing the engine speed increased DV_{0.5} values such that the 90-μm size requirement was met.

Based on the resulting spray droplet size, the sprayer settings were adjusted such that the resulting droplet size would comply with the label requirements. Following the trends seen in the initial round of testing, the majority of the sprayers was adjusted via the engine speed or spray pressure such that the resulting spray’s volume median diameter was greater than or equal to 90 μm. As the equipment tested here represent the most typical application equipment used in Florida for Asian citrus psyllid control, these results will provide applicators, growers, and extension agents with general guidelines to...
Table 6. Spray droplet size measurements for Curtis Dyna-Fog LV8 (Curtis Dyna-Fog, Westfield, IN) and London Fog model 18–20 (London Fog, Long Lake, MN) sprayers in the citrus spray calibration rodeo with original setting results followed by the adjusted setting results for a water plus nonionic surfactant solution. The sprayers were adjusted to comply with the droplet size requirements of the Special Local Needs permits granted to some insecticides in the State of Florida.

<table>
<thead>
<tr>
<th>Model no.</th>
<th>Original settings</th>
<th>Results after adjusting sprayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayer</td>
<td>Droplet size&lt;sub&gt;0.1&lt;/sub&gt; (μm ± SD)</td>
<td>Droplet size&lt;sub&gt;0.5&lt;/sub&gt; (μm ± SD)</td>
</tr>
<tr>
<td></td>
<td>DV0.1</td>
<td>DV0.5</td>
</tr>
<tr>
<td></td>
<td>Spray rate (gal/acre&lt;sup&gt;y&lt;/sup&gt;)</td>
<td>DV0.1</td>
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<td>2500</td>
<td>2200</td>
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<tr>
<td>LV8</td>
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<td>2300</td>
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<td>2400</td>
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<tr>
<td>LV8-V2</td>
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</tr>
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<td>LV8-V3</td>
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<tr>
<td>LV8-V20</td>
<td>4600</td>
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</table>

- **Note:** DV0.5, DV0.9, and DV0.1 refer to the droplet diameter where 50%, 90%, and 10% of the spray volume is contained in droplets smaller than this value, respectively.
- **Unit Conversion:** 1 gal/acre = 9.3540 L/ha; 1 psi = 6.8948 kPa.
- **Other References:**
Appendix

Fig. 2. Handout given to applicators at the citrus sprayer calibration rodeos to explain the results of the tests; 1 μm = 1 micron, 1 gal = 3.7854 L, 1 psi = 6.8948 kPa, 1 m/s = 1 m S⁻¹ = 2.2369 mph.