Laser Tag: Intelligent Sprayers Change the Pest Management Game©

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INTRODUCTION

Pests pose a substantial threat to the sale of nursery crops (LeBude et al., 2012) and increase the cost of producing ornamental crops. For example, losses due to plant disease in Georgia nurseries were estimated at $43.4 million in 2007 (Martinez, 2008). Application of pesticides, as part of an Integrated Pest Management (IPM) program, can serve an important role in decreasing plant mortality, maintaining plant quality to a market acceptable level, and complying with plant trade requirements (Cloyd, 2008). However, pesticide use by its very nature can pose a threat to human and ecosystem health. By refining pesticide applications, environmental and human risk can be reduced.

Air-assisted sprayers are conventionally used to apply pesticides to nursery crops. However, less than 30% of pesticide applications are intercepted by the intended nursery canopy (Zhu et al., 2006). Increasing spray application efficiency could improve worker safety by reducing active ingredient residue on plant surfaces and air contamination. Additionally, because of the increased efficiency, the tank would be refilled less frequently, reducing opportunities for the spray applicator to come into contact with concentrated pesticides during mixing. Increasing efficiency would not only reduce the total amount of active ingredients applied but also decrease the water footprint of each pesticide application, improving environmental quality.

To increase spray application efficiency, two variable-rate output spray systems that integrate plant characteristics in real time were developed for nursery applications: an air-assisted sprayer for wide species of nursery and fruit tree crops (Chen et al., 2012) and a hydraulic boom sprayer for young, narrow trees such as liners (Jeon and Zhu, 2012). Both sprayers are sensor-guided, employing a high-speed laser scanning sensor and ultrasonic sensor for the air-assisted and boom sprayers, respectively. The sensors detect the presence or absence of a plant, plant architecture, canopy volume, and tractor speed, while controllers manipulate the solenoids to produce variable-rate spray outputs based on plant characteristics and plant occurrence in real time. Sprayers were developed at the USDA-ARS Application Technology Research Unit in Wooster, Ohio.

SPRAYERS

Variable-Rate Air-Assisted Sprayer Performance

Spray consumptions between the intelligent sprayer, non-intelligent sprayer, and a conventional air-assisted sprayer in an orchard were compared at three different growth stages (Beginning to leaf, half foliage, and full foliage). Application rate for the conventional sprayer was 50 gpa, determined by a tree-row volume method.

Variable-Rate Hydraulic Boom Sprayer Performance
Tests were conducted to verify deposition uniformity inside tree canopies at different travel speeds. The test plot consisted of two rows of six tree species (*Acer rubrum* 'Franksred'; *Carpinus betulus*; *Malus sargentii*; *Prunus* ×*cistena*; *Acer* ×*freemanii* 'Jeffersred'; *Acer palmatum*). Tree species ranged in height from 0.8 to 2.5 m, and in caliper from 0.5 to 5.4 cm. The travel speeds for the test were 2, 3, 4, and 5 m/h. Spray deposition and coverage by the hydraulic boom sprayer were compared with 100 gpa constant-rate application and tree row volume estimated rate applications. Water sensitive papers were mounted inside canopies to measure the spray coverage, and a fluorescent tracer was mixed with water to quantify spray deposits.

Variable-Rate Hydraulic Boom Sprayer Pest Control
In Oregon, *Quercus rubra* liners were rated from 16 June to 30 Sept. 2011 to monitor aphid levels and compare control of aphids by variable-rate and constant rate applications with a modified vertical boom sprayer. One side of the sprayer contained the intelligent system and produced variable-rate output, while the other side of the sprayer remained a conventional boom sprayer to produce constant-rate output. *Acer platanoides* liners were also rated from 6 June to 30 Sept. 2011 to monitor powdery mildew and to compare control achieved by the two applications. For both experiments, five of the newest, fully expanded leaves were examined for each of the 20 trees per treatment.

Variable-Rate, Air-Assisted Sprayer Pest Control
Cornus florida trees grown in a nine-row block were used to compare powdery mildew control by a conventional air-assisted sprayer with the variable-rate air-assisted sprayer and to determine if tree position within the block affected powdery mildew control. Trees were sprayed with Daconil on 20 June and 19 July 2013. Powdery mildew infection level was evaluated on the date of fungicide application and weekly thereafter for three weeks.

RESULTS AND DISCUSSION

Variable-Rate Air-Assisted Sprayer Performance
Pesticide consumption was dramatically reduced with the variable-rate intelligent sprayer. Spray application rate and percent spray volume reduction by the intelligent air-assisted sprayer at three growth stages are shown in Figure 1. The intelligent sprayer had 70, 66, and 52% spray mixture reduction at the beginning to leaf, half foliage and full foliage growth stages, respectively. Intelligent sprayer coverage and deposition were more stable over different growth stages at approximately 40% coverage compared to approximately 45-90% saturated coverage for the non-intelligent and a conventional air-assisted sprayer (data not shown).

Variable-Rate Hydraulic Boom Sprayer Performance
Spray deposit and coverage were relatively uniform regardless of changes in the canopy size, plant morphology, and travel speed (data not shown). Conventional spray application rates estimated with the tree-row volume method were 131, 60, 40, 36, and 28 gpa, compared with variable-rates of 38, 32, 25, 16, and 16, respectively. The variable-rate sprayer reduced spray volume up to 86.4 and 70.8% compared to a constant 100 gpa and tree-row volume estimated rate applications, respectively.

Variable-Rate Hydraulic Boom Sprayer Pest Control
Following the insecticide application, aphid populations decreased with no significant difference due to sprayer type until 30 Sept. 2011 when the plants sprayed with the intelligent sprayer had a lower aphid population (Table 1). Once fungicide applications commenced, powdery mildew ratings were not different or infection was lower for plants sprayed with the intelligent sprayer on all dates but one (Table 2).

Variable-Rate Air-Assisted Sprayer Pest Control

Powdery mildew infection was not different at the beginning of the experiment (Week 1) and was not affected by sprayer type on six out of seven dates thereafter (Table 3). Trees in rows within the interior of the block did not have higher levels of infection than one or the other exterior row of trees (data not shown).

Field laboratory and nursery tests demonstrated that both variable-rate intelligent sprayers controlled spray outputs by continually matching canopy characteristics and consequently reduced off-target losses. In the pest control evaluation of the variable-rate, intelligent- sprayers with the conventional sprayers, insect and disease control was generally not affected by sprayer type. Thus, both intelligent sprayers have the potential to effectively control pests while drastically decreasing pesticide use and associated economic inputs, and potentially increase environmental quality and enhance worker safety.

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Table 1. Comparison of aphids on red oak trees sprayed with the variable-rate or conventional boom sprayer in a commercial nursery.

Date	Average number of aphids	
	Variable-rate	Conventional
6/16	0 a[y]	0 a
8/4	2.3 a	1.8 a
8/18	11.6 a	9.1 a
8/30	46.1 a	39.5 a
9/8[z]	0.6 a	0.4 a
9/15	0.4 a	0.1 a
9/30	0.3 b	3.4 a

[z]8 days following Diazinon insecticide application.

[y]Values in a row followed by the same letter are not significantly different at the 0.05 level.

Table 2. Comparison of powdery mildew infection on Norway maple trees sprayed with the variable-rate or conventional boom sprayer in a commercial nursery.

Date	Average disease rating	
	Variable-rate	Conventional
6/16	0.06 a[wv]	0.05 a
6/30	0.52 b	0.67 a
7/6[z]	0.79 a	0.84 a
7/14	0.99 a	1.00 a
7/26	1.01 a	1.08 a
8/1[y]	0.68 b	0.84 a
8/11	0.12 a	0.17 a
8/18[x]	0.56 a	0.47 a
8/25	0.83 a	0.61 b
9/30	1.10 b	1.70 a

[z], [y], [x]Five, six, and six days following Chlorothalonil 720 SFT (July 1, 2011), Eagle 20 EW (July 26, 2011), and 3336F (August 12, 2011) treatments, respectively.

[w]Values in the same row followed by the same letter are not significantly different at the 0.05 level.

[v]The following rating system was used: 0=no sign of powdery mildew, 1=1 to 25% powdery mildew, 2=26 to 50%, and 3=51 to 100%.

Table 3. Dogwood powdery mildew infection level following fungicide application with conventional and intelligent, air-assisted sprayers.

Sprayer type	Date							
	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8
Intelligent sprayer	1.8	2.4	3.2a[z]	4.4	4.9	3.9	6.3	6.3
Conventional sprayer	1.7	2.4	2.9b	3.7	3.7	3.1	5.6	5.4

Abbreviation: Wk = week.

[z]Values in the same column followed by different letters are different at the 0.05 level.

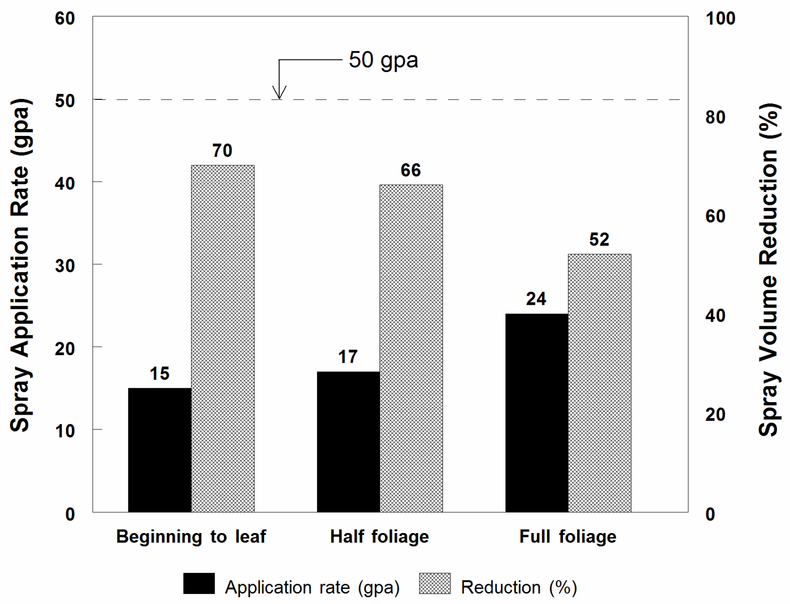

Fig. 1. Spray application rate and percent spray volume reduction from intelligent sprayer, compared with the conventional 50 gpa spray application rate at beginning to leaf, half foliage and full foliage stages.