Comparing Greenhouse Handgun Delivery to Poinsettias by Spray Volume and Quality

R. C. Derksen, J. Frantz, C. M. Ranger, J. C. Locke, H. Zhu, C. R. Krause

Abstract. *Insecticide and fungicide labels often lack specific recommendations on the spray volume and spray droplet sizes that will provide the most efficacious pest management of ornamental pest problems. A greenhouse trial was established to determine differences in spray retention in a poinsettia canopy between single-nozzle, handgun applications made using three different spray volumes and three different spray qualities. For the same areas of the canopy, there were few differences in spray deposit between treatments. Canopy position was a significant factor in the amount of spray found on foliar and artificial targets. Higher deposits were measured in the fronts and upper areas of the canopy than the backs and lower areas of the canopy. There were no significant differences in recovery of fungicide from leaves between treatments. The high-volume application produced the highest deposits on artificial targets across all spray qualities. There were no significant differences in overall spray deposit between the low- and medium-volume treatments.*

Keywords. *Deposition, Diseases, Droplet size, Insects, Ornamental plants, Poinsettia, Spray, Tracer.*

Consumer demand for floral crops continues to increase. In 2005, floriculture sales were 1.5% greater than 2004 sales or $5.4 billion (USDA, 2006). The greatest increase in sales in the most recent reporting period was in potted plants. Due to the cosmetic needs of ornamental crops, intensive pest management programs are required to provide the high-quality products that consumers seek. Despite these requirements, little information is available to ornamental growers on how to most efficaciously apply crop protection materials. A large number of equipment options are available to producers. Complicating the management decisions further is the high number of different production systems in use.

High-volume applications are used frequently in greenhouse production because of label language and because growers can easily visualize the type of spray coverage they are producing. Longer application times associated with high-volume, dilute applications help the spray equipment operator treat the target area more uniformly. Label language usually provides little guidance on application techniques, other than directing the operator to provide good coverage.

Several different studies have reported the effectiveness of greenhouse applicators. The configuration of many greenhouse production systems favors use of handheld equipment. Lindquist and Powell (1991) reported on use of handheld rotary atomizers. The differences in sprayer effectiveness in these results could be attributed to canopy density and plant arrangement, which would affect spray and air movement. Electrostatic spray technology use in greenhouse production has been reported by several authors. Abdelbagi and Adams (1987) reported on the use of a spinning atomizer delivering charged sprays. This sprayer was most effective in canopy areas that did not interfere with spray movement. Lindquist et al. (1988) reported on the use of an air-assisted, electrostatic sprayer used to treat potted chrysanthemums. These researchers reported that spray deposition was influenced by target (plant and leaf) location.

Derksen et al. (1991) compared the effectiveness of a low-volume, air-assist electrostatic sprayer and a high-volume, handgun sprayer for treating poinsettias. Analysis of foliar deposits showed that the electrostatic sprayer produced similar or higher foliar deposits than the high-volume sprayer while using only 1/25 the spray volume and treating the test area in only 1/3 the time. Conducting bioassay evaluations of two-spotted spider mite (*Tetranychus urticae* Koch), western flower thrip (*Frankliniella occidentalis* (Pergande)), and soybean aphid (*Aphis glycines* Matsumura) control using dilute and concentrate sprayers in greenhouse grown, potted soybeans, Ebert et al. (2004) showed that the three different forms of handgun-type application equipment (high-volume, coldfogger, and air-assist electrostatic) affected efficacy differently when used to apply the same volume of spray.

Thermal foggers have the advantage of being able to fill an enclosed space like a greenhouse very quickly with a fog of pesticide. Thermal fogger use was reported by Jarrett and

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Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Burges (1978) and Lindquist and Powell (1990). These studies report that rather than direct application, the delivery process relies more on settling of the product into the canopy over time. The uniformity of the deposition in the canopy still depended on how the material was directed over the canopy.

Knewitz et al. (2003) reported on the use of a boom nozzle for glasshouse applications. The 1 m boom was carried by hand, and the effective spray width could be changed by turning nozzles on and off along the boom. Overall, the boom using cone nozzles provided more uniform spray distribution in the ornamental canopy than a single-nozzle handgun. Nuyttens et al. (2004) found that 35 cm spacing of 80° flat-fan nozzles on a boom provided better spray distribution than the same nozzles on a 50 cm spacing and that the best nozzle-to-target distance for 80° flat fan nozzles was 30 cm. Langenakens et al. (2002) observed that boom spraying provided more uniform distribution of spray material than a handgun application for treating greenhouse plants on the floor.

Many factors influence the fate of spray and biological efficacy. Himel (1969) reported the importance of droplet size on the efficacy of pesticide sprays. His results showed that smaller droplet sizes were the most efficacious. Ebert et al. (1999a, 1999b) reported that small droplets are not necessarily the most efficacious and that the interactions among deposit size, number of deposits, and concentration of pesticide in a deposit are more important than any single factor.

With evidence of the importance of spray volume and droplet size on pesticide efficacy, the objective of this research was to determine the effect of spray volume and spray quality on the fate of spray in a mature poinsettia canopy using handgun applications. The results of this research can help floral producers make more informed decisions on their application options.

Material and Methods

Tests were conducted at greenhouses located at the Toledo Botanical Gardens in Toledo, Ohio. Plots consisted of mature poinsettias, cv. Sonora Jingle and cv. Enduring Pink, in 15 cm diameter pots arranged in a 3 × 8 arrangement on 1.2 × 2.4 m benches (replicate), as shown in figure 1. Pots were spaced approximately 25 cm on center. Plants were approximately 30 cm tall and near the stage of bracts changing color. There were two rows of guard plants were around the sides of the test area and four rows on each end of the test area. The test plants were positioned on a bench that could be moved into and lifted out of the area lined with guard plants. The bench holding the test plants was lifted out of place following treatment and moved from the treatment area into a second room where all untreated and treated plants could be held without risking contamination from the treatment area. There were three benches or replicates for each treatment. To help the operator maintain consistency in his application technique, all three replicates of each treatment were completed before starting the next treatment. The order of treatments was grouped by spray volume within each spray quality. The order of spray volume was from low to high rate. The order of spray quality was from the smallest droplet spectrum to the largest.

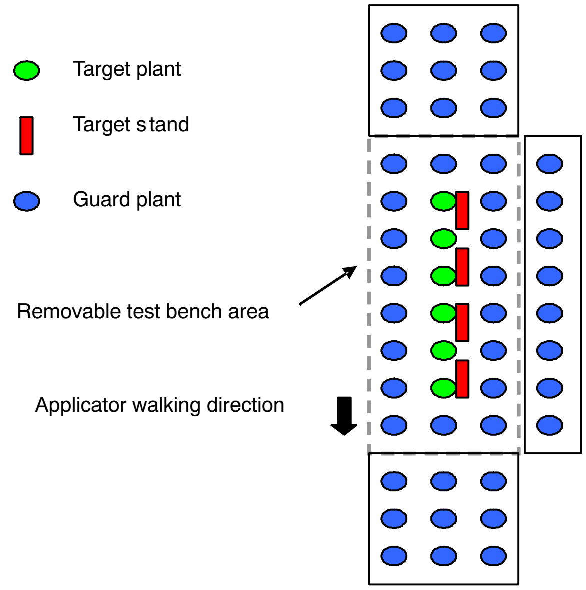

Figure 1. Greenhouse treatment area.

Droplet Size and Velocity Measurement

Several nozzles and pressure combinations were evaluated to determine parameters that fit the descriptions of Very Fine, Medium, and Coarse spray quality as defined by ASAE Standard S572 (*ASAE Standards*, 2004). Droplet size distributions and droplet velocities from the three groups of nozzles were determined using a particle/droplet laser image analysis system (VisiSizer and PIV, Oxford Lasers, Oxfordshire, U.K.), as described by Güler et al. (2007). During the tests, the laser image analysis system setting was lens option 3 at magnification setting 1. At this setting, the system could measure droplets from 42.8 to 1023.7 μm. Droplet samples were taken 50 cm below the nozzle orifice and across centerline along the long axis of the spray pattern by scanning within a 20 cm range (10 cm on either side of centerline). The measurement for each condition was replicated once. At least 10,000 droplets were sampled in each pass across the spray pattern. The particle image velocimetry (PIV) with 2D setting of the laser image analysis system was used to determine average velocities of all in-focus droplets passing through an 8 × 8 cm area 50 cm below the nozzle orifice. Velocity measurement results were averaged from at least 20 pairs of frames.

A description of the equipment parameters used in these trials is given in table 1. Figure 2 shows the handguns used in these trials. Three spray rates were used for each treatment to represent high, medium, and low spray volumes: 934.6, 467.3, and 233.6 L ha^{-1}, respectively. Spray rates were adjusted by changing the speed at which the treatment area was sprayed. The Medium quality spray was produced by a Dramm Hydra trigger gun (model MS40-TG, 1.0 mm tip, Dramm Corp., Manitowoc, Wisc.) operated at 861 kPa. The Very Fine and Coarse quality sprays were produced by a Dramm trigger-style spray gun (model MSO) operated at 3548 and 482 kPa, respectively.

Foliar Fungicide Deposits

A broad-spectrum fungicide (Milstop, BioWorks, Fairport, N.Y.) that requires good coverage for control was

Table 1. Spray equipment parameters.

Sprayer Nozzle	Liquid Pressure (kPa)	Nozzle Output (mL s^{-1})	Droplet Spectrum Characteristics $D_{V.10}$ (µm)	$D_{V.50}$ (µm)	$D_{V.90}$ (µm)	Avg. Drop Speed (m s^{-1})
Dramm trigger gun	3548	46.7	54.2	105.4	209.3	19.82
Dramm Hydra (1.0)	861	28.3	111.3	293.0	596.0	16.98
Dramm trigger gun	482	16.7	146.3	391.8	672.0	15.93

applied as if being used to manage powdery mildew infection on poinsettias. The active ingredient in Milstop is potassium bicarbonate. The formulated product was applied at the recommended rate of 1.14 kg per 378.5 L of water. Following application and sufficient time for foliage to dry, two fully expanded leaves from the top 1/3 of the plant canopy were sampled from each replicate bench on the side facing the spray and the side away from the sprayer, making a total of four leaves sampled per bench. Leaf samples were obtained from the treated plants as well as from plants on untreated replicate benches. Leaves were cut at the base of the leaf lamina using a clean razor blade. Blades were rinsed with deionized water between each cut. After cutting, the leaf was placed face up in a 10 × 16 cm polypropylene box with a depth of 7 cm. The leaves were photographed with a digital camera positioned 0.8 m directly above the box, and then 15 mL of 0.1 N HCl was added to the box to rinse the leaf.

During the rinse, leaves were shaken by hand and flipped twice to ensure that both sides of the leaf were thoroughly rinsed. After rinsing for 30 to 45 s, the leaf was discarded and the rinse solution was collected in a sealed tube (50 mL Falcon tubes, BD Biosciences, San Jose, Cal.). The solution was frozen in a -20°C freezer until analysis.

To prepare the samples, HNO_3 was added until the solution concentration was 3.5% HNO_3 (0.55 N) in each tube. The acidified solution was then injected into the inductively coupled optical emission spectrometer (ICP-OES, Iris Intrepid, Thermo Corp, Waltham, Mass.) for potassium analysis, which is an ion from the active ingredient in the spray.

Leaf area for the harvested leaves was determined using image analysis software (Assess, APS Press, American Phytopathological Society, St. Paul, Minn.), as described by Klassen et al. (2003). Briefly, the digital image was imported

(a) (b)

Figure 2. (a) Dramm trigger gun and (b) Dramm Hydra.

Figure 3. Artificial targets suspended in upper and lower canopy areas.

into the software, and the number of green pixels was counted and compared against an image containing a circular disk of known area. The pixel number was then converted into cm^2 of leaf. The potassium concentration was then divided by the leaf area to account for differences in leaf size.

Foliar spray retention data were analyzed using SigmaStat (version 2.03, Jandel Scientific, San Rafael, Cal.) using a three-way analysis of variance with spray quality, spray volume, and side of the plant relative to spray direction as the three main effects.

Artificial Canopy Deposits

The fate of spray within the poinsettia canopy was determined by spraying a tank mix of water-soluble Brilliant Sulfaflavine (MP Biomedicals, Inc., Aurora, Ohio) at a concentration of 2 g L^{-1}. Artificial targets were suspended inside foliage in the upper and bottom sections of the canopy (fig. 3). Each target was placed within the foliage rather than outside of the canopy, so there were always leaves above the target. Targets were placed along the front and back of the plant with respect to the direction of sprayer travel. Those targets located on the side facing the nozzle were designated as the front of the canopy. Targets located on the far side of the canopy were designated as the back of the canopy. The targets consisted of small dishes of 9.7 mm depth and 33.9 mm diameter. All targets were supported by 12-gauge, coated, electrical wire. Each dish sat inside a loop created at the end of the wire and was held in place by one diameter length of wire.

Artificial targets were retrieved approximately 18 h following treatment. To minimize contamination of the targets, each target was released from its holder as it was held over a 60 mL wide-mouth sample bottle. Tracer was extracted from the targets by adding 25 mL of purified water to each bottle and then shaking the bottle vigorously 15 times. Tracer samples were quantified by comparing the intensity of the emission at 460 nm with calibration solutions using a luminescence spectrometer (LS50B, Perkin-Elmer, Nor–walk, Conn.).

The interactions and main effects of quality, volume, orientation, and elevation on deposition were analyzed using a four-way ANOVA (PROC GLM, SAS Institute Inc., Cary N.C.). All p-values were compared against the test criteria of $\alpha = 0.05$ to determine significance. The influences of the aforementioned main effects on percent tracer deposition were also analyzed using a four-way ANOVA, with the data being converted into proportions by dividing by 100 and then arcsine square root transformed prior to analysis. In both cases, means were separated using Tukey's Studentized range test at $\alpha = 0.05$.

Results and Discussion

Droplet Size and Velocity Measurement

Droplet size characteristics and droplet velocity measurements for the treatments used in these trials are shown in table 1. The high-pressure (3548 kPa) Dramm trigger gun treatment produced the smallest droplet spectrum and the highest velocity droplets 50 cm below the nozzle. The Coarse spray quality was achieved by reducing the nozzle pressure of the Dramm trigger gun. The Dramm Hydra nozzle crossed the Medium spray quality line between the $D_{v.10}$ and $D_{v.50}$ droplet sizes.

Table 2. Three-way ANOVA of fungicide deposition on foliage for greenhouse handgun trials using three different spray volumes and three different spray qualities.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Quality	2	0.00696	0.00348	1.611	0.205
Volume	2	0.00195	0.000974	0.451	0.638
Orientation	1	0.0633	0.0633	29.297	<0.001
Quality*volume	4	0.0124	0.00311	1.439	0.228
Quality*orientation	2	0.000299	0.000150	0.0693	0.933
Volume*orientation	2	0.00145	0.000724	0.336	0.716
Quality*volume*orientation	4	0.00526	0.00131	0.609	0.657

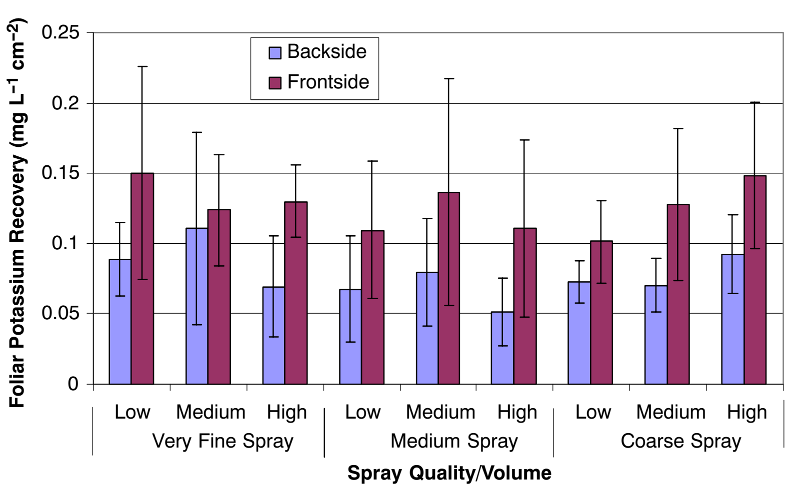

Figure 4. Average foliar potassium recovery by treatment and standard error bars on the front and back of the target plants in relation to the direction sprays were applied.

Table 3. Four-way ANOVA for artificial tracer deposit.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Quality	2	109039.6059	54519.8029	3.71	0.0264
Volume	2	426876.2362	213438.1181	14.52	<0.0001
Orientation	1	235381.9223	235381.9223	16.02	<0.0001
Elevation	1	354570.9537	354570.9537	24.13	<0.0001
Quality*volume	4	175738.9033	43934.7258	2.99	0.0202
Quality*orientation	2	61339.0077	30669.5038	2.09	0.1271
Quality*elevation	2	43184.5962	21592.2981	1.47	0.2329
Volume*orientation	2	164386.8385	82193.4193	5.59	0.0044
Volume*elevation	2	185788.4513	92894.2257	6.32	0.0022
Orientation*elevation	1	162657.2795	162657.2795	11.07	0.0011
Quality*volume*orientation	4	80244.6979	20061.1745	1.37	0.2479
Quality*volume*elevation	4	126992.1946	31748.0487	2.16	0.0753
Quality*orientation*elevation	2	49348.9356	24674.4678	1.68	0.1895
Volume*orientation*elevation	2	70802.2000	35401.1000	2.41	0.0928
Quality*volume* orientation *elevation	4	28556.2380	7139.0595	0.49	0.7462

Foliar Fungicide Deposits

Table 2 shows that there were no significant effects except for the orientation of the foliar sample in relation to the spray direction. Foliar deposits on the front of the plant were significantly higher than on leaves from the back of the plant. No corrections were made in the data to account for differences in the amount of fungicide applied by each treatment. Figure 4 shows the mean levels of potassium found on treated foliage and the standard error bars associated with each spray volume and spray quality treatment relative to the orientation (front/back) of the leaf on the plant. Despite a four-fold difference in the amount of fungicide applied between the highest and lowest spray volumes, no significant difference in the amount of fungicide on the leaves was observed between treatments.

Artificial Canopy Deposits

Table 3 shows the ANOVA for the four-way analysis of the tracer deposits on targets placed inside the canopy. The raw tracer deposit data were not normalized to account for differences in the amount of tracer applied during each treatment. There were significant two-way interactions detected in the analysis. For the orientation*elevation interaction, deposition was significantly higher on the front/upper of the canopy than the other three sections. For the volume*elevation interaction, deposition by the high-volume treatment on the upper canopy area was significantly higher than all other combinations. For the volume*orientation interaction, deposition by the high-volume treatment on the front side of the canopy was higher than the other combinations of volume and plant canopy orientation. For the quality*volume interaction, deposition for the Medium spray quality and highest spray volume was significantly higher than all of the other combinations except for the combination of the Coarse spray quality at the highest spray volume. There were no significant three-way or four-way interactions.

Tables 4 through 7 show the comparisons of spray deposits for each spray volume and spray quality combination at all four canopy sampling areas canopy locations and the Tukey groupings. Table 4 shows that significantly higher deposits were produced by the Coarse spray quality compared to the other spray qualities at the medium spray volume in the front/upper sampling area of the canopy. In addition, for the Medium spray quality, the high spray volume produced significantly higher deposits than the low or medium spray volume in the front/upper sampling area of the canopy.

In the back/upper canopy sampling area, the only significant difference in deposition occurred using the Medium spray quality and high spray volume (table 5). The handgun producing the Medium spray quality at the high spray volume produced significantly higher deposits than all other spray quality and spray volume combinations.

Table 6 shows that the high spray volume using Medium and Coarse spray quality produced significantly higher spray deposits than all other spray quality and spray volume combinations. In the most difficult area of the canopy to treat, the back/lower, there were no significant differences in spray deposits by spray volume or spray quality (table 7) despite the differences in the rate of application of the tracer.

Table 8 shows the ANOVA for the four-way analysis of the percent of artificial tracer deposit. The deposit data were normalized to account for differences in the amount of tracer

Table 4. Spray tracer deposition (μg cm^{-2}, mean ±standard error) on artificial targets in canopy for quality*volume interaction for front of plant and upper elevation.[a]

Spray Volume	Spray Quality		
	Very Fine	Medium	Coarse
Low	68.63 ±30.92 Aa	56.74 ±19.90 Aa	105.74 ±60.39 Aa
Medium	31.57 ±8.15 Aa	53.78 ±17.58 Aa	170.83 ±62.81 Ba
High	112.02 ±32.74 Aa	527.22 ±165.90 Ab	363.31 ±207.26 Aa

[a] Values with the same lowercase letters in columns and the same uppercase letters in rows are not significantly different (α = 0.05).

Table 5. Spray tracer deposition (μg cm^{-2}, mean ±standard error) on artificial targets in canopy for quality*volume interaction for back of plant and upper elevation.[a]

Spray Volume	Spray Quality		
	Very Fine	Medium	Coarse
Low	46.00 ±24.08 Aa	25.17 ±13.23 Aa	12.52 ±3.46 Aa
Medium	12.25 ±2.10 Aa	19.69 ±11.63 Aa	32.32 ±8.98 Aa
High	55.53 ±18.15 ABa	145.82 ±35.70 Bb	52.43 ±15.45 Aa

[a] Values with the same lowercase letters in columns and the same uppercase letters in rows are not significantly different (α = 0.05).

Table 6. Spray tracer deposition (μg cm^{-2}, mean ±standard error) on artificial targets in canopy for quality*volume interaction for front of plant and lower elevation.[a]

Spray Volume	Spray Quality		
	Very Fine	Medium	Coarse
Low	13.08 ±6.80 Aa	7.24 ±4.10 Aa	11.32 ±5.40 Aa
Medium	21.46 ±10.37 Aa	5.31 ±1.88 Aa	15.67 ±6.23 Aa
High	12.19 ±4.82 Aa	77.18 ±35.00 Ab	103.19 ±25.61 Ab

[a] Values with the same lowercase letters in columns and the same uppercase letters in rows are not significantly different (α = 0.05).

Table 7. Spray tracer deposition (μg cm^{-2}, mean ±standard error) on artificial targets in canopy for quality*volume interaction for back of plant and lower elevation.[a]

Spray Volume	Spray Quality		
	Very Fine	Medium	Coarse
Low	7.82 ±4.08 Aa	44.78 ±43.74 Aa	10.52 ±4.14 Aa
Medium	3.32 ±0.80 Aa	8.47 ±3.52 Aa	11.19 ±3.45 Aa
High	11.29 ±2.33 Aa	23.46 ±5.19 Aa	45.55 ±18.13 Aa

[a] Values with the same lowercase letters in columns and the same uppercase letters in rows are not significantly different (α = 0.05).

Table 8. Four-way ANOVA for tracer deposit as a percent of amount applied.

Source of Variation	DF	SS	MS	F value	Pr > F
Quality	2	0.00010647	0.00005323	2.82	0.0620
Volume	2	0.00017646	0.00008823	4.68	0.0104
Orientation	1	0.00044541	0.00044541	23.63	<0.0001
Elevation	1	0.00110810	0.00110810	58.79	<0.0001
Quality*volume	4	0.00022207	0.00005552	2.95	0.0217
Quality*orientation	2	0.00005520	0.00002760	1.46	0.2340
Quality*elevation	2	0.00001494	0.00000747	0.40	0.6733
Volume*orientation	2	0.00001439	0.00000720	0.38	0.6832
Volume*elevation	2	0.00002796	0.00001398	0.74	0.4777
Orientation*elevation	1	0.00023919	0.00023919	12.69	0.0005
Quality*volume*orientation	4	0.00004426	0.00001106	0.59	0.6724
Quality*volume*elevation	4	0.00013520	0.00003380	1.79	0.1321
Quality*orientation*elevation	2	0.00007403	0.00003701	1.96	0.1433
Volume*orientation*elevation	2	0.00000718	0.00000359	0.19	0.8267
Quality*volume*orientation *elevation	4	0.00001507	0.00000377	0.20	0.9381

applied by each of the three spray volumes by dividing the amount of tracer found on each target by the total amount of tracer delivered during that particular treatment. There were no significant three-way or four-way interactions for the analysis of the percent tracer deposit.

There were two significant two-way interactions in percent tracer deposit. For the orientation*elevation interaction, deposition was significantly higher on the front/upper of the canopy than the other three sections. There were no significant differences in the percent tracer deposit found between targets in the front/lower and the back/upper canopy areas. The percent tracer deposit was lowest on the back/lower canopy area than all other sampling locations except for the front/lower area. For the quality*volume interaction, there were no significant differences between spray quality and volume combinations except for the difference between the percent tracer deposited by the Medium spray quality/high spray volume combination and the Very Fine spray quality/medium spray volume combination.

For three of the four orientation and elevation canopy areas, there were no significant differences between either the spray qualities or spray volumes or the interaction quality*volume. In

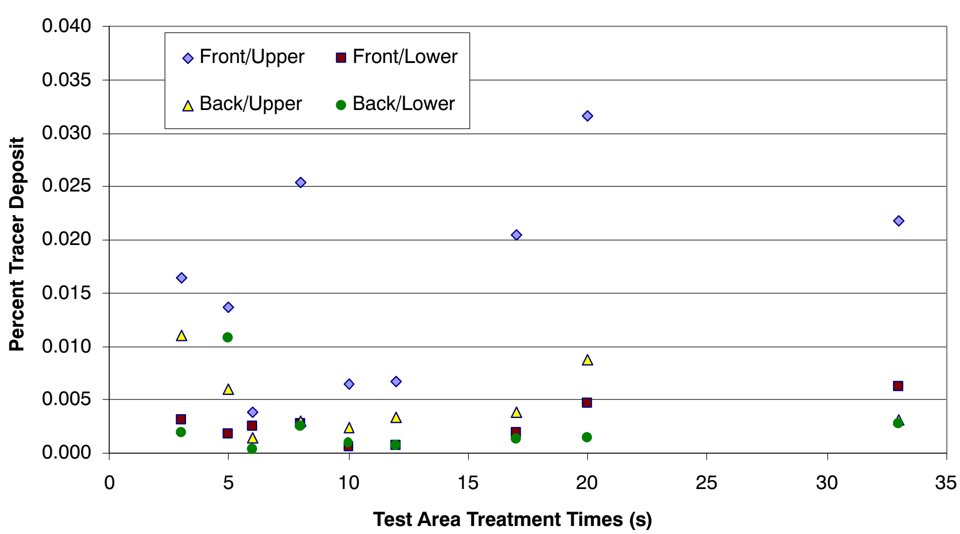

Figure 5. Percent tracer deposit for each canopy sampling location for each treatment application time.

the front/lower section of the canopy, the high spray volume provided significantly higher percent of spray deposit than the medium spray volume across all spray qualities.

Spray volume was changed by changing the time required to treat the test area while using the same nozzle tip for each spray quality rather than holding time constant and changing nozzle flow rate. Figure 5 shows the percent tracer deposit data based on the time required to treat the test area for each of the nine treatment combinations. As expected, the highest overall percent tracer deposit was found in the front/upper section of the canopy. There were smaller differences in the percent tracer deposited in the other three canopy locations across all application times. It can also be seen in figure 5 that the differences in percent tracer deposit across all application times in the three canopy sections other than the front/upper sections were relatively small, indicating that the tracer deposit in those canopy sections was not a function of the overall application time. The time to make the application had the smallest affect on the percent tracer deposit found in the back/lower of the canopy, which received the least amount of spray overall.

Summary

Results for the analysis of fungicide on foliage and fluorescent tracer on artificial targets positioned in the canopy were similar. As also reported by Lindquist et al. (1988), canopy orientation (front/back), canopy elevation (upper/lower), and the operator's ability to direct spray at each target plant had more influence over deposition in the canopy than spray volume or spray quality in these trials. It was more difficult to treat the lower canopy areas and the back of plants with respect to the nozzle orientation. There was no benefit to treating with the small droplet, high-volume sprayer parameters used in this study. However, these findings do not take into account the quality of the spray deposits on the foliage, and as suggested by Ebert et al. (1999a, 1999b), spot size, density, and concentration may be important factors in determining the efficacy of the application.

Based on differences in the amount of spray found on the front and back of plants, treating the target area from two directions would help improve the uniformity of the application. One continuing problem with a single-nozzle, handgun sprayer not addressed in this study is the variability in deposition across the treatment area. As noted previously, Langenakens et al. (2002) observed that a broadcast spray boom produced more uniform spray deposition than handgun applications. Producers would benefit from methods that help ensure more uniform applications while providing the flexibility and maneuverability of the handgun sprayer. Further research is needed to evaluate the relationship between canopy deposition and biological efficacy for other types of ornamental canopies and pesticides with different modes of action.

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