

# Fate of Preemergence Herbicide Applications Sprayed Through Containerized Hydrangea Canopies<sup>1</sup>

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## Abstract

Preemergent herbicides are applied to the soil or potted-substrate surface to prevent weed seedling establishment. Spraying through a canopy above the soil surface represents a challenge because of the filtering effect of the canopy on the spray stream and because of the additional distance created between the soil surface and nozzle. The objective of this work was to determine the effect spray quality, spray volume, and air delivery had on delivery of sprays to the substrate surface through a potted hydrangea canopy. Petri dishes and water sensitive paper were placed on the substrate surface of potted hydrangeas (*H. paniculata* 'DVPpink') to collect spray material falling through the canopy. Eight targets were used for each plant and were placed around the circumference of the pot in the four cardinal directions. Different sizes of TeeJet flat fan extended range (XR) and air induction (AI) nozzles were selected to provide 187 and 374 liters·ha<sup>-1</sup> (20 and 40 gal·A<sup>-1</sup>) application rates with medium (XR) and very coarse (AI) droplet spectrums. A specially designed, five-port, air-assist delivery device was used to make air-assisted delivery applications using TeeJet XR8001 flat fan tips. Treatments were applied over the top of a 3 × 5 pot arrangement of potted plants at a speed of 4.0 km·h<sup>-1</sup> (2.5 mph). No irrigation was applied either before or after treatment applications. Foliage sampled from the top of the hydrangea canopy had 8–10 times higher spray deposits than foliage from the middle elevation and the targets on the substrate surface. Surface coverage under the canopy ranged from 2–10% and average spot density ranged from 17–41% spots·cm<sup>-2</sup> on water sensitive paper targets. Overall, the AI11003 used to make very coarse spray applications at 374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>) produced the highest mean spray deposits and coverage on the soil surface. The air-assist sprayer produced the highest deposits in the canopy but the lowest deposits and coverage on the substrate surface. On average, only about 5% of the spray actually reached the intended target (substrate surface) across all treatments and approximately 50–60% of the spray material was accounted for on the foliage. Larger droplet sizes and higher spray volumes will help ensure better delivery through the canopy.

**Index words:** container production, weed control, preemergent herbicide, spray deposit, spray coverage.

## Significance to the Nursery Industry

Preemergent herbicide applications are developed to prevent establishment of weed seeds. In potted shrubs, these surface treatments may be made over the top of an existing

shrub canopy. A canopy may intercept spray and limit penetration to the substrate surface. These studies document the inefficiencies of application of preemergent herbicide through a potted hydrangea (*H. paniculata* 'DVPpink') canopy. Applications were made at 187 and 374 liters·ha<sup>-1</sup> (20 and 40 gal·A<sup>-1</sup>) with conventional flat fan nozzles producing a medium and very coarse spray quality and an air-assisted spraying system. The mean rate of spray deposit detected on the substrate surface under the plant canopy was only 5% of the rate detected on the substrate without a canopy above it. Even at 374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>), only 10% coverage was observed on water sensitive paper under the canopy. Overall differences in spray coverage between the five treatments were small. The high volume treatment made with larger droplet sizes produced the highest mean spray deposits under the canopy. The air-assist sprayer was the least effective method of applying the preemergent herbicide treatment. Because of these findings, producers should check the cover-

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age produced by preemergent herbicide applications using commercially available water sensitive paper and adjust spray volume and droplet size to increase penetration through the canopy to ensure more effective applications.

## Introduction

Numerous studies have documented the importance of application technique for successful delivery to ornamental crop foliage, including among them potted ivy (*Hedera algeriensis*) (2), poinsettias (*Euphorbia pulcherrima*) (6), red maple (*Acer rubrum* L.) and Turkish hazel (*Corylus colurna* L.) (4), and Canadian hemlock (*Tsuga canadensis*) (10). There is comparatively little work addressing delivery of agrichemicals through a crop canopy and onto the substrate surface. It is important from a weed control standpoint to deliver preemergent herbicides to a soil or substrate surface providing sufficient coverage to provide efficacious control rather than the actual plant canopy.

If the plant's canopy is dense, spray will not be able to reach the substrate surface below. Zhu et al. (17) looked at spray penetration into peanut (*Arachis hypogaea* L.) canopies with single- and twin-row planting systems at three growth stages with four different hydraulic nozzle tips. Peanut canopies become very large and dense, and this makes it difficult to coat all of the plant, especially the base, with insecticide to prevent insect damage. Three spray penetration tests were conducted on the peanut canopy 46, 75, and 104 days after planting. Three conventional (80° flat fan, hollow cone, and low pressure air induction) nozzles and one twin jet flat fan nozzle were evaluated. It was determined that the flat fan nozzle deposited less spray at the bottom of the canopies than the other three nozzles. It was also determined that the air induction nozzle had the highest mean deposition of spray at the bottom of canopies. The air induction nozzle is designed to lower the pressure at which the spray is exiting and thus produce larger droplets which have better penetration.

Canopy penetration typically refers to the ability to deposit spray in the middle and lower sections of the plant canopy. Ozkan et al. (13) looked at various spraying equipment and its effectiveness with fungicide application to soybeans to control Asian soybean rust (*Phakopsora pachyrhizi*). Soybean rust usually shows up in the lower part of the plant first so it is important that the fungicide spray penetrate the soybean canopy. Five sprayers were tested, and it was found that the air-assisted sprayers had higher spray deposition on targets in the middle and bottom of the canopy than the treatments that used the conventional boom sprayer. The Jacto air-assist sprayer provided the best spray penetration as far as it was measured through the canopy.

Air-assisted spraying is used to help deliver spray through greater distances and to cause foliage to deflect which increases the chances of deposition on more of the foliage surface. Several studies examining row-crop canopy spray deposits have demonstrated that at the same carrier rate, air-assisted delivery improves canopy penetration and deposition compared to conventional delivery through non-air-assisted techniques (3, 12, 14, 16). However, May (11) reported that spray retention results could vary depending on the design of the air-assist boom sprayer making the application. Fluorescent dye spray coverage studies conducted by Derksen et al. (5) found that air-assisted delivery produced greater spray coverage on the abaxial surface of bell pepper (*Capsicum annuum*) leaves than non-air-assisted delivery using either

twin-fan or air induction nozzles. Zhu et al. (18) investigated the use of a specially designed air-assisted spray to improve spray penetration and air jet velocities inside dense nursery crops. They tested three nozzle heights of 65, 75, 85 cm (26, 30, and 33 in) from the orifice at the center port of each nozzle to the ground. It was found that the specially designed five-port air-assisted sprayer had good penetration and spray deposition capability. Reducing nozzle height from 35 to 15 cm (14 to 6 in) above yew (*Taxus media* 'L. C. Bobbink') canopy did not increase spray deposition at the bottom of the canopy, but reducing the nozzle height from 25 to 15 cm (10 to 6 in) above the canopy significantly increased spray deposits in the middle of the canopy.

Most application research under a canopy has treated surface deposition as an off-target consequence of the lack of spray retention in a target canopy. Yet these studies do yield clues about how to move spray through a canopy. Jensen and Spliid (9) conducted a study to evaluate deposition on the soil through winter wheat (*Triticum* spp.) and spring barley (*Hordeum vulgare*) with different amounts of ground cover through the growing season. They showed that a high proportion of spray material reached the soil surface during early crop growth stages but decreased as the crop cover area increased. At later growth stages, less than 15% of the applied dose was found on the soil surface and was lower for wheat than for the barley test areas. Taylor and Anderson (15) showed that sprays made with flat fan nozzles with different droplet size spectrums demonstrated no differences in deposition on soil surface through a cereal canopy. Gyldenkarne, et al. (8) also showed that droplet size was not a significant factor in the soil surface deposits under a cereal canopy. But the difference in volume median diameter between the treatments was relatively small (215 vs. 267  $\mu\text{m}$ ) for the range of all nozzles available to growers to make applications.

Preemergent herbicides inhibit growth or kill germinating seedlings thus preventing their establishment. For preemergent weed management to be effective the herbicides must be applied to the soil surface. This kind of spraying requires a high canopy penetration to ensure that the spray is deposited on the soil or substrate surface. The goal of this project was to determine how spray application parameters could aid penetration through a containerized nursery crop canopy and deposition of preemergent herbicide on a substrate surface under the canopy. Droplet size, as characterized by spray quality, and spray volume were varied to determine differences in spray retention on the non-target canopy and spray deposition on the potting substrate surface. Air-assisted delivery was also evaluated because of the demonstrated potential for increasing canopy penetration.

## Materials and Methods

**Droplet sizing.** Droplet size distributions for test nozzles were determined using a particle/droplet laser image analysis system (Oxford Lasers VisiSizer and PIV, Oxford Shire, UK) described by Güler, et al. (7). During the tests, the laser image measured droplets from 42.8 to 1023.7  $\mu\text{m}$  (0.0017 to 0.04 in). At least 10,000 droplets were counted for the size measurements. Droplet samples were taken 50 cm (20 in) below all nozzles and across the centerline along the long axis of the spray pattern by scanning within 30 cm (12 in) on either side of the centerline of the spray patterns. Atomization characteristics of the XR11001 nozzle used for the air-assist treatments were measured using discharge from only the

**Table 1. Droplet size characteristics resulting from different nozzle types and applied pressures. Nozzles and pressures were selected to produce sprays with either medium or very coarse spray qualities.**

Nozzle tip	Spray quality	Nozzle pressure (kPa)	Application rate (liters·ha <sup>-1</sup> )	Mean nozzle flow rate (liters·min <sup>-1</sup> )	Droplet spectrum characteristics			
					D <sub>V,10</sub> (µm)	D <sub>V,50</sub> (µm)	D <sub>V,90</sub> (µm)	Maximum (µm)
XR8002	Medium	206.7	187	0.610	103.2	188.0	356.7	487.0
XR8004	Medium	210.1	374	1.233	104.7	227.4	481.4	592.2
AI110015	Very coarse	372.1	187	0.616	157.6	398.2	725.7	894.0
AI11003	Very coarse	375.5	374	1.236	150.9	440.3	783.4	925.4
Air-assist, XR8001	Medium	103.4	187	0.224	115.2	216.4	360.3	488.8

center nozzle and air blowing through the five-port manifold at the test condition speed.

**Treatment descriptions.** Each of five treatments listed in Table 1 were replicated four times. Treatments were selected to evaluate the effect of spray volume (187 and 374 liters·ha<sup>-1</sup>) (20 and 40 gal·A<sup>-1</sup>), spray quality (medium and very coarse), and air assistance on delivery of spray through a canopy to the surface of the potting substrate. Nozzle spray quality was determined using manufacturer's published ratings. All treatments were applied at a travel speed of 4.0 km·h<sup>-1</sup> (2.5 mph). The nozzle spacing for the TeeJet® XR8002, AI110015, XR8004, and AI11003 (Spraying Systems Co., Wheaton, IL) broadcast boom nozzle treatments was 48.3 cm (19 in). The spray boom supported three nozzles for each treatment. Nozzle height over the canopy was 45.7 cm (18 in) for the 80° degree treatments and 48.3 cm (19 in) for the 110° nozzles.

The five-port nozzle (Fig. 1) consists of an air manifold with five ports (Montana Industrials, Dal Negro, Brazil; distributed by Pickin' Patch, Inc., Plymouth, IN) and five nozzles. The internal geometric construction of the five-port air manifold is described by Zhu et al. (18). The manifold was cast with five ports at 15° radial separation, each with an inside diameter of 3.6 cm (1.4 in). The liquid discharger was a modified TeeJet®, XR8001, flat fan tip (Spraying Systems Co., Wheaton, IL) and was mounted at the centerline of each port of the five-port air manifold. The five-port manifold was operated at 30° forward of vertical with the center of the manifold 35.6 cm (14 in) above the canopy. The effective spray width for the air-assist, XR8001 treatment was 91.4 cm (36 in). The air for the air-assist nozzle was provided by a leaf blower/vacuum (model BV4000, Black & Decker, Towson, MD) mounted on the irrigation boom. Air velocity measurements of the modified five-port spray nozzle were made using a TSI Model 8386A VelociCalc air velocity meter (Shoreview, MN). The air velocity at the five outlets was measured directly at each nozzle port. The air velocity measurements were offset from the spray tips, which were mounted in the center of the spray nozzles and interfered with measures directly at the outlet. The blower produced an average outlet speed of 36.0 m·s<sup>-1</sup> (80 mph).

The four boom and one air-assist treatments were mounted on a horizontal, 5.2 m (17 ft) tower irrigation boom supported on the ends by rails. A common sense controller (Greenhouse Technology, Inc., Richmond, KY) was used to control travel speed over the treatment area. The liquid spray mix delivery system consisted of an air pressurized, 2 liter (0.53 gal) bottle tank and a handgun trigger valve for starting and stopping spray delivery. Spray delivery was activated by an operator

walking with the automated irrigation boom system and activating the trigger valve during treatment (Fig. 1).

Spray coverage and spray deposit tests were performed using mature hydrangea (*H. paniculata* 'DVPpinky') canopies planted in #3 pots [11.3 liter (3 gal)]. Plants were approximately 50 cm (20 in) tall at the time of the tests. Fig. 2 illustrates the layout for the test plot. Thirteen plants were used as guard plants that surrounded two hydrangeas assigned as target plants (Fig. 2). New target plants were used for each application. The orientation of target plants was preserved for repeated tests by labeling target plant pots with cardinal directions before the tests. Target plants were oriented with regards to the sprayer's starting position with North (N) being the area furthest from the sprayer. An empty pot turned upside down was used to simulate a no-canopy spray situation where canopy would not interfere with spray movement to the potting substrate surface.

**Spray coverage assessment.** Water sensitive paper (WSP) targets [50.8 × 38.1 mm (2.0 × 1.5 in)] (Syngenta Crop 132 Protection AG, Basle, Switzerland) were positioned under the canopy to detect spray coverage. All coverage tests were completed using only tap water as the test spray liquid. Targets were placed on the potting substrate surface and aligned with the four cardinal directions with one target set near the



**Fig. 1. Air-assist sprayer five-port nozzle mounted on irrigation boom with operator controlling spray release with a handgun trigger valve in operation over test plot of potted plants and no-canopy check pot. Insert shows close-up of five-port nozzle with nozzles centered in the outlets.**

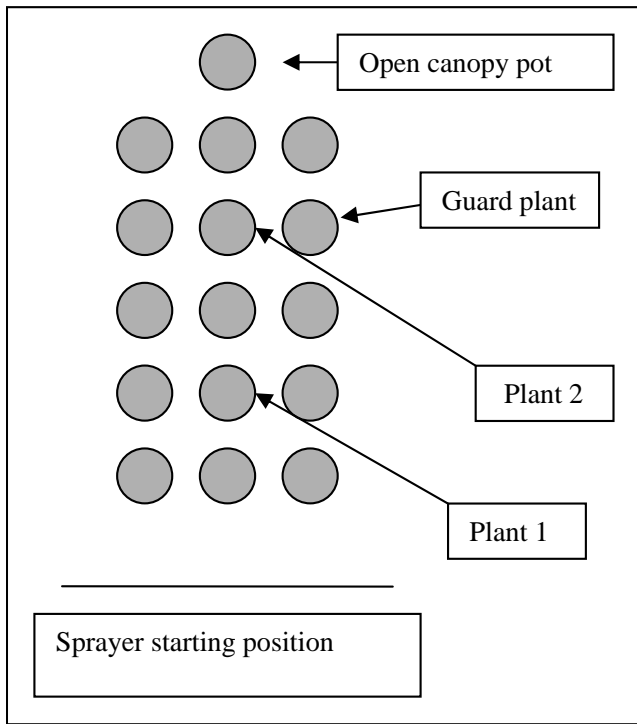


Fig. 2. Experimental layout showing location of target plants and open canopy pot changed for each application and guard plant locations reused for each application.

plant stem and one target half-way between the plant stem and the edge of the pot (Fig. 3). The WSP used for the air-assisted sprayer tests had a metal washer attached to the back with double-sided tape to ensure they did not move during the tests. The WSP were labeled by cardinal direction position and location relative to the plant stem. Two WSP were labeled as either cardinal directions east (E) or west (W) for the open canopy target. After drying, WSP targets were collected and stored until they could be analyzed.

Spray coverage on WSP targets was measured with a handheld business card scanner (NeatReceipts, NEAT Business Cards color scanner, Philadelphia, PA), a laptop computer, and a custom-designed program 'DepositScan' (<http://www.ars.usda.gov/mwa/wooster/atru/depositscan>). The resolution of the scanned images was 600 dpi.

**Spray deposit assessment.** Spray deposit assessments were made the day following the spray coverage assessments using the same experimental plan. The same target plants were used for each replication of each treatment. The placement and orientation of each target plant was also the same as for the spray coverage assessments. All treatments applied a spray mixture containing water and Brilliant Sulfaflavine (BSF) (MP Biomedicals, Inc., Aurora, OH). Spray mix concentrations of 6 and 3 g·liter<sup>-1</sup> (0.8 and 0.4 oz·gal<sup>-1</sup>) were used for the 187 and 374 liters·ha<sup>-1</sup> (20 and 40 gal·A<sup>-1</sup>) treatments respectively to ensure that all treatments applied the same amount of tracer over the treatment area.

Petri dish targets [35 mm (1.4 in) diameter] were placed in the same location as the WSP (Fig. 3) before each treatment including two target dishes on the pot representing the no-canopy situation. After treatment and a drying period, petri dishes were collected using forceps and stored in capped 180

ml (6 oz) glass bottles. Forceps were cleaned with alcohol wipes after handling each treated petri dish target to prevent cross-contamination of samples.

After the petri dishes were collected, three leaves were collected from each of two elevations: the upper part of the canopy and the middle of the plant. Samples collected from the upper part of the canopy were not the top-most leaves but below leaves with direct exposure to spray and in the upper third of the plant. The middle canopy area was defined as the area approximately 23 to 25 cm (9 to 10 in) above the top of the potting substrate surface. This sampling protocol ensured that the leaves being sampled were located above the pot rather than overhanging the pot and to also ensure that spray directed at these leaves was also directed at the potting substrate surface rather than off to the side of the pot. Leaves were held with forceps while being cut from the stem and then placed in 180 ml (6 oz) glass bottles. The three leaves sampled from the same elevation were placed in the same capped storage bottle. The forceps were cleaned with alcohol wipes after all three leaves from each elevation had been sampled to prevent cross-contamination between elevations and plants.

After all the petri dishes and leaves were collected, sample bottles were stored in a cool and dark area. Spray deposit was removed from leaves by adding 50 ml (1.7 oz) of purified water to the storage jar, recapping the jar and hand shaking for 20 s. A similar procedure was followed for washing the petri dishes but only 20 ml (0.68 oz) of purified water was added to each collection jar. After shaking the samples, 4 ml (0.14 oz) of the rinse solution was placed into a cuvette, and the sample was put in a luminescence spectrometer (model LS 50B, Perkin-Elmer, Ltd., Beaconsfield, UK) using an excitation wavelength setting of 460 nm to determine the fluorescent intensity of the sample. The fluorescent intensity of each sample was read against a standard calibration curve to determine the mass of dye in each sample. If a sample concentration fell above the calibration range, it was further diluted and measured again.

After the leaves were washed, they were removed from the collection bottle and towel-dried in preparation for measurement of the area of each sample. The area of each leaf was measured using a video-based measurement system (Delta-T, Cambridge, England). These area measurements were

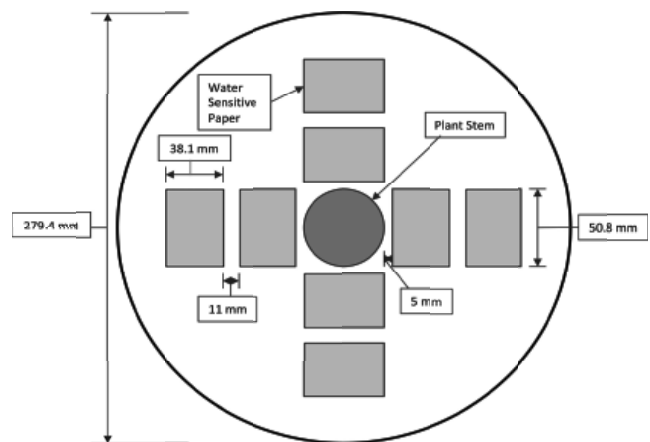


Fig. 3. Position of water sensitive paper targets on potting substrate surface under canopy.

**Table 2. Fluorescent dye deposits on canopy foliage and potting substrate surface, with or without a hydrangea shrub canopy obstructing the spray.**

Nozzle tip	Spray quality	Application rate (liters·ha <sup>-1</sup> )	Within canopy		Substrate below canopy	Substrate without canopy
			Upper	Middle		
						μg·cm <sup>-2</sup>
XR8002	Medium	187	1.65	0.16	0.29ab <sup>z</sup>	3.84ab
XR8004	Medium	374	1.70	0.08	0.13cd	3.66b
AI110015	Very coarse	187	1.62	0.16	0.19bc	3.94a
AI11003	Very coarse	374	1.53	0.17	0.31a	3.78ab
Air-Assist, XR8001	Medium	187	2.36	0.15	0.05d	3.11c
East					0.07b	
North					0.16b	
South					0.27a	
West					0.28a	

<sup>z</sup>Means with different letters are significantly different according to Fisher's protected least significant difference test.

doubled to account for abaxial and adaxial leaf surfaces. The amount of spray deposit on leaves was calculated by dividing the mass of BSF dye measured from the wash sample by the leaf surface area.

*Statistical analysis.* Data were subjected to analysis of variance (ANOVA) to determine the influence of random and fixed effects on spray deposition. Fisher's protected least significant difference (LSD) test was performed to compare means.

## Results and Discussion

The AI110015 and AI11003 nozzles produced coarser droplet spectrums than the XR8002, XR8004, and XR8001 nozzles (Table 1). There was nearly a 2× difference in the  $D_{v,50}$  between the medium and very coarse treatments used at the same application rate. The XR8001 nozzle used for the air-assist treatment produced a slightly narrower droplet size spectrum than the other medium spray quality nozzles, the XR8002 and XR8004.

Spray deposits detected on foliar and potting surface targets are shown in Table 2. Within the hydrangea canopy, significant differences were detected between the spray deposits found on leaves taken from the upper and middle canopy sections. While not the primary treatment target area, the 10–20× difference in the amount of spray deposit measured between the two elevations demonstrates how difficult it is to uniformly treat a canopy even when sampling sites are only different by 25 cm (10 in). These results also demonstrate how difficult it is for spray to penetrate into different parts of a canopy with increasing distance from the sprayer. While mean deposits in the upper canopy for the air-assist XR8001 treatment were higher than the other treatments, no significant differences in leaf deposits were detected between treatments. Also, no significant differences in leaf deposits were detected on samples taken from the middle canopy section.

No differences in substrate level spray deposits were detected between targets along the same cardinal direction but at different distances from plant stem. Differences in substrate level spray deposits were significant by sampling location around the pot (Table 2). However, the treatment by sampling location interaction was not significant. All

substrate level spray deposits for each pot were combined to determine if differences existed between treatments. Despite producing similar leaf deposits as the other treatments, the air-assist, XR8001 treatment produced significantly lower deposits in petri dishes under the canopy than all treatments except for the XR8004 treatment at 374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>). The ability of the air-assist treatment to deposit material on the ground targets under the canopy may have been the result of the air reflecting off the potting substrate surface and carrying spray droplets away from the targets. The very coarse spray quality, AI11003 treatment at 374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>), produced the highest mean deposits on the ground targets except for the medium spray quality, XR8002 treatment. There were no significant differences in the ground target deposits between the two, non-air-assist, 187 liters·ha<sup>-1</sup> (20 gal·A<sup>-1</sup>) treatments despite the differences in spray quality. At the higher application rate [374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>)] the very coarse spray quality AI11003 treatment produced significantly higher deposits on the ground targets than the medium spray quality XR8004 treatment.

Comparing by spray volume for the medium spray non-air-assist treatments, the lower application rate XR8002 treatment produced higher ground deposits than the higher application rate XR8004 treatment. For the very coarse spray treatments, the higher application rate, AI11003 treatment produced significantly higher deposits than the lower application rate AI110015 treatment on the ground targets.

The open canopy assessments provide an estimate of the spray deposit on the potting substrate with no canopy to intercept the spray material. Table 2 shows the mean deposits on the Petri dish ground targets used at the open canopy target location (Fig. 1). Mean open canopy ground target deposits were more than 1700% higher than ground deposit targets (3.66 vs. 0.20 μg·cm<sup>-2</sup>) measured under the canopy demonstrating the effect of the canopy on the ground deposits. No significant differences in ground target deposits were detected between the two 187 liters·ha<sup>-1</sup> (20 gal·A<sup>-1</sup>) treatments and the very coarse, AI11003, 374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>) treatment. The air-assist XR8001, treatment produced significantly lower mean deposits on the open canopy ground targets than all the other treatments. This trend for the air-assist treatment is similar to that observed for the substrate level ground target deposits under the canopy and can likely be attributed to reflection of the air and spray stream

**Table 3. Effect of droplet type and spray volume on spray solution deposition on potting substrate surface located beneath the canopy of hydrangea.**

Nozzle tip	Spray quality	Application rate (liters·ha <sup>-1</sup> )	Coverage (%)	Spot density (drops·cm <sup>-2</sup> )
XR8002	Medium	187	5.3	38.2
XR8004	Medium	374	5.7	41.0
AI110015	Very coarse	187	3.1	16.6
AI11003	Very coarse	374	10.0	32.1
Air-Assist, XR8001	Medium	187	1.7	24.2
LSD <sup>a</sup>			1.9	6.4
Main effects				
Spray quality			0.1291	0.0001
Application rate			0.0001	0.0001
Interaction			0.0001	0.0065
Air-assist vs others			0.0001	0.0027

<sup>a</sup>Value for Fisher's least significant difference test.

off the substrate surface. Overall, there was less variability in deposits for the open canopy treatment targets than those for ground targets under the plant canopy.

Spray coverage and spot density provide insight into the distribution of spray on the potting substrate surface under the plant canopy. Since herbicides tend not to move far from the impact point, efficacy should be improved with better coverage and distribution of spray. Significant differences in coverage were detected among the spray quality treatments (Table 3). The AI11003, medium spray quality treatment produced significantly higher coverage (10%) than all other treatments. There was no significant difference in coverage between the two non-air-assist (XR8002 and XR8004) and medium spray quality treatments. With a mean coverage of 1.7%, the air-assist treatment produced significantly lower spray coverage than all the other treatments. Between the four, non-air-assist treatments, spray quality was not a significant effect in the spray coverage. However, there were significant differences detected between applications rate with the higher volume treatments [374 liters·ha<sup>-1</sup> (40 gal·A<sup>-1</sup>)] producing higher mean coverage overall than the lower volume treatments [187 liters·ha<sup>-1</sup> (20 gal·A<sup>-1</sup>)]. The spray quality and application rate interaction was significant and likely a result of the coverage being similar for the low and high application rates for the medium spray quality but being different between the different application rates for the very coarse spray quality treatments (3.1 vs. 10.0%). The overall trend in the variation in ground target spray coverage was similar to the trend in the ground target spray deposits under the canopy. In each case the air-assist XR8001 treatment produced the lowest value and the AI11003 treatment produced the highest value. The mean spot density measured on WSP ground targets under the canopy is shown in table 3. Spray quality and application rate effects produced significant differences in spot density. The spray quality by application rate interaction was significant. The medium spray quality, high volume, XR8004 treatment produced significantly greater spot density (41.0 spots·cm<sup>-2</sup>) than all other treatments except for the lower volume, medium spray quality XR8002 treatment. The spot density for the XR8004 treatment was not significantly greater than that for the XR8002 treatment despite a 2× greater application rate. The low volume, very coarse spray quality AI110015 treatment produced the lowest

spot density at 16.6 spots·cm<sup>-2</sup>. The smaller spot density for the AI110015 treatment than the XR8002 treatment at the same application rate was expected based on the droplet size characteristics measured for each nozzle treatment (Table 1). On the other hand, the higher volume nozzle treatments did not exhibit the same trend. The very coarse AI11003 treatment produced significantly lower spot density on the WSP ground targets than the medium spray quality XR8004 treatment at the same volume. However with the mean droplet size measured for the AI11003 (Table 1) being approximately twice that of the XR8004 treatment, the spot density for the AI11003 nozzle was still high enough to produce higher coverage (Table 3) on the WSP ground targets than the XR8004 nozzle at the same application rate. Similarly, while the air-assist XR8001 treatment produced significantly higher spot density on the WSP under the canopy than the AI110015 nozzle at 187 liters·ha<sup>-1</sup> (20 gal·A<sup>-1</sup>), the  $D_{v,50}$  of the AI110015 treatment (398.2 μm) was nearly twice that of the air-assist XR8001 treatment (216.4 μm) offsetting differences in spot density and producing similar spray coverage. However, the recommendation from a pesticide manufacturer (1) is 20–30 spots·cm<sup>-2</sup> for efficacious pre-emergent herbicide application. Based on this recommendation, the range of spot density observed for all treatments except the AI110015 nozzle may provide adequate control.

These results demonstrate how a canopy interferes with herbicide sprays directed at a potting substrate beneath that canopy. Most of the herbicide spray mix is captured within the non-target canopy. Treatments evaluated in this study resulted in anywhere from 6–40 times higher deposits captured in the upper third of the hydrangea canopy compared to ground target deposits. Coverage across the potting substrate surface was also affected by the canopy. Treatments in this study produced only 2–10% coverage and 17–41 spots·cm<sup>-2</sup> on the WSP on the potting substrate surface. However, further studies are necessary to determine if this level of coverage and spot density will provide the desired level of control.

On average, the air-assist treatment as used in these trials would be less effective than the non-air-assist treatments because it produced the lowest mean deposits on the potting substrate surface as well as the lowest spray coverage. Slowing air speed and increasing droplet size would reduce

the chances of spray reflecting off the potting substrate surface. The spray deposit results by spray volume or spray quality used in these trials were inconsistent. While the medium spray quality XR8002 and XR8004 treatments demonstrated a potentially greater density on the ground targets under the canopy than the very coarse treatments, the higher spray volume, very coarse spray quality, AI11003 treatment produced greater spray deposits and spray coverage on the ground targets. Future efficacy evaluations will aid in determining the spray coverage and deposits guidelines that can be used to determine the most efficacious application technique for pre-emergent herbicide application over a production canopy.

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