Detection and Quantification of Nursery Spray Penetration and Off−Target Loss with Electron Beam and Conductivity Analysis

C. R. Krause, H. Zhu, R. D. Fox, R. D. Brazee, R. C. Derksen, L. E. Horst, R. H. Zondag

Abstract. *Spray penetration and off−target loss from a conventional, air−assist, axial−fan sprayer and a high−clearance, boom−type sprayer were investigated in Honey Locust (*Gleditsia triacanthos*) and Canadian Hemlock (*Tsuga canadensis*) trees located in two different production nurseries. Aqueous tracer solutions of either $Ca(NO_3)_2$ foliar fertilizer or $Cu(OH)_2$ fungicide were used in the experiments. Spray deposition distributions within canopies and off−target loss to drift and the ground were assessed via residues collected on foliage, electron microscope stubs, artificial plates, vertical and ground−level profile plastic tapes, and high−volume air samplers. Electron beam analysis (EBA) was used to assay residues on stubs, leaves, and needles placed and collected at several locations and heights in the canopy. Plastic tape samples were evaluated with a laboratory spray deposit analyzer using a conductivity detector. Both assessment methods used in the present study were useful for detection and quantification of Ca or Cu spray penetration within nursery canopies. The average spray deposit on upper surfaces of leaves was three times that deposited on lower surfaces within the Honey Locust trees. Spray deposit at the top of Canadian Hemlock tree canopies was 14 times higher than that at the middle and bottom of canopies. Spray deposit on ground targets greatly decreased as the distance from the spray path increased in both nurseries; however, airborne spray deposits did not decrease as much with increasing downwind distance as ground deposits.*

Keywords. *Electron beam analysis, Nursery crops, Penetration, Pesticide, Spray drift.*

Horticulture industries generally produce high−value crops, usually on smaller acreage operations than field crops. Nurseries may range in size from a few acres to several hundred acres depending on the varieties of stock grown. While horticultural industries use less total volume of pest control materials, the variety of those materials and frequency of use is greater due to the vulnerability of ornamental and food−use crops to many insect pests and diseases.

The nursery and horticulture industry is one of the fastest growing enterprises in U.S. agriculture. It produces over 10% of all income from agricultural products. Many of the products are attacked by pests and require sprayed chemical or natural pest control agents. Some research on spraying nursery stock has been conducted, mainly on Christmas trees (Groszkiewicz et al., 1991; Groszkiewicz and Hilton, 1991), but widespread spray trials have not been reported in the literature. Based on the experience with measuring spray deposit (Hall et al., 1975), canopy penetration (Franz et al., 1987, Khdair et al., 1994), drift from spraying fruit trees (Fox et al., 1993), and electron beam analysis (EBA), a combination of scanning electron microscopy, energy dispersive x−ray analysis, and digital image analysis (Krause, 1985; Krause and Powell, 1986; Krause et al., 1996; Krause et al., 1997; Zhu et al., 1997), experiments were conducted at production nurseries to assess the performance of two grower application programs.

Bache and Johnstone (1992) have stated that more precise knowledge of fungicide coverage and plant canopy penetration is required to maximize the effectiveness of chemical and biological crop management strategies. Many types of collectors have been used to measure deposits in plant canopies and downwind deposits of spray drift. Salyani and Whitney (1988) evaluated a fluorescent tracer and copper as tracers for spray deposit experiments in citrus. They measured similar spray deposits using both tracers on leaves and on artificial targets, but the colorimetic results with copper appeared more stable. Miller et al. (1992) compared the collection efficiencies of Teflon spheres and flat cards. They conducted still−air studies and found similar deposition, but greater wind speeds reduced deposits on flat cards compared to spheres mounted above the ground. Miller (1993) reviewed several sampling techniques used to measure the spray drift.

Many nurseries operate in areas close to residential districts and urban or suburban areas. Due to the circumstance of nursery crop production, advanced sampling techniques are needed to efficiently and accurately detect spray distributions

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in nursery crop areas. In addition, to obtain the optimum pesticide spray management, delivery systems must be operated economically and effectively with minimum canopy disturbance and minimum spray drift. Many nursery growers expressed interest in evaluating the effectiveness of their application programs, including deposit uniformity throughout the canopy, spray loss on the ground, and spray drift from the sprayed area. The objective of this research was to detect and quantify spray penetration, off−target loss, and coverage on two different types of nursery crops by using conductivity analysis and electron beam analysis as application assessment methods.

Materials and Methods

Spray Experiment in Canadian Hemlock Nursery

The 1.5 m tall Canadian Hemlock (*Tsuga canadensis*) trees were sprayed with a high−clearance, boom−type, over−the−row sprayer (Hagie Manufacturing Company, Clarion, Iowa). Weather conditions are shown in table 1. A plot map of the site is shown in figure 1. The hemlock was planted in rows 1.2 m on center, trees were 0.9 m apart in the rows, and the bottoms of the canopies were touching within rows. Two rows were treated with each pass of the sprayer. Sprays were directed downward toward tree canopies. Five hollow−cone nozzles (TeeJet D4−25, Spraying Systems Co., Wheaton, Ill.), one over the top and two on each side, were used to spray each row. The operating pressure on the nozzles was approximately 1378 kPa. The sprayer traveled along the tree rows with travel speed of 1.8 m/s. Kocide 101 compound (Griffin Corporation, Valdosta, Ga.) containing copper hydroxide, $Cu(OH)_2$, was selected as the tracer and applied at a rate of 1.56 L/ha. Copper hydroxide is relatively non−phytotoxic and has relatively high conductivity. Low ambient levels of copper naturally occurring in the background also facilitated electron beam analysis of spray targets. The spray mixture was applied at a rate of 1403 L/ha. Tests were repeated three times.

Samples of spray deposition at different levels within tree canopies, beside trees, and on the ground and spray drift in the

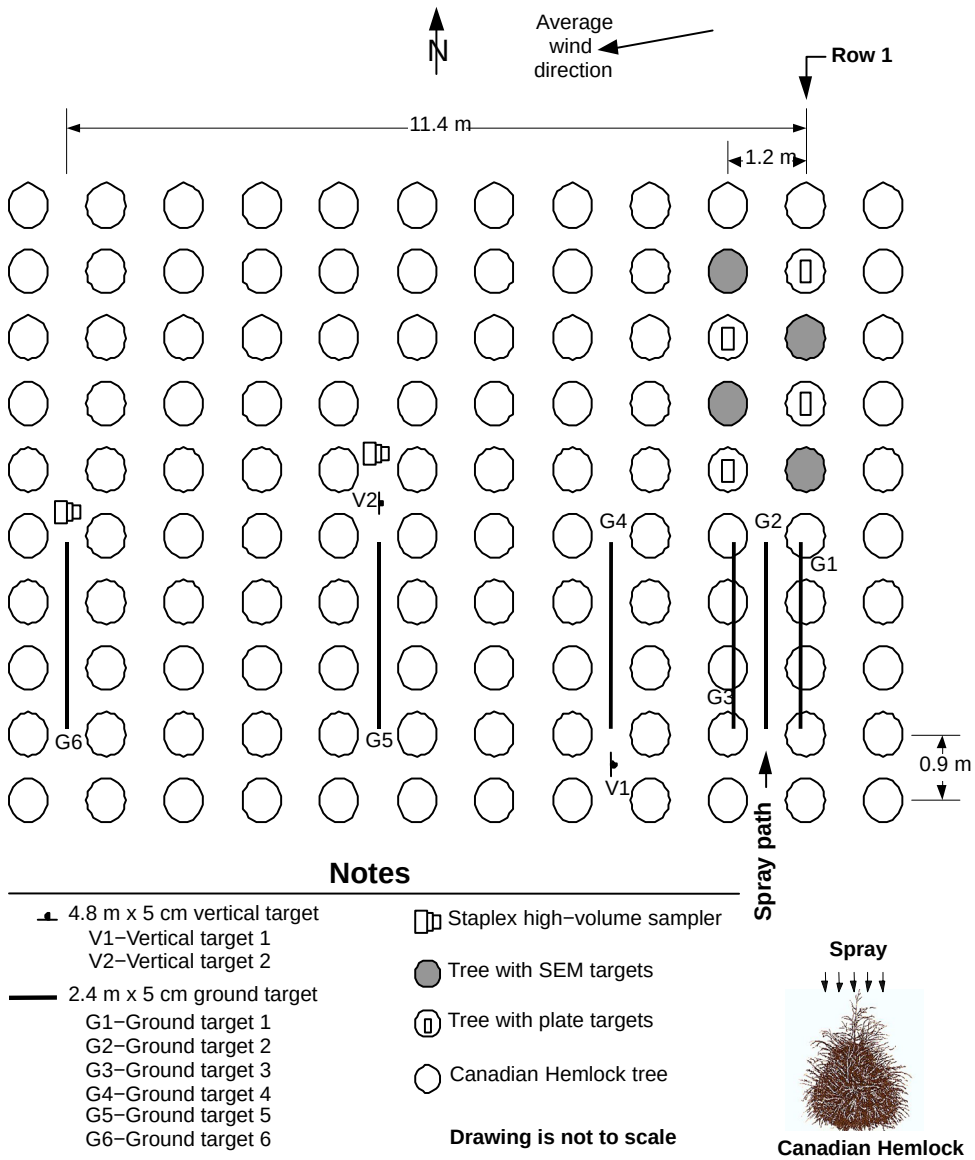

Figure 1. Plan view of Canadian Hemlock nursery spray site showing location of spray collectors.

Table 1. Average weather conditions at spray sites.

	Spray Site	
	Honey Locust	Canadian Hemlock
Temperature (°C)	28.1	27.6
Relative humidity (%)	67	60
Wind speed (m/s)	1.6	1.0
Wind azimuth (degree)	276.5	81

air were collected. Sample collector positions relative to the spray path are shown in figure 1. Inert sample collectors were used to collect spray deposits at 0.12 m (low), 0.9 m (medium), and 1.4 m (high) above the ground adjacent to the trunk (shown as SEM targets in fig. 1). The inert sample collectors were conductive sticky stubs. Five needles were also sampled at each level next to the inert sample collectors. The inert stubs and needles were collected and placed in storage boxes after each of the three spray trials, which were moved upwind between each pass to ensure that unsprayed canopy was used.

To compare the sampling method with inert stubs, spray deposits at each of three levels (0.05, 0.51, and 1.30 m above the ground) within canopies were collected with four sheet−metal plates (fig. 1). Each plate was 2.5 × 7.6 cm and was horizontally mounted on a stake. Two sample stakes were placed in a tree on each sprayed row for each test. One stake (with collectors) was placed as near to the tree trunk as possible, and another stake was placed about half way from the center of the row to the edge of the canopy. The four simulated−leaf plates at each level and location were put into a 250 mL bottle after each spray test.

Two vertical plastic tape targets (V1 and V2 in fig. 1) were used to collect off−target spray and airborne movement from the sprayer. The vertical target was 4.8 m long and 5 cm wide and was mounted with two rubber bands in two galvanized, 2.4 m long sheet−metal tape holders. The two holders were attached to a 5.3 m long and 2.5 cm diameter steel pipe, which was secured to the ground. The first vertical target was between the fourth and fifth downwind rows (3.0 m from the first row centerline), and the second vertical target was 6.6 m from the first row centerline. After each replication, every tape was folded with its two holders and stored in a 7.6 cm diameter and 3.0 m long PVC pipe in order to protect the tape from contamination during its transportation to the laboratory.

Three 2.4 m × 5 cm plastic tape collectors (G1, G2, G3) were used to collect ground deposits within the spray area, with three more (G4, G5, G6) located in downwind rows (fig. 1). Distances of the ground targets from the first row centerline were 0, 0.6, 1.2, 3, 6.6, and 11.4 m for G1, G2, G3, G4, G5, and G6, respectively. Each sample tape was wound and put into a 400 mL bottle after each spray trial.

To determine airborne spray movement, two Staplex high−volume samplers (model TFIA, Staplex Company, Brooklyn, N.Y.) were placed between the fourth and fifth rows (6.6 m from the first row centerline) and between the eighth and ninth downwind rows (11.4 m from the first row centerline) at the 3 m elevation (fig. 1). The Staplex high−volume sampler used a 10 cm diameter cellulose filter, while the actual sampling area was within the 9 cm diameter region. The average air velocity through the filter was about 1.5 m/s. The paper filters were removed from the samplers and stored in 400 mL bottles after each spray trial.

Spray Experiment in Honey Locust Nursery

The seven−year old Honey Locust trees (*Gleditsia triacanthos*) were sprayed with a Durand−Wayland Streamliner 1500, a conventional, air−assist, axial−fan sprayer. This type of sprayer was typically used to spray tall trees in the nursery. The trees were approximately 4 m in height, and branches were not present on the trunk below 1 m elevation. A plot map of the site is given in figure 2. The spacing between drive rows was 3.7 m, and row spacing within double rows was 2.7 m. Trees were 1.8 m apart in the rows. Four TeeJet D5−45 nozzles and one D8−56 disc/core hollow−cone nozzle (Spraying Systems Co., Wheaton, Ill.) were used on each side of the sprayer from bottom to top, respectively. Nozzle operating pressure was approximately 2,067 kPa. Nozzles only on one side of the sprayer were used to discharge spray normal to the row. The sprayer traveled at 2.2 m/s on spray path 1, and then was returned to the starting line while it sprayed along spray path 2 before the targets, except for two Staplex samplers and two ground targets (G3 and G4), were collected from the first spray pass. This was necessary for spray drift measurement because the wind direction changed in the range of about 270° after the first spray treatment. Weather conditions are shown in table 1. The spray mixture was 100 ppm of calcium nitrate, $Ca(NO_3)_2$, and water. Calcium nitrate was used as the tracer because of its non−phytotoxic nature at this rate and relatively high conductivity. The spray mixture was applied at a rate of 823 L/ha.

The positions of deposition and drift collectors relative to the spray path are shown in figure 2. Foliar samples for spray deposition within canopies were collected from 2 m (low), 3 m (medium), and 4 m (high) elevations in four trees, only after the first spray pass. The foliage was mounted on 12 mm diameter, conductive/sticky tabs on stubs that were fastened onto specimen mounts (Ted Pella, Redding, Cal.). Inert sample collectors were also placed at 2, 3, and 4 m elevations within tree canopies on trees 1 and 3 in the first row and on trees 2 and 4 in the second row (shown as SEM targets in fig. 2).

Four 4.8 m × 5 cm vertical plastic tape targets were used to collect spray distributions from the sprayer in the vertical direction and to evaluate spray penetration through the trees. The first vertical target (V1) was located at the middle of two trees on the first row, the second target (V2) was located behind the first tree, the third target (V3) was located between two trees in the second row, and the fourth target (V4) was located behind a tree in the fourth row.

Four 2.4 m × 5 cm plastic tape collectors were used to sample ground deposits (fig. 2). The first collector (G1) was located in the middle of the first and second rows, the second collector (G2) was located between the third and fourth rows, and the third (G3) and fourth (G4) ground collectors were located 19.8 and 32 m downwind from the spray path, respectively.

To sample airborne spray, two Staplex high−volume samplers were placed 19.5 and 31.5 m downwind from the spray path at an elevation of 3 m (fig. 2).

Similar to the tests in the Canadian Hemlock nursery, the tests in the Honey Locust nursery were repeated three times with the same trees. Spray samples were collected 15 min after each trial and then placed in storage boxes for inert stubs and foliages, in 400 mL bottles for ground targets and paper filters, and in 3.0 m long PVC pipes for vertical targets.

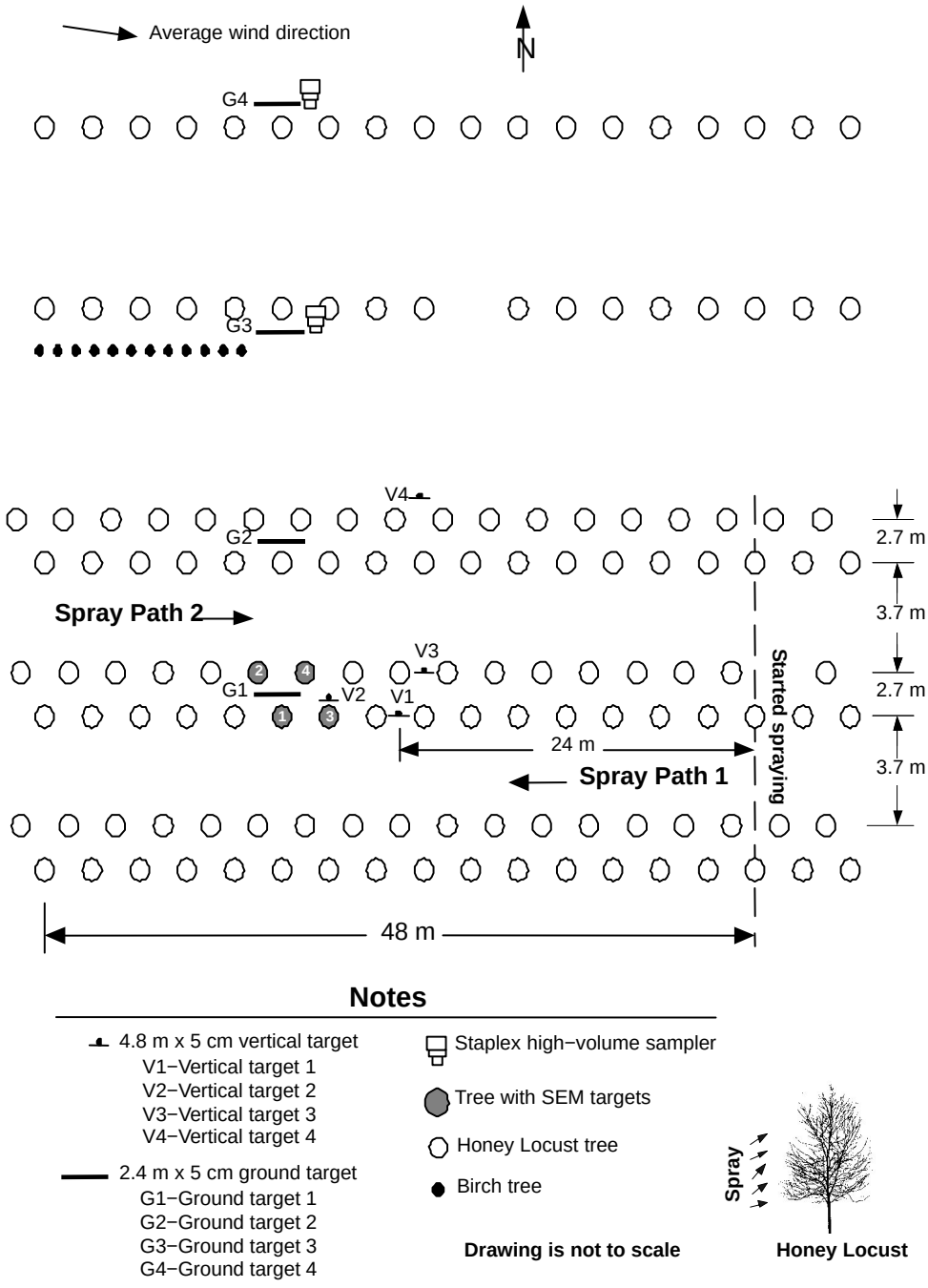

Figure 2. Plan view of Honey Locust nursery spray site showing location of spray collectors.

Spray Sample Analysis

Spray deposition at different levels within tree canopies, beside trees, and on the ground and spray drift in the air were determined with electron beam and conductivity analyses, respectively.

An EBA system, consisting of a scanning electron microscope (model S−500, Hitachi Instruments, Inc., San Jose, Cal.) equipped with an energy−dispersive x−ray analyzer and digital image analysis (model 5504, Thermo Noran, Inc., Middleton, Wisc.), was used to analyze spray deposits on both leaflets and inert stub surfaces. The EBA was performed to directly identify and quantify spray residue, both morphologically and chemically, and data were recorded as percent residue coverage on the average of three sample 500 μm^2 areas per stub surface, examined at a magnification of 130X, 20 kV with 15 mm working distance.

A laboratory−built spray−deposit conductivity analyzer (fig. 3) was used to analyze spray deposits on plastic tapes suspended vertically at various locations near trees. The analyzer consisted of a tape stand, an 8 cm diameter copper drum, a 4 cm diameter print roller, an 8002 fan pattern nozzle (Spraying Systems, Co., Wheaton, Ill.), a conductivity probe and meter (Engineering Systems and Designs, Newark, Del.), and a portable computer. The copper drum continuously pulled the plastic tape at a constant speed of 330 cm/min under the distilled water jet discharged from the nozzle. The flow rate of water spray jet was 195 mL/min. Spray deposits on the plastic tape were washed off and then flowed through a

Plexiglas slot and over a conductivity probe. Preliminary tests verified that spray deposits on plastic tapes could be completely washed off by the spray jet at a flow rate of 195 mL/min. The conductivity meter measured conductivity of the solution and transmitted the results through an A/D converter to a portable computer. The volume of spray deposit (μL/cm^2) on the plastic tape was calculated from the following formula:

$$\text{Spray deposit} = \frac{C \cdot Q}{\rho \cdot W \cdot V} \quad (1)$$

where

C = tracer concentration (μg/mL or μL/mL) calculated from conductivity reading

Q = distilled water flow rate from an 8002 flat fan nozzle (195 mL/min)

ρ = concentration (μg/μL or μL/μL) of field spray mixture containing water and tracer

W = plastic tape width (5 cm)

V = tape travel speed (330 cm/min).

For the plastic tapes containing the ground deposit and paper filters containing the airborne spray, 50 mL of distilled water was added to each bottle to wash spray deposits from each target for analysis. For the sheet metal plates containing spray deposits within canopies, 20 mL of distilled water was added to each bottle. Bottles were shaken well, and a conductivity probe of the same conductivity meter used in the deposition analyzer was placed into each bottle to read the solution conductivity. The volume of spray deposits (μL/cm^2) on the targets was determined from the following equation:

$$\text{Spray deposit} = \frac{C \cdot V}{\rho \cdot A} \quad (2)$$

where

C = tracer concentration (μg/mL or μL/mL) calculated from conductivity reading

V = volume (mL) of distilled water to wash the tracer

ρ = concentration (μg/μL or μL/μL) of field spray mixture containing water and tracer

A = Target surface area (cm^2).

Data were statistically analyzed by one−way ANOVA, and differences among means were determined with Duncan's new multiple−range test using Mac−SAS version 6.12. All significant differences were determined at the 0.05 level of significance.

Results and Discussion

Spray Penetration Determined with EBA

$Ca(NO_3)_2$ and $Cu(OH)_2$ residues on targets within tree canopies were characterized and detected with EBA (figs. 4 and 5). Figure 4a shows typical spray droplets (arrows) observed in this study as globular deposits and Ca prominent in the complementary x−ray distribution map (fig. 4b) with a substantial Ca peak (fig. 4c) on both leaves and stubs. Similarly, a combination of secondary electron images, x−ray spectra, and x−ray distribution maps were used to identify $Cu(OH)_2$ residue as annular−shaped spray droplets on both needles of Canadian Hemlock and inert stubs (fig. 5). The percent residue coverage on both leaf and stub surface areas was then explicitly obtained from the image and energy spectrum analysis. Comparatively, figure 5d shows that there was no contamination on needles previously unexposed to $Cu(OH)_2$ with EBA revealing the surface structure. Apparently, EBA provided both visualized images and explicit amounts of coverage on both natural and artificial sampling targets.

Statistical analysis indicated no significant differences ($p \leq 0.05$) between coverage on leaves and coverage on inert stubs measured by EBA. Table 2 shows the percent $Ca(NO_3)_2$ coverage per Honey Locust tree relative to spray path, surface, and tree position, measured by EBA. Each value is the mean of 18 observations. Analysis of variance showed that coverage on leaves was significantly affected by tree position ($p \leq 0.05$) and leaf surfaces ($p \leq 0.05$). The highest coverage on leaves was at the 3 m elevation on trees 1 and 3 in row 1. Trees 1 and 3 appeared to have quite different coverage of $Ca(NO_3)_2$ from trees 2 and 4. The lowest coverage was at 4 m elevation, which

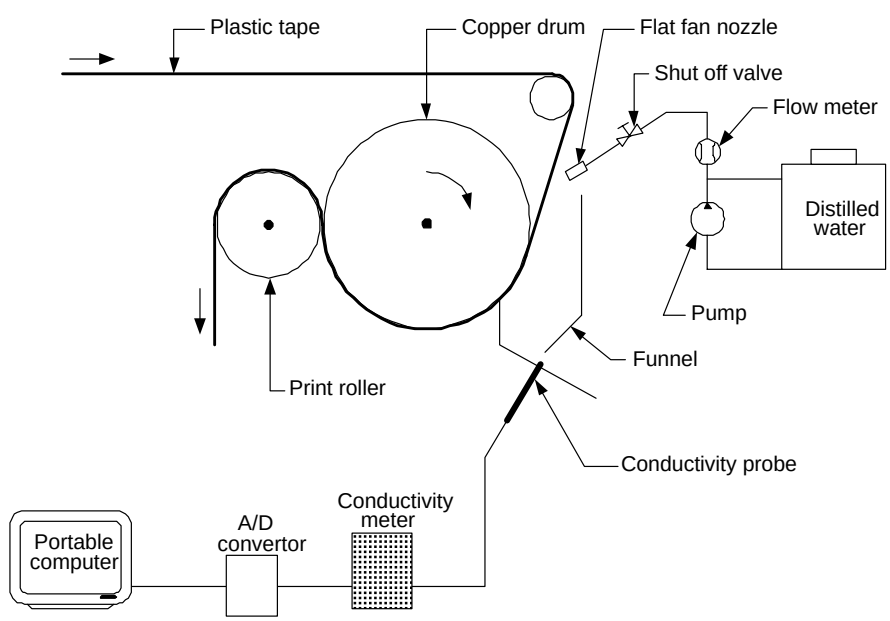

Figure 3. Schematic drawing of the conductivity spray deposit analyzer.

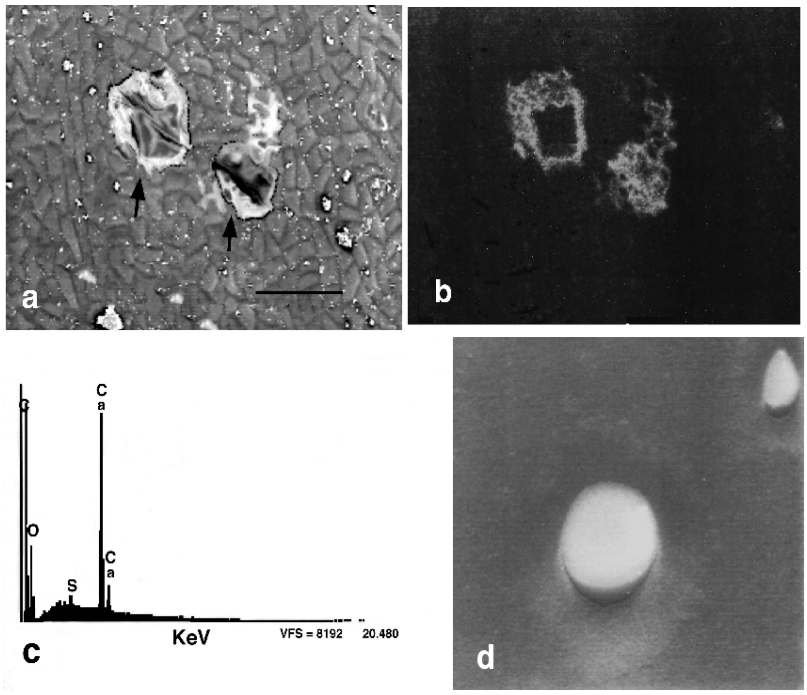

Figure 4. Electron beam analysis of $Ca(NO_3)_2$ on Honey Locust leaf and stub: (a) secondary electron image of a typical globular, uniformly $Ca(NO_3)_2$ smooth spray droplet (arrow), bar = 50 µm; (b) x−ray distribution map of $Ca(NO_3)_2$ droplet from (a); (c) energy dispersive x−ray analytical spectrum of the $Ca(NO_3)_2$ spray droplet in (a), note Ca peak; and (d) $Ca(NO_3)_2$ droplets on stub observed in the Honey Locust trees.

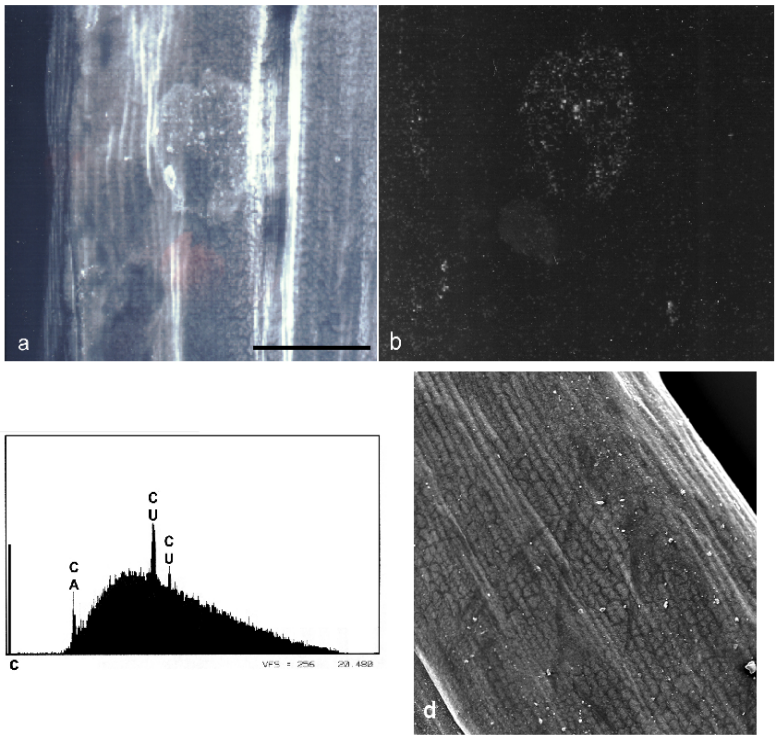

Figure 5. Electron beam analysis of $Cu(OH)_2$ droplets on Canadian Hemlock needles: (a) secondary electron image, bar = 50 µm; (b) x−ray distribution map of $Cu(OH)_2$ droplets in (a); (c) x−ray spectrum of droplet in (a), note Cu peak; and (d) Hemlock needle surface before sprayed.

was from the first tree. Overall, the coverage found on lower surfaces within Honey Locust trees was significantly less than that found on upper surfaces regardless of elevation above the ground ($p \leq 0.05$, fig. 6). The average spray deposit on upper surfaces of leaves was three times that deposited on lower surfaces (table 2). Tree position, elevation, and leaf surface were all significant factors in percent coverage.

Canadian Hemlock trees varied slightly in shape, foliage density, and tree size compared to Honey Locust trees. Sprays were discharged from above the hemlock trees with the over−the−row sprayer. Results from EBA analysis illustrated

Table 2. Mean percentage of $Ca(NO_3)_2$ coverage per Honey Locust tree relative to spray path, leaf surface, and tree position, as measured by electron beam analysis. Coefficients of variation (%) are given in parentheses.

	Sample Elevation (m)			Leaf Surface	
Tree	2	3	4	Upper[a]	Lower[b]
1	20.7 (48)	27.5 (29)	5.7 (36)	30.3 (71)	5.6 (68)
2	28.8 (42)	10.9 (43)	12.7 (36)	28.5 (77)	6.4 (61)
3	16.7 (32)	32.4 (40)	13.6 (53)	30.3 (189)	11.5 (43)
4	29.0 (20)	8.4 (33)	11.0 (42)	20.1 (94)	12.2 (80)
Avg.	23.8 (36)	19.8 (36)	10.7 (42)	27.3 (108)	8.9 (63)

[a] Average spray coverage on upper leaf surfaces across three elevations.
[b] Average spray coverage on lower leaf surfaces across three elevations.

that averaged total percent Cu coverage on needles and stubs was significantly different ($p \leq 0.05$) between the tree locations (table 3). There were no significant differences between coverage on needles and coverage on inert stubs ($p \leq 0.05$). Coverage versus position within trees averaged from 0.4% on the lowest needle position (0.12 m) to 52.1% at the highest position (1.4 m) in the canopy, while coverage averaged from 3.7% to 69.0% on stubs at the lowest and highest positions. Many of the lowest needles and stubs had no detectable residue. The average coverage in four trees was 60.1% on needles and 82.6% on stubs. However, statistical tests using Duncan's new multiple range test showed that there was no significant difference in the deposits for the two sampling methods ($p \leq 0.05$). Data in tables 2 and 3 illustrate that spray deposition at different elevations in the Honey Locust trees with the conventional axial−fan sprayer had much less variation than in the Canadian Hemlock trees with the over−the−row sprayer.

Data in table 3 also show the amount of spray deposits on simulated leaf plates at the top, middle, and bottom of Canadian Hemlock trees. Results are the average of three locations in the four tree canopies. Many of the top collectors were outside the canopy and were directly exposed to spray, which produced large deposits. Because tree foliage was very dense, only a small portion of spray droplets penetrated the foliage. There was no significant difference between deposits on the targets in the middle and at the bottom of trees ($p \leq 0.05$). Average spray deposit at the top of Canadian Hemlock tree canopies was 14 times higher than that at the middle and the bottom of canopies. The coverage determined with metal plates was similar to that measured by EBA on needles and stubs; however, EBA provided both visual information on droplet deposit location and the coverage of spray deposition on targets.

Deposition on Vertical Targets

Figure 7 shows spray deposit distributions discharged with the axial−fan sprayer on vertical targets at four locations with Honey Locust trees. The average spray deposit across the entire vertical target determined with the spray deposit analyzer was 90.1, 35.7, 38.0, and 2.6 μL/cm^2 on V1, V2, V3, and V4, respectively. For collector V1, most sprays were deposited on the area from 1.8 to 4.5 m above the ground. Spray profiles across vertical targets V2 and V3 were very similar, and most deposition was also in the area from 1.8 to 4.5 m. Conversion of spray deposition on V2 and V3 to percent total spray indicated that about one−third of the total spray passed through the first tree. The total spray deposit on the V3 collector was slightly higher than on the V2 collector because there was no tree in front of the collector. These deposits were much lower than on the V1 collector, which was located in the center of the first tree row. This result indicates that about two−thirds of the spray deposited on the ground and dispersed before reaching the center of the second tree row. However, there was very little deposition on the V4 vertical collector behind the fourth tree.

Figure 8 shows spray deposit distributions discharged from the over−the−row sprayer on two vertical targets 3.0 m (V1) and 6.6 m (V2) downwind from the first row centerline in the Canadian Hemlock nursery. Each point in the graph represents the average deposit on a section of 30.5 cm long plastic tape. Although spray droplets were discharged downward toward trees, there was still some drift collected on both vertical targets. The highest spray deposition on V1 was 4.1 μL/cm^2 from the area about 2.5 m above the ground, while the average spray deposition on V2 was less than 1.0 μL/cm^2 across the entire target height.

Deposition on Ground Targets

Figure 9 shows spray deposits on ground collectors 2.1, 7.6, 19.8, and 32 m north of the first spray path in the Honey Locust

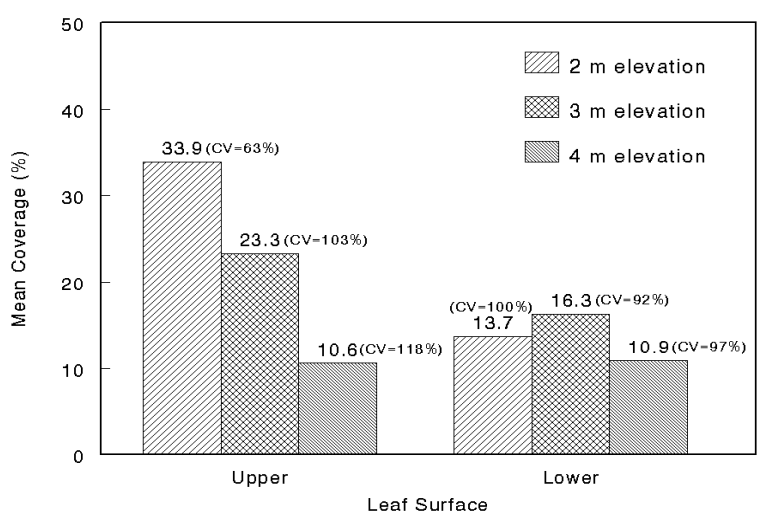

Figure 6. Percent $Ca(NO_3)_2$ coverage versus surface sampled according to height in Honey Locust trees. Each bar is the mean of 18 observations (three upper surfaces and three lower surfaces with three replications).

Table 3. Deposit of $Cu(OH)_2$ on Canadian Hemlock needles, SEM stubs, and sheet−metal plates on each sample tree as a function of elevation above the ground. Coefficients of variation (%) are given in parentheses.

Elevation (m)	Mean Coverage (%)		Mean Deposit on Plate (μL/cm^2)
	Needle	Stub	
0.05	−−	−−	0.265 (30)
0.12	0.4 (82)	3.7 (102)	−−
0.51	−−	−−	0.247 (12)
0.90	7.6 (40)	9.9 (60)	−−
1.30	−−	−−	3.788 (48)
1.40	52.1 (17)	69.0 (11)	−−

nursery. Spray deposits on ground targets greatly decreased as the distance from the spray path increased. The average spray deposit was 212.9 μL/cm^2 on the ground target at 2.1 m north of the spray path and 0.90 μL/cm^2 on the ground target at 19.8 m north of the first spray path. Large amounts of spray were displaced on the ground near the first and second rows.

Compared to the experiment with Honey Locust trees, the experiment with Canadian Hemlock trees yielded less spray on the ground. Figure 10 shows the spray deposit on six ground targets in the Canadian Hemlock nursery with the over−the−row sprayer. The spray deposit on the ground target (G2), which was between first and second rows, was over two times as great as deposits on targets G1 and G3, which were under first and second rows. The spray deposit on ground targets decreased from an average 40.92 to 0.82 μL/cm^2 as the distance from the first row centerline increased from 0.6 to 11.4 m.

Airborne Spray

The amount of airborne spray collected by Staplex high−volume samplers at the 3 m elevation in the Honey Locust nursery decreased 28.4% as the distance downwind from the spray path increased from 19.8 to 32.0 m (table 4). However, the airborne spray deposit in the Canadian Hemlock nursery was nearly equal at 6.6 and 11.4 m downwind the first row centerline. Airborne spray deposits did not decrease as much with increasing downwind distance as ground deposits in both nurseries. Compared to the axial−fan sprayer used in the Honey Locust nursery, the over−the−row sprayer used in Canadian Hemlock nursery had a considerably lower amount of spray drift because the sprayer discharged material downward.

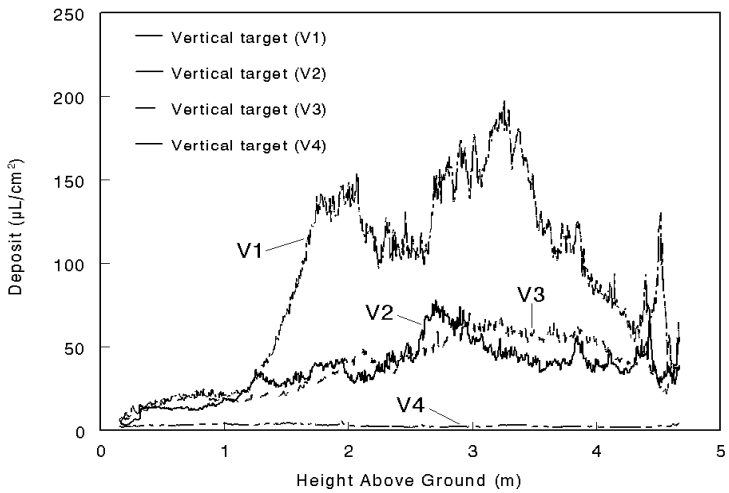

Figure 7. Profiles of spray deposits on vertical collectors downwind from Honey Locust trees sprayed with an axial−fan sprayer.

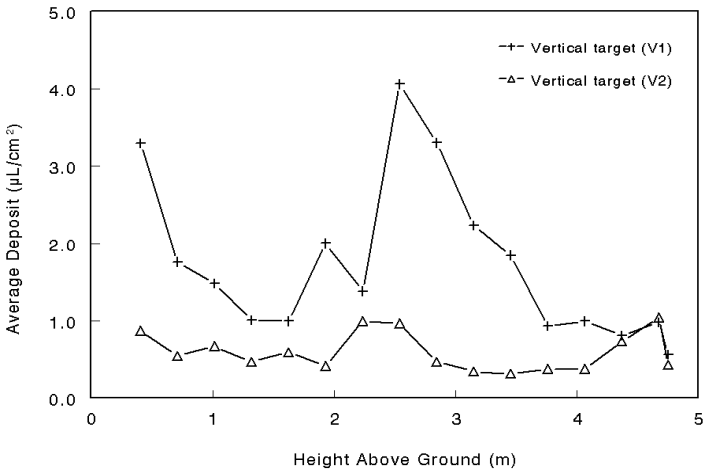

Figure 8. Profiles of spray deposits on vertical collectors downwind from Canadian Hemlock trees sprayed with a high−clearance sprayer.

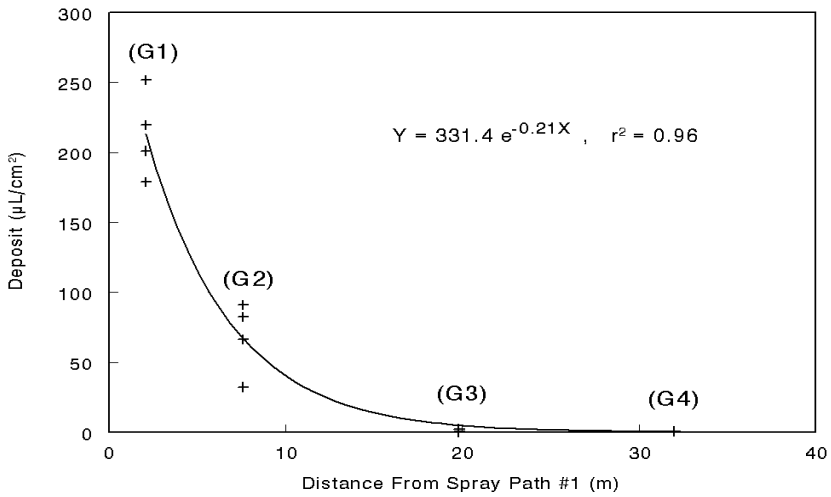

Figure 9. Spray deposits on ground collectors downwind from Honey Locust trees sprayed with an axial−fan sprayer.

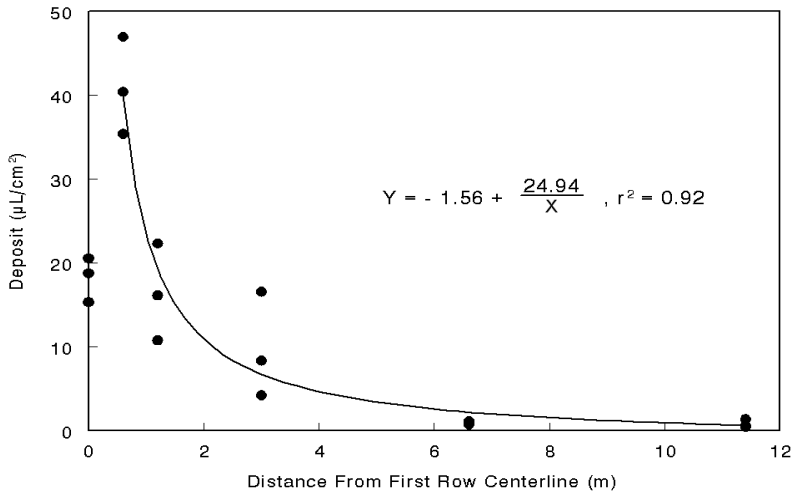

Figure 10. Spray deposits on ground collectors downwind from Canadian Hemlock trees sprayed with a high−clearance sprayer.

Table 4. Mean airborne spray deposits captured on air volume sampler filters downwind in the Honey Locust nursery sprayed with an axial−fan sprayer and in the Canadian Hemlock nursery sprayed with a high−clearance sprayer.

Spray Site	Distance (m)[a]	Airborne (µL/cm^2)	CV (%)
Honey Locust	19.8	102.38	12.5
	32.0	73.34	20.5
Canadian Hemlock	6.6	15.50	33.7
	11.4	16.54	19.9

[a] For the Honey Locust site, distance was between the sampler and spray path 1; for the Canadian Hemlock site, distance was between the sampler and the centerline of the first row.

Conclusions

The EBA determined the percent Ca and Cu residue coverage on both leaf and stub surface areas within tree canopies and provided an assessment method with both visualized image and quantification analysis to determine spray deposition for nursery spray applications.

The coverage on the lower surfaces of Honey Locust trees was significantly less than that found on the upper surfaces regardless of elevation above the ground. Average total percentage of Cu coverage on needles and stubs within Canadian Hemlock trees was significantly different between the tree locations.

Canopy penetration coverage measured with EBA on needles and stubs had similar trends to deposits measured on metal plates with conductivity analysis.

The spray deposit analyzer quantified spray deposition profile across trees. About one−third of the total spray passed through the first row of Honey Locust trees with the axial−fan sprayer.

Ground deposits decreased rapidly with increased distance from the spray path. Airborne spray deposits did not decrease as much with increasing downwind distance as ground deposits.

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