

Investigation of nursery canopy and ground deposition with three spray techniques

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Summary

Spray techniques are needed in the nursery industry to obtain optimum pesticide spray management practices economically and effectively with minimum canopy disturbance and minimum pesticide waste. Spray deposits inside crabapple trees and off-target loss at different distances downstream from the sprayer were investigated with three different treatments (conventional hollow cone nozzles, air induction nozzles, and conventional hollow cone nozzles with a drift retardant) used by an air blast sprayer in a nursery field. Droplet size distributions across spray patterns were measured with a laser particle/droplet image analysis system. In general, there was no significant difference for deposits within nursery tree canopies and on the ground with three different spray techniques. Using the orchard application rate in nurseries resulted in saturated spray deposition within tree canopies and excessive spray deposition on the ground. The application rate should be reduced to reduce pesticide waste and labour cost. In nursery application, it was not necessary to place a large capacity nozzle at the top of the air blast sprayer as normally recommended for orchard spray applications. There was no advantage to use air induction nozzles or hollow cone nozzles with drift retardant in the air blast sprayer to reduce off-target loss potential especially on the ground.

Key words: Spray nozzle, Drift retardant, Air induction nozzle, Air blast sprayer, Airborne, Drift, Nursery crop

Introduction

Applications of pesticides and other production strategies have ensured adequate and high quality food, fibre, floral and nursery crops to meet the wide variety of canopy structure characteristics, growing circumstance, and marketing requirements. Transport of spray to target plant surfaces with high quality atomization is essential to ensure effective spray application in crop protection. Little information is available on nursery crop production practices whereby applications of required amounts of pesticides achieve effective pest and disease control with minimum chemical loss. Spray trials with drift retardants or air induction nozzles used for nursery tree applications have not been reported in the literature. Questions remain whether drift retardants and air induction nozzles have potential advantages over conventional nozzles in field crops and nurseries, and whether performances similar to air induction nozzles can be achieved by using conventional nozzles with larger orifices and/or operating the sprayer at lower pressure.

Drift retardants were reported to reduce spray drift in many laboratory studies (Ozkan et al., 1992; Smith, 1993). Laboratory tests indicated that drift retardants could increase the volume median diameter of spray initially, but most polymer based drift retardants lost effectiveness when recirculated through pumps (Bouse et al., 1988; Reichard et al., 1996; Zhu et al. 1997). Although there are some disadvantages associated with adding drift retardants to spray mixtures, some nursery growers have expressed interest in using these chemicals if they can reduce potential drift damages to adjacent crops, or contamination of nearby residential areas.

During the past decade, several types of hydraulic air induction nozzles (also called “low-drift” nozzles) were introduced into the market for improving pesticide delivery methods and reducing drift. Most air induction nozzles were configured with two small holes on the nozzle chamber upstream from nozzle orifices and their internal fluid chamber was extended much longer than the conventional hydraulic nozzles. These nozzles have been reported to produce higher volume deposits at lower part of canopies (Zhu et al., 2004) because they could produce greater portion of large droplets than conventional hydraulic nozzles (Koch et al., 2001). Some reports indicated these “low-drift” nozzles did not significantly reduce drift in orchards (Heijne et al., 2002; Landers, 2000).

The objective of this research was to compare canopy and ground spray deposits from an air blast sprayer with conventional hollow cone nozzles, conventional hollow cone nozzle applying a drift retardant spray, and air induction nozzle under nursery field conditions.

Materials and Methods

A model 1500 air blast sprayer (Durand-Wayland, Inc., LaGrange, GA) was used, and operated with five identical nozzles equally spaced on one side of the 0.91-m diameter air deflector. The sprayer produced 40 m/s average air velocity near the nozzles when operated at the high gear setting. Spray deposits within crabapple tree canopies and on the ground were compared with three different spray treatments: hollow cone nozzles with water only (HC), hollow cone nozzles with water and a drift retardant (HCDR), and air induction nozzles with water only (AI). Nozzles used for HC and HCDR were five conventional hollow cone nozzles (D5-45, Spraying Systems Co., Wheaton, IL) and nozzles used for AI were five flat fan air induction nozzle (AI110-08, Spraying Systems Co., Wheaton, IL). The flow rate from the sprayer was maintained at 24.2 L/min for all three application methods. The sprayer travel speed was 6.4 km/hr at which the application rate was 700 L/ha if both sides of the sprayer were used.

The spray mixture used in the two trials was 3 g of Brilliant Sulfaflavine (MP Biomedicals, Inc., Aurora, OH) per litre of water for HC, HCDR and AI. For HCDR, the spray mixture was additionally mixed with STA-PUTTM drift retardant distributed by Helena Chemical Company (Collierville, TN). The drift retardant was a liquid formulation with 1% polyvinyl polymer as active ingredient. Concentration of the drift retardant used in the HCDR tank mixture was 0.49% (v/v).

Spray deposits within tree canopies, under the sprayed trees, and on the ground at different distances from the sprayer were collected with nylon screens, plastic plates and plastic tapes, respectively. Tests were conducted with two trials at different times during the growing season (Fig. 1). The detail information on test conditions, spray deposition samples and sprayer operating conditions were given in detail by Zhu et al. (2005).

Field target samples were collected 15 minutes after each spray, and placed in clean glass bottles in non transparent boxes. Spray deposits on all sampling targets were washed with distilled water immediately after they were brought to the laboratory. Peak fluorescent intensity of each wash solution was determined with a Model LS 50B luminescence spectrometer (Perkin-Elmer Limited, Beaconsfield, Buckinghamshire, England) at an excitation wavelength of 460 nm.

All field data were analysed by one-way ANOVA, and differences among means were determined with Duncan's New Multiple-Range Test using ProStat version 3.8 (Poly Software International, Inc., Pearl River, NY). All differences were determined at the 0.05 level of significance.

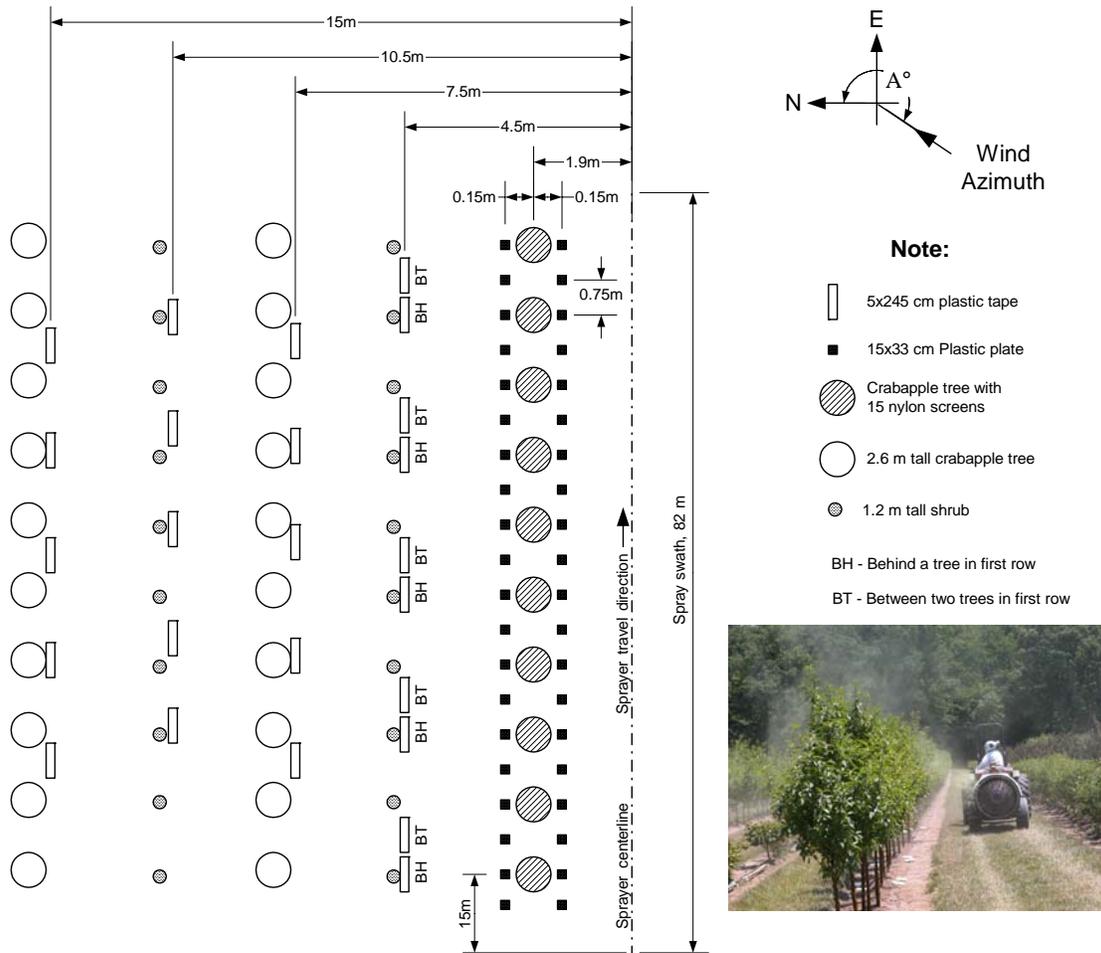


Fig. 1. Plan view of spray site showing location of spray collectors downstream from the air blast sprayer for two trials in the field test.

Droplet sizes from nozzles for AI at 830 kPa, and HC and HCDR at 1660 kPa without air assist were measured with the VisiSizer particle/droplet image analysis system (Oxford Lasers, Oxfordshire, UK). Droplet size distributions were determined 0.5 m below the nozzle orifice across the centreline of the spray pattern width with 5 cm intervals. A minimum 10,000 droplets were counted at each sampling position for the droplet size distribution analysis.

Results and Discussion

Deposits inside crabapple canopies

Except for the screen position at the 0.9 m elevation, there were no significant differences in spray deposits on screens at different elevations within crabapple tree canopies among the three spray techniques (AI, HC and HCDR) in both trials (Table 1). Therefore, statistically AI, HC and HCDR treatments produced almost the same quantity of spray deposits within tree canopies.

Also, there were no significant differences among deposits at four elevations within the tree canopy for the three treatments. To produce uniform spray deposits across the tree canopy, air blast sprayers for nursery applications are usually recommended to operate with the same nozzle settings as orchard applications. Specifically, recommendations are to use a larger nozzle at the top of each side, with the flow rate of the top nozzle at least three times greater than other individual nozzles. However, results in this study with three different spray techniques showed that spray deposition was uniform across the tree canopy from top to bottom with the equal capacity nozzles on the air blast sprayer. Nursery trees are usually much thinner and sharper with less canopy volume per area than orchard trees. It was reasonable to assume from this study that the sprayer with the equal capacity nozzles had the capability to deliver uniform spray deposits throughout the trees.

Table 1. *Spray deposits at four elevations within crabapple tree canopies with AI, HC, and HCDR treatments for two trials in field 1. Standard deviations are given in parentheses.*

Test	Elevation (m)	Average Spray Deposit ($\mu\text{L}/\text{cm}^2$)		
		AI ^[u]	HC ^[v]	HCDR ^[w]
Trial 1	2.0	2.11 (0.83)a ^[x]	2.83 (0.94)a	2.23 (1.03)a
Trial 1	1.6	1.61 (1.05)a	2.23 (1.38)a	2.07 (1.21)a
Trial 1	1.2	1.54 (0.75)a	1.74 (0.93)a	1.61 (0.86)a
Trial 1	0.9	1.93 (0.56)b	2.41 (0.92)a	2.29 (0.63)ab
Trial 2	2.0	1.94 (0.64)a	1.66 (0.94)a	1.55 (0.87)a
Trial 2	1.6	1.49 (0.71)a	1.50 (0.96)a	1.41 (0.81)a
Trial 2	1.2	1.06 (0.65)a	1.07 (0.82)a	1.39 (0.89)a
Trial 2	0.9	1.23 (0.48)b	1.29 (0.62)b	1.82 (0.78)a

^[u] AI – Air induction nozzle with water only.

^[v] HC – Hollow cone nozzle with water only.

^[w] HCDR – Hollow cone nozzle with water and drift retardant.

^[x] Means in a row followed by different letters are significantly different ($p < 0.05$).

Table 2. *Average spray droplet sizes at 0.5 m below the nozzle orifice for AI across 90 cm spray pattern width at 830 kPa, and HC and HCDR across 5 cm main spray sheet at 1660 kPa. The droplet size measurement was conducted with the laser particle/droplet image analysis system under laboratory conditions without air blast.*

Nozzle	Average Droplet Size ^[x] (μm)		
	D _{v,1}	D _{v,5}	D _{v,9}
AI ^[u]	158	407	824
HC ^[v]	150	202	290
HCDR ^[w]	157	222	332

^[u] AI – Air induction nozzle with water only.

^[v] HC – Hollow cone nozzle with water only.

^[w] HCDR – Hollow cone nozzle with water and drift retardant.

^[x] For HC and HCDR, droplet sizes were counted only from 5 cm cone spray sheet because a very small portion of spray volume was found in the centre of the hollow cone spray pattern.

Fig. 2 shows average spray deposits in percentage of total spray application rate on 12 nylon screen collectors for ten crabapple trees with the air blast sprayer using AI, HC, and HCDR in two trials. In both trials, about 21% of total spray volume from the AI treatment deposited on 12 nylon screen collectors within each tree canopy, about 24% of total spray volume from the HC treatment deposited on 12 nylon screen collectors within each tree canopy, and about 25% of

total spray volume from the HC treatment deposited on 12 nylon screen collectors within each tree canopy. Although wind velocities and directions were not the same for the three spray methods, total spray deposits on 12 screens within a tree canopy were not significantly different among sprays for the AI, HC and HCDR treatments.

The volume median diameter of water droplets in the main spray sheet from a conventional hollow cone nozzle at 1660 kPa was 202 μm (Table 2). The volume of 1.28 $\mu\text{L}/\text{cm}^2$ spray deposit is equivalent 296 droplets of 202 μm sustained on a 1- cm^2 area. The recommended droplet density in the target area was from 20 to 30 droplets per square centimetre for spraying insecticides and 50 to 70 droplets per square centimetre for spraying fungicides (Anonymous, 2004). The number of 202- μm droplets with the 1.28 μL volume within the tree canopy was 4 to 15 times the number of 202- μm droplets actually required for the target area.

Based on the insecticide and fungicide coverage recommendation, the tree canopies received excessive spray deposits discharged from AI, HC and HCDR treatments at the 700 L/ha application rate. A typical application rate in commercial nurseries is 1060 L/ha with varying nozzle flow rates so that the capacity of the nozzles at the top of the sprayer is three times the capacity of other individual nozzles. This is similar to the recommendation for orchard applications.

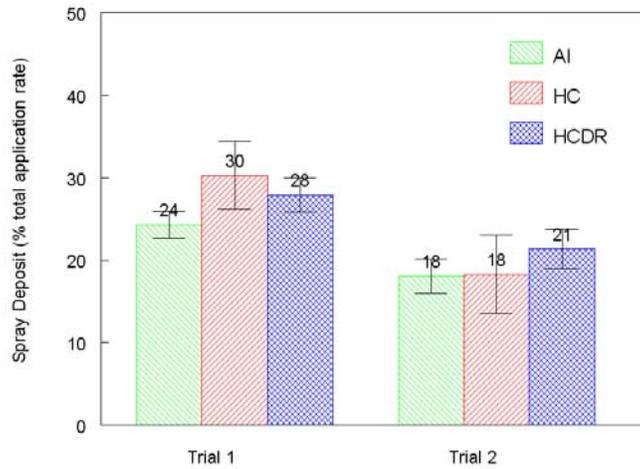


Fig. 2. Average percentage of total spray application rate deposited on 12 screen collectors within a tree canopy for ten crabapple trees discharged from the air blast sprayer with AI, HC and HCDR, respectively. Error bars represent standard deviations of means.

Ground deposits

Fig. 3 shows the average ground spray deposits under the sprayed trees and at different distances from the sprayer with two trials. Statistical analysis indicated that there was no significant difference for ground deposits on targets under the sprayed trees and between two sprayed trees for the AI, HC and HCDR treatments in two trials. Therefore, compared to the total amount of spray deposits on the ground near the sprayed trees, the amount of spray runoff from tree leaves to the ground was not significantly different among the three treatments. The average spray deposit on the ground beneath the sprayed trees was about 24% of the average foliar deposit within tree canopies with AI, HC and HCDR treatments in two trials.

There were no significant differences among spray deposits on the ground 4.5 m downstream from the sprayer for AI, HC and HCDR treatments in trial 1 (Table 3); however, the deposits from HC were significantly lower than those from AI and HCDR in trial 2 possibly due to changes in wind velocities and directions. There was no significant difference in deposits between the plastic tapes placed behind sprayed trees and gaps of two sprayed trees because there were very few leaves on the trees below 0.9 m from the ground. The average ground deposit collected by the plastic tapes at 4.5 m from the sprayer with AI, HC and HCDR for the two trials was 20.6, 17.6, and 22.5% of the total spray volume, respectively. Therefore, a

significant amount of spray volume was lost on the ground with all three treatments at the 700 L/ha application rate.

Table 3. Average ground spray deposits collected by plastic tapes at different distances downstream from the sprayer with three spray methods for two trials in field 1. Standard deviations are given in parentheses.

Trial	Downstream distance (m)	Spray deposit ($\mu\text{L}/\text{cm}^2$)		
		AI ^[u]	HC ^[v]	HCDR ^[w]
1	Under tree	0.31 (0.13)a	0.82 (0.42)b	0.36 (0.15)a
1	4.45	1.47 (0.16)a ^[x]	1.33 (0.20)a	1.56 (0.32)a
1	7.65	1.06 (0.11)a	0.40 (0.23)b	0.96 (0.26)a
1	10.58	0.38 (0.18)b	0.00 (0.01)c	0.57 (0.11)a
1	14.55	0.00 (0.00)b	0.00 (0.00)b	0.10 (0.07)a
2	Under tree	0.72 (0.40)b	0.30 (0.05)a	0.92 (0.20)b
2	4.45	1.42 (0.31)a	1.13 (0.27)b	1.58 (0.27)a
2	7.65	0.54 (0.36)a	0.48 (0.04)a	0.58 (0.20)a
2	10.58	0.39 (0.09)a	0.26 (0.04)b	0.11 (0.04)c
2	14.55	0.08 (0.07)a	0.02 (0.01)a	0.02 (0.01)a

^[u] AI – Air induction nozzle with water only.

^[v] HC – Hollow cone nozzle with water only.

^[w] HCDR – Hollow cone nozzle with water and drift retardant.

^[x] Means in a row followed by different letters are significantly different ($p < 0.05$).

Data in Table 3 and Fig. 3 also illustrate that spray deposits on the ground greatly decreased as the downstream distance from sprayer increased. With the three treatments, about 10% total spray volume was lost on the ground at 7.7 m downstream from the sprayer, about 4% total spray volume lost on the ground at 10.6 m from the sprayer, and about 0.5% total spray volume was lost on the ground at 15 m from the sprayer. A large portion of spray volume lost on the ground downstream the sprayer.

Zhu et al. (1997) reported nonionic polymer drift retardants could lose their effectiveness and perform similar to water after 2 to 3 recirculations through a centrifugal pump. Laboratory measurements illustrated that the average $D_{V,1}$, $D_{V,5}$ and $D_{V,9}$ of droplets on the edge of hollow cone spray sheet 0.5 m below the nozzle orifice from HCDR were slightly higher than HC (Table 2), and the $D_{V,5}$ at locations 10 cm within hollow cone area for both HC and HCDR was almost equal and ranged from 30 to 82 μm (Fig. 4). Bouse et al. (1988) reported increases in portions of spray volume in both droplet diameter smaller than 99 μm and larger than 415 μm for water soluble polymer drift retardants discharged by conventional hollow cone nozzles in the air flow of 53 m/s.

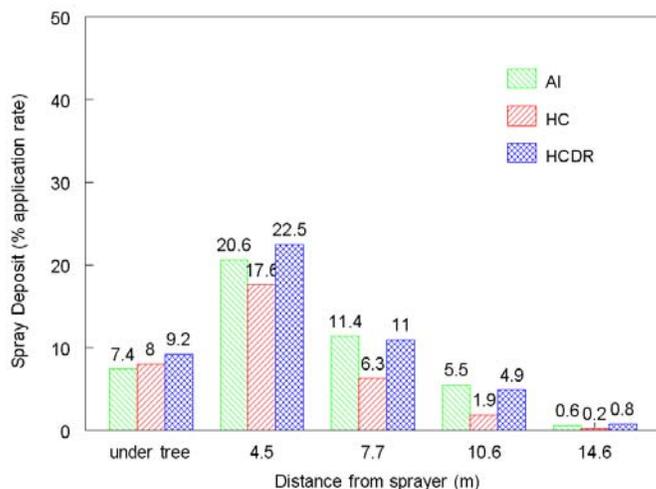


Fig. 3. Average percentage of total spray application rate deposited on the ground at different distances from the sprayer for AI, HC and HCDR, respectively.

Likewise, the air induction nozzles did not provide significant drift reduction, compared to using the conventional hollow cone nozzles. For water droplets, the critical relative velocity at which the droplet will continue to breakup is given by the equation (Lefebvre, 1989),

$$U_R = \frac{784}{\sqrt{D}} \quad (1)$$

where, U_R is the critical relative velocity in m/s and D is droplet diameter in micrometers. For the air blast sprayer, the air velocity near the nozzle is approximately 40 m/s. According to equation (1), any droplets larger than 350 μm in diameter from AI, HCDR and HC would be further breakup by the aerodynamic pressure produced by the parallel air flow from the air blast sprayer. Data in Table 2 illustrate that the droplet size with more than 50% of spray volume from AI at 830 kPa was larger than 407 μm , and more than 90% of spray volume from HC at 1660 kPa was smaller than 290 μm , and more than 90% of spray volume from HCDR at 1660 kPa was in droplets smaller than 332 μm , respectively. Obviously, a great portion of droplets from AI in the air blast sprayer might have encountered some breakup due to air shearing effect. Data in Table 2 also shows that the AI treatment produced almost the same $D_{V,1}$ of droplets as the HC and HCDR treatments produced in the hollow cone spray sheet. Therefore, AI and HCDR might not achieve their advantages of producing large droplets as normally claimed to reduce drift potential from the air blast sprayer in the nursery field tests.

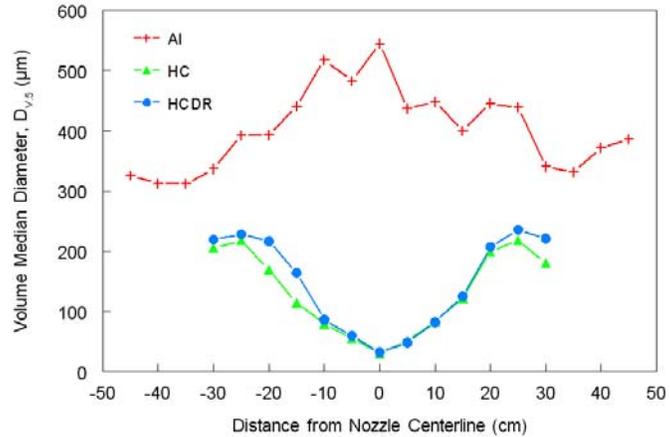


Fig. 4. Comparison of volume median diameter ($D_{V,5}$) across spray pattern width 0.5 m below the nozzle orifice for HC and HCDR at 1660 kPa and AI at 830 kPa under laboratory conditions without air blast.

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References

Anonymous. 2004. A user card containing the recommended droplet density in the target area.

- Syngenta Crop Protection Ag CH-4002, Basle, Switzerland.
- Bouse L F, Carlton J B, Jank P C. 1988.** Effect of water soluble polymers on spray droplet size. *Transactions of the ASAE* **31(6)**: 1933-1641, 1648.
- Heijne B, Wennerer M, Van De Zande J C. 2002.** Air inclusion nozzles don't reduce pollution of surface water during orchard spraying in the Netherlands. *Aspects of Applied Biology* **57**, International advances in pesticide application, pp. 193-199.
- Koch H, Knewitz H, Fleischer G. 2001.** Drift reduction and biological efficacy by means of coarse droplet application of pesticides in orchards. *Gesunde Pflanzen* **53**: 120-125.
- Landers A. 2000.** Drift reduction in the vineyards of New York and Pennsylvania. *Aspects of Applied Biology* **57**, Pesticide Application, pp. 67-73.
- Lefebvre A H. 1989.** Atomization and Sprays. Hemisphere Publishing Corporation. New York, NY.
- Ozkan H E, Reichard D L, Zhu H, Akerman K D. 1992.** Effect of drift retardant chemicals on spray drift, droplet size and spray pattern. ASAE Paper No. 92-1613. St. Joseph, Mich.: ASAE.
- Reichard D L, Zhu H., Downer R A, Fox R D, Brazee R D, Ozkan H E. 1996.** A laboratory system to evaluate effects of shear on spray drift retardants. *Transactions of the ASAE* **39(6)**: 1993-1999.
- Smith A. 1993.** Adjuvants in crop protection. Grow Bus. Report DS 86. New York, N.Y.: PharmaBooks Ltd.
- Zhu H, Derksen R C, Krause C R, Brazee R D, Zondag R H, Fox R D, Reding M E, Ozkan H E. 2005.** Spray deposition and off-target loss in nursery tree crops with conventional nozzle, air induction nozzle and drift retardant. ASAE Paper No. 051007. (American Society Agricultural Engineers, St. Joseph, MI 49085).
- Zhu H, Dexter R W, Fox R D, Reichard D L, Brazee R D, Ozkan H E. 1997.** Effects of polymer composition and viscosity on droplet size of recirculated spray solutions. *Journal of Agricultural Engineering Research* **67**: 35-45.
- Zhu H, Dorner J W, Rowland D L, Derksen R C, Ozkan H E. 2004.** Spray penetration into peanut canopies with hydraulic nozzle tips. *Biosystems Engineering* **87(3)**: 275-283.