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DRIFT POTENTIAL OF CITRUS AIR-CARRIER SPRAYERS

MASOUD SALYANI[1] AND MUHAMMAD FAROOQ
University of Florida, IFAS
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred, FL 33850

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Abstract. **Five commonly used citrus air-carrier sprayers were used to investigate the effects of sprayer type and operating parameters on drift potential of the applications. Spray drift potential was estimated by quantifying deposits of a fluorescent tracer dye on polyester string targets. A pair of string collector was hung vertically at each sample location, on two sides of the spray application line. The targets were collected shortly after the applications and the dye deposit on the string was determined by fluorometry. Weather data were also recorded during the applications. Every spray application resulted in some measurable drift deposit. The magnitude and the direction of the spray drift largely depended on prevailing wind direction.**

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[1]Corresponding author.

The off-target movement of spray cloud (spray drift) is a matter of concern in most agricultural pesticide applications. Semmes et al. (1990) recorded fallout and airborne drift deposits as far as 3.2 km from the application line, in a grassland area. In orchard applications, drifted material could travel over 200 m from the downwind edge of the grove (Fox et al., 1993; Miller et al., 2000; Salyani and Cromwell, 1992). These off-target materials could contaminate air, soil, water, and food resources, thus should be minimized as much as possible.

Spray drift is mostly dependent on droplet size spectrum and prevailing weather conditions (Fox et al., 2000). In general, smaller droplets and higher winds tend to increase drift potential of the applications. Droplet size, in turn, is a function of equipment design, application parameters, and tank mix properties (Akesson and Gibbs, 1990). Increasing hydraulic nozzle pressure or rotary atomizer speed usually results in smaller droplet size spectrum. On the other hand, higher spray flow rate and more viscous tank mix tend to produce larger droplets. Some adjuvants have been found effective in increasing droplet size range and reducing spray drift (Butler et al., 1969; Hanks, 1995; Sanderson et al., 1991; Salyani and Cromwell, 1993). Using nozzles that generate smaller fraction of fine drift-able droplets, reducing sprayer air volume rate, and matching spray volume to tree size and shape are among other strategies that could reduce drift potential of the orchard applications (Koch, 2003; Van de Zande et al., 2002). Salyani and Cromwell (1992) found that more than 70% of drift deposits originate from sprays applied to the last two rows downwind of the applications. Treating these rows with less drift-prone equipment could have a significant impact on drift reduction. Miller et al. (2000) concluded that atmospheric stability is the major determinant of spray drift from application site. Stable conditions resulted in much higher drift deposits than unstable conditions.

Semmes et al. (1990), Salyani and Cromwell (1992), and Fox et al. (1993) used flat plastic sheets and high-volume air samplers (with cellulose filters) to measure downwind fallout and airborne drift deposits, respectively. Airborne drift was higher than fallout deposits in all sample locations. Miller et al. (1989), Fox et al. (1993), and Fox et al. (2004) compared capture efficiencies of several artificial targets in assessment of airborne drift. The targets included plastic tubing, pipe cleaner, hair curler, microscope slide, plastic tape, nylon screen, and cotton, polyester, or plastic strings. Capture efficiencies of the samplers varied substantially and, in general, the differences were related to their frontal areas and local wind conditions. String and hairy surfaces collected much more spray than flat surfaces.

In Florida, most of the citrus foliar sprays are applied with air-carrier ground sprayers (Summerhill et al., 1989). These sprayers vary significantly in design features and they are operated at different volume rates and ground speeds (Salyani, 1997). The differences, coupled with varying weather parameters, could affect drift potential of the sprayers in commercial pesticide applications. The objective of this research was to collect data on drift potential of various sprayers used in citrus foliar applications and identify sprayer operating conditions that tend to reduce spray drift.

Materials and Methods

The study included five commonly used sprayers: Curtec 648, Power-Blast (PB) 500, Durand-Wayland (DW) AF500, FMC 9100, and Titan 1093. The Curtec (BEI, Inc., South Haven, Mich.) was a tower sprayer equipped with three vertically stacked cross-flow fans on each side and two rotary atomizers per fan. PB sprayer (Rears Manufacturing Co., Eugene, Ore.) was a standard low-profile, PTO-powered sprayer. It was operated with either "Lilac" or "Blue" Albuz (Ceramiques Techniques Desmarquest, Evreux, France) nozzles (12/side) at fast (5.8 km h^{-1}) or slow (2.8 km h^{-1}) ground speeds to obtain low- to high-volume application rates. DW sprayer (Durand-Wayland, Inc., LaGrange, Ga.) was also a standard low-profile, PTO-powered sprayer. It was operated with either small (D4-C23) or large (D5-C25) Spraying Systems Co. (SS) ceramic disc-core nozzles (10/side). FMC sprayer (John Bean Sprayers, Hogansville, Ga.) was a large engine-driven sprayer, using FMC ceramic #4 disc and 2-hole whirl plate (12/side). The Titan (John Bean Sprayers, Hogansville, Ga.) was an engine-driven tower sprayer using 34 SS D4/25 nozzles on each side. The treatments included volume rates of 230-4200 L ha^{-1} (25-450 gal/acre) and ground speeds of 2.4-5.8 km h^{-1} (1.5-3.6 mph). Table 1 shows details of the application parameters. Each sprayer treatment was replicated 3-5 times.

Spray solutions contained a fluorescent dye tracer (Pyranine-10G; Keystone Aniline, Inc., Chicago, Ill.) at 200-4,000 mg L^{-1} (ppm). The dye solutions were applied from both sides of sprayers on two rows of hedge-rowed Valencia orange trees (Fig. 1). The trees, set at 2.3 m × 6.1 m (7.5 ft × 20 ft) spacings, were hedged and topped at 4.3-4.8 m (14-16 ft) before the experiment. Sprayer nozzles were open for about 30.5 m (100 ft) travel distance.

Drift potential of the spray applications was estimated by capturing spray droplets on vertical string targets supported by a PVC pole structure (Fig. 1). The targets were positioned on a line perpendicular to the middle of the spray application course. The "Near" (A_w, A_e), and "Far" (B_w, B_e) targets were located at about 11 m (36 ft) and 23 m (76 ft) from the application line, respectively. At each sample location, the target consisted of a pair of polyester string targets, 9.1 m (30 ft)

Table 1. Sprayer treatments and weather conditions.

Sprayer[z]-treatment code[y]	Nozzle type[x]	Spray vol. rate (L ha^{-1})	Ground speed (km h^{-1})	Weather data summary[w]			
				Temp. (°C)	Rel. hum. (%)	Wind vel. (ms^{-1})	Wind Dir.
CURTEC	BEI rotary	230	4.8	25-31	42-71	1.5-3.0	NE-E
PB-LF	Albuz lilac	270	5.8	31-34	55-68	0.8-1.5	W-SW
PB-LS	Albuz lilac	550	2.8	31-35	53-68	0.4-1.8	NE, SW
DW-423	SS D4/23	1000	2.8	30-33	66-77	0.6-1.5	NW-SE
DW-525	SS D5/25	1725	2.8	27-36	53-80	0.3-1.2	NW-SE
FMC	FMC 4/2	2235	2.4	31-37	40-71	0.6-2.1	NW-SE
PB-BF	Albuz blue	1890	5.8	31-33	63-75	1.4-1.7	W-NW
PB-BS	Albuz blue	3870	2.8	28-33	58-80	2.8-4.3	S, SW
TITAN	SS D4/25	4200	2.4	31-39	35-69	0.4-1.5	NE-SW

[z]Sprayers: Curtec 648 (BEI, Inc., South Haven, Mich.); three fans, six rotary atomizers/side; Power-Blast (PB) 500 (Rears Manufacturing Co., Eugene, Ore.); 12 nozzles/side; Durand-Wayland (DW) AF500 (Durand-Wayland, Inc., LaGrange, Ga.); 10 nozzles/side; FMC 9100 (John Bean Sprayers, Hogansville, Ga.); 12 nozzles/side; Titan 1093 (John Bean Sprayers, Hogansville, Ga.); 34 nozzles/side.

[y]Treatment codes: LF/S (lilac-fast/slow), BF/S (blue-fast/slow), 423 (D4-C23), 525 (D5-C25).

[x]Nozzles: Albuz lilac/blue (Ceramiques Techniques Desmarquest, Evreux, France); SS ceramic disc-core (Spraying Systems Co., Wheaton, Ill.); FMC ceramic disc-core (John Bean Sprayers, Hogansville, Ga.).

[w]The range of weather data in 3-5 replications.

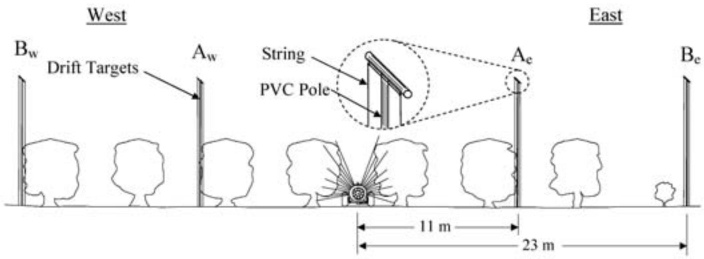

Fig. 1. Schematic view of spray application and drift target locations

long and 2 mm (0.08 in) in diameter. Before each spray application, new string lines were hung from the PVC structures.

Shortly after spray applications, the string lines were wound on customized collection spools, sealed in plastic bags, and stored in a cooler. In laboratory, string lines were cut into smaller pieces corresponding with sampling heights of 0.15-4.6, 4.6-6.1, 6.1-7.6, and 7.6-9.1 m (0.5-15, 15-20, 20-25, and 25-30 ft). Tracer dye deposit on the string was determined by fluorometry (Salyani, 2000). Drift deposit data were calculated based on the frontal area of the string pieces and expressed as percent of the applied rates. In this way, the data were normalized for differences in volume rates and dye concentration in tank mixes. Variability of the means (in replications) was expressed by the standard error (SE). The vast difference in weather conditions of various treatments and replications was not conducive to performing a meaningful analysis of variance or multiple comparisons.

The weather data, including temperature, relative humidity, wind speed, and wind direction were recorded during the experiment, using two weather stations. One of the weather stations (Campbell Scientific, Inc., Logan, Utah) was located inside the grove, about 27.5 m (90 ft) west of the application line. The other one (Davis Weather Monitor II, Davis Instruments Corp., Hayward, Calif.) was positioned in the open area about 38 m (125 ft) east side of the application line.

Results and Discussion

The ranges of temperature, relative humidity, and wind speed were 25-39 °C, 35-80%, 0.3-4.3 m s^{-1} during the applications (Table 1). Within each treatment, wind speed and direction changed substantially during the replications. These changes are shown graphically on data plots of Figures 2-4 (wind circles). Each ring represents wind speed of 1 m s^{-1} and the lines show the mean (prevailing) wind direction during each replication. It should be noted that wind direction was not constant, momentarily, during any application; therefore, spray droplets could move in any direction.

Average drift deposits of the Curtec and low-volume Power-Blast treatments (PB-LF and PB-LS) are shown in Fig. 2. The "No Data" at B_w and/or B_e indicates that there were no samples from those locations. Each bar represents average deposit of the replications at various sampling heights. During the Curtec sprays, the winds were coming from East (E) to Northeast (NE); therefore, airborne droplets moved towards the west and deposited mostly on A_w target. The results showed a significant portion of the drifted droplets moved above the canopy level (4.6-9.1 m). During the PB-LF applications, the winds came from West (W) to Southwest (SW); therefore, drifted droplets were collected on the eastern targets. The highest amount of deposit was captured at the 7.6-9.1 m level. This could in part be attributed to radial (air-blast) discharge of the spray. Using the same sprayer at slower ground speed (PB-LS) increased the droplet movement through the canopy (0.1-4.6 m). Also, during the PB-LS applications the winds were coming from NE or SW directions; therefore, significant amounts of drift deposits were observed on both eastern and western targets. The "Far" target (B_w), contained mainly above canopy (4.6-9.1 m) deposits.

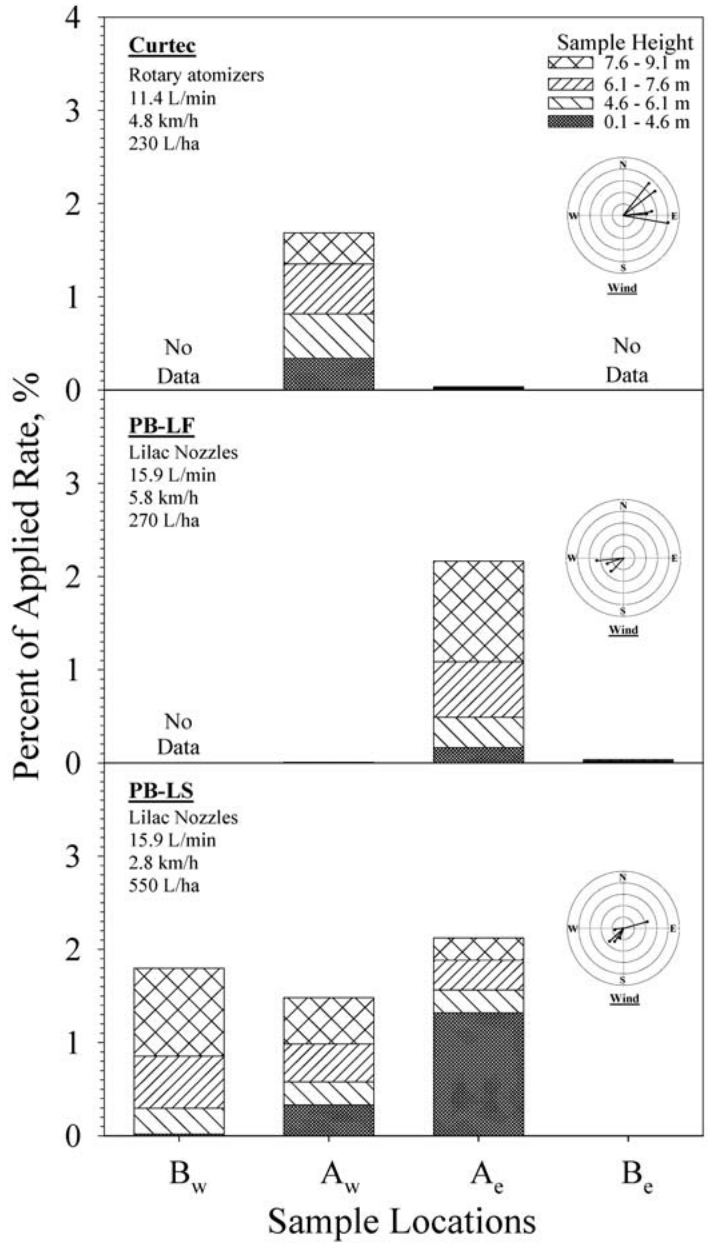

Fig. 2. Spray drift deposits of the Curtec and low-volume Power-Blast sprayers.

Figure 3 shows the data pertinent to DW and FMC sprayers. In both DW-423 (smaller droplet) and DW 525 (larger droplet) applications, wind direction changed substantially; therefore, spray droplets moved in opposite directions. During the FMC applications, winds were coming from NW, SW, or SE directions. This changing wind direction resulted in drift deposits at all target locations. This air-blast sprayer gen-

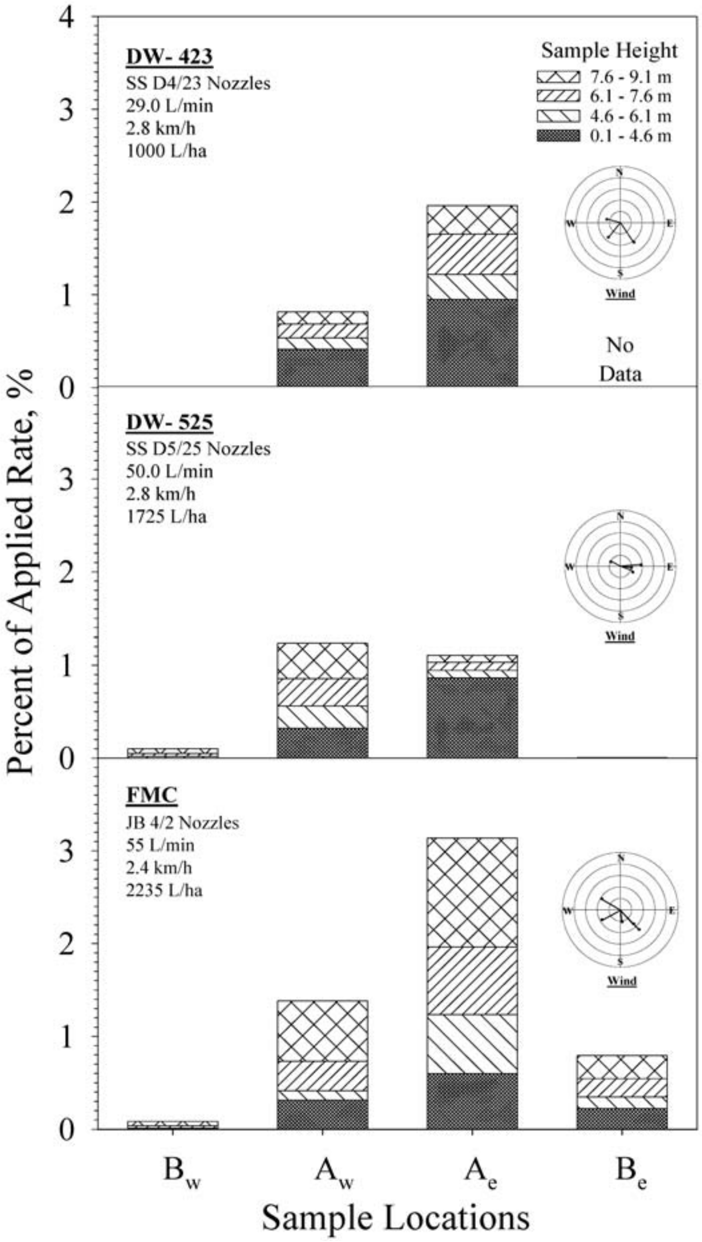

Fig. 3. Spray drift deposits of the Durand-Wayland and FMC sprayers.

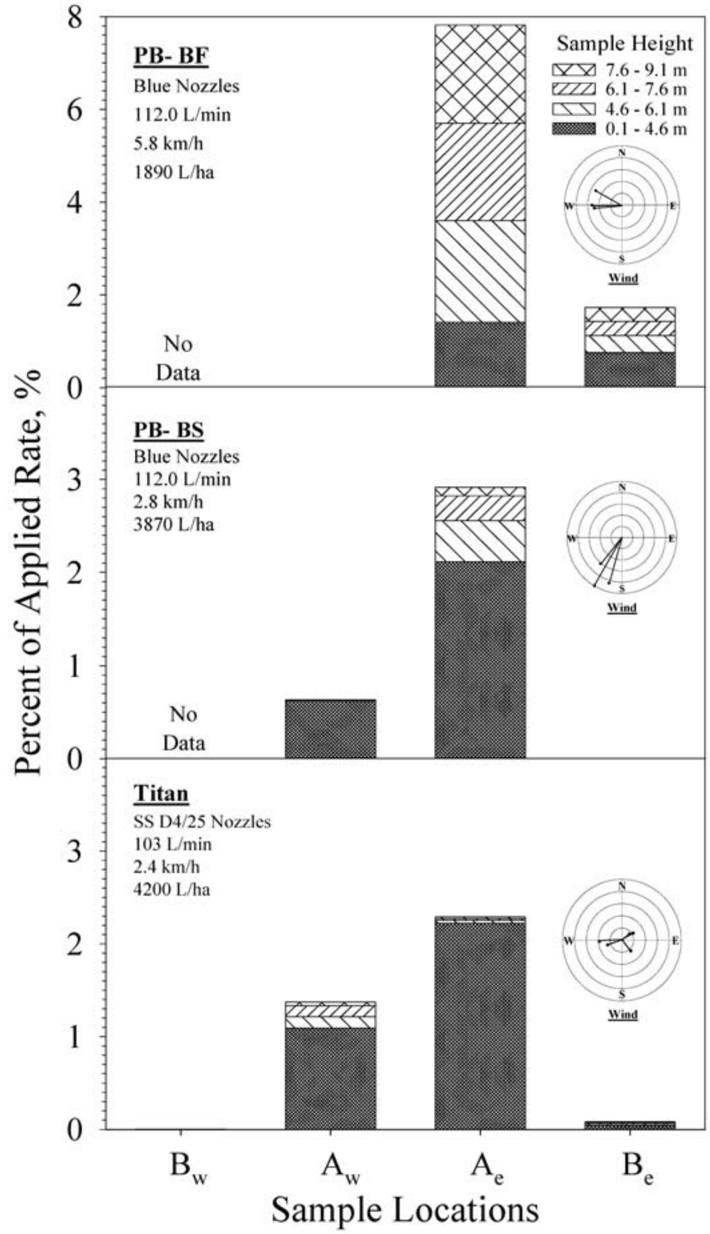

Fig. 4. Spray drift deposits of the high-volume Power-Blast and Titan sprayers.

erated substantially higher drift deposits above canopy level, probably due to its high air volume rate of about 50 $m^3 s^{-1}$.

Figure 4 shows average drift deposits of the high-volume Power-Blast (PB-BF and PB-BS) and Titan sprayers. PB-BF generated the highest amount of above canopy drift deposits at A_e location. The winds were consistently coming from West (W) or Northwest (NW); therefore, no appreciable deposit was found on the western targets. Using the same sprayer at lower ground speed (PB-BS) generated less drift above the canopy (4.6-9.1 m) but higher droplet movement through the canopy (0.1-4.6 m). The winds were mostly coming from South (S) or Southwest (SW); consequently, there was some deposit on west side of the sprayer. Titan sprayer showed the highest amount of droplet movement through the canopy but minimal drift above the canopy.

Figures 5 and 6 show the means of deposits on the "Near" targets (A_w and A_e). These targets had valid data for all treatments (Figs. 2-4). The results indicated that every sprayer and application treatment had some drift potential but the amounts of deposits could vary at different sample heights. At the canopy level (0.1-4.6 m), the Titan, PB-BS and PB-LS had the three highest amounts of deposits among the nine treatments (Fig. 5). In fact, these and other treatments that were applied at lower ground speeds (2.4-2.8 km h^{-1}) appeared to have resulted in more through-canopy spray movement than the treatments applied at higher ground speeds (4.8-5.8 km h^{-1}). This difference is more evident in comparison of low- and high-speed Power-Blast treatments: PB-BS vs. PB-BF and PB-LS vs. PB-LF (Fig. 5, 0.1-4.6 m level). At the three upper sampling heights, the relative drift deposits of the treatments were comparable (Fig. 5). The PB-BF, FMC, and PB-LS treatments generated the three highest drift deposits at the uppermost sampling height (7.6-9.1 m). At this level, PB sprays at 5.8 km h^{-1} appeared to have more drift potential than PB sprays at 2.8 km h^{-1}.

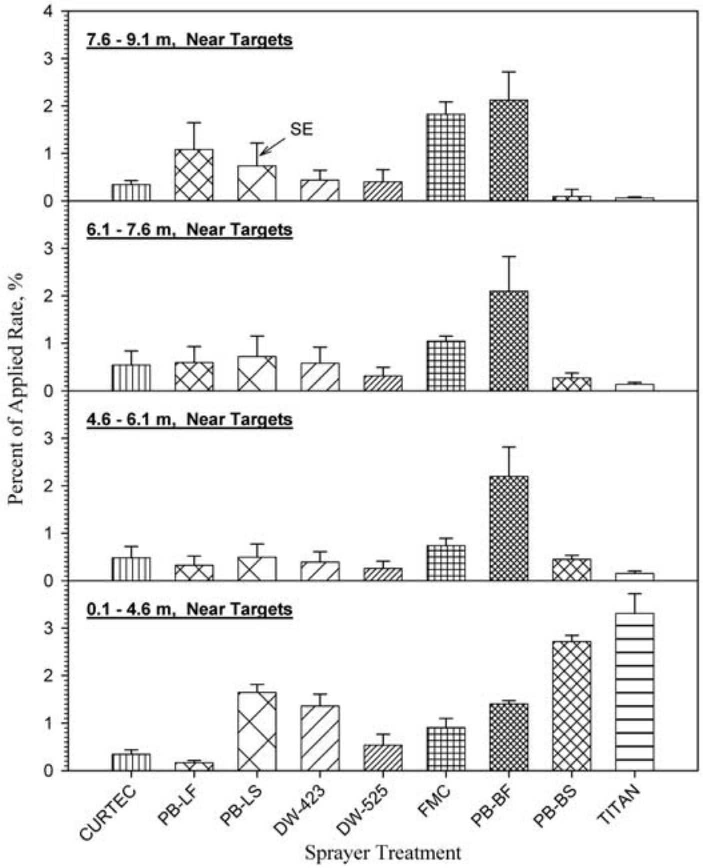

Fig. 5. Comparative drift deposits of the sprayers at different sampling heights.

Comparison of the treatments using nozzles with relatively smaller and larger droplets (DW-423 vs. DW-525 or BB-LS vs. PB-BS) revealed somewhat higher drift potential for smaller droplets at upper levels (Fig. 6). However, this comparison was not valid for PB-LF vs. PB-BF. Overall, every treatment appeared to have some drift potential. In general, sprayers with tower configuration appeared to have lower above canopy drift potential compared to radially discharging air-blast sprayers. The above canopy drift potential of all treatments was less than 4% of the applied rates, except for the PB-BF.

It should be noted that the results could be affected by capture efficiency of sampling targets. The canopies of the hedge-rowed trees of the test site had medium foliage densities and were continuously connected. Drift potential could be higher if there were gaps between tree canopies. At any rate, the magnitude of the drift depended on prevailing wind speed and direction.

Conclusions

1. Every sprayer was capable of generating some measurable drift deposits.

2. The above canopy drift potential was generally higher for low-profile air-blast sprayers, smaller nozzles (droplets), and higher ground speeds.

3. Overall, the off-target deposit (drift) was less than 4% of the applied rates, for most treatments.

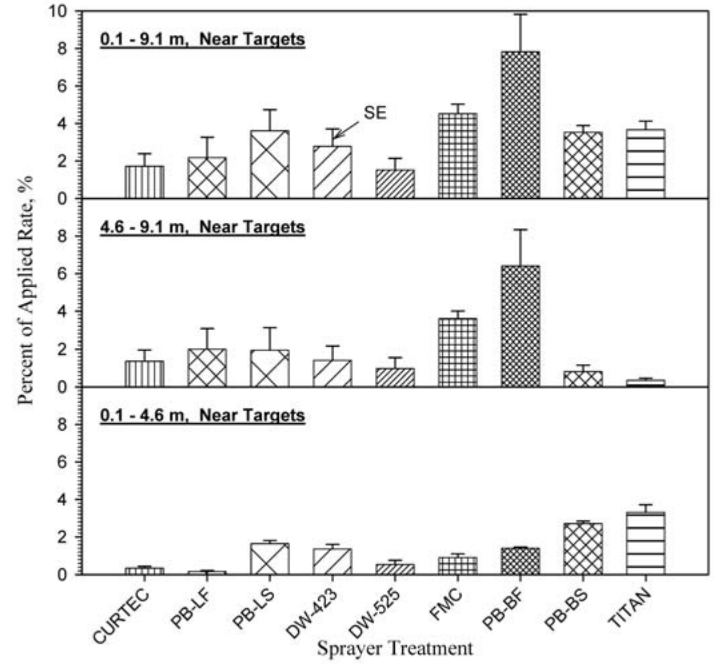

Fig. 6. Comparative drift deposits of the sprayers at and above canopy levels.

4. Wind speed and direction affected the magnitude of the drift deposit at each sample location.

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