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SPRAY DEPOSITION AND DRIFT FROM TWO "MEDIUM" NOZZLES

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Abstract. The labels of many crop protection and production materials include specific directions for application, such as "apply as a MEDIUM spray." Therefore, aerial applicators are utilizing computer models and printed materials to comply with these labels. The objective of this study was to determine spray deposition and drift from two "MEDIUM" nozzles used in an aerial application. With an application rate of 28 L/ha (3 gal/acre), CP nozzles were configured to produce a volume median diameter ($D_{v0.5}$) of 304 µm (T1) and Spraying Systems D8 straight stream nozzles were configured to produce a $D_{v0.5}$ of 413 µm (T2). Under the ASAE nozzle classification system, both would be classified as Medium sprays; however, the spray volume contained in droplets less than 200 µm was 15.5% and 8.7% for the CP and D8 nozzles, respectively.

These studies show that very different downwind deposition can occur from two aerial spray nozzles that are classified as MEDIUM based on droplet spectra. T1 contained two times more spray volume in droplets less than 200 µm than T2. As a result of this difference, T1 produced significantly higher downwind deposition than T2. At 50 m from the downwind edge of the spray swath, the deposition was 1.7% and 0.53% of the deposition at 0 m for T1 and T2, respectively. T1 also produced more airborne material at 50 m downwind of the spray swath edge than T2 at heights up to 10 m. These results were valid for spray applications made in crop canopies or over concrete runways. The results highlight the need for aerial applicators to consider all of the droplet spectra data when selecting the most appropriate spray nozzle for a given application situation.

Keywords: droplet spectra, aerial application, drift, nozzle classification, spray deposition

Spray Deposition and Drift from Two "Medium" Nozzles

By

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Introduction

Nozzle and atomization researchers characterize spray nozzle characteristics in terms of the droplets that are generated by a nozzle under a set of given application parameters. These researchers refer to droplet size measurements such as volume median diameter ($D_{V0.5}$) and Sauter mean diameter (D_{32}). To avoid this technical jargon and increase the applicability of atomization data to users, the British Crop Protection Council (BCPC) devised a nozzle classification system that placed nozzles into five classes (very fine, fine, medium, coarse, and very coarse) based on the characteristics of the droplet spectrum (Doble et al., 1985; Southcombe et al., 1997). Nozzles can change from one classification to another when spray pressure and/or orientation are changed. The BCPC classification scheme was modified for the United States (Womac et al., 1999) through ASAE Standard S572 AUG99 (ASAE Standards, 2000b). The U.S. classification scheme uses droplet spectra to place a nozzle into one of six categories (very fine, fine, medium, coarse, very coarse, or extremely coarse) as defined by a set of reference nozzles.

Many crop protection and production materials are now requiring specific droplet sizes for application, such as "apply as a MEDIUM spray." Since these terms are on the label, applicators are legally required to configure their application equipment to operate in the specified manner. Aerial applicators are utilizing computer models (Kirk, 2001, 2002) to comply with these labels. These models allow applicators to select a nozzle, input the specific application parameters such as airspeed, spray pressure, and nozzle orientation, and determine the spray droplet spectra classifications for the specified conditions. In addition to nozzle classification, these models also show the applicator the volume median diameter, relative span, and percent of spray volume in droplets smaller than 100 µm ($V_{<100\mu m}$) and 200 µm ($V_{<200\mu m}$) (Kirk 2002). The $V_{<200\mu m}$ is generally considered as the portion of spray that is most likely to move out of intended spray area (i.e., drift). Teske and Thistle (1999) showed that as droplet size increases, the downwind drift is reduced; therefore, applicators should consider $V_{<200\mu m}$ and $D_{v0.5}$ when selecting their application equipment

Objective

The objective of this study is to evaluate the downwind movement of spray from two nozzles that produce MEDIUM droplet spectra as defined by ASAE Standard S572 (ASAE, 2000b). The hypothesis in selecting these two MEDIUM nozzles was that one nozzle setup would producer higher downwind depositions than the second nozzle setup because one nozzle setup had a much higher portion of the spray volume in droplets less than 200 µm.

Materials and Methods

Spray Treatments

The spray solution was water, Triton X-100 at 0.1% v/v, and Caracid Brilliant Flavine FFN fluorescent dye at 25 g/ha. The fluorescent dye was used as a tracer to measure the deposition and downwind movement of the spray during the tests. The same AirTractor 402B aircraft was used in all tests and it's operational parameters were: speed – 193 km/hr (120 mph) or 209 km/hr (130 mph); approximate boom height – 1.8 m (6 ft); swath width – 19.8 m (65 ft); spray rate – 28.0 L/ha (3 gal/acre). Tests were conducted twice over crop canopies and twice over a concrete runway over four different testing dates. The crop canopies were a soybean canopy approximately 0.6 m (2 ft) and 50% closed canopy and a harvested sorghum field approximately 1 m (3 ft) tall and 70% closed canopy. At each testing date, each treatment (T1 and T2) was replicated four times.

Table 1. Nozzle operational and atomization parameters for the two nozzle setups

	Treatment 1 (T1)	Treatment 2 (T2)
Nozzle Type	CP-03[a]	Disc Orifice[b]
Number of Nozzles Used	25	26
Orifice	0.125	#8 (no core)
Nozzle Orientation	0º	0º
Nozzle Deflector	30º deflector	None
Operating Pressure [kPa (psi)]	207 (30)	276 (40)
Volume Median Diameter, $D_{V0.5}$ [µm]	304	413
$V_{<200\mu m}$[c]	15.5%	8.7%
Aircraft Speed [km/hr (mph)]	193 (120)	209 (130)

[a] CP Products, Inc. Mesa, AZ; [b] Spray Systems Inc., Wheaton, IL; [c] Percent of spray volume contained in droplets less than 200 µm

Based on ASAE Standard S572 Spray Nozzle Classification by Droplet Spectra (ASAE, 2000b), two sets of nozzles or treatments (T1 and T2) were selected and configured (Table 1) to fit into the MEDIUM droplet spectra classification. While the nozzles differed in the percent of the spray volume contained in droplets less than 200 µm, which are generally considered to be the most likely to drift, and volume median diameter, both were classified as MEDIUM. Standard S572 states "in the event a reference threshold division is intercepted or crossed, the finer of the classification categories shall be reported to indicate the smallest droplet size of the categories involved." T2 is classified as a COARSE nozzle based on the diameter of droplet such that 10% of the spray volume is in droplets of smaller diameter ($D_{v0.1}$) and $D_{v0.5}$ but falls in the MEDIUM classification based on the diameter of droplet such that 90% of the spray volume is in droplets of smaller diameter ($D_{v0.9}$).

Test Layout and Sampling Procedure

The deposition and movement of applied material released from the aircraft was measured by flying the aircraft perpendicular to the prevailing wind. Sampling stations were placed parallel to the wind (Fig. 1) and at specified distances from the downwind edge of the spray swath. There were three parallel sampling lines (A, B, and C) for each treatment replication treated under the same weather conditions. The lines were spaced 5 m (16.4 ft) apart. At each sampling location, mylar cards (100 cm²) were secured horizontally on a metal plate that was positioned at the top of the canopy or on the runway at each sampling distance. The aircraft made two passes over the described course for each of the four replications of each treatment always turning on the spray 300 m before the sampling lines and turning off the spray 300 m after the sampling lines. One pass was made with the left wing on the downwind side and one pass was made with the right wing on the downwind side.

After each replication and allowing sufficient time for the spray material to move downwind, each mylar card was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. The cards were exposed to the sunlight for less than 15 min following an application; therefore, no appreciable degradation of the fluorescent dye would be expected. Forty or twenty ml of ethanol was pipetted into each bag, the bags were agitated, and 6 ml of the effluent was poured into a cuvette. The cuvettes were then placed into a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) with an excitation wavelength of 453 nm and an emission at 488 nm. The fluorometric readings were converted to µg/cm². The minimum detection level for the dye and sampling technique was 0.00007 µg/cm².

At 50 m from the edge of the spray swath, two vertical towers were positioned 10 m apart. Monofilament line was suspended between these towers at crop height in the canopy tests (0.6-1 m) or 1 m in the runway tests, 5 m, 7.5 m, and 10 m (Fig. 1). The lines were parallel to the flightline and provided a measure of the airborne component of the spray. After each replication, the towers were lowered and the monofilament line was collected on spools that were built for this study.

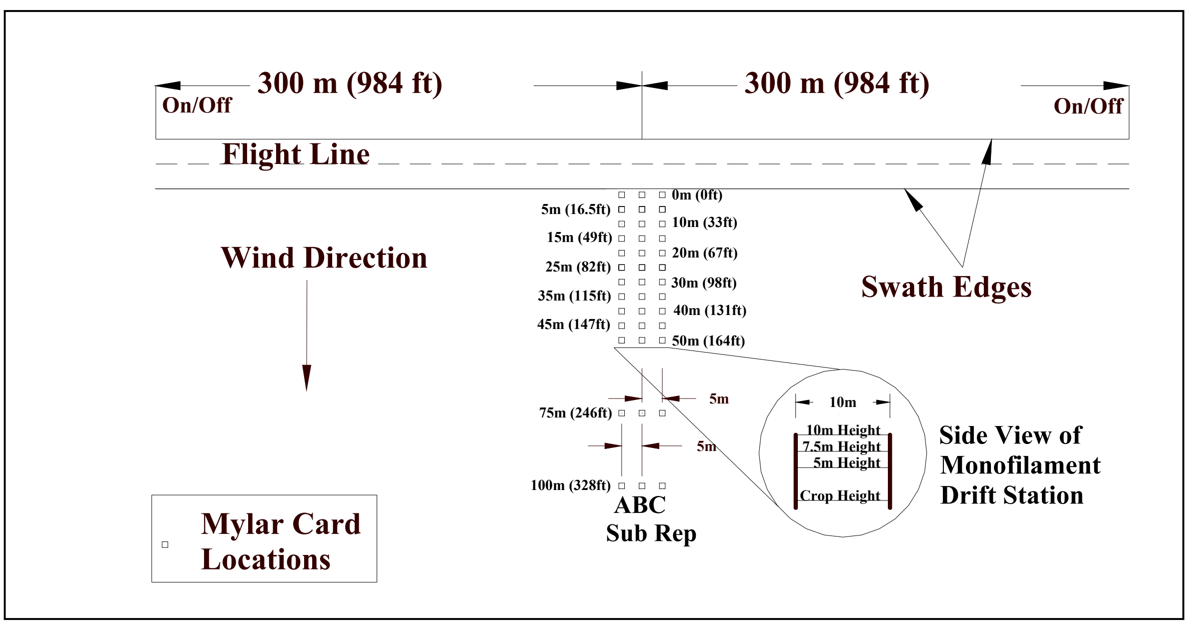

Figure 1. Test layout for field studies

These spools allowed the line to be collected without touching the crop canopy or runway. Each spool was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. After pipetting 40 ml of ethanol into each bag, sample analyses were performed as described for the horizontal deposition samples.

Meteorological Conditions

Meteorological conditions were recorded during all of the tests. The range of each measurement over all replications is shown in Table 2. The data presented represent one-minute averages at the time that the aircraft was spraying. When the wind direction deviated by more than ±30º from the sampling line orientation during a replication (i.e., Crop (20 Sep)), the data was discarded and not used in the data analysis (ASAE Standard, 2000a).

Table 2. Range of Meteorological Conditions During Field Studies

Test Site (Test Date)	Temp (ºC)	RH (%)	Wind Speed (m/s (mph))	Wind Deviation[a]
Crop (10 June)	25.2 - 27.3	76-81	2.6 - 4.1 (5.8 - 9.1)	-12.3º to 10.6º
Runway (18 July)	25.8 – 29.2	82-92	2.3 – 3.2 (5.2 – 7.2)	-5.5º to 13.2º
Runway (18 Sep)	20.8 – 27.4	54-85	5.2 – 6.1 (11.6 – 13.6)	-12.2º to 1.6º
Crop (20 Sep)	27.1 – 30.4	82-91	2.1 – 3.1 (4.6 – 6.9)	-15.2º to 14.8º

[a] Deviation of the wind direction from the sampling lines at the time of application

Data Analysis

All statistical inferences of significant differences refer to the $\alpha=0.05$ level. The horizontal deposition or mylar data was analyzed as a repeated measures by distance data set using PROC MIXED (Littell et al., 1996) in SAS (SAS Institute, 2001). The three sampling lines (A, B, and C) were considered as fixed-effect measurements in the analyses. The component of the wind vector parallel to the sampling line was a covariant, which accounted for differences in wind velocity during each of the replications. Separate analyses were performed for the canopy and runway data sets. The monofilament line or vertical samples were analyzed using PROC GLM in SAS (SAS Institute, 2001). Means were separated using a least significant difference (LSD) test where appropriate.

Results and Discussion

Horizontal Deposition

The hypothesis that T1 ($V_{<200\mu m}$=15.5%) would produce more downwind deposition than T2 ($V_{<200\mu m}$=8.7%) was confirmed. Deposition curves were significantly different in both the runway ($F=6.90$, $P<0.001$) and crop ($F=4.85$, $P<0.001$) testing conditions. The area under the curve was higher for T1 than for T2 in both the runway and crop tests indicating that more material deposited out of the intended swath in T1 than in T2 (Fig. 2). At 0 m or the edge of the downwind swath, T2 had higher deposition amounts. This was likely the result of swath displacement due to the crosswind during the tests (Kirk, 2000). However, T2 deposition was lower than T1 at all other distances. Deposition was significantly higher in the crop tests than in the runway tests for each treatment. These results are similar to previous results comparing deposition in crop canopy and fallow or bare ground samples (Hoffmann, 2001).

Assuming that the deposition at 0 m was representative of the in-swath deposition as suggested in the previous discussion, the percent of spray that deposits at 50 m as a percentage of deposition at 0 m was calculated. Drift deposits from T1 at 50 m were 1.73 and 1.75% of the deposition at 0 m for the crop and runway tests, respectively. Drift deposits from T2 at 50 m were 0.60 and 0.46% of the deposition at 0 m for the crop and runway tests, respectively. Therefore, T1 produced a 3-fold increase in material depositing at 50 m over that from T2.

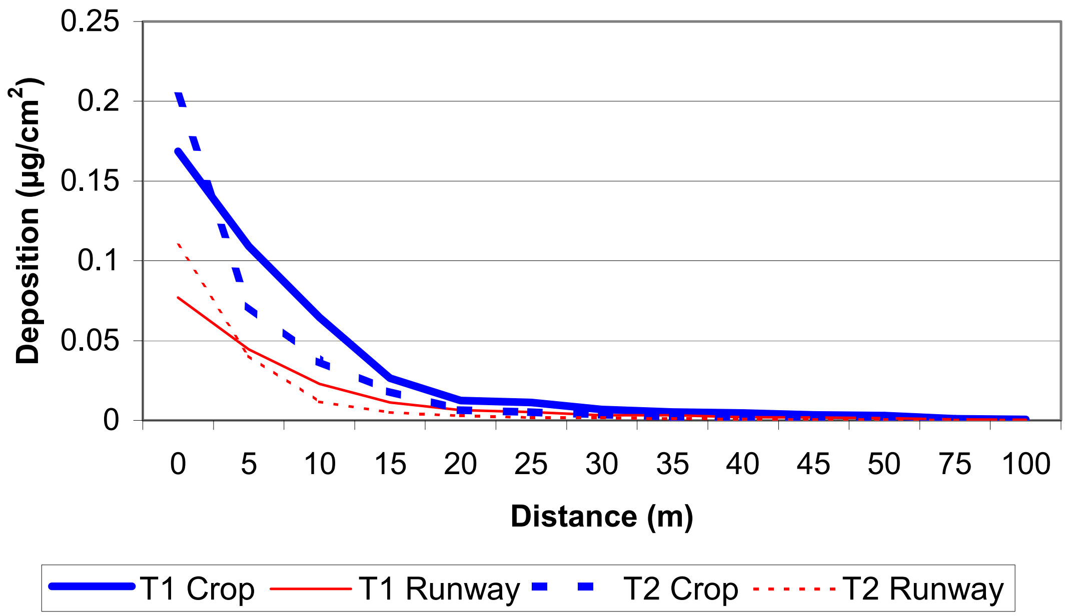

Figure 2. Deposition by Distance for Treatments 1 and 2 in the Crop and Runway Tests.

Monofilament Line Deposition at 50 m

The results from the monofilament line at different heights placed 50 m from the downwind swath edge are presented (Fig. 3). Data were analyzed two different ways. The first analysis grouped the data by height and treatment to determine the effects of the different testing environments (i.e. crop canopy or runway) (Fig. 3A). There were no significant differences between tests conducted over crop canopies or the runway for either treatment at any sampling height. Mokeba et al. (1998) stated that when droplets stop accelerating (i.e. travel the same speed as the surrounding air), their dispersal becomes controlled by random turbulence effects or air currents. As the small droplets begin dispersing from the site of application and gaining in height, the effects of boundary layer turbulence near the crop or runway becomes negligible resulting in the non-significant effects shown in Figure 3A.

The second analyses grouped the data by height and testing environment to determine the effects of the different treatments (T1 and T2) (Fig. 3B). T1 had significantly higher deposition on the monofilament line at 50 m than T2 over crop canopies and the runway at each sampling height, except, at the 10 m height in the runway tests. These results confirm the horizontal deposition results, which indicated that T1 produced higher drift deposits downwind.

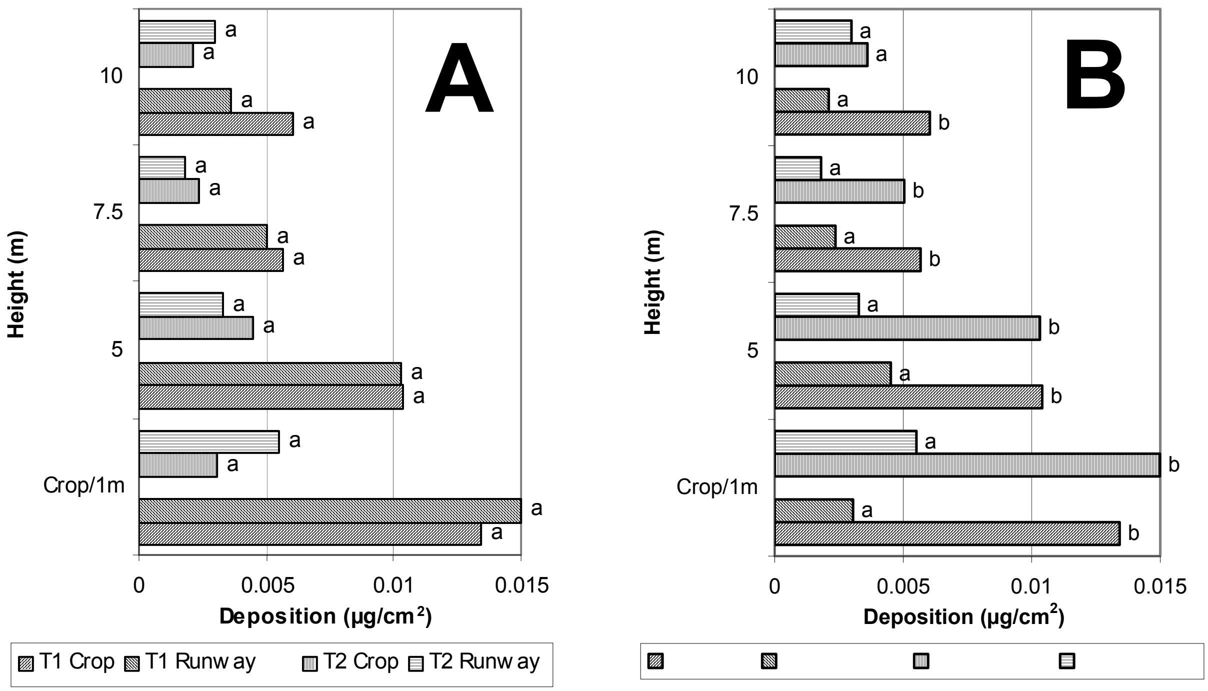

Figure 3. Deposition from Monofilament Line Collector by Height at 50 m from Swath Edge (Means grouped by treatment (A) or sampling environment (B) at each height followed by the same letter are not significantly different (LSD, P>0.05))

Conclusion

These studies show that very different downwind deposition can occur from two aerial spray nozzles that are classified as MEDIUM based on droplet spectra. One nozzle setup (T1) contained two times more spray volume in droplets less than 200 µm compared to the second nozzle setup (T2). As a result of this difference, T1 produced significantly higher downwind drift deposition than T2. At 50 m from the downwind edge of the spray swath, the drift deposition was 1.7% and 0.53% of the deposition at 0 m for T1 and T2, respectively. T1 also produced more airborne material at 50 m downwind of the spray swath edge than T2 at heights up to 10 m. These results were valid for spray applications made in crop canopies or over concrete runways. The results highlight the need for aerial applicators to consider all of the droplet spectra data when selecting the most appropriate spray nozzle for a given application situation.

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