Poster Articles

Drift Characteristics of Boom Sprayer Nozzles Measured in a Wind Tunnel

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Abstract

A wind tunnel, water-sensitive papers (wsp), and DropletScan® software was used to collect and compare the movement of spray droplets downwind from 22 different ground sprayer nozzles. The wind tunnel was equipped with a plant canopy and a single nozzle boom to simulate a field application. A constant wind speed of 4.6 m/s was used for the test and all nozzles were individually tested with a perpendicular orientation to the wind direction. Each nozzle was tested at a flow rate of 1.5 liters per minute and a pressure of 276 kPa. Water-sensitive papers were placed at canopy height 1, 2, and 3 meters downwind to collect the spray droplets escaping the spray swath. Percent area coverage for each wsp was generated by DropletScan® for comparative purposes. High amounts of coverage would support an increased potential for spray drift. At the 1-meter location, the amount of coverage ranged from a high of 99 percent with traditional flat-fan nozzles to a low of 8 percent with the chamber design turf flood. The venturi nozzles as a group performed best overall with coverage's ranging from 36-9 percent with no significant differences in coverage found between the top seven drift reducing nozzles. The group mean for the venturi nozzles was 20 percent. This is compared to the flat-fan group at 90 percent, the preorifice and chamber nozzles at 42 percent, and the hollow cones at 72 percent. This study supports the use of drift reducing nozzles as a means for minimizing the potential for spray drift.

Introduction

Controlling or minimizing the off-target movement of sprayed crop protection products is critical. Researchers have conducted numerous studies over time to better understand spray drift problems. Particularly, a recent group of studies conducted by the industries Spray Drift Task Force (SDTF, 1997) generated numerous reports to support an Environmental Protection Agency (EPA) spray drift data requirement for product reregistration and future label guidance statements on drift minimization.

Even though a better understanding of the variables associated with spray drift exists, it is still a challenging and complex research topic. Environmental variables, equipment design issues, many other application parameters, and all their interactions make it difficult to completely understand drift related issues (Smith, et al., 2000). Droplet size and spectrum has been identified as the one variable that most affects drift (SDTF, 1997). Many forces impinge on droplet size, but it is still the drop size that must be manipulated to optimize performance and eliminate associated undesirable results (Williams, et al., 1999). Drift is associated with the development of high amount of fine droplets (Gobel and Pearson, 1993). Wolf, et al., (1999, 2000, 2001, 2001) in field studies, found that commonly used flat spray nozzle types exhibited significantly different potential to drift.

Over the last several years there has been an increased interest by nozzle manufactures to design nozzles that will effectively reduce the volume of driftable fines found in spray droplet spectrums. This is being successfully accomplished with the use of a preorifice and also with turbulation chambers (R. Wolf, 2000). A recent trend with spray nozzle design is to incorporate a 'venturi' that includes the spray droplet in air to lessen the drift potential while still maintaining adequate efficacy. Several nozzle manufacturers are including this new design as a part of a marketing campaign for drift control. Early research would indicate that the venturi nozzle is producing larger spray droplets (Womac, et al., 1997; Ozkan and Derksen, 1998; R. Wolf, et al., 1999, 2001, 2001).

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Spray drift data collection in the field is very complicated, expensive, and time consuming. Efforts and techniques to use wind tunnels to measure spray drift from various boom sprayer nozzle types are being developed (Phillips and Miller, 1999). Wind tunnel studies with simple nozzle mounting structures can provide valuable nozzle performance data independent of a sprayer and tractor while reducing much of the variability experienced in the field measurement process (Miller, 1993). Phillips and Miller (1999) determined that wind tunnel experiments are adequate to simulate the results of field measurements for spray drift.

Objective

The objective of this study was to compare in a wind tunnel the amount of downwind spray droplet movement (drift) from several different boom sprayer nozzles.

Procedure

This study was designed to measure and compare in a wind tunnel the amount of downwind spray droplet movement (drift) from 22 different nozzle designs (table 1). All nozzles were compared at a flow rate of 1.5 liters per minute. The spray pressure was maintained at 276 kPa for all treatments.

Table 1. Nozzle types evaluated with group, company, and spray pattern style.

Nozzle Type[1]	Group[2]	Company	Pattern Style
XR8004	1	Spraying Systems	Flat-fan
XR10004	1	Spraying Systems	Flat-fan
TR80-04	1	Hypro	Flat-fan
TR110-04	1	Hypro	Flat-fan
DG11004	2	Spraying Systems	Preorifice Flat-fan
RF4	2	Delavan	Preorifice Flat-fan
TKVS2	1	Spraying Systems	Flooding Flat-fan
TFVP2	2	Spraying Systems	Chamber Flooding Flat-fan
TFVS2	2	Spraying Systems	Chamber Flooding Flat-fan
TTJ04	2	Spraying Systems	Chamber Turf Flooding Flat-fan
TT11004	2	Spraying Systems	Chamber Flat-fan
AI11004	4	Spraying Systems	Venturi Flat-fan
TD04-XR11008	4	Greenleaf/Spraying Systems	Venturi Flat-fan
AIR MIX 110-04	4	Greenleaf	Venturi Flat-fan
ULD 120-04	4	Hypro	Venturi Flat-fan
AB11004	4	Air Bubble Jet-BJ Agri Products	Venturi Flat-fan
RAINDROP ULTRA 4	4	Delavan/CP	Venturi Flat-fan
AVI110-04	4	Hypro/Albuz	Venturi Flat-fan
DR80-04	2	Wilger	Preorifice Flat-fan
TD04-TT11004	4	Greenleaf/Spraying Systems	Venturi Flat-fan
RA4	3	Delavan	Hollow Cone
MC1.875	3	Great Plains	Hollow Cone

[1] All nozzles were calibrated to spray at 1.5 liters per minute at 276 kPa.
[2] Groups: 1 = Traditional flat-fan; 2 = preorifice and/or chamber; 3 = hollow-cone; 4 = venturi

Applications using water with a single nozzle boom configured for use in a wind tunnel were made at a constant wind speed of 4.6 m/s throughout the experiment. Each nozzle treatment was positioned perpendicular to the wind direction. The nozzles were located from 45 to 51cm above the canopy. A canopy, 25 cm high, was placed on the wind tunnel floor to simulate field conditions for a postemergence spray application. The canopy consisted of plastic broadleaf plants that were placed randomly through the entire length and width of the tunnel. Simulated grass was placed on the floor of the tunnel under the boom to minimize spray droplet bounce.

Water sensitive papers (Syngetna, 2002), were placed at canopy height downwind from the spray boom to function as collectors for the droplets moving away from the spray swath. Three water sensitive papers (wsp) were located at 1, 2, and 3 meters downwind over four replications for each treatment. A flatbed scanner (HP 6200Cse, 1200 pixels, Hewlett Packard, Palo Alto, CA), a computer, and DropletScan® software (WRK of Arkansas and Oklahoma, Devore Systems, Inc, Manhattan, KS) were used to capture the droplet images and generate the droplet information. Tests for equality of means were performed using PROC GLM. The nozzles were placed into four groups based on design and pattern for further statistical analysis (table 1). The groups compared were: traditional flat-fan, preorifice and chamber flat-fan, hollow-cone, and venturi flat-fan.

A boom with pressure gauge was designed to position one nozzle per treatment in the wind tunnel 14 meters downwind from the beginning of the working section of the wind tunnel. A QJC364 nozzle body (Spraying Systems Co., Wheaton, IL) with a pulse width modulation (PWM) valve (Capstan Ag Systems, Inc., Topeka, KS) attached to the diaphragm check valve was used for connecting and controlling each nozzle. The collector was designed for removal from the wind tunnel after each treatment to facilitate wsp removal and replacement with dry, clean wsp for the next treatment.

Nozzles and wsp were placed in position for each treatment by the researcher and assistants. The PWM valve was connected to a timer and used to control the length of spray cycle. The PWM valve allowed the system to be preset to the treatment pressure for instant and accurate spray volume control. In this study it was determined that a 2-second spray interval was needed to achieve adequate coverage to analyze the droplets on the water sensitive paper. All controls were actuated from a control room outside the wind tunnel. The wall was equipped with a door to facilitate nozzle changing and a viewing window to verify the equipment functioned properly.

The wind tunnel used in this study had a working section 17m long, 1.5m wide, and 1.9m high. A recirculating push-type fan (tip to tip blade measurement, 2.0 m) driven by a 93kW General Electric DC motor was used to develop the air stream. A diffuser the size of the wind tunnel cross-section was placed at the start of the working end of the tunnel. The diffuser was made from steel pipe (5.1 cm in circumference by 30.5 cm long) welded to form a honeycomb design. Spires, designed to increase both the depth and turbulence level of the wind tunnel boundary layer, were placed at the base of the diffuser. There were no adjustments to turbulence for this study.

Temperature and humidity were measured using a Campbell Scientific CR10X probe system with data logger. The probes were positioned at boom height. Values for each, temperature – 23 degrees C and humidity – 6 percent, were averaged over the duration of the experiment. A KURZ Model 1440M air velocity meter positioned above and near the center of the boom was used to continually monitor wind velocity. Wind velocity was controlled by adjusting the amperage to the fan motor.

Results and Discussion

Water-sensitive papers (wsp) are often used as an indicator for the presence of spray deposition (Matthews, 1992). Water in the spray stains the wsp and the spot size can be observed or measured, thus, permitting the use of wsp to evaluate the number of droplets per unit area and for measuring the percent area covered (Syngenta, 2002). Spray droplets moving downwind and collected on water sensitive paper are a good indicator of a spray tips potential for drift when measuring the amount of coverage obtained on the cards (Wolf, 1999). One statistic generated by DropletScan® software is percent area coverage. Since the wsp are placed outside and downwind from each treatments swath, differences in the amount of area covered on the wsp will reflect the amount spray droplets moving away from the swath. The percent area coverage for each nozzle treatment for the wsp positioned 1 meter downwind are compared and presented in table 2. Figures 1 and 2 are included to highlight the differences at the one meter collector location.

Table 2. Coverage means for all nozzle types by nozzle, by group, and group mean[1].

	WSP all locations			WSP location – 1 meter downwind				
Nozzle Type[2]	1 meter	2 meters	3 meters	Group1	Group 2	Group 3	Group 4	Group Mean
tr8004	98.7	83.0	28.4	98.7				
tr110-04	97.3	94.8	63.2	97.3				
xr8004	92.7	60.4	22.1	92.7				1 = 90.4
mci1.875	91.2	68.1	26.9			91.2		
xr11004	90.1	66.1	27.1	90.1				
tkvs2	72.4	54.1	26.8	72.4				2 = 42.0
dg11004	72.0	57.4	20.0		72.0			
tt11004	64.6	35.2	16.7		64.6			
ra4	53.0	12.1	3.7			53		3 = 72.3
tfvp2	50.7	33.4	15.2		50.7			
tfvs2	43.6	27.1	13.7		43.6			
ab11004	35.7	14.4	3.9				35.7	
dr80-04	30.2	8.9	2.6		30.2			
am110-04	27.1	9.9	3.1				27.1	
rf4	24.6	11.2	4.2		24.6			
avi110-04	20.9	8.0	3.0				20.9	
ai11004	18.7	8.7	2.3				18.7	
td04-xr11008	17.8	7.1	2.0				17.8	4 = 20.2
ru-4cp	16.0	7.8	2.7				16.0	
td04-tt11008	15.2	4.8	1.7				15.2	
uld120-04	9.4	4.1	1.2				9.4	
ttj04	8.4	3.1	1.1		8.4			

[1] Percent area coverage on water sensitive paper. Higher coverage percentages indicate more potential for spray drift.

[2] See table 1 for nozzle type manufacturer.

The percent area coverage generated by DropletScan® for each nozzle treatment at the 1-meter location downwind ranges from 98.7 to 8.4 percent. The traditional flat-fan nozzle types and the hollow cone (MC 1.875) all show significantly higher coverage amounts (LSD = 12.7) than the other nozzle styles or groups. The nozzle types with less coverage represent designs for reducing spray drift with the venturi types showing the least downwind coverage. The preorifice and chamber style nozzles exhibited less coverage on the collectors than the nozzles in group 1 but more than the group 4 nozzles. Very little differences were evident within the venturi group except for the Air Bubble (ab11004). The ab11004 had 35.7 percent area coverage (LSD = 12.7) when compared to the AVI 11104 (20.9%), AI11004 (18.7%), TD04-XR11004 (17.8%), RU-4CP (16.0%), TD04-TT11004 (15.2%), and ULD120-04 (9.4%). The group mean was 20.2 percent area coverage. The ULD120-04 had the least amount of coverage for the venturi group of nozzles. The chamber style turf flood had the least amount of coverage (8.4%) compared to all nozzles in the study.

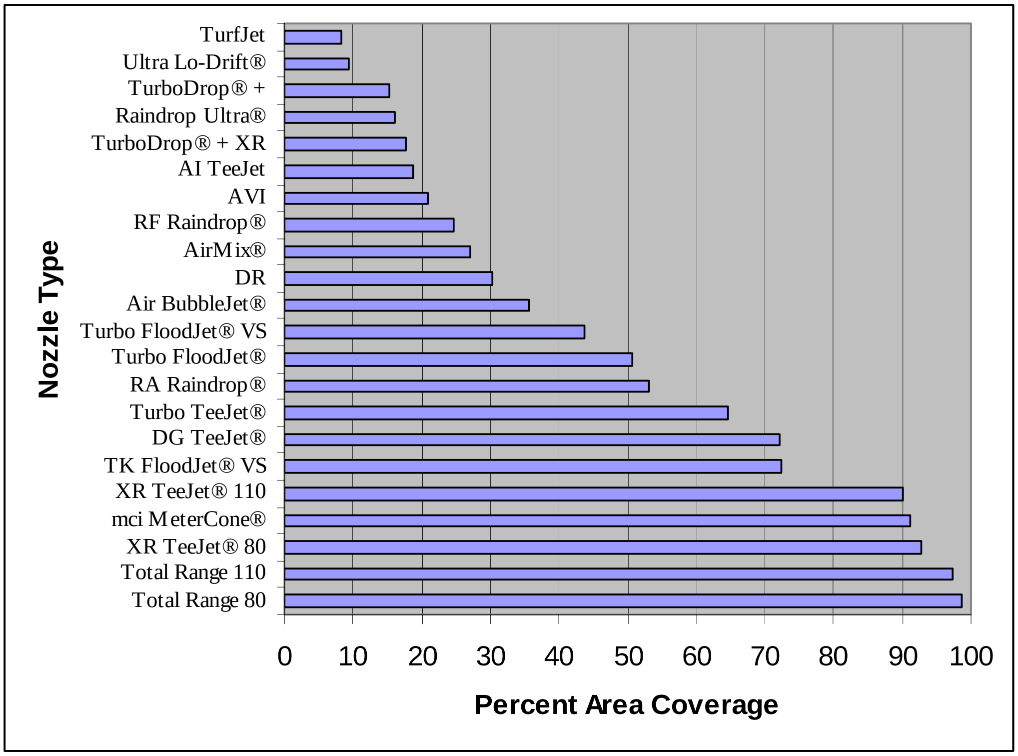

Figure 1. Coverage means at 1-meter downwind for all nozzle types. LSD=12.7

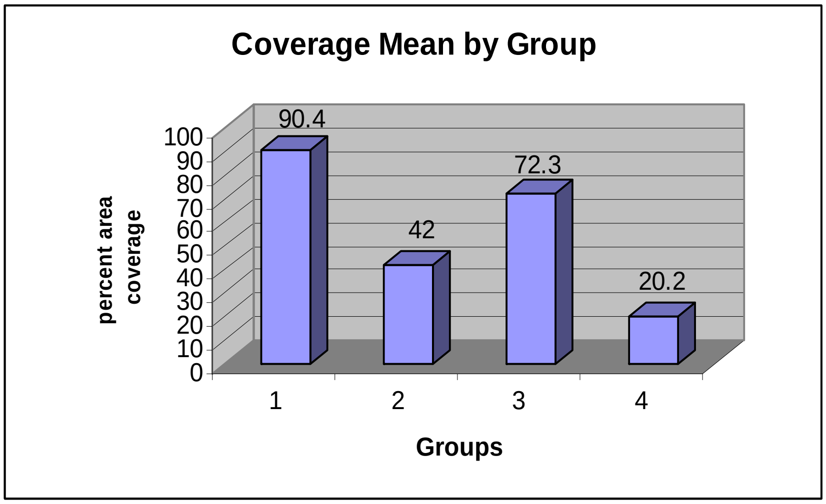

Figure 2. Group mean for coverage at 1-meter.

Similar trends are found at the 2 and 3-meter downwind locations (table 2). As distance from the nozzle increased the amount of coverage decreased. Within the flat-fan group (XR and TR), the 110-degree fan angle exhibited more coverage at the farther distances than the 80-degree versions. Designs to reduce the development of smaller spray droplets, as in groups 2 and 4, exhibited less coverage with differences less significant at the second and third collector positions.

Individual nozzles means within each group are reported in table 1 and figure 2. The group 1 nozzles had the most coverage (90.4%) at 1-meter. The two nozzles in group 3 were next highest (72.3%); followed by group 2 nozzles (42%) and then the group 4 nozzles had the least amount of coverage (20.2%). This trend was true at all three locations downwind.

Conclusions

Comparisons of the twenty-two nozzles types show a wide variation in the percent area coverage on the wsp downwind from the swath. The highest amount of coverage and potential for spray drift occurred with the traditional flat-fans and the MC 1.875 hollow cone tip. The preorifice and turbulation designs were significantly lower in coverage when compared to the flat-fan nozzle types. The nozzles in group 2 exhibit a significant degree of difference within the group ranging from 72-8.4 percent coverage. The two hollow cone designs were significantly different in coverage from each other (91.6 – 53%). The nozzles in group 4 were overall the best for reducing the amount of downwind movement of spray droplets which is evidenced by the dramatically reduced amounts of coverage on the collectors.

The data in this study would support that certain nozzle designs will minimize the creation of small spray droplets. In this study with all the variables held constant including the wind speed significant differences are present for drift potential. Nozzles with the least amount of coverage on the water sensitive papers downwind would be considered good choices for reducing the drift potential.

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