Spray Drift Reduction Evaluations
of Spray Nozzles Using a Standardized Testing Protocol

Editor's Note: *Over the last decade the USDA-ARS Aerial Application Technology Group has steadily increased the number of peer-reviewed scientific articles it publishes to the point that it is averaging nearly 20 peer-reviewed publications a year. This paper on drift reduction testing protocols was originally published last year in the* Journal of ASTM International. *What follows is an abridged version.*

AUTHORS
W. Clint Hoffmann and Bradley K. Fritz
USDA-ARS
College Station, Texas

Jonathan W. Thornburg
RTI International
Research Triangle Park, N.C.

W. E. Bagley
Wilbur-Ellis Company
San Antonio, Texas

Norman B. Birchfield and Jay Ellenberger
US EPA
Washington, D.C.

Summary

The development and testing of drift reduction technologies has come to the forefront of application research in the past few years in the United States. Drift reduction technologies can be spray nozzles, sprayer modifications, spray delivery assistance, spray property modifiers (adjuvants), and/or landscape modifications. A protocol for testing DRTs in high speed wind tunnels has been previously reported and was expanded to test spray nozzles. This manuscript reports on the initial implementation of the DRT program for conducting DRT evaluations of three spray nozzles under high speed conditions (i.e.,45–65 m/sec (100–140 mph)), which are relevant to the aerial application of crop production and protection materials. The spray nozzles were evaluated in the USDA-ARS High Speed Wind Tunnel facility. Droplet size of each of the nozzles with different airspeeds, spray pressures, and orientation were measured with a Sympatec Helos laser diffraction instrument. The droplet size spectra for each test was input in a spray dispersion model (AGDISP), which calculates the downwind drift expected from a typical aerial application scenario. As compared to the reference nozzle (Flat fan 11003 at 43 psi), the three spray nozzles reduced spray drift by 70–84 percent as compared to the reference nozzle. The nozzles generated spray droplets with volume median diameters 60–80 microns (μm) larger than the reference nozzle. One of the aerial application industry's Best Management Practices (BMP) is to not spray directly on the downwind edge of a field. The spray swath near this edge is moved upwind (i.e. offset) by ½ to 1 swath width. When this BMP was combined with the drift reductions from the spray nozzles, the amount of drift reduction was slightly increased; however, application efficiencies increased to 93–96 percent. These results demonstrate the possibility of combining multiple drift reduction techniques and technologies to greatly reduce spray drift.

Introduction

The first step in implementing the EPA-Drift Reduction Technology (DRT) program is to develop a set of protocols, standard operating procedures and data quality assurance steps so that the results from any trials or research conducted are scientifically valid and repeatable; data quality and protection must also be maintained throughout the study. Best Management Practices (BMP) are common industry practices that are used to apply agrochemicals to optimize swath deposition while minimizing off-target movement. For aerial applications, common BMPs are identification of sensitive areas around a field to be sprayed, modifying spray applications to account for changes in wind speed and direction, proper equipment setup to optimize agrochemical delivery and other professional practices all directed at making the most effective spray application. One common BMP is the use of a swath offset to minimize off-target deposition when an application is made near a downwind field edge.

Sampling spray swath uniformity in cotton fields using cotton string. The balloon in the background in used to lift the string up out of the cotton so that it can be collected on reels for later analyses.

Atomization of the spray from nozzles is influenced by nozzle type, pressure, orientation, airspeed and spray solution. All of these factors are researched by the Aerial Application Technology Group.

This practice involves moving a spray swath some distance upwind of a downwind field edge while spraying in a crosswind.

Objective: To evaluate the DRT testing program for aerial applications under high airspeeds (i.e. >100 km/hr (~60 mph), which is typical for these type of crop production and protection material applications.

Testing Methods

This testing will gather information and data for evaluating the applicability of the pesticide spray DRT protocol for successfully testing commercially ready pesticide spray DRT nozzles. All high speed tests were conducted in the USDA-ARS wind tunnel located in College Station, Texas. Three test nozzles and a reference nozzle were tested using the pesticide spray DRT protocol. The three test nozzles were a Hypro ULD 120-04 nozzle, a Teejet AI-110 VS nozzle and a CP11TT 4008 Flat Fan nozzle. The nozzle used to define the Fine/Medium boundary in the ASABE Standard was selected as the reference nozzle. Specifically,

Drift Reduction (%)[1]	25 ≤ 50	50 ≤ 75	75 ≤ 90	90 ≤ 95	95 ≤ 99	≥ 99
LERAP Drift Classification	*	**	***	***	***	***
ISO Drift Classification	F	E	D	C	B	A

[1] Drift reduction is the percentage of drift reduction achieved by a technology as compared to a standard reference.

TABLE 1. Drift reduction classification for the LERAP and ISO system based on percentage reduction of candidate system as compared to reference system.

this reference nozzle was a Spraying Systems 110° Flat fan nozzle with an #03 orifice operated at 43 psi.

Modeling Inputs and Setup

Computer models are typically very sensitive to the input variables and AGDISP (Agricultural Dispersion model) is not different. AGDISP Ver. 8.21 was used in the modeling scenarios with the following inputs standard across all scenarios reported in this manuscript:

- **Aircraft:** Air Tractor AT-401 with 66 ft swath width
- **Application Scenario:** 11.5 ft release height with 10 spray applications moving upwind
- **Meteorological Conditions:** Wind Speed: 5 mph @ 90° (crosswind), Temperature: 80°F, Relative Humidity: 70 percent

Based on the droplet size measurements from each of the nozzle evaluations, the corresponding droplet size data were input into the AGDISP model. One of the default settings in the AGDISP model is a swath offset of 0. The effects of changing this offset from 0 to a ½ swath offset were modeled. As noted previously, the practice of using ½ to 1 full swath offset is a common BMP that aerial applicators use during spray applications.

How are DRT's Rated?

The two most commonly used drift reduction classification systems are the Local Environmental Risk Assessment for Pesticide (LERAP) and the International Standards Organization (ISO) systems. The LERAP system uses a system of stars (No stars to ***) to denote the level of drift reduction that a given technology provides as compared to a reference system. The ratings may be used to determine the size of the spray buffer mitigation the applicator can use with a given spray technology. The ISO drift reduction standard defines the six drift reduction classes ranked alphabetically (A-F) with the A class having the greatest percentage reduction and the F class the least (Table 1). The ISO classification is also used as a method to mitigate the size of a no-spray buffer area. Unlike the ISO classification system, the LERAP method groups systems with a 75 percent reduction or greater into a single classification group.

Results

As expected, the droplet size decreased for each of the nozzles as the airspeed in the wind tunnel increased from 120 mph to 140 mph. The droplet sizes also increased with N1 and N2 when the spray pressure was increased from 30 to 60 psi. These data were used in all of the subsequent AGDISP modeling work.

Modeling Application Efficiency

After running AGDISP using the droplet size measurements for the different testing scenarios (nozzle, pressure, airspeed), the modeling outputs were recorded. Application efficiency is the amount of spray material, expressed as a percentage of spray released from the simulated aircraft, that deposits in the field or targeted area. For all of the simulations, downwind deposition out to 30 ft was modeled. This is representative of the spray deposition from the edge of the swath to a distance 30 ft downwind. The airborne drift at 10 m represents the portion of the spray volume that remains in the air at this distance. The reference nozzle generated an application efficiency of 86.7 percent with 1.5% of the spray in the air 30 ft from the field boundary in the 120 mph modeling runs. The three nozzles (N1,

Spray nozzles are positioned at the outlet of the high speed wind tunnel, which can generate air-speeds up to 220 mph. The spray droplets are measured about 20 inches downstream with a laser droplet sizing instrument (red and silver instrument in the background).

N2 and N3) tested all had improved application efficiencies (90–92 percent) and large decreases in airborne drift as compared to the reference nozzle. In the 140 mph tests, the Reference nozzle had an application efficiency of 84.6% and 2.45% of the spray was still airborne at 30 ft from the downwind edge of the field. The three nozzles tested all had improved application efficiencies (87–90 percent) and decreases in airborne drift.

Drift Reduction from Nozzles

Drift reduction is defined as the reduction in the airborne portion of the spray as compared to a reference (ISO Standard). The test nozzles reduced airborne spray drift by 70–84 percent in the 120 mph airstreams and from 41–74 percent in the 140 mph airstream tests. At the lower airspeed, the tested nozzles received E and D ratings based on the ISO drift classification scheme and ** and *** based on the LERAP scheme. At 140 mph, the test nozzles received F and E ratings based on the ISO drift classification scheme and * and ** based on the LERAP scheme.

Effects of Swath Offset on Application Efficiency and Drift Reduction

All of the previous scenarios were rerun with a ½ swath offset except the reference nozzle settings. A ½ swath offset was the equivalent of making a spray application 33 ft further upwind from the field edge. For both of the airspeeds, the three nozzles combined with a ½ swath offset resulted in application efficiencies between 93–97 percent and only minor changes in the airborne drift percentages. The offset results in more material depositing in the field, which is why aerial applicators have adopted this practice.

Conclusions

This work examined a drift reduction testing protocol comparing three different nozzles to a reference nozzle. Additionally, an industry Best Management Practice (BMP) of offsetting near field edge spray swaths was examined. The techniques and procedures for determining the nozzle effects on spray droplet size under high-speed air-sheer showed distinct differences between the nozzles tested and the reference nozzle. Using the AGDISP model, these droplet size results were translated to estimates of downwind deposition and airborne drift as a means of comparing the relative efficiencies of each nozzle as compared to the reference nozzle under different airspeeds and pressures. When compared to the reference nozzle, the results showed that:

- The three spray nozzles reduced spray drift potential by 40–84 percent due mainly to the larger $D_{V0.5}$ values, which were 30–80 microns (μm) larger than the $D_{V0.5}$ for the reference nozzle.
- After modeling the aerial application industry's Best Management Practices (BMP) of ½ swath offset, the results showed further increases in drift reduction and large increases application efficiency with application efficiencies ranging from 93–97 percent.
- The combination of multiple drift reduction techniques/technologies can greatly reduce spray drift. ■