AERIAL SPRAY DRIFT AND ATOMIZATION RECOMMENDATIONS

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Abstract

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A sensitivity analysis was run using three different aerial spray drift models. The combined analysis indicated that droplet size, downwind distance, wind speed and boom (flight) height were the four most important, drift related variables of the 10 studied. Two of these variables can be controlled directly by the applicator and the other two can be influenced via management decisions. Equipment and operating conditions are given for three specific droplet sizes when a pilot wants to use any of four aircraft speeds or four gallonages.

Introduction

The subject of spray drift is an important topic to the aerial applicator as well as surrounding land owners and/or operators. A lot of research effort has been devoted to spray drift problems during the past 40 years. However, these efforts have not answered all of the questions related to drift nor has it provided all of the answers for specific problems. Probably, the primary reason why all of the drift questions have not been answered is due to the inherent complexity of the problem. When one considers that the problem involves not only the design of a particular aircraft but also the meteorological and atomization variables related to a specific application (and the interactions of some of the variables), it is not difficult to comprehend the complexity of spray drift problems. There are about 16 variables which are likely to have some influence on the magnitude of aerial spray drift deposits. These variables are in addition to those such as the type and growth stage of a crop growing downwind of a treated area and the type of pesticide applied. The problem is further complicated from an applicator's perspective since: 1) the 'drift' cannot be detected visually at the increased downwind distances and 2) quantification of the drift deposits, meteorological variables and spray atomization require sophisticated, expensive equipment for their accurate measurement.

Aerial drift research projects have been conducted by universities, industry and the federal government. These data bases have been used to develop mathematical models (of varying degrees of sophistification) which can be used in conjuntion with computers. The advantages of these models are that they can provide answers quickly and drift deposit predictions for a variety of application conditions can be compared. Their disadvantages lie in the fact that each one was developed and verified while using the data which was available at that time. Thus there will never be a 'perfect' aerial drift model and researchers certainly can't afford to run tests involving every combination of every possible variable which is thought to influence drift deposits. With these thoughts in mind, the authors have used three of the available aerial drift models in order to provide guidance to aerial applicators. The recommendations contained herein have taken the limitation(s) of each drift model into consideration.

Spray Drift Evaluations

Ten of the 16 variables which would likely influence drift deposits were selected for evaluation. The variables selected were aircraft weight, downwind distance, spray droplet size distribution, flight height, pesticide application rate, % of the spray which is non-volatile, air relative humidity and temperature, wind direction and the wind speed at an elevation of 16 ft. An aircraft's boom length was not considered since boom lengths for applications in Mississippi are regulated at no more than 70% of the wing span. Several other important, atomization related variables (i.e. nozzle type and size, boom pressure, nozzle orientation, aircraft speed and increased viscosity of the spray) were not considered since three discrete droplet size distributions were selected for inclusion in the study.

A nominal value for each drift related variable studied was selected (Table 1). The 'typical' aircraft was an Air Tractor AT-502 which has an empty weight of 4123 lb. The 'typical' airplane was considered to have 1/2 tank of spray (2085 lb.) and 1/2 tank of fuel (388 lb.) for a nominal weight of 6596 lb. Each of these independent variables were separately decreased by 50% (minimum value) and increased by 50% (maximum value) in order to study the effect of each variable on downwind drift deposits. For example, the first simulation with each drift model

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involved only the nominal values for the 10 independent variables. The second simulation used an aircraft weight of 5360 lb [i.e. 6596 -0.5(388 + 2085)]along with the nominal values for all other variables; etc.

We used drift deposit predictions resulting from the FSCBG, Dow and MSU drift models. The FSCGB model was developed by the U.S. Forest Service, the Dow model was developed by Dow Elanco personnel and the MSU model was developed by MAFES personnel in the Agricultural and Biological Engineering Dept. We used 400 and 1300 ft. as baseline downwind distances at which the magnitude of the drift deposits would be calculated. The relative importance of a given independent variable as related to spray drift was calculated using the following equation::

% deviation =

$$\frac{ABS\ (DEP_{nominal} - DEP_{nominal\ +\ or\ -\ 50\%\ of\ nominal}) * 100}{DEP_{nominal}}$$

The % deviations are all positive values since the absolute value (ABS) of a difference in two drift deposits was used in the equation. For each of the three drift models, the average '% deviation' was calculated based on predicted deposits for two distances (400 and 1300 ft.) and two departures from the nominal values (maximum and minimum) for each independent variable. The 'average % deviations' shown in Table 2 are the averages for the combined data from all three models. These data indicate the change in drift deposits when the magnitude of the independent variable was changed by 50% of it's nominal value. The information in the second column in Table 2 also indicates whether increasing an independent, drift variable will increase or decrease the resulting drift deposits.

The 'Average % deviations' (Table 2) indicate that droplet size and downwind distance are the two most important drift variables we investigated (i.e. recall that pesticide type, crop type, crop growth stage and variables affecting atomization were not considered). A 50% change in the volume median diameter of the spray (i.e from 300 to 450 µm) caused an 'average % deviation' of the drift deposits to be 228% (i.e. over a 70% reduction in drift deposits. A similar size change in the downwind distance resulted in a 164% change in the resultant deposits. Other independent variables which have an important influence on drift deposits were wind speed, flight height, relative humidity and pesticide application rate. Notice that an applicator can directly control two (i.e. droplet size and flight height) of the six most important, drift related variables and may be able select an appropriate day or time-of-day when three other variables (i.e. downwind distance to a sensitive area, wind speed and relative humidity) are at more nearly optimal conditions. For example, a change in the wind direction could well change the downwind distance to a sensitive area. Also, the wind speed is typically lower and relative humidity higher early or late in the day. However, be sure that the atmosphere is not stable (i.e. released smoke hovers near the ground) if early or late applications are desired.

Atomization Guidelines

Since droplet size was shown to be a very important drift related variable for aerial applications and the applicator cannot readily and accurately measure droplet sizes, we have developed a table to provide guidance for such decisions. Table 3 lists the nozzle types and sizes, pressures, nozzle orientations and the 'number of nozzles needed per foot of swath width' to deliver either 250, 350 or 450 micron volume median diameters (VMD) when applying 2,3,5 or 10 gallons per acre at either 110, 120, 130 or 140 mph aircraft speeds.

An aerial spray atomization spreadsheet (developed by personnel in the Agricultural & Biological Engineering Dept. at MSU) or published atomization data were used to make the selections shown in Table 3. There may be some nozzle selections which are not shown in Table 3 which would be appropriate choices for a particular application. The 'number of nozzles needed per foot of swath width'(NNPFSW)is a minimum number since pressure drops along the boom's length may require more nozzles. The approximate limits for NNPFSW were based on: 1) a 2 gpa application using a 35 ft. boom while spraying a 72 ft. swath with about 72 nozzles (1 nozzle / ft. swath) and 2) a minimimum of about 25 nozzles for a 50 ft. swath (0.5 nozzles / ft. swath). The selections listed in Table 3 are for usual spray solutions/suspensions which would have a viscosity of about 1 centipoise and a surface tension of about 30 dynes per cm. For example, 0.83 % (v/v) Rely + 0.25% Ortho X-77 would be expected to have a viscosity and surface tension of 1.1 mPa·s and 30.5 centipoise, respectively. However, if 0.03% of Sta-Put is added to the spray, then these liquid properties would be about 2.9 mPa·s and 31.6 centipoise, respectively.

Consider an aircraft which is normally operated at 110 mph. If the operator wants to apply 2 gpa while using a VMD of 250 microns, two possible choices (Table 3) are either a TK-3 flooding fan or a D6-45 (Disc-Core) nozzle. If the D6-45 nozzle is selected and a 50 ft wide swath is desired, then the operator will need a minimum of (0.82 nozzles/ft. of swath x 50 ft. =)41 nozzles.

For an aircraft speed of 140 mph, 5 gpa and a VMD of 450 microns, two possible choices are a 6520 flat fan or a D8 Disc nozzle. Both the 6520 nozzle operated at 35 psi and the D8 nozzle (i.e. no core) operated at 45 psi would require a minimum of 0.76 nozzles per foot of swath width. If an applicator wants a 65 ft. swath width, then he will need a minimum of (0.76 x 65 = 49.4) 50 nozzles.

DO **NOT** change the pressures indicated in Table 3 in order to increase or decrease the gallonage (i.e. gallons per acre) applied. As illustrated in Figure 1, pressure changes can have a very big effect on the VMD produced by a given nozzle. Change the gallonage by increasing or decreasing the number of nozzles on the spray boom. We have attempted to include two or more nozzle types for each aircraft speed-gallonage-VMD combination in Table 3. However, this was not always possible. As the aircarft speed increased above 120 mph, it became increasingly difficult to find nozzles, pressures, etc. which would deliver the 350-450 µm droplet sizes in combination with the 10 gpa applications.

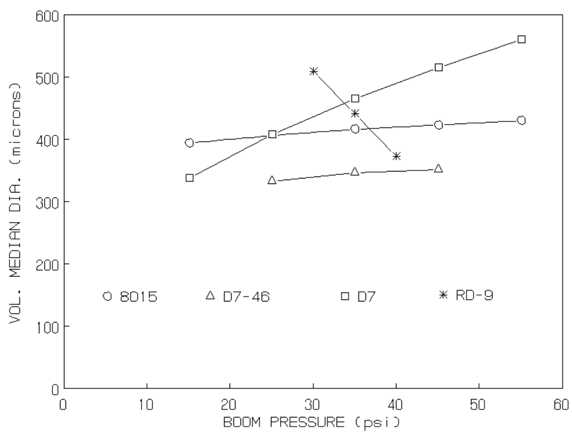

Figure 1 -- Example of the effects that boom pressure can have on the volume median diameter droplet size with the spray directed straight back, an aircraft speed of 130 mph and when using nozzles which have flow rates of about 1.4 gpm @ 40 psi.

Table 1. The independent variables and their values used in simulation along with the effect of each variable on aerial spray drift.

	Magnitude of Independent Variables				Average %
Variables	Minimum	Nominal	Maximum	Trend[a]	deviation
Droplet Size (μm)	175	350	525	decrease	228
Downwind Distance (ft.)	200	400	600	decrease	164
	650	1300	1950		
Wind Speed @ 16 ft. (mph)	3.5	7	10.5	increase	88
Flight Height (ft.)	6	12	18	increase	64
Relative Humidity (%)	30	60	90	decrease	51
Pestic. Appl. Rate (lb/A)	0.5	1	1.5	increase	50
Temperature (°F)	35	70	105	increase	32
Wind Direction w.r.t. to spray line (deg.)	45	90	N.A.	decrease	27
Aircraft Weight (lb)	5360	6596	7833	decrease	17
% Non-volatile Fraction	2.5	5	7.5	increase	15

[a] Trend in drift deposits for increasing values of the independant variables

Table 2 - Equipment and operating conditions which can be used to produce VMD droplet sizes of 250, 350 or 450 microns in conjunction with total gallonages of either 2, 3, 5 or 10 gpa with aircraft speeds of either 110, 120, 130 or 140 mph.

Speed (mph)	Area (gpa)	VMD (μm)	Nozzle[1]	P (psi)	NOA (deg.)	Nozzle #/ft[4]
110	2	250	TK-3	25	75	0.94
			D6-45	35	90	0.82
		350	6506	30	0	0.86
			D6-45	30	0	0.88
110	3	250	TK-3	30	75	0.86
			D8-45	45	90	0.82
		350	6508	45	45	0.78
			D8-45	35	0	0.84
		450	D7	25	0	0.58
			RD-8	40	0	0.60
110	5	250	TK-7.5	40	120	0.74
			D10-45	45	90	0.96
		350	11015	30	45	0.86
			D8-56	25	45	0.80
		450	8015	30	0	0.86
			D7	45	45	0.72
110	10	350	D10-46	35	90	0.96
		450	D10-46	40	0	0.90
120	2	250	9506	35	90	0.86
			D7-45	30	90	0.82
		350	6506	45	0	0.76
			D6-46	25	0	0.62
120	3	250	CP 0.078", 90° anvil	40	90	0.74
			D6-46	35	90	0.78
		350	9508	45	0	0.86
			D6-46	30	0	0.84
			AccuFlo; 16, 1.6 mm diam. tubes; w/ restrictor	20	0	0.78
120	3	350	RegloJet; nozzle body pointed straight back	40	45	0.74
		450	D6	20	0	0.90
			RD-8	30	45	0.76
120	5	250	LF-15 (73°)	35	135	0.86
			D7-46	45	90	0.82
		350	8015	35	45	0.86
			D7-46	45	45	0.82
		450	D10-46	40	0	0.48

Table 2 continued.

Speed (mph)	Area (gpa)	VMD (μm)	Nozzle[1]	P (psi)	NOA (deg.)	Nozzle #/ft[4]
120	10	350	D10-46	45	90	0.92
		450	D10-46	45	0	0.92
130	2	250	TK-4	25	75	0.84
			D6-46	25	90	0.66
		350	6508	30	0	0.76
130	3	250	9510	35	90	0.84
			D10-45	25	90	0.90
		350	11010	35	0	0.84
			D7-46	35	0	0.60
			D10-45	40	0	0.72
		450	D6	25	0	0.86
			RD-8	35	0	0.76
130	5	250	11015	45	90	0.82
			D7-46	45	90	0.88
		350	8020	25	45	0.84
			D7-46	45	0	0.88
		450	8020	25	0	0.84
			D8	40	0	0.76
130	10	350	D10-46	50	90	0.94
		450	D10-46	50	0	0.94
140	2	250	LF-8 (110°)	25	45	0.90
			D7-45	40	45	0.84
			D6-45	45	0	0.92
		350	6508	40	0	0.70
140	3	450	6520	15	0	0.70
			D6	30	0	0.86
140	5	250	LF-20 (110°)	30	90	0.82
			D8-46	40	90	0.86
140	5	350	6520	35	45	0.76
			D8	50	45	0.74
			RD-10	40	0	0.92
		450	6520	35	0	0.76
			D8	45	0	0.76
		140	10	350	??[3]	
		450	??			

1 Most nozzles listed here are manufactured by either Spraying Systems Co. Or Delavan Mfg. Co. Exceptions include the CP, AccuFlo and ReglоJet nozzles.

2 The Nozzle Orientation Angles (NOA) listed herein refer to the angle between the spray sheet and the direction of travel of the aircraft. Spray initially directed straight back equals zero degrees, spray directed down and back at 45° equals 45°, etc.

3 Atomizers and operating conditions which would satisfy these conditions were not found.

4 Number of nozzles per foot of swath