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Field Comparisons for Drift Reducing/Deposition Aid Tank Mixes

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Abstract. *A field study was conducted to determine the influence of adding spray drift control/deposition aid products to tank mix solutions for fixed wing aerial applications. Two agricultural aircraft, an Air Tractor 502A and a Cessna 188 Ag Husky, were used to apply treatments at 28 l/ha with 21 different products. Each aircraft was configured to simulate a typical herbicide application scenario representative of its design and style. Downwind horizontal and vertical drift characteristics and droplet spectra characteristics in a canopy were evaluated for each product. Results of the study show that drift control/deposition aid products added to the tank mix do affect the amount of horizontal and vertical spray drift, for the application scenarios and operating conditions used. Results indicate that several products tended to result in more downwind deposits when compared to water while others reduced the amount of downwind drift deposits. Some of the products performed the same as water alone. Droplet spread factors were determined for each tank mix and used to calculate VMD, VD 0.1, VD 0.9, and percent area coverage using DropletScan™. Droplet spectra characteristics were influenced by the different products.*

Keywords. Aerial application, drift, drift minimization, droplet size, spread factors, spray, drift control products, deposition aids

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 the 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).

Off-target drift is a major source of application inefficiency. Application of crop protection products with aerial application equipment is a complex process. In addition to meteorological factors, many other conditions and components of the application process may influence off-target deposition of the applied products (Threadgill and Smith, 1975; Kirk et al., 1991; Salyani and Cromwell, 1992). Spray formulations have been found to affect drift from aerial applications (Bouse et al., 1990). Materials added to aerial spray tank mixes that alter the physical properties of the spray mixture affect the droplet size spectrum. (SDTF, 2001). With new nozzle configurations and higher pressure recommendations (Kirk, 1997), and with the continued development of drift reducing tank mix materials, applicators seek to better facilitate making sound decisions regarding the addition of drift control products into their tank mixes.

Water-sensitive papers 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). Droplet sizing is also possible when a proper spread factor (Syngenta, 2002) or calibration equation has been prepared for a particular imaging process (Smith et al., 1997). Fox et al. (2000) found while comparing water and oil-sensitive papers that laboratory spray trials confirmed spot values very similar to calculated values and concluded that percent area covered was a highly reliable parameter when using wsp.

Spray droplet stains collected on wsp are a good indicator of the amount of downwind movement of spray droplets (drift) when comparing the amount of coverage obtained on the wsp (Wolf et al., 1999, Wolf and Frohberg 2002). Since the cards are placed outside and downwind from each treatments target area, differences in the amount of area covered on the wsp will reflect the amount of drift.

Objective

The objective of this study was to evaluate the influence of selected drift control products/deposition aids on horizontal and vertical spray drift and the spray droplet spectra during two selected fixed wing aerial application scenarios.

Materials and Methods

A field study was conducted to determine the influence on reducing drift and increasing deposition when selected tank mix drift control products/deposition aids were added to the spray tank during fixed wing aerial applications. Two aircraft with different application scenarios were used to make the comparisons. One of the fixed wing aircraft, an Air Tractor 502A (Air Tractor Inc., Olney, Texas), was equipped with drop booms; CP-09 nozzles (CP Products, Inc., Mesa, Arizona) with a 5-degree deflection; using a combination of .078 and .125 orifice settings; and spraying at 276 kPa (40 psi). The second, a Cessna 188 Ag Husky (Cessna Aircraft Co., Wichita, KS), was equipped with Ag-Tips (Ag-Tips, Arrowwood, Alta, Canada); CP-03 nozzles with a 30-degree deflector; also using a combination of .078 and .125 orifice settings; and was spraying at 179 kPa (26 psi). The AT 502A ground speed was radar measured at 241 km/h (150 MPH) and the Cessna was measured at 185 km/h (115 MPH). Pilots were instructed to use an application height of 3.0-3.7 m (10-12 feet). Both aircraft made all treatments.

The study was conducted on September 25 and 26, 2002 at the Goodland airport in Goodland, Kansas. The study area was flat, open and dry with a 15-25 cm (6-10 inches) desert-like grass and weed canopy. Twenty-one different products (two were water only) were evaluated in three repetitions using the two airplanes (Appendix A). All products and both airplanes were completely randomized over both days of the study. There were 121 treatments evaluated. Spray mixes containing 560 liters (60 gal) of tap water, X-77 Spreader (Loveland Industries, Greeley, Colorado) at 0.25% volume/volume, and individual drift control additives/deposition aids were applied at 28 L/ha (3 GPA). All tank mix treatments were prepared based on recipes provided by each participating company (Appendix A). Temperature, relative humidity, and maximum and average wind velocities were recorded using Kestrel 3000 (Nielson-Kellerman, Chester, PA) hand-held instruments averaged during the time of application for each treatment. To minimize tank mix contamination between treatments, a hot water-high pressure washer was used to facilitate hopper cleanout. Water was included on both days of the study as a check. Products were divided into four groups dependent on chemistry. The groups were specified by the researchers and each company indicated which group its product should be placed in. The groups were polyacrylamide, guar, oil, and non-traditional or combination. Appendix B lists the different classifications for the products used in this study.

Spray drift deposits were collected for measurement and analysis using horizontal collectors, a drift tower with vertical collectors, and 2.5 X 7.6 cm (1 X 3 inch) water sensitive paper (wsp) (Spraying Systems Company, Wheaton, Illinois). To collect the horizontal drift, wsp was placed on 2.5 X 10 cm blocks sloped toward the flight line and placed downwind from the flight line along the drift line at 15.25 m (50 feet) increments to a distance of 106.75 m (350 feet). A total of seven horizontal wsp were collected for each treatment (H50, H100, H150, H200, H250, H300, and H350). A retractable tower capable of extending to 12.2 m (40 feet) and designed to hold WSP at 1.53 m (5 feet) increments was used for the vertical drift collection. A total of nine vertical wsp were collected for each treatment (V0, V5, V10, V15, V20, V25, V30, V35, and V40). The collector layout is shown in Appendix C. Each treatment included four parallel back and forth passes along the flight line for a minimum distance of 213.5 m (700 feet), 106.75 m (350 feet) before and after the drift collection line. Marker flags were positioned along the flight line to assist the pilot in locating the flight line and with the spray timing. To facilitate timing and shorten the duration of the study two identical drift collection stations were used to simulate the repetitions. Collection station I was used to record data for each treatment as repetition 1 and 3. Collection station II was used for all treatments representing repetition 2. As test airplane 1 cycled through the collector stations (3 repetitions of 4 passes), airplane 2 was being rinsed and readied for the next test treatment. Each 3-rep treatment took approximately 20 minutes.

Except for a wind delay on day 1 and a brief rain shower on day 2 the collection process preceded smoothly. All treatments were applied in a crosswind. The crosswind average speed averaged for the two days was 11.9 Km/h (7.4 mph). The average for the maximum wind speeds was 17.1 Km/h (10.6 MPH). Crosswind average was used in the initial analysis for this report. The collector system was easily shifted to maintain the 90-degree crosswind for each treatment. Wind direction was monitored by observing a flag and ribbon placed at the top of the tower. For purposes of improving the statistical analysis of the data, three wind speeds according to observed percentiles during the study (low – 6.8 Km/h (4.2 MPH), medium – 11.3 Km/h (7.0 MPH), and high – 18.5 Km/h (11.5MPH) were calculated. Average temperature for the two days was 12.7C (55F). Average humidity was 50 percent.

Between the 2nd and 3rd repetitions for each treatment of the drift tower tests the pilots were asked to fly a single pass into a head wind over a simulated canopy at another location on the airport. WSP was placed on collectors at the top of the canopy at eleven symmetrical locations across the swath width to help determine differences in the droplet spectra for each treatment (Appendix D). To obtain useful droplet spectra statistics for each treatment, a relationship between stain size and the droplet size (spread factor) is needed for each spray mixture. Spread factors for each spray mix sample were determined at The Laboratory for Pest Control Application Technology (LPCAT), Wooster, OH. Calibration of WSP for each spray mixture was accomplished using an established LPCAT laboratory procedure. Each laboratory sample was made using the same Goodland water source. The results of the spread factor determinations are found in Appendix E.

After each repetition of each treatment (drift and canopy), the collection cards were placed in prelabeled-sealable bags for preservation. Data envelopes were used to organize and store the cards until analysis was complete. DropletScan™ (WRK of Arkansas, Lonoke, AR; and WRK of Oklahoma, Stillwater, OK; Devore Systems, Inc., Manhattan, KS) was used to analyze the cards. For the drift portion of this study, the percent area coverage for the horizontal and vertical drift profiles was used as a means to separate differences in treatments. There were 2,016 water sensitive papers analyzed by DropletScan™ in this phase of the study. DropletScan™ with adjusted spread factor coefficients was also used to calculate VMD, VD 0.1, VD 0.9, and percent area coverage from the wsp placed at the canopy top. A total of 231 (11 positions, 21 treatments) water sensitive papers were analyzed to compare the canopy top treatments.

Statistical analyses of the data were conducted with SAS 8.2 (SAS Institute, Cary, NC, 2003). Modeling was done using the general linear model (GLM) procedure to analyze the water sensitive paper data separately by horizontal and vertical distance. The average crosswind speed was used as a covariate to account for deviation in wind velocity during each treatment. Models incorporating main effects of wind and its interactions with product and airplane were considered first and reduced by backward elimination separately for each horizontal and vertical distance to include only those terms that were significant at alpha = .10. Covariate-adjusted least squares means were computed for each combination of product and airplane at three wind speeds according to observed percentiles during the study (low – 6.8 Km/h (4.2 MPH), medium – 11.3 Km/h (7.0 MPH), and high – 18.5 Km/h (11.5MPH). These means were compared within wind speed group using pair wise t-tests to report the differences found at each horizontal and vertical distance.

Results and Discussion

Summary data from the field study are shown in Tables 1-7 with the graphical representation of the same data shown in Figures 1-7. The graphical information is included as an addendum to this paper. Because of the range of the deposits through the collector distance, a single graphical display does not facilitate observing the differences that may exist between products. Also, the presence of heavy deposits on the first horizontal (H50) collector position is likely to be the result of wind blown swath displacement. Even with the swath displacement consideration, differences at the H50 location in drift control/deposition aid products are evident.

In the initial statistical analysis, the products were compared by averaging across both airplanes at each sample location and are arranged by the three observed wind profiles. Refer to Tables 1-3 and Figures 1-3 to review the LS means used to estimate differences. Using the water treatments as a reference for each comparison, products that contained more coverage at the horizontal sample locations (H50-H350) can be differentiated from those that had less coverage. With some variability at all horizontal locations and across all three wind profiles, approximately 30-40 percent of the products show more percent area coverage when compared to the water treatments as a baseline. The remaining products were measured with similar or less coverage than the water treatments. Variability and differences are also exhibited between the two aircraft.

Vertical measurements taken from the tower collectors present some interesting findings. Except for in a limited number of treatments, coverage amounts were measured for all products for all nine collector positions (V0-V9) which is to a height of 12.2m (40 feet). Refer to Tables 4-6 and Figures 4-6 to review this data. As was indicated with the horizontal measurements, in general, approximately 30-40 percent of the products had more deposition and coverage than the averaged water treatments. The remainder would be equal to or less. It is also noted that the results indicate a peak in coverage for most treatments at the V10-V15 collection height. This is evidence of a higher concentration of droplets moving in the wind stream at release height from the aircraft. Differences in volume median diameter (VMD) on the vertical collectors were averaged across product comparing the effect of airplane. The VMD for the Cessna 188 (158 microns) was significantly larger than the VMD for the Air Tractor 502A (138 microns).

Droplet spectra characteristics for each treatment measured in the canopy top are recorded in Table 7. A graphical representation is displayed in Figure 7. Since this portion of the study did not contain any replications no statistics were generated to measure differences. The reported data represents a composite measurement for each treatment taken from a DropletScan® calculation of 11 wsp's across each treatment swath. To increase the value of this data a laboratory analysis of the spread factor was performed for each tank mix. The same water used in each field study tank mix was also included in the laboratory spread factor determination. The spread factor results with coefficients are recorded in Appendix E. Each spread factor coefficient was incorporated into the DropletScan® analysis. When compared to water, the added tank mix materials had an affect on the droplet spectra. In general when compared to water the range of droplet sizes for VMD, VD 0.1, and VD 0.9 increased with the addition of the drift control/deposition aid products. The increases are variable across products and aircraft.

Another factor to include in evaluating each product relates to considerations given to the mixing, loading, and tank cleanout properties. Observations recorded during the mixing and loading phase of this study indicate that certain products exhibited characteristics that may hinder good application techniques. Products A, E, F, J, P were noted as difficult to mix with A and P indicated as hanging up in the tank. Products E, F, and P were noted to form globules in the tank. Product F was noted for being difficult to get clean from the system. Since a high-pressure/hot-water system was used to clean the tank and booms, most products were not noted as difficult to remove from the system. A later observation indicates that the water used in this study may have negatively influenced the mixing ability of some of the above products. Since there was no formal evaluation of the mixing and loading phase in this study the researchers would suggest performing a compatibility test before using any tank mix products.

Conclusions

This study was conducted to determine the influence of 21 drift control/deposition aid products on crosswind drift and canopy top coverage from practical aerial applications using fixed wing aircraft. An Air Tractor 502A and a Cessna 188 were used to apply the treatments. Differences in products are shown at all horizontal and vertical collector positions. Coverage variability for each product indicate that wind speed fluctuation was a major factor in the drift portion of this study. Results show that some of the products did not provide any benefits for drift reduction and in fact may have increased the drift potential. A few of the products exhibited the potential to reduce the amount of drift. Even though differences are present please note that many are very subtle and statistically non-significant. Considerations given to treatments with extremely high or low coverage's when compared to other treatments are noteworthy. Findings also indicate that the droplet spectra were impacted by the addition of the various materials into the tank mix. All three recorded measurements show increased micron sizes when compared to the water treatments. Do to the complexities in interpreting the results of this study the researchers would advise a thorough review of this data making a treatment by treatment comparison to water, other treatments, and each aircraft before making specific decisions regarding the use of a particular tank mix additive. Tank mix compatibility and the ability to reduce drift and increase coverage when compared to water should highly influential your decision making process. The researchers are confident that the results in this study will provide useful information to aerial applicators regarding decisions they need to make about drift control/deposition aid products.

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Appendix

Appendix A: Product Code Assignments				
Product Code	Product Name	Product Company*	Suggested Mixing rate**	Experiment Mixing Rate/60 gallon load**
A	Formula One	United Suppliers	3 qt/100 gal	1.8 quarts
B	HM0226	Helena	1% v/v	76.8 ounces
C	AMS 20/10	United Suppliers	10 lb/100 gal	6 pounds
D	Border EG 250	Precision Labs	10 oz/100 gal	169.8 grams
E	Control	Garrco Products	4 oz/100 gal	2.4 ounces
F	INT VWZ	Rosen's	15 lb/100 gal	9 pounds
G	Inplace	Wilbur-Ellis	8 oz/acre	1.25 gallons
H	Garrco #3	Garrco Products	8 oz/100 gal	4.8 ounces
I	INT YAR	Rosen's	9.0 lb/100 gal	5.4 pounds
J	Border Xtra 8L	Precision Labs	2.5% v/v	192 ounces
K	HM 2005C	Helena Chemical	9 lb/100 gal	5.4 pounds
L	Double Down	United Suppliers	2.5 gal/100 gal	1.5 gallons
M	Liberate	Loveland Industries	1 qt/100 gal	19.2 ounces
N	Target LC	Loveland Industries	2 oz/100 gal	36 ml
O	HM 2052	Helena Chemical	1% v/v	76.8 ounces
P	INT HLA	Rosen's, Inc	2 lb/100 gal	1.2 pounds
Q	HM 0230	Helena Chemical	0.5% v/v	38.4 ounces
R	Valid	Loveland Industries	1 pt/100 gal	288 ml
S	Tap Water	Goodland, KS		
S2	Tap Water	Goodland, KS		
T	41-A	San-Ag	2 oz/100 gal	34.05 grams

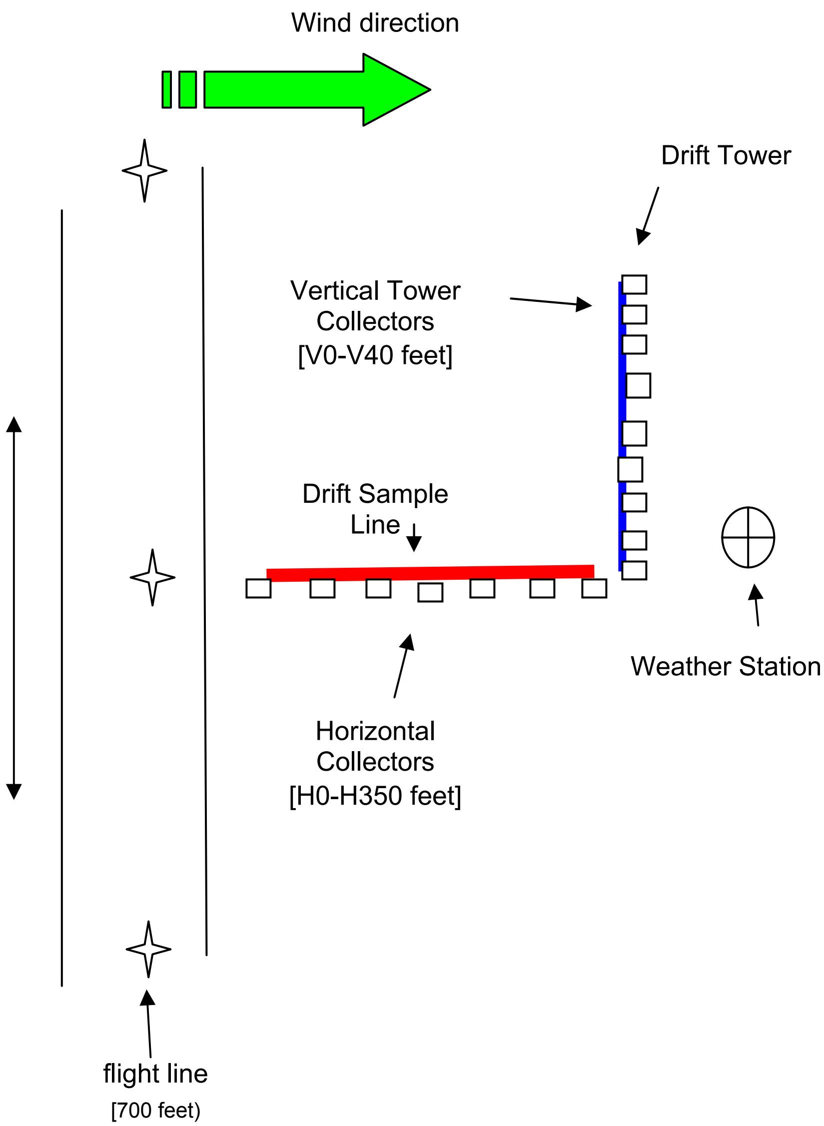
*As of Dec. 2002

**All tank mixes included X-77 at .25% v/v.

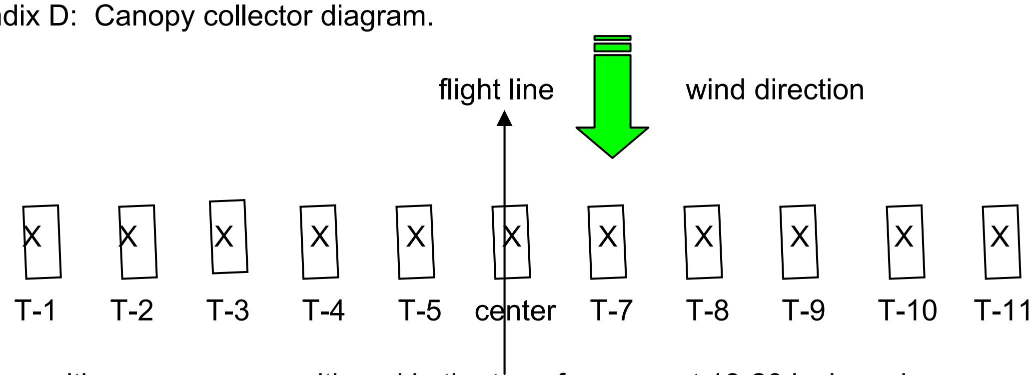
Appendix B: Product Group Assignments Based on Solution Chemistry*				
	Polyacrylamide	Guar	Oil	Non-traditional or combination
Product	A,C,L,T,N,Q	D,F,J,I,P,K	G,B	E,H,M,R,O

*Designation determined by submitting company to fit suggested group assignment determined by the researcher.

Appendix C: Drift collector diagram.



Appendix D: Canopy collector diagram.



Water sensitive paper was positioned in the top of canopy at 18-20 inches above ground.

Appendix E. Regression coefficients for the polynomial regression analysis of the different treatments*. Products B, K, O, and Q were not included in the spread factor testing.				
Treatment**	Spread factor where intercept=0	R^2 (squared)	Spread factor where intercept is computed****	R^2 (squared)
S (Water)***	$y = -6E-06x^2 + 0.4754x$	$R^2 = 0.9808$	$y = 2E-05x^2 + 0.3949x + 29.533$	$R^2 = 0.9847$
A	$y= -7E-05x^2 + 0.6378x$	$R^2 = 0.8885$	$y = -7E-05x^2 + 0.6477x - 3.3723$	$R^2 = 0.8885$
C	$y = 9E-06x^2 + 0.4248x$	$R^2 = 0.9478$	$y = 2E-05x^2 + 0.3986x + 10.42$	$R^2 = 0.9481$
D	$y = 1E-05x^2 + 0.4541x$	$R^2 = 0.9830$	$y = -2E-05x^2 + 0.5421x - 31.266$	$R^2 = 0.9853$
E	$y = -5E-05x^2 + 0.5653x$	$R^2 = 0.8937$	$y = 3E-05x^2 + 0.3078x + 96.556$	$R^2 = 0.9197$
F	$y = -1E-05x^2 + 0.4749x$	$R^2 = 0.9828$	$y = -1E-05x^2 + 0.4606x + 5.0232$	$R^2 = 0.9829$
G	$y = 4E-06x^2 + 0.4235x$	$R^2 = 0.9769$	$y = -4E-07x^2 + 0.4368x - 4.7645$	$R^2 = 0.9769$
H	$y = 3E-06x^2 + 0.5018x$	$R^2 = 0.9599$	$y = 2E-06x^2 + 0.5036x - 0.5712$	$R^2 = 0.9599$
I	$y = -8E-06x^2 + 0.4594x$	$R^2 = 0.9833$	$y = -1E-06x^2 + 0.4389x + 7.0701$	$R^2 = 0.9834$
J	$y = -1E-05x^2 + 0.4465x$	$R^2 = 0.9793$	$y = 5E-06x^2 + 0.3916x + 19.257$	$R^2 = 0.9803$
L	$y = -1E-05x^2 + 0.5121x$	$R^2 = 0.9729$	$y = -2E-05x^2 + 0.548x - 12.349$	$R^2 = 0.9733$
M	$y = 1E-05x^2 + 0.4637x$	$R^2 = 0.9852$	$y = 7E-06x^2 + 0.4694x - 1.8849$	$R^2 = 0.9852$
N	$y = 7E-06x^2 + 0.4781x$	$R^2 = 0.9338$	$y = 6E-05x^2 + 0.3316x + 52.725$	$R^2 = 0.9393$
P	$y = 3E-05x^2 + 0.4229x$	$R^2 = 0.9814$	$y = 2E-05x^2 + 0.4424x - 7.1237$	$R^2 = 0.9815$
R	$y = -2E-05x^2 + 0.453x$	$R^2 = 0.9744$	$y = -3E-05x^2 + 0.4852x - 14.638$	$R^2 = 0.9752$
T	$y = -3E-06x^2 + 0.4879x$	$R^2 = 0.9472$	$y = 2E-05x^2 + 0.4193x + 27.949$	$R^2 = 0.9485$
*LPCAT laboratory measured values (fall 2003).				
**Product code is located in Appendix A.				
***Goodland water was provided; solution temperature = 72°F; laboratory temperature = 75°, relative humidity = 25%. All mixes included .25% v/v X-77 as a pesticide stimulant.				
**** Intercept computed value used to calculate droplet spectra statistics in DropletScan™ software. The intercept value for water was used for products B, K, O, and Q.				

Table and Figures

Table 1. LS Means for horizontal drift deposits at 6.8 Kmh (4.2 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

		Feet						
Product**	Airplane***	hpct050****	hpct100	hpct150	hpct200	hpct250	hpct300	hpct350
A	AT	12.54	1.35	1.38	0.73	0.34	0.17	0.07
A	C	10.01	1.51	1.32	0.33	0.22	0.13	0.05
B	AT	14.66	3.10	0.81	0.62	0.32	0.13	-0.02
B	C	12.98	2.00	1.85	0.82	0.52	0.24	0.35
C	AT	6.51	0.84	0.17	0.09	0.02	0.00	0.00
C	C	14.52	2.41	0.80	0.45	0.48	0.14	0.17
D	AT	11.42	6.10	0.53	0.97	0.42	0.53	0.44
D	C	7.46	2.17	0.78	0.34	0.09	0.10	0.14
E	AT	10.48	2.21	0.40	0.17	0.16	0.01	-0.01
E	C	7.06	1.94	0.48	0.27	0.14	-0.02	-0.04
F	AT	21.84	5.20	1.25	0.45	0.27	0.21	0.19
F	C	9.12	0.99	1.33	0.19	0.09	0.06	0.02
G	AT	19.11	4.16	1.74	0.96	0.32	0.21	-0.01
G	C	16.61	4.48	2.17	1.46	0.27	0.04	0.10
H	AT	11.28	1.63	0.76	0.20	0.13	-0.03	-0.04
H	C	6.95	0.71	0.23	0.17	0.08	0.07	0.03
I	AT	12.22	3.21	0.43	0.24	0.11	0.22	0.15
I	C	12.27	2.63	1.32	0.34	0.19	0.22	0.15
J	AT	15.48	1.61	1.15	0.15	0.15	0.15	0.08
J	C	11.80	1.98	0.78	0.27	0.22	0.26	0.18
K	AT	19.36	5.12	1.95	0.92	0.56	0.31	0.30
K	C	16.09	13.78	3.55	1.44	0.61	0.70	0.76
L	AT	14.34	1.90	0.43	0.14	0.16	0.09	0.02
L	C	10.68	1.27	0.64	0.21	0.13	0.01	0.03
M	AT	17.86	3.85	0.99	0.39	0.16	0.09	0.02
M	C	14.77	7.69	2.81	0.74	0.54	0.05	0.11
N	AT	23.91	1.88	0.71	0.52	0.36	0.02	0.03
N	C	22.67	3.08	1.43	0.56	0.33	0.17	0.22
O	AT	10.19	13.31	1.81	1.72	1.04	0.39	0.48
O	C	9.03	1.47	0.86	0.35	0.32	0.10	0.14
P	AT	2.57	1.30	0.21	0.04	0.02	-0.02	-0.02
P	C	7.54	1.80	0.52	0.25	0.08	0.06	0.06
Q	AT	12.39	2.46	1.12	0.80	0.31	0.37	0.19
Q	C	13.08	1.48	0.92	0.36	0.18	0.05	0.08
R	AT	13.61	6.39	1.22	1.18	0.73	0.44	0.23
R	C	13.58	1.95	0.90	0.35	0.21	-0.02	0.07
S	AT	15.04	2.14	0.81	0.51	0.26	0.18	0.11
S	C	10.9	0.84	0.73	0.33	0.23	0.13	0.10
T	AT	13.24	2.37	0.54	0.24	0.21	0.03	-0.01
T	C	10.26	1.38	0.72	0.22	0.16	0.01	0.04

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna
****Heavier amounts are a result of swath displacement in wind.

Table 2. LS Means for horizontal drift deposits at 11.3 Km/h (7.0 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

Feet								
Product**	Airplane***	hpct050****	hpct100	hpct150	hpct200	hpct250	hpct300	hpct350
A	AT	14.88	1.56	1.69	0.73	0.34	0.26	0.11
A	C	11.91	1.74	1.09	0.33	0.22	0.21	0.09
B	AT	17.36	3.54	1.04	0.62	0.32	0.27	0.13
B	C	15.39	2.33	1.57	0.82	0.52	0.39	0.55
C	AT	7.80	1.01	0.32	0.09	0.02	0.07	0.04
C	C	17.19	2.71	0.62	0.45	0.48	0.22	0.22
D	AT	13.57	5.51	0.73	0.97	0.42	0.48	0.38
D	C	8.92	1.90	0.60	0.34	0.09	0.06	0.09
E	AT	12.46	1.98	0.58	0.17	0.16	0.11	0.05
E	C	8.45	1.73	0.33	0.27	0.14	0.08	0.02
F	AT	25.78	4.68	1.53	0.45	0.27	0.17	0.14
F	C	10.86	0.83	1.09	0.19	0.09	0.03	-0.03
G	AT	22.57	4.72	2.10	0.96	0.32	0.36	0.14
G	C	19.64	5.07	1.85	1.46	0.27	0.17	0.26
H	AT	13.39	1.44	0.98	0.20	0.13	0.06	0.02
H	C	8.32	0.59	0.11	0.17	0.08	0.17	0.09
I	AT	14.50	2.86	0.61	0.24	0.11	0.17	0.11
I	C	14.56	2.33	1.08	0.34	0.19	0.18	0.10
J	AT	18.32	1.39	1.43	0.15	0.15	0.11	0.04
J	C	14.01	1.73	0.60	0.27	0.22	0.22	0.13
K	AT	22.87	4.61	2.33	0.92	0.56	0.27	0.24
K	C	19.04	12.54	3.09	1.44	0.61	0.64	0.69
L	AT	16.99	2.16	0.61	0.14	0.16	0.17	0.06
L	C	12.69	1.47	0.47	0.21	0.13	0.09	0.07
M	AT	21.11	3.51	1.25	0.39	0.16	0.20	0.09
M	C	17.49	7.08	2.43	0.74	0.54	0.16	0.18
N	AT	28.20	2.14	0.93	0.52	0.36	0.09	0.07
N	C	26.74	3.44	1.18	0.56	0.33	0.25	0.26
O	AT	12.12	12.30	2.17	1.72	1.04	0.52	0.58
O	C	10.76	1.30	0.67	0.35	0.32	0.21	0.21
P	AT	3.18	1.10	0.37	0.04	0.02	-0.05	-0.06
P	C	9.01	1.56	0.37	0.25	0.08	0.02	0.02
Q	AT	14.70	2.77	1.39	0.80	0.31	0.47	0.24
Q	C	15.51	1.70	0.73	0.36	0.18	0.13	0.12
R	AT	16.12	5.87	1.50	1.18	0.73	0.58	0.31
R	C	16.09	1.74	0.71	0.35	0.21	0.07	0.14
S	AT	17.81	4.3	1.04	0.51	0.26	0.16	0.15
S	C	12.9	4.23	0.55	0.33	0.23	0.11	0.15
T	AT	15.70	2.67	0.74	0.24	0.21	0.11	0.03
T	C	12.20	1.59	0.54	0.22	0.16	0.08	0.08

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna
****Heavier amounts are a result of swath displacement in wind.

Table 3. LS Means for horizontal drift deposits at 18.5 Km/h (11.5 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

Feet								
Product**	Airplane***	hpct050****	hpct100	hpct150	hpct200	hpct250	hpct300	hpct350
A	AT	19.50	1.95	2.27	0.73	0.34	0.41	0.18
A	C	15.67	2.14	0.76	0.33	0.22	0.36	0.16
B	AT	22.71	4.35	1.48	0.62	0.32	0.52	0.41
B	C	20.17	2.92	1.16	0.82	0.52	0.67	0.94
C	AT	10.36	1.31	0.60	0.09	0.02	0.20	0.11
C	C	22.49	3.27	0.36	0.45	0.48	0.37	0.30
D	AT	17.81	4.66	1.10	0.97	0.42	0.40	0.29
D	C	11.81	1.52	0.35	0.34	0.09	0.01	0.02
E	AT	16.38	1.65	0.92	0.17	0.16	0.29	0.16
E	C	11.20	1.43	0.12	0.27	0.14	0.25	0.13
F	AT	33.58	3.94	2.08	0.45	0.27	0.10	0.07
F	C	14.32	0.59	0.76	0.19	0.09	-0.03	-0.09
G	AT	29.43	5.74	2.76	0.96	0.32	0.63	0.43
G	C	25.65	6.16	1.40	1.46	0.27	0.40	0.58
H	AT	17.58	1.17	1.41	0.20	0.13	0.24	0.13
H	C	11.03	0.41	-0.07	0.17	0.08	0.36	0.20
I	AT	19.01	2.35	0.96	0.24	0.11	0.11	0.03
I	C	19.09	1.89	0.75	0.34	0.19	0.12	0.03
J	AT	23.95	1.08	1.95	0.15	0.15	0.05	-0.03
J	C	18.37	1.37	0.35	0.27	0.22	0.15	0.05
K	AT	29.82	3.87	3.04	0.92	0.56	0.20	0.16
K	C	24.87	10.77	2.44	1.44	0.61	0.55	0.58
L	AT	22.23	2.63	0.95	0.14	0.16	0.31	0.13
L	C	16.68	1.84	0.24	0.21	0.13	0.22	0.14
M	AT	27.55	3.01	1.73	0.39	0.16	0.39	0.20
M	C	22.87	6.19	1.89	0.74	0.54	0.34	0.29
N	AT	36.71	2.61	1.35	0.52	0.36	0.23	0.14
N	C	34.82	4.10	0.84	0.56	0.33	0.40	0.34
O	AT	15.94	10.83	2.84	1.72	1.04	0.77	0.73
O	C	14.19	1.04	0.41	0.35	0.32	0.40	0.33
P	AT	4.40	0.83	0.66	0.04	0.02	-0.10	-0.12
P	C	11.93	1.23	0.15	0.25	0.08	-0.03	-0.05
Q	AT	19.27	3.33	1.90	0.80	0.31	0.65	0.32
Q	C	20.31	2.10	0.45	0.36	0.18	0.27	0.19
R	AT	21.11	5.11	2.04	1.18	0.73	0.83	0.44
R	C	21.06	1.44	0.44	0.35	0.21	0.24	0.25
S	AT	23.29	11.45	1.47	0.51	0.26	0.14	0.23
S	C	16.95	6.3	0.31	0.33	0.23	0.09	0.22
T	AT	20.56	3.21	1.12	0.24	0.21	0.24	0.10
T	C	16.04	1.98	0.30	0.22	0.16	0.22	0.15

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna
****Heavier amounts are a result of swath displacement in wind.

Table 4. LS Means for vertical drift deposits at 6.8 Km/h (4.2 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

		Feet								
Product**	Airplane***	vpct0	vpct05	vpct10	vpct15	vpct20	vpct25	vpct30	vpct35	vpct40
A	AT	-0.01	0.28	-0.04	0.07	-0.13	0.44	0.01	0.14	0.21
A	C	-0.04	0.17	0.26	0.11	0.19	0.33	0.16	0.36	0.05
B	AT	0.02	0.17	0.19	0.22	0.01	0.60	0.00	0.21	0.05
B	C	0.19	0.36	0.56	0.30	0.34	0.74	0.45	0.25	0.43
C	AT	-0.01	-0.01	-0.03	-0.02	-0.03	0.02	-0.02	0.01	0.00
C	C	0.13	0.67	0.77	0.77	0.73	0.64	0.65	0.82	0.43
D	AT	0.34	1.43	1.58	1.47	0.71	0.59	0.12	0.27	0.01
D	C	0.10	0.24	0.50	0.22	0.46	0.19	0.52	0.35	0.29
E	AT	0.00	0.07	0.08	0.21	0.28	0.24	0.50	0.42	0.43
E	C	-0.01	0.01	0.19	0.17	0.36	0.41	-0.20	-0.17	-0.26
F	AT	0.09	0.31	0.49	0.45	0.33	0.34	0.18	0.18	0.13
F	C	0.02	0.11	0.12	0.07	0.14	0.11	0.12	0.11	0.07
G	AT	0.00	0.14	0.16	0.18	0.06	0.68	0.16	0.31	0.16
G	C	-0.08	0.00	0.35	0.24	0.49	0.95	0.43	0.60	0.89
H	AT	-0.05	-0.07	-0.05	0.05	0.09	0.05	0.24	0.25	0.36
H	C	0.05	0.10	0.05	0.09	0.02	0.07	0.25	0.17	0.19
I	AT	0.15	0.39	0.41	0.41	0.30	0.32	0.12	0.21	0.11
I	C	0.10	0.41	0.68	0.35	0.49	0.29	0.51	0.38	0.36
J	AT	0.18	0.30	0.34	0.30	0.22	0.25	0.11	0.16	0.14
J	C	0.19	0.53	0.88	0.69	0.72	0.41	0.44	0.49	0.36
K	AT	0.25	0.76	1.10	0.58	0.51	0.39	0.24	0.30	0.06
K	C	0.69	2.99	8.14	3.33	3.68	1.46	3.72	1.75	1.50
L	AT	-0.05	0.08	0.01	0.19	0.07	0.24	0.11	0.13	0.16
L	C	-0.04	0.01	0.11	0.08	0.08	0.17	0.14	0.10	0.01
M	AT	0.02	0.18	0.22	0.21	0.26	0.27	0.37	0.31	0.29
M	C	0.10	0.60	1.85	1.37	3.57	1.31	-0.40	-0.32	-0.52
N	AT	-0.01	0.21	0.01	0.20	0.05	0.32	0.09	0.19	0.26
N	C	0.13	0.28	0.34	0.33	0.33	0.42	0.32	0.32	0.12
O	AT	0.89	1.59	1.72	2.46	2.21	1.68	3.21	2.89	4.01
O	C	0.17	0.22	0.54	0.49	0.79	0.44	-0.10	-0.01	-0.19
P	AT	0.00	0.10	0.06	-0.01	0.03	0.02	0.11	0.05	0.08
P	C	0.08	0.36	0.33	0.39	0.32	0.34	0.21	0.19	0.20
Q	AT	0.21	0.75	0.74	0.77	0.40	0.94	0.36	0.32	0.37
Q	C	0.03	0.17	0.25	0.15	0.16	0.17	0.15	0.11	0.07
R	AT	0.26	0.76	0.95	0.99	0.99	0.89	1.57	1.50	1.60
R	C	0.07	0.11	0.66	0.53	1.02	0.43	-0.14	-0.07	-0.19
S	AT	0.21	0.28	0.19	0.25	0.18	0.32	0.44	0.41	0.20
S	C	0.26	0.44	0.45	0.34	0.37	0.41	0.33	0.27	0.27
T	AT	-0.07	0.04	-0.08	0.08	-0.08	0.17	-0.10	-0.02	0.03
T	C	-0.05	0.07	0.12	0.09	0.16	0.38	0.25	0.27	0.04

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna

Table 5. LS Means for vertical drift deposits at 11.3 Km/h (7.0 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

		Feet								
Product**	Airplane***	vpct0	vpct05	vpct10	vpct15	vpct20	vpct25	vpct30	vpct35	vpct40
A	AT	0.12	0.47	0.29	0.23	0.10	0.44	0.22	0.27	0.24
A	C	0.08	0.34	0.42	0.27	0.28	0.33	0.23	0.34	0.14
B	AT	0.22	0.54	0.64	0.62	0.42	0.60	0.30	0.32	0.20
B	C	0.43	0.80	0.81	0.73	0.61	0.74	0.56	0.32	0.27
C	AT	0.11	0.14	0.30	0.13	0.23	0.02	0.18	0.12	0.02
C	C	0.27	0.91	1.00	1.03	0.87	0.64	0.74	0.79	0.55
D	AT	0.34	1.31	1.48	1.32	0.75	0.59	0.32	0.35	0.10
D	C	0.09	0.18	0.22	0.15	0.28	0.19	0.30	0.22	0.20
E	AT	0.07	0.21	0.23	0.24	0.26	0.24	0.27	0.18	0.12
E	C	0.05	0.14	0.15	0.20	0.15	0.41	0.17	0.13	0.10
F	AT	0.08	0.25	0.43	0.36	0.36	0.34	0.39	0.25	0.23
F	C	0.01	0.05	-0.09	0.00	0.00	0.11	-0.04	0.00	-0.01
G	AT	0.20	0.50	0.59	0.56	0.49	0.68	0.51	0.42	0.33
G	C	0.10	0.33	0.57	0.64	0.79	0.95	0.54	0.70	0.67
H	AT	0.02	0.05	0.09	0.07	0.07	0.05	0.05	0.04	0.06
H	C	0.12	0.25	0.01	0.11	-0.14	0.07	0.84	0.59	0.78
I	AT	0.14	0.32	0.35	0.33	0.33	0.32	0.32	0.29	0.21
I	C	0.10	0.34	0.37	0.27	0.31	0.29	0.29	0.25	0.26
J	AT	0.17	0.24	0.29	0.22	0.25	0.25	0.31	0.23	0.23
J	C	0.19	0.46	0.53	0.59	0.51	0.41	0.24	0.34	0.27
K	AT	0.24	0.68	1.02	0.49	0.55	0.39	0.46	0.38	0.15
K	C	0.68	2.80	6.42	3.07	3.10	1.46	3.04	1.49	1.33
L	AT	0.07	0.23	0.35	0.36	0.36	0.24	0.34	0.26	0.19
L	C	0.07	0.15	0.25	0.24	0.16	0.17	0.21	0.08	0.10
M	AT	0.09	0.33	0.39	0.24	0.24	0.27	0.16	0.09	0.01
M	C	0.17	0.80	1.75	1.43	2.86	1.31	-0.12	-0.08	-0.28
N	AT	0.11	0.39	0.35	0.38	0.33	0.32	0.32	0.33	0.29
N	C	0.27	0.47	0.51	0.53	0.44	0.42	0.40	0.30	0.22
O	AT	1.02	1.92	2.09	2.55	2.17	1.68	2.55	2.23	2.91
O	C	0.25	0.38	0.48	0.53	0.51	0.44	0.32	0.34	0.21
P	AT	0.00	0.05	0.02	-0.07	0.06	0.02	0.32	0.12	0.17
P	C	0.08	0.30	0.08	0.30	0.15	0.34	0.04	0.08	0.12
Q	AT	0.36	1.00	1.33	1.02	0.77	0.94	0.64	0.47	0.41
Q	C	0.16	0.34	0.41	0.32	0.25	0.17	0.21	0.09	0.16
R	AT	0.34	0.99	1.22	1.04	0.97	0.89	1.17	1.08	1.03
R	C	0.15	0.25	0.60	0.56	0.71	0.43	0.27	0.26	0.20
S	AT	0.12	0.28	0.44	0.43	0.37	0.31	0.25	0.20	0.11
S	C	0.17	0.44	0.51	0.53	0.37	0.41	0.35	0.25	0.22
T	AT	0.05	0.19	0.23	0.24	0.17	0.17	0.08	0.09	0.05
T	C	0.06	0.22	0.27	0.25	0.26	0.38	0.33	0.24	0.12

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna

Table 6. LS Means for vertical drift deposits at 18.5 Km/h (11.5 MPH) recorded as percent area coverage* on water sensitive paper for twenty-one products with airplane interaction.

		Feet								
Product**	Airplane***	vpct0	vpct05	vpct10	vpct15	vpct20	vpct25	vpct30	vpct35	vpct40
A	AT	0.34	0.82	1.05	0.53	0.61	0.44	0.65	0.51	0.29
A	C	0.29	0.66	0.73	0.58	0.46	0.33	0.35	0.30	0.30
B	AT	0.63	1.42	1.73	1.54	1.46	0.60	0.98	0.50	0.50
B	C	0.92	1.82	1.30	1.72	1.16	0.74	0.75	0.45	0.04
C	AT	0.33	0.41	1.07	0.41	0.79	0.02	0.60	0.33	0.06
C	C	0.53	1.37	1.43	1.53	1.12	0.64	0.91	0.74	0.76
D	AT	0.33	1.14	1.33	1.10	0.82	0.59	0.72	0.49	0.25
D	C	0.09	0.09	-0.13	0.05	0.03	0.19	0.01	0.03	0.07
E	AT	0.19	0.47	0.51	0.29	0.24	0.24	-0.04	-0.13	-0.25
E	C	0.18	0.39	0.08	0.25	-0.13	0.41	1.18	0.84	1.10
F	AT	0.08	0.15	0.34	0.23	0.42	0.34	0.82	0.39	0.40
F	C	0.00	-0.03	-0.35	-0.09	-0.19	0.11	-0.25	-0.15	-0.12
G	AT	0.61	1.36	1.65	1.46	1.57	0.68	1.32	0.62	0.65
G	C	0.48	1.08	1.00	1.58	1.41	0.95	0.73	0.86	0.36
H	AT	0.14	0.28	0.34	0.12	0.05	0.05	-0.20	-0.23	-0.29
H	C	0.25	0.52	-0.05	0.16	-0.34	0.07	2.41	1.59	2.39
I	AT	0.13	0.22	0.27	0.21	0.38	0.32	0.72	0.42	0.37
I	C	0.09	0.24	-0.02	0.15	0.06	0.29	0.00	0.06	0.13
J	AT	0.16	0.14	0.21	0.11	0.30	0.25	0.72	0.36	0.40
J	C	0.18	0.35	0.09	0.44	0.22	0.41	-0.04	0.14	0.13
K	AT	0.23	0.55	0.89	0.35	0.61	0.39	0.91	0.53	0.31
K	C	0.67	2.51	4.32	2.69	2.31	1.46	2.15	1.11	1.08
L	AT	0.29	0.53	1.15	0.70	0.98	0.24	0.82	0.50	0.24
L	C	0.29	0.43	0.53	0.55	0.32	0.17	0.32	0.05	0.25
M	AT	0.22	0.62	0.72	0.29	0.22	0.27	-0.12	-0.19	-0.32
M	C	0.31	1.19	1.58	1.53	1.94	1.31	0.63	0.50	0.38
N	AT	0.34	0.72	1.15	0.72	0.94	0.32	0.78	0.58	0.35
N	C	0.52	0.82	0.84	0.91	0.64	0.42	0.53	0.27	0.39
O	AT	1.25	2.56	2.81	2.70	2.11	1.68	1.70	1.39	1.62
O	C	0.40	0.68	0.39	0.59	0.15	0.44	1.45	1.19	1.31
P	AT	-0.01	-0.03	-0.04	-0.16	0.10	0.02	0.72	0.24	0.33
P	C	0.07	0.20	-0.22	0.18	-0.07	0.34	-0.19	-0.09	0.00
Q	AT	0.63	1.47	2.72	1.52	1.59	0.94	1.22	0.75	0.46
Q	C	0.39	0.65	0.71	0.64	0.42	0.17	0.33	0.06	0.32
R	AT	0.50	1.42	1.74	1.13	0.93	0.89	0.65	0.54	0.36
R	C	0.28	0.52	0.51	0.63	0.30	0.43	1.35	1.06	1.30
S	AT	0.04	0.29	1.01	0.76	0.76	0.31	0.10	0.03	0.04
S	C	0.04	0.45	0.61	0.88	0.37	0.41	0.39	0.22	0.15
T	AT	0.26	0.47	0.96	0.55	0.71	0.17	0.47	0.30	0.09
T	C	0.28	0.51	0.54	0.55	0.43	0.38	0.45	0.21	0.28

*Percent area coverage from scanned water sensitive paper - 2.54 X 7.62 cm.
**Product code is located in Appendix A.
***AT=Air Tractor, C=Cessna

Table 7. Droplet spectra characteristics measured on wsp in the top of a canopy*.

Material	Airplane	VMD	Vd.1	Vd.9	% Area Coverage
A	AT	833	414	1374	2.7
A	C	1137	485	1739	3.9
B	AT	378	205	620	2.4
B	C	488	262	774	3.8
C	AT	693	270	1713	4.2
C	C	877	424	1183	4.3
D	AT	859	450	1877	2.9
D	C	1272	612	2253	4.9
E	AT	491	213	917	4.1
E	C	881	337	1266	3.1
F	AT	696	373	1171	3.7
F	C	820	336	1317	3.8
G	AT	431	218	687	2.7
G	C	671	265	1023	3.1
H	AT	601	307	984	2.5
H	C	850	379	1432	4.1
I	AT	790	358	1270	3.9
I	C	938	415	1975	3.8
J	AT	418	210	706	3.1
J	C	798	334	1032	4.2
K	AT	487	222	789	3.3
K	C	1020	622	1300	1.0
L	AT	657	341	1050	5.6
L	C	927	465	2348	4.2
M	AT	449	249	768	3.2
M	C	500	277	739	2.3
N	AT	355	180	598	7.0
N	C	715	290	2408	4.9
O	AT	547	311	884	1.7
O	C	685	316	1212	3.6
P	AT	669	314	1300	3.6
P	C	919	341	1446	5.4
Q	AT	318	156	601	1.4
Q	C	509	250	833	2.8
R	AT	500	216	1051	1.7
R	C	670	314	1052	3.7
S	AT	373	188	584	3.1
S	C	529	235	866	4.0
T	AT	566	295	980	4.7
T	C	651	324	1529	3.2

*Determined using DropletScan™ and includes laboratory determined spread factor regression coefficients** calibrated for water sensitive paper. Each calculation is a composite of 11 wsp's.

**Coefficients can be found in Appendix E.