Paper Number: AA05-003
An ASAE Meeting Presentation

Determining the Affect of Flat-fan Nozzle Angle on Aerial Spray Droplet Spectra

Robert E. Wolf

Biological and Agricultural Engineering Dept., Kansas State University, 145 Seaton Hall, Manhattan, KS 66506. rewolf@ksu.edu

Scott Bretthauer

Agricultural and Biological Engineering Dept., University of Illinois, 1304 W. Pennsylvania Dr., Urbana, IL 61801. sbrettha@uiuc.edu

Dennis R. Gardisser

Biological and Agricultural Engineering Dept., University of Arkansas Division of Agriculture-Cooperative Extension, 2301 University Drive, Little Rock, AR 72204. dgardisser@uaex.edu

Written for presentation at the
2005 ASAE NAAA/ASAE Technical Session
39th Annual National Agricultural Aviation Association Convention
Silver Legacy Hotel and Casino, Reno, Nevada, USA
December 4-7, 2005

Abstract. Field studies were conducted to determine the influence of flat-fan nozzle angle on the droplet spectrum of fixed wing aerial applications. The study involved several different aircraft representing typical application scenarios. An Air Tractor 502, two AT 802's, an Ayres 510 Thrush, and a two different Cessna 188's were used to spray water at various nozzle angles. Application volumes ranged from 19 to 47 l/ha. The CP11TT with 40-degree flat-fan nozzles were used and angles ranging from 8 to 75 degrees were evaluated. Angles were manually adjusted by either arranging the nozzle body or by using the new CP-06 CP® Swivel. Water sensitive paper was used to collect the droplets across the application swath in each treatment. Comparisons were made using Dropletscan™ software to calculate droplet statistics. The statistics reported are VD 0.1, VMD, VD 0.9. The measured statistics are compared to the USDA Droplet Spectrum Model.

Results show that the actual measured droplet spectrum is very comparable to the model predictions. Increasing the angle (8 to 75 degrees) reduces the size of the droplet spectra. Droplet size adjustments were not as pronounced when changing orifice size. Data supports that adjusting the flat-fan angle is a possible method for managing the droplet spectra for a given application.

Keywords. Aerial application, aerial nozzles, spray angle, deflection angle, droplet size, spray

Introduction

Advances in aerial application equipment technology enable the pilots to fine-tune their applications to match the requirements for controlling the targeted pest and minimizing drift. One such parameter, management of spray droplet spectrum, is a critical issue in the search of accurate and efficient crop protection application systems. Applicators need to understand as much as possible regarding droplet spectra to better comply with crop protection label requirements (Kirk, 2001). One of the most critical aspects of any crop protection product application is determining the proper set-up parameters for the equipment used to make that particular application. Concerns about application volumes (GPA), tank-mix components, application height, nozzle type and pressure, angle of spray deflection, droplet size, coverage, canopy deposition, and other critical application parameters are being commonly debated. If proper adjustments are made to the aircraft, then nozzle type, orifice size, pressure, shear orientation, and aircraft speed can all be factored into determining a specified droplet spectrum which can then be evaluated. Models are currently available for this purpose.

SPDT (1997) data indicates that air shear and a combination of air shear and aircraft speed will influence droplet size. With new nozzle configurations and higher pressure recommendations (Kirk, 1997), and with the continued development of nozzles and mounting configurations, applicators seek to better facilitate making sound decisions regarding the adjustments they can make to their nozzle and boom configurations. This study was designed to evaluate the influence on droplet spectrum from mechanical adjustments to the angle of shear for the CP11TT equipped flat-fan nozzles. Comparisons to the USDA Model will be made to see if these adjustments are similar to the model predictions.

Objective

The objective of this study was to evaluate the effect of CP11TT flat-fan nozzle angle on the droplet spectra of fixed wing aerial applications.

Materials and Methods

Several field studies were conducted to determine the effect of flat-fan nozzle angle on droplet spectrum during fixed wing aerial applications. The studies were conducted at separate sites in Illinois, Colorado, and Kansas. The Kansas studies were completed at two different locations – Burlington in May, 2005 and Wamego in October, 2005. The Colorado treatments were conducted in LaJunta during Sept. 2005. The Kansas and Colorado treatments were completed using a Cessna 188 Ag Husky (Cessna Aircraft Co., Wichita, KS) equipped with the CP11TT nozzle system (CP Products, Inc., Mesa, Arizona) comparing the flat-fan orifice sizes 4008, 4015, and 4020 configured to deliver application volumes of 19 and 47 l/ha (2 and 5 GPA) at 276 kPa (40 PSI). In these studies the new CP-06 CP® Swivel (CP Products, Inc., Mesa, Arizona) was used to vary the nozzle angle with compared angles ranging from 8 to 75 degrees (Figure 1). The ground speed for the Cessna trials averaged 185 km/h (115 MPH). Table 1 provides the detail for these treatments.

Figure 1. CP swivel used to adjust angle of flat-fan nozzle from standard 8 to 90 degrees.

The Illinois treatments were conducted in Mattoon in April 2005 and in Lincoln in May 2005. These tests were conducted using an AT502, two different AT802's, a 510 Thrush, and a Cessna 188 (Air Tractor Inc., Olney, Texas; Aryes Thrush, Georgia; and Cessna Aircraft Co., Wichita, KS). All the Illinois tests were completed using CP11TT nozzle systems comparing flat-fan orifice sizes 4015, 4020, 4025, and 4030. Application volumes compared ranged from 19 to 47 l/ha (2 to 5 GPA) with a pressure range of 193 to 317 kPa (28 to 46 PSI).Angles tested in these comparisons were the standard, 8 degrees, compared to 30 degrees. Angle of deflection was set by rotating the nozzle mount and adjusting the deflection angle to the desired position (Figure 2). This method does not allow for as accurate of angle determination as with the CP Swivel. Average ground speed for the AT502 was 217 km/h (135 MPH), the two AT802's was 241 km/h (150 MPH), the 510Thrush was 214 km/h (133 MPH), and the Cessna 188 was 185 km/h (115 MPH). See table 1 for a complete listing of treatments.

Figure 2. Angle adjustment method for the Illinois treatments.

Temperature, relative humidity, and wind velocity was recorded and averaged for all treatment locations. Wind speed averages ranged from 8.7 to 21 km/hr (5.4 to 13.0 MPH) with all flights attempted into the wind. Relative humidity ranged from 28 to 58% and temperature ranged from 14.6 to 23.7°C (58.2 to 75 F) across all study locations. See table 2 for weather details.

Spray deposits were collected for measurement and analysis using either 2.54 x 7.62cm (1 x 3 inch) or 5.08 x 7.62cm (2 x 3 inch) water sensitive paper (wsp). The papers were equally spaced in a linear pattern under the swath. Marker flags were positioned at the treatment center line to assist the pilot in verifying swath locations

After all treatments and replications were completed and dried, the collection papers were placed in prelabeled-sealable bags for preservation. Data envelopes were used to organize and store the papers 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 papers. DropletScan™ has been tested as a reliable source for predicting droplet stain characteristics when compared to other card reading methods (Hoffman 2004).

The USDA Aerial Spray Models for CP small and large orifice flat-fan nozzles were used to compare the results (Kirk, 2001). See table 3 for a summary of the model data.

Results and Discussion

Aerial application studies were completed to measure the effect on droplet spectrum of nozzle angle while using flat-fan nozzles. Several trials were conducted with different aircraft using CP11TT flat-fan nozzles at various application volumes and fan angle orientations. The variety of aircraft and methods used allowed for different application speeds and orifice sizes in the comparisons. With such a wide variety of aircraft used, comparisons between each are not made. Results reported reflect the effect of orifice size and orientation on droplet spectra.

The most stable set of data came from the Wamego, KS location. In these comparisons a full range of nozzle orientations (8 to 75 degrees) were compared at both 19 and 47 l/ha (2 and 5 GPA) using a Cessna 188 at 185 km/h (115 MPH). All tests used CP11TT flat-fan nozzles. As the nozzle angle increased all three measured droplet statistics (VD 0.1, VMD, VD 0.9) decreased in size. This trend is true for both the 19 and 47 l/ha (2 and 5 GPA) data sets. At 19 l/ha (2 GPA) the measured VMD decreased from 415 microns at 8 degrees down to 224 microns at 75 degrees (Figure 3). For the 47 l/ha (5 GPA) treatments the VMD ranged from 495 down to 333 microns over the same orientation range (Figure 4). Both of these data sets have trends similar to the USDA Droplet Spectrum Model. However, for the 19 l/ha (2 GPA) treatments, the droplet spectra were smaller than the model predicted. In the 47 l/ha (5 GPA) treatments, the droplet spectra are more closely matched to the model.

While the Wamego data reflects specific comparisons to nozzle angle the Illinois data uses a variety of airplanes to compare various orifice sizes at a limited number of angles. All the Illinois tests were conducted using the CP11TT flat-fan nozzles. Application volumes change reflecting the orifice size used and pressures and speeds are adjusted to represent a typical application scenario for the airplane type. This data is referenced in Figure 5, A - E. With the AT502, increasing the orifice size from 4020 to 4025 slightly increased the droplet size for the measured statistics (VMD = 428 to 433 microns). Increasing the angle of deflection from 8 degrees to 30 degrees reduced the VMD micron size from 422 to 323 microns (Figure 5 A). These comparisons were all at 276 kPa (40 PSI). With the higher speed AT802 the trends were similar but not as dramatic. In fact there was a slight decrease in droplet size when comparing the 4025 to the 4030 at 8 degrees. When comparing the 4030 in a second AT802 treatment, the droplet size decreased slightly from the 8 to 30 degree setting (Figure 5 B and C). Using the same 4030 with the 510 Thrush a larger decrease in droplet size occurred when adjusting the angle from 8 to 30 degrees (Figure 5 D). A similar trend was observed when using the Cessna 188 to compare the 8 and 30 degree angle with the 4015 (Figure 5 E). In the above treatments, droplet size variations were less pronounced when compared to the model for orifice size adjustments. In all the Illinois comparisons except the Cessna data, the droplet spectra were consistently larger than the model predicted.

The remaining two data sets were with the Cessna 188 in Burlington, KS and LaJunta, CO. These data are not being reported do to extreme fluctuations in the wind conditions during the collections which tended to disrupt the uniformity of the collections.

Conclusions

This study was conducted to determine the influence on droplet spectra of nozzle angle for flat-fan nozzles during fixed wing aerial applications. Increasing the nozzle angle reduces the size of the droplet spectra. In the multiple angle tests with the Cessna 188, the measured VMD at 19 l/ha (2 GPA) exhibited a similar reducing trend but the droplets were consistently smaller than the model predicted. For the 47 l/ha (5 GPA) volumes the numbers were very comparable to the model.

In the multiple airplane and orifice size comparisons the droplet differences were not as pronounced when compared to the size changes attributed to the angle adjustments. In the higher speed tests with the Air Tractor's and the Thrush the measured VMD's were consistently larger than the model even though the trends were as expected. In these same higher speed tests angle changes resulted in reduced droplet sizes as the model predicted. The Cessna with the lower pressure treatments was very consistent with the model. This data would indicate that one could expect a 2-3 micron reduction in VMD for each degree of downward angle.

In summary, the data in these studies support that by adjusting the angle of the flat-fan nozzle from the standard 8 degrees to something more inclined the droplet spectra is reduced. For the most part the reductions are similar to the trends predicted by the model. Applicators can consider using this method as a means to manage the spray droplet spectrum for flat-fan nozzles.

Acknowledgements

Special appreciation is expressed to Carey Rucker, Rick Reed, Harley Curless, Don Haley, David Kurtz, and Les Cady for the donation of their aircraft and for taking the time to fly the many passes across the collection area at the respective locations. Also, I would especially like to thank Carolyn Baecker, CP Products Inc., for her cooperation with this study.

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Table and Figures

Table 1. Location, airplane, nozzle, orifice, number of nozzles, application volume, and nozzle angle for all comparisons.

Location	Airplane	Nozzle	Orifice/Number	LPA/GPA	Nozzle Angle
Burlington, KS	Cessna 188 (N2093J)	CP11TT	4008/35	19/2	8,15,30,45,60,75
			4020/15	19/2	8,60,75
LaJunta, CO	Cessna 188 (N2093J)	CP11TT	4008/35	19/2	8,15,30,45,60,75
			4015/19	19/2	8,60,75
			4020/35	47/5	8,15,30,45,60,75
Wamego, KS	Cessna 188 (N2093J)	CP11TT	4008/35	19/2	8,15,30,45,60,75
			4015/19	19/2	8,60,75
			4020/35	47/5	8,15,30,45,60,75
Mattoon, IL	AT502 (N1025A)	CP11TT	4020/46	37/4	8
			4025-47	47/5	8,30
Mattoon, IL	AT802 (N9124N)	CP11TT	4015/39	19/2	8
			4025/39	28/3	8
			4030/50	47/5	8
Mattoon, IL	AT802 (8519R)	CP11TT	4015/39	19/2	8
			4025/39	28/3	8
			4030/49	47/5	8,30
Lincoln, IL	510 Thrush (N4001X)	CP11TT	4030/37	47/5	8,30
Lincoln, IL	Cessna 188 (N9498G)	CP11TT	4015/33	19/2	8,30

Table 2. Meteorological data averaged for all treatment locations.

Location	Treatment	Ground Speed km/h-mph	PSI kPa/ PSI	Wind Speed km/h-mph	Humidity %	Temp C/F
Burlington, KS	Cessna 188 (N2093J)	185/115	276/ 40	21/13	55	17.2/63
LaJunta, CO	Cessna 188 (N2093J)	185/115	276/ 40	8.7/5.4	38	21.7/71
Wamego, KS	Cessna 188 (N2093J)	185/115	276/ 40	9.8/6.1	58	18.3/65
Mattoon, IL	AT502 (N1025A)	217/135	317/ 46	19/11.8	43	14.7/58 .5
Mattoon, IL	AT802 (N9124N)	241/150	310/ 45	10.1/6.3	42	17.5/63 .5
Mattoon, IL	AT802 (8519R)	241/150	310/ 45	18.5/11.5	47	14.6/58 .2
Lincoln, IL	Thrush (N4001X)	214/133	255/ 37	13.7/8.5	38	18.9/66
Lincoln, IL	Cessna 188 (N9498G)	185/115	193/ 28	12.1/7.5	28	23.7/75

Table 3. Droplet characteristics determined from UDSA Nozzle Model for CP small and large flat-fan orifices and angle of defection at 115 MPH and 40 PSI.

Orifice	Angle	VD 0.1	VMD	VD 0.9	RS	DCS
4008	8	201	390	642	1.13	medium
	15	189	389	630	1.13	medium
	30	164	379	596	1.14	medium
	45	139	363	555	1.15	fine
	60	116	338	506	1.16	fine
	75	93	306	450	1.17	fine
4015	8	241	433	735	1.14	medium
	15	231	416	694	1.11	medium
	30	209	382	610	1.05	medium
	45	187	347	531	.99	medium
	60	165	311	459	0.94	fine
	75	142	276	392	0.91	fine
4020	8	265	430	730	1.08	medium
	15	256	414	690	1.05	medium
	30	237	381	608	0.97	medium
	45	218	348	532	0.9	medium
	60	199	314	462	0.84	fine
	75	180	281	398	0.78	fine
4025	8	267	427	730	1.09	medium
	15	259	413	691	1.05	medium
	30	244	381	612	0.97	medium
	45	228	350	538	0.89	medium
	60	212	318	471	0.81	fine
	75	195	286	409	0.75	fine
4030	8	247	425	735	1.15	medium
	15	241	411	697	1.11	medium
	30	228	382	620	1.03	medium
	45	216	352	549	0.95	medium
	60	203	322	484	0.87	fine
	75	189	292	424	0.81	fine

Figure 3. USDA Model droplet characteristics compared to measured data at Wamego.

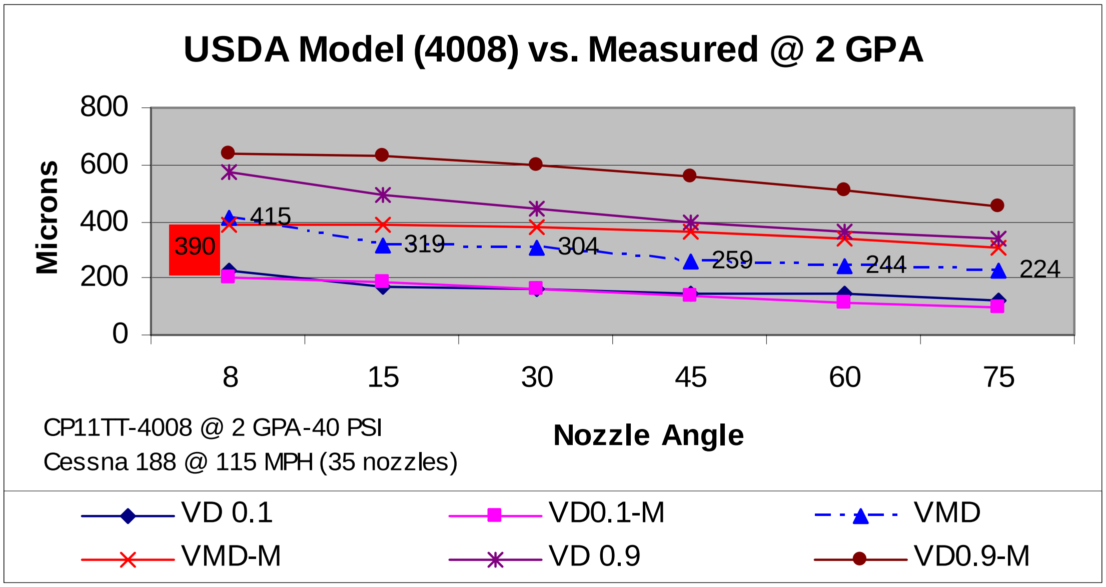

Figure 4. USDA Model droplet characteristics compared to measured data at Wamego.

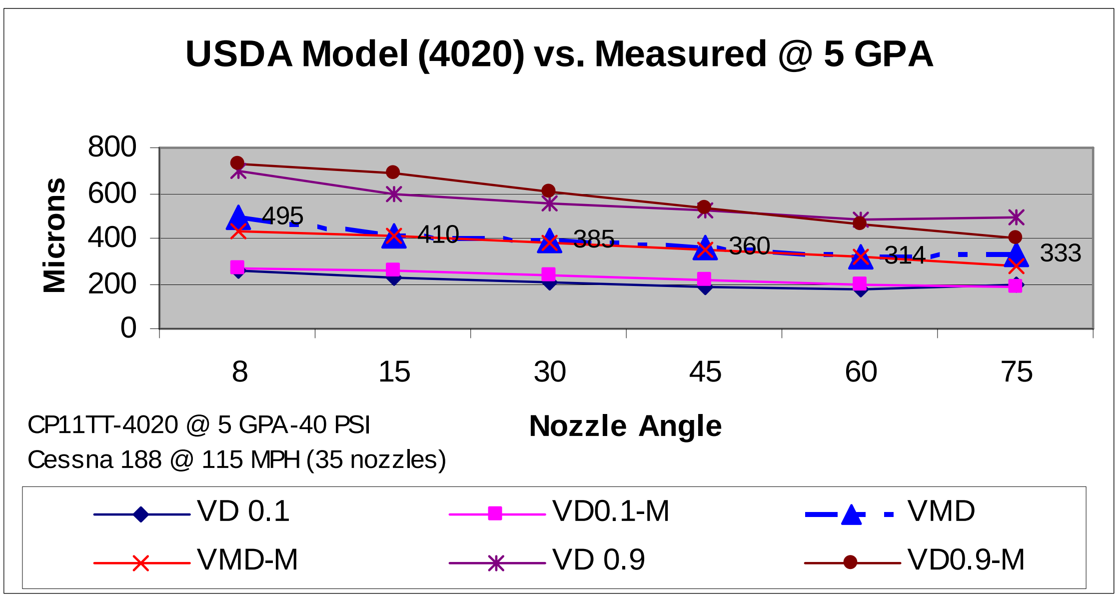

Figure 5. Droplet characteristics from the Illinois comparisons.