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Effect of Nozzle Type on Fungicide Applications to Corn

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Abstract. *Proper nozzle selection and setup to create the most effective droplet size are critical when applying foliar fungicides to corn at lower spray application rates. The purpose of this study was to compare the performance of flat-fan nozzles and rotary atomizers at a spray application rate of 2 gallons per acre. Kromekote papers placed at ear height on 10 corn plants in each of 4 plots per treatment for a flat-fan and rotary atomizer treatment were analyzed to determine percent coverage, GPA deposition, and droplet size statistics. The flat-fan nozzle provided higher coverage and deposition, and also had a larger droplet spectrum. A regression analysis showed a significant relationship between droplet size and coverage, with a larger $D_{V0.5}$ providing higher coverage, presumably through better canopy penetration. A $D_{V0.5}$ of around 250 µm in two of the four flat-fan nozzle plots provided the highest coverage. An analysis using both nozzle type and $D_{V0.5}$ as explanatory variables indicated that droplet size was more important than nozzle type in determining coverage.*

Keywords. *Aerial application, flat-fan nozzle, rotary atomizer, coverage, deposition, droplet size, fungicide application, application technology*

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Introduction

The application of foliar fungicides on corn in the Midwest has generated considerable interest in the past few years. Most of these fungicides are applied by agricultural aircraft at low spray application rates, typically 2 gallons per acre (GPA). In order to maximize effectiveness, it is critical to properly setup the aircraft and appropriately use spray adjuvants to achieve suitable coverage and deposition.

Several studies in the last few years have examined the influence of spray adjuvants on the performance of aerial fungicide applications (Gardisser et al., 2007; Wolf and Bretthauer, 2008). Gardisser et al. (2007) examined several adjuvant treatments in four separate fields across three states. While they did find differences in coverage among the four different nozzle types used in the study, a lack of replication between the different fields and weather conditions prevented any strong conclusions. The results, however, did show that flat-fan nozzles provided the highest coverage over all three sampling heights (top, middle, and bottom of corn canopy), while the rotary atomizers provided the highest coverage in the bottom of the corn canopy. Flat-fan nozzles and rotary atomizers show potential for providing optimal atomization for low volume fungicide applications.

Objective

The objective of this study was to compare the coverage and deposition performance of flat-fan nozzles and rotary atomizers for aerial fungicide applications on corn.

Methods

The study was conducted in a corn field near Middletown, Illinois. The field was 100 acres in size, with a length oriented north and south of approximately 4,500 feet and a width of approximately 1,300 feet. It was divided into three segments for the study. The northern 45 acre portion received the fungicide application with the rotary atomizers, the southern 45 acre portion received the fungicide application with the flat-fan nozzles, and the middle 10 acre portion was left as an untreated check (figure 1).

Two treatments were evaluated in the study: an aircraft setup with flat-fan nozzles and an aircraft setup with rotary atomizers. Both aircraft were pattern tested prior to the study using water and dye with 7 water sensitive papers used to evaluate droplet size and coverage. Treatment details, including droplet size and coverage information from the pattern testing, are presented in Table 1.

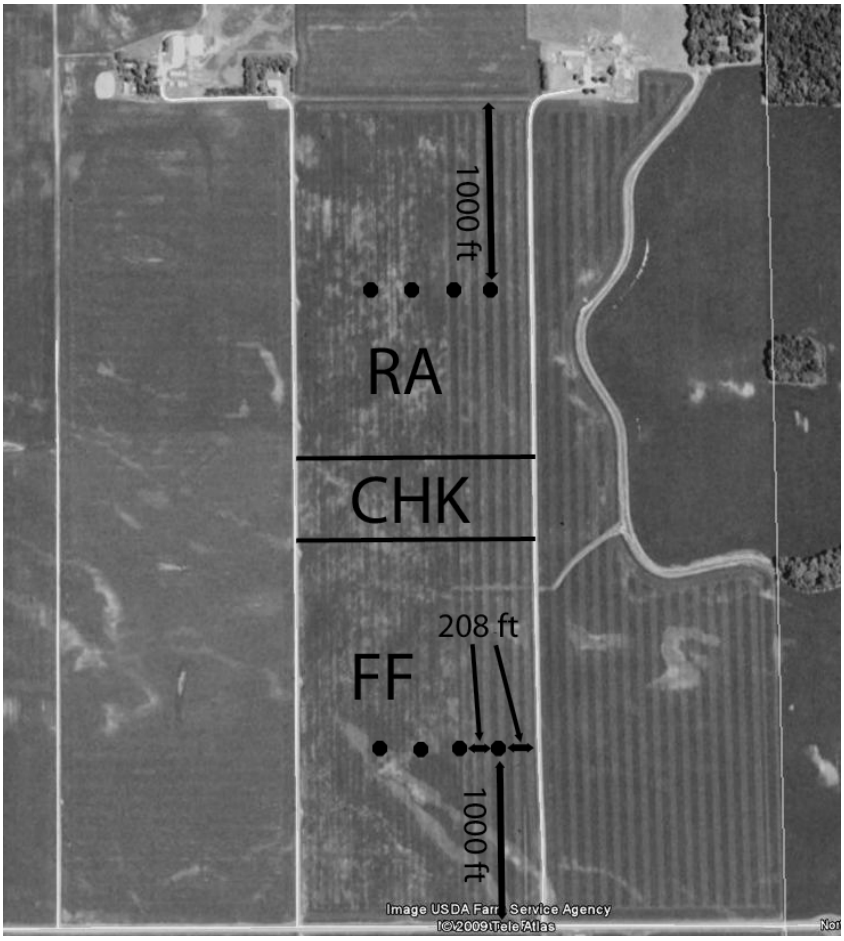

Figure 1. Aerial photograph showing the location of treatments and study plots, and distances for plot location. RA = rotary atomizers; FF = flat-fans; CHK = untreated check.

Table 1. Treatments and parameters used in corn fungicide study.

Parameter	Rotary atomizer treatment	Flat-fan nozzle treatment
Aircraft type	AT-402B	AT-402B
Airspeed	140 MPH	140 MPH
Application height	12 feet	12 feet
Nozzle	Micronair AU5000/VRU = 13	CP-11TT w/FF4010
Pressure	35 psi	35 psi
Deflection	0 degrees	15 degrees
Blade/setting	EX6353/90 degrees	NA
Number of nozzles	11	38
Swath width	70 feet	65 feet
Pattern testing $D_{V0.5}$	250 µm	372 µm
Pattern testing percent coverage	9.97%	4.69%

Applications were made on July 10, 2009. The flat-fan treatment was applied between 5:35 and 5:45 pm and the rotary atomizer treatment was applied between 6:23 and 6:33 pm. A north-south racetrack pattern was flown for both treatments. Weather was monitored using a weather station located in an opening near the northeast corner of the field (table 2). Flight pattern directions were mostly parallel to wind direction.

Table 2. Weather data and flight pattern directions for both the rotary atomizer and flat-fan treatments.

Weather/flight parameter	Rotary atomizer	Flat-fan
Average temperature	85º F	85º F
Average relative humidity	63%	59%
Average wind speed	4 mph	3 mph
Maximum wind gust	8 mph	7 mph
Average wind direction	176º	193º
Flight direction	0º/180º	0º/180º

The spray solution for both treatments was identical. A spray application rate of 2 GPA was used, with the foliar fungicide Stratego (propiconazole and trifloxystrobin) applied at a rate of 10 fl oz/acre. Vision Pink dye (Garrco Products Inc., Converse, IN) was mixed at a rate of 1 quart per 50 gallons of spray solution to provide a stain on the sampling cards needed for analysis. No additional spray adjuvants were used.

Four plots were used to access spray coverage and deposition for each treatment (figure 1). The four plots were systematically located in each treatment area, with no attempt made to situate them in the center of an aircraft swath. In both treatment areas, all plots were located in a straight east-west line, perpendicular to the flight pattern, 208 feet apart, with the first plot 208 feet from the eastern edge of the field. In the northern section the plots were situated 1,000 feet from the northern edge of the field; in the southern section plots were situated 1,000 feet from the southern edge of the field.

From the center of each plot location, five corn plants were sampled to the west and five corn plants were sampled to the east for a total of 10 corn plants per plot. On each corn plant, a bent piece of aluminum used as a card holder was fastened to the stalk using zip ties at ear height, about 5 feet above the ground. The card holders were all oriented so that the cards were located on the west side of the plant, facing west between the rows, and parallel to the ground. Kromekote cards, 2 inch by 3.5 inch in size, were attached to the card holder using paper clips, with the outer edge of the card located 7 inches from the corn stalk. Cards were collected immediately following both treatments and placed in manila envelopes for storage until analysis was completed.

The Kromekote cards were analyzed using DropletScan (WRK of Arkansas, Lonoke, AR; WRK of Oklahoma, Stillwater, OK). The percent area of card surface covered, gallons of spray per

acre deposited on the cards, and the $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ in µm (microns) were calculated for the cards. For the droplet size and GPA calculations, the spread factor for water was used.

Card data was analyzed using SAS Mixed Procedures (SAS Institute, Cary, NC, 2007) with treatment as the independent variable. A separate analysis was done for each of the five card variables: percent coverage, GPA, $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$. In each analysis, treatment was the fixed effect and plot and individual corn plant nested within plot were random effects. Alpha was set at 0.05. A regression analysis using percent coverage as the dependant variable and $D_{V0.5}$ as the independent variable was done to determine if there was a relationship between the spray droplet spectrum and coverage on the cards. For this analysis, the data from both treatments was combined into a single data set using the SAS Reg procedure. The standard deviations for all variables were calculated for both treatments using the SAS Means procedure. Based on the results of these analyses, a final Mixed Procedure analysis was done, with percent coverage as the dependant variable, treatment, plot and corn as class variables, and $D_{V0.5}$ as a quantitative variable. In this analysis, treatment, $D_{V0.5}$, and their interaction were used as fixed effects, with plot and individual corn plant nested within plot used as random effects. Alpha was set at 0.05.

Results

The treatment means and standard deviations for the variables calculated from the Kromekote card analysis are given in table 3. The flat-fan treatment had significantly higher values for all of the variables analyzed. The rotary atomizer treatment had lower standard deviations for all variables.

Table 3. Means and standard deviations for percent coverage (% cov), gallons of spray per acre deposited on the cards (GPA) and droplet spectrum statistics for both treatments. All variables were significantly different between the two treatments at alpha = 0.05.

Treatment	% cov	GPA	$D_{V0.1}$(µm)	$D_{V0.5}$ (µm)	$D_{V0.9}$ (µm)
Rotary atomizers	0.83 ± 0.57	0.26 ± 0.20	100 ± 21	162 ± 35	230 ± 49
Flat fans	1.47 ± 1.79	0.58 ± 0.73	128 ± 40	209 ± 53	303 ± 77

The regression analysis showed a significant relationship between the percent coverage on the cards and the $D_{V0.5}$ ($P < 0.001$). The r-square value was 0.58. Figure 1 displays the increase in percent coverage with an increase in $D_{V0.5}$ for the ranges of $D_{V0.5}$ collected in this study.

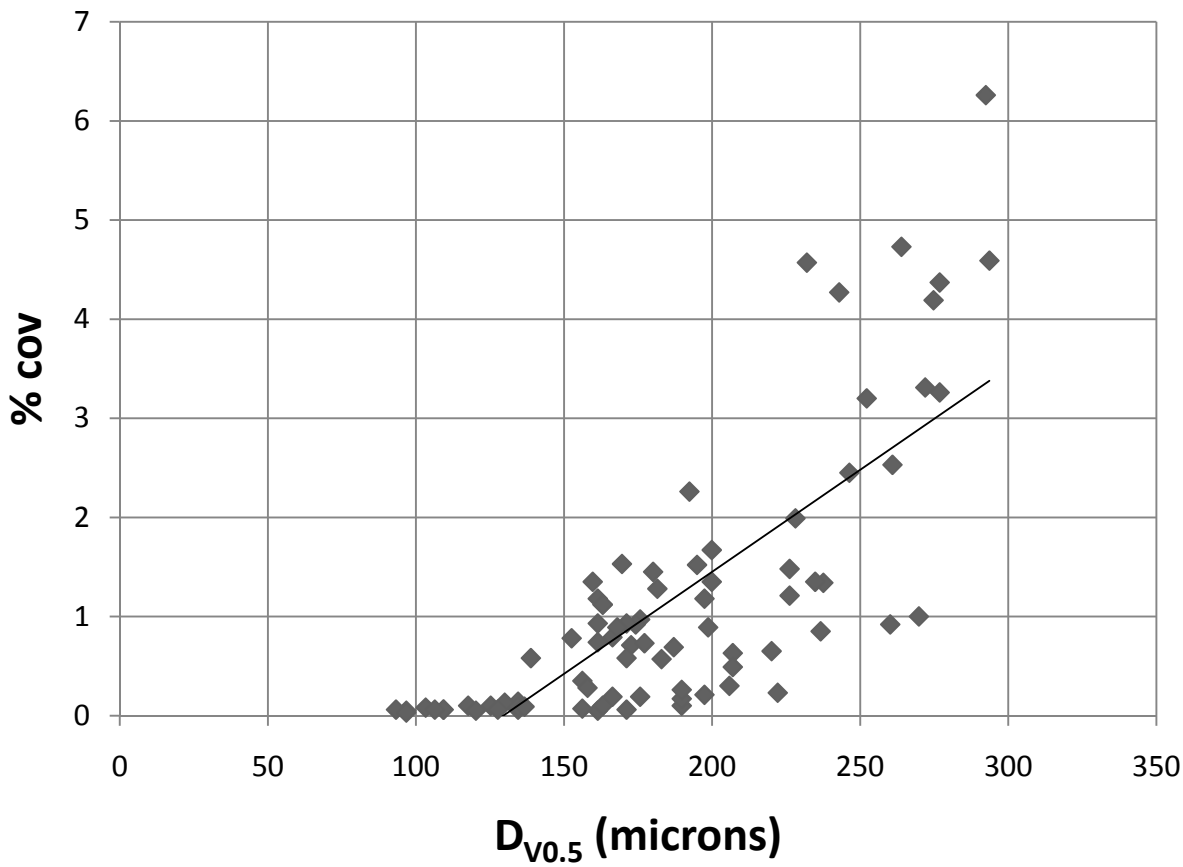

Figure 1. Scatter plot of percent coverage (% cov) and $D_{V0.5}$ (µm) using a data set with both treatments combined. Linear regression: % cov = -2.665 + 0.021 * $D_{V0.5}$; R^2 = 0.58

The final mixed procedure with nozzle treatment, $D_{V0.5}$, and their interaction as predictor variables showed that all three effects significantly affected coverage (table 4), but $D_{V0.5}$ had the greatest influence, more so than nozzle type.

Table 4. F and P values for nozzle type treatment, $D_{V0.5}$, and their interaction from the mixed procedure modeling the effects of these variables on percent coverage.

Effect	F Value	P Value
Treatment	10.59	0.0017
$D_{V0.5}$	74.84	<0.0001
$D_{V0.5}$ x Treatment	8.17	0.0055

In figure 2, the mean percent coverage and $D_{V0.5}$ can be seen for each of the eight individual plots for both treatments. The trend of higher percent coverage associated with a larger $D_{V0.5}$ is

evident for all plots except the fourth flat-fan plot, which had a lower percent coverage than other plots with similar $D_{V0.5}$ values.

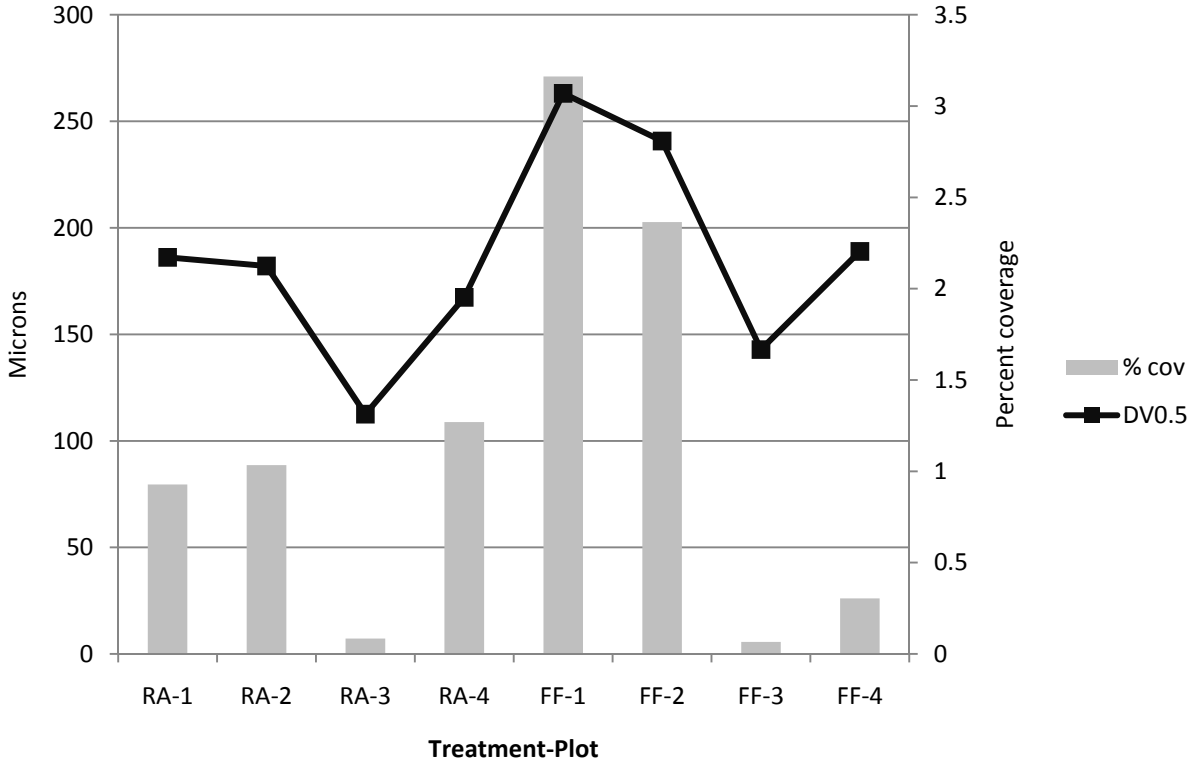

Figure 2. Mean percent coverage and $D_{V0.5}$ for each individual plot for both treatments. RA = rotary atomizer treatment; FF = flat-fan treatment.

Discussion

The greater spray coverage and deposition from the flat-fan nozzles compared to the rotary atomizers appears to be directly related to the slightly larger deposited spray droplet spectrum. Based on the results of the regression analysis, it appears that a relatively larger droplet spectrum, with a $D_{V0.5}$ around 250 µm, improved spray coverage and deposition, likely because the slightly larger droplet size increased canopy penetration to ear height. The rotary atomizers had a more consistent coverage and droplet spectrum over all the samples, as indicated by the lower standard deviations from this treatment for all of the variables. The final analysis indicates that droplet size had a stronger effect on coverage than nozzle type did in this study. The significant interaction in this analysis is not surprising since the droplet size is directly related to the nozzle type and setup.

It is interesting to compare the results from the pattern testing, where the smaller droplet spectrum of the rotary atomizers provided greater coverage, to the field study results, where the opposite occurred. It is important to remember, though, that the $D_{V0.5}$ and coverage from the pattern testing were collected in the open with no canopy and no fungicide in the spray solution.

The $D_{V0.5}$ from the field study is only for that portion of the droplet spectrum that penetrated the canopy. In addition, there was fungicide in the study spray solution which very likely substantially reduced the droplet spectrums for both the flat-fan and rotary atomizer treatments compared to the droplet spectrum measured with water and dye only. For the rotary atomizers, this smaller droplet spectrum appears to have reduced canopy penetration, resulting in lower coverage and deposition compared to the flat-fan nozzles.

Other deposition studies comparing different droplet size spectrums have found that the larger droplet spectrums (larger relative to the other tested droplet spectrums) tended to improve coverage and deposition. The flat-fan nozzles that provided the highest coverage over all three canopy height locations in Gardisser et al. (2007) had a pattern testing (water and dye) $D_{V0.5}$ of 364 µm. The rotary atomizers that provided the second highest overall coverage and the highest coverage in the lower part of the canopy had a pattern testing $D_{V0.5}$ of 277 µm. The two other treatments with deflector style nozzles that provided lower coverage had $D_{V0.5}$'s of 272 and 232 µm. Another study done on corn (Fritz et al., 2008) found that a $D_{V0.5}$ of 400 µm provided higher deposition than a $D_{V0.5}$ of 230 µm at 5 GPA. On wheat, Fritz et al. (2006) found that lower spray application rates of 2 and 5 GPA with a $D_{V0.5}$ of 350 µm provided better deposition than treatments with a $D_{V0.5}$ of 175 µm.

Conclusion

Droplet size spectrum had a greater effect on percent coverage than nozzle type did, indicating the importance of proper nozzle setup regardless of nozzle type chosen. The flat-fan nozzles provided higher percent coverage and GPA deposition than the rotary atomizers. A droplet spectrum with a $D_{V0.5}$ of around 250 µm provided the highest percent coverage.

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