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Effects of Nozzle Type and Carrier Application on the Control of Leaf Spot Diseases of Soybean

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Abstract. *Midwestern soybean growers seek information on effective application of foliar fungicides that do not translocate throughout the plant. Field application treatments included using a two-orifice nozzle tip producing fine droplets at 187 l/ha (20 gal/ac) and 112 l/ha (12 gal/ac) and a single-orifice nozzle tip producing a coarse droplet size more typical of herbicide applications at 168 l/ha (18 gal/ac). In addition an air-assisted sprayer was used at one of the two sites of the trials. Measurements included droplet size, droplet coverage, and foliar disease severity in the top, middle, and lower parts of the plant canopy, and soybean yield.*

Droplet size for application treatments generally followed expected manufacturer specifications. Percentage area covered and drops/cm^2 were not statistically different among application treatments except at top of the plant canopy at one site. Percentage area covered and drops/cm^2 were statistically greater at the top of the canopy (17 - 18% coverage) than at the middle or bottom (1 – 8% coverage) at both sites. Foliar disease pressure was light so that yield or disease severity was unaffected by application method or as compared to a check area without application.

Keywords. air-assist, application, disease, fungicide, nozzle tip, soybean, canopy penetration

Effects of Nozzle Type and Carrier Application on the Control of Leaf Spot Diseases of Soybean

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Introduction

Soybeans (*Glycine max L.*) are a major commodity crop grown on over 29 million hectare (72 million acres) in the United States. A large part of the cropland base in Iowa, 5 million hectare (11 to 13 million acres) annually, is devoted to soybean production. Although long term crop yield trends are upward, soybean yield increases have been more stagnant than corn, the common companion rotational crop, causing growers to question factors such as disease that might be slowing yield growth.

In late 2004 Asian Soybean Rust (*Phakopsora pachyrhizi*) was detected in the United States. Because of the potential for yield loss as observed in other countries, grower concern has resulted in increased interest in this and other foliar leaf spot diseases that may be affecting yield. Midwestern U.S. agronomic row-crop growers are generally familiar and experienced with herbicide and insecticide application, but have very limited experiences in field application of fungicides. Growers customarily have existing sprayer equipment set up to apply systemic herbicides with relatively large droplets to reduce drift and carrier application rates of 94 to 143 L/ha (10 to 15 gal/acre) to minimize water transported and maximize the range of application area covered by an individual tank.

Womac et al. (1992) examined characteristics of over-the-top, drop-nozzle, and air-assisted spray application in mature cotton. Increased spray rate (from 47 to 94 L/ha; 5 to 10 gal/acre) predominantly increased deposition and chemical efficacy under most conditions. Howard et al. (1994) measured penetration and deposition of air-assisted sprayers as compared to a conventional over-the-top sprayer in cotton. Although results among sprayers were comparable in the top of the canopy, in the middle of the canopy air-assisted sprayers had increased deposition.

Objective

Because of the scarcity of information on foliar fungicide application techniques to Midwestern U.S. soybeans a field experiment was conducted to determine effects of nozzle type, carrier application, and application technique on droplet deposition within the crop canopy, foliar disease severity, and soybean yield. In particular, it was desired to compare the effects of: a) reduced carrier rate, b) larger droplet size common for herbicide application, and c) air-assisted sprayer with a spray application applying smaller droplet sizes at a greater than normal carrier application rate.

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Methods and materials

Treatments

To increase the chance of applying fungicides at a location with foliar disease pressure, experimental plots were conducted at two sites, Iowa State University's Agricultural Engineering and Agronomy Farm near Boone in central Iowa and Iowa State University's McNay Farm near Chariton in south-central Iowa.

Each site had four application treatments and a fifth unsprayed check treatment. Three application treatments were common to both sites. A relatively high 187 L/ha (20 gal/acre) application was made with two-orifice nozzle tips listed by the manufacturer as producing droplets in the larger size of the fine droplet spectrum (ASAE Standards, 2005). A lower application treatment, 112 L/ha (12 gal/acre), used two-orifice nozzle tips listed as also producing droplets in the larger end of the fine droplet spectrum. The third common application treatment used single-orifice nozzle tips commonly used in soybeans for systemic herbicide application (Turbo TeeJet, Spraying Systems, Wheaton, IL). Although the carrier application rate was relatively high (168 L/ha; 18 gal/acre) the droplet spectrum produced as listed by the manufacturer was in the smaller portion of the coarse droplet spectrum.

The fourth application treatment at Boone was an air-assisted application with an air-curtain type sprayer of the high-rate application (187 L/ha (20 gal/acre) with two-orifice nozzle tips). Due to resource limitations in transporting this sprayer, the fourth application treatment at Chariton was instead an application with a newer style Turbo TeeJet Duo nozzle (Spraying Systems, Wheaton, IL). The nozzle consisted of two Turbo TeeJet tips producing a medium droplet spectrum according to the manufacturer while applying a 187 L/ha (20 gal/acre) application. More specific details of each treatment are listed in table one.

Table 1. Application treatments and operating conditions

Treatment	Carrier application rate		Nozzle	Pressure		Speed		Spray Quality
	L/ha	gal/acre		kPa	psi	km/h	mi/h	
High-rate	187	20	2-orifice 8004	276	40	9.6	6.0	fine
Low-rate	112	12	2-orifice 8003	207	30	10.3	6.4	fine
Herbicide-style	168	18	1-orifice, Turbo TeeJet 11003	276	40	8.0	5.0	coarse
Air-assist	187	20	2-orifice 8004	276	40	9.6	6.0	fine
Turbo duo	187	20	2-orifice, Turbo TeeJet Duo 11002 (2 tips)	276	40	9.6	6.0	medium

At the Boone location a 3-point-mounted sprayer with air-assist was used (Falcon Vortex, Jacto Manufacturing, Pompeia, Brazil) for all application treatments. It had a 14-m (46-ft) boom with control over four boom sections. When the fan operated (only in the air-assist treatment), a curtain of air at speeds up to 100 km/h (62 mi/h) directed nozzle output down into the plant canopy. At the Chariton location an older custom-built research sprayer with a 4.6-m (15-ft) long boom was used. Both sprayers had nozzles placed on 51-cm (20-in.) centers.

Site details, field layout, and measurements

Soybean row spacing at each site differed and reflected local planting practices. Row spacing at Boone was 76 cm (30 in.) in an east-west orientation and at Chariton was 38 cm (15 in.) in a north-south orientation. All treatments, including the unsprayed check were replicated in four field blocks at each location. Buffer areas at least one plot width wide were left unsprayed adjacent to each plot to avoid significant spray drift moving between plots. The number of nozzles used was adjusted so that full appropriate nozzle overlap was used across the width of each plot. At Boone individual plots were five rows wide (3.8 m; 12.5 ft) by 35 m (115 ft) long. A side section of the boom was used so that tractor operating the sprayer did not travel through any plot areas. At Chariton, plots were eleven rows wide (4.2 m;13.8 ft) by 61 m (200 ft) long with the sprayer tractor driving down the centerline of each plot.

Measurements included droplet deposition on cards, foliar disease severity present on soybeans, and soybean yield. Measurement areas for deposition and foliar disease were at the bottom, middle, and top of the soybean plant canopy on eight soybean plants evenly spaced along a single measurement row within each plot. The measurement row location was selected to be in the interior of the plot, but not directly adjacent to sprayer tractor wheel traffic or brushed by the tractor chassis.

Because of possible wet conditions within the plant canopy, Kromekote paper (kkp) and dye were used rather than water-sensitive paper. Droplet collection cards (5 cm by 7.6 cm; 2 in. by 3 in.) constructed of Kromekote photographic paper were mounted with paper clips on individual leaf petioles inside the canopy before spraying. Pink sprayer dye (Tracer Hot Pink Foam Dye, Precision Labs, Northbrook, IL) was mixed into the spray solution at a concentration of 0.275%. Approximately one hour after spraying, cards were collected for later analysis. After droplet cards were scanned on a flatbed scanner, software (DropletScan; WRK of Arkansas, Lonoke, AR; and WRK of Oklahoma, Stillwater, OK; Devore Systems, Inc., Manhattan, KS) measured the number of droplets, droplet size, and area covered on each card.

Near each droplet card measurement area, 10 soybean trifoliate leaf samples were collected about two hours before spraying. Leaf samples were again collected near the same measurement sites almost three weeks later. Foliar disease severity (percent leaf area affected) was evaluated on each leaf sample to measure disease level immediately before and about three weeks after spraying. Harvested soybean yield was measured at the end of the season by harvesting interior plot rows. Meteorology measurements (wind speed and direction, dry- and wet-bulb air temperature) were made several times during approximately 1.5 to 2.0 h of spray applications across all treatments at a location.

Tebuconazole fungicide (Folicur 3.6F, Bayer CropScience, Research Triangle Park, NC) was applied on all spray application treatments at an active ingredient rate of 113 g/ha (1.55 oz a.i./ac or product rate of 0.292 L/ha; 4 oz/ac).

Statistical analysis

Deposition, foliar disease, and yield data were statistically analyzed in analyses of variance to determine if observed treatment means were statistically different. Differences were measured at a 95% confidence level unless otherwise noted.

Results and discussion

Field conditions at the time of spraying are listed in table 2.

Table 2. Field conditions during application

Location	Date	Air temp.		Relative humidity	Wind direction	Wind speed		Soybean growth stage
		˚C	˚F	%		km/h	mi/h	
Boone	7-27-06	24	75	38	NNW	4.8 – 9.6	3 – 6	early R4
Chariton	7-29-06	29	85	44	SSW	3.2 – 8.0	2 – 5	late R3

Deposition

Deposition measurements from droplet cards near the bottom of the soybean leaf canopy are shown in table 3. Spray droplet volume diameters are listed for the droplet size below which 10% (VD0.1), 50% (VD0.5), and 90% (VD0.9) of the spray volume was being applied.

At the Boone location, the coarser droplet spectrum produced by nozzles in the herbicide-style treatment produced larger VD0.5 and VD0.9 values as expected. At Chariton, VD0.5 and VD0.9 droplet sizes for the herbicide-style treatment were also larger than the high-rate and low-rate treatments. The Turbo Duo produced a medium droplet spectrum as expected at VD0.5 and VD0.9 but had numerically the largest droplet size at VD0.1. Differences among treatments were statistically significant at a reduced 90% confidence level for VD0.1 measurements.

Variability in values precluded detecting statistical differences in percent area covered or droplet number although the high-rate treatment at Chariton did have a statistically more drops/cm^2 at a reduced confidence level of 90%.

Table 3. Droplet measurements from collection cards near bottom of leaf canopy

Site/treatment	Area %	Area Drops/cm^2	Volume diameter, µm 0.5[a]	Volume diameter, µm 0.1[b]	Volume diameter, µm 0.9[c]
Boone					
High-rate	1.73	28.5	225	128	379
Low-rate	0.75	13.8	255	120	379
Herbicide-style	1.28	15.3	354	143	558
Air-assist	1.10	18.3	268	130	424
$LSD_{\alpha=0.05}$[d]	NS[e]	NS	79	NS	51
Chariton					
High-rate	6.40	85.0	307	137	497
Low-rate	1.78	31.0	265	125	414
Herbicide-style	3.95	41.8	390	152	610
Turbo duo	3.53	25.0	350	166	527
$LSD_{\alpha=0.05}$	NS	10%[f]	55	10%	47

[a]Volume median diameter; 50% of spray volume is contained in droplets smaller than this size
[b]VD0.1; 10% of spray volume is contained in droplets smaller than this size
[c]VD0.9; 90% of spray volume is contained in droplets smaller than this size
[d]Least significant difference at 95% confidence level for a card position at a specific location
[e]No significant difference
[f]Differences not significant at 95% confidence level, but are significant at reduced 90% confidence level

Deposition measurements in the middle of the leaf canopy are shown in table 4. At Boone, for the herbicide-style treatment VD0.5 was larger than for the low-rate treatment and VD0.9 was larger than all other spray treatments. At Chariton, both VD0.5 and VD0.9 were largest for the herbicide-style treatment and the medium droplet spectrum of Turbo duo treatment had larger values than the low-rate treatment. VD0.1 (at Chariton) of both the herbicide-style and Turbo duo treatments was larger than that of finer droplet spectrum produced in the low- and high-rate treatments. No statistically significant differences were detected in percent area covered or drops/cm^2.

Table 4. Droplet measurements from collection cards near middle of leaf canopy

Site/treatment	Area %	Area Drops/cm^2	Volume diameter, µm 0.5[a]	0.1[b]	0.9[c]
Boone					
High-rate	6.48	68.5	317	145	483
Low-rate	3.73	54.0	250	132	401
Herbicide-style	4.85	40.5	378	153	604
Air-assist	7.75	72.5	321	168	483
$LSD_{\alpha=0.05}$[d]	NS[e]	NS	70	10%[f]	88
Chariton					
High-rate	8.13	91.5	335	150	531
Low-rate	4.25	56.0	302	143	464
Herbicide-style	10.65	69.3	461	198	708
Turbo duo	7.75	56.0	375	180	551
$LSD_{\alpha=0.05}$	NS	NS	57	30	82

[a]Volume median diameter; 50% of spray volume is contained in droplets smaller than this size
[b]VD0.1; 10% of spray volume is contained in droplets smaller than this size
[c]VD0.9; 90% of spray volume is contained in droplets smaller than this size
[d]Least significant difference at 95% confidence level for a card position at a specific location
[e]No significant difference
[f]Differences not significant at 95% confidence level, but are significant at reduced 90% confidence level

Deposition values at the top of the leaf canopy are shown in table 5. At the Boone site, both VD0.5 and VD0.9 values were greatest for the herbicide-style treatment, intermediate for the high-rate and air-assist treatments, least for the low-rate treatment. VD0.1 values were greatest for the herbicide-style and air-assist treatments, intermediate for the high-rate treatment and least for the low-rate treatment. The air-assist and high-rate treatments had more drops/cm^2 and greater area covered than low-rate and herbicide-style treatments.

At the Chariton site, VD0.5 for the herbicide-style treatment was greater than for the low- and high-rate treatments. Differences among treatments were statistically significant at a reduced 90% confidence level for VD0.9 measurements.

Table 5. Droplet measurements from collection cards near top of leaf canopy

Site/treatment	Area %	Area Drop/cm^2	Volume diameter, µm 0.5[a]	Volume diameter, µm 0.1[b]	Volume diameter, µm 0.9[c]
Boone					
High-rate	21.18	156.3	395	181	637
Low-rate	9.53	115.5	302	147	460
Herbicide-style	16.68	86.5	470	200	710
Air-assist	24.23	148.8	394	202	594
$LSD_{\alpha=0.05}$[d]	4.52	32.7	32	16	66
McNay					
High-rate	18.23	155.0	445	205	725
Low-rate	14.65	100.3	400	192	634
Herbicide-style	20.25	90.0	530	228	806
Turbo duo	12.90	62.3	472	234	691
$LSD_{\alpha=0.05}$	NS[e]	NS	84	NS	10%[f]

[a]Volume median diameter; 50% of spray volume is contained in droplets smaller than this size
[b]VD0.1; 10% of spray volume is contained in droplets smaller than this size
[c]VD0.9; 90% of spray volume is contained in droplets smaller than this size
[d]Least significant difference at 95% confidence level for a card position at a specific location
[e]No significant difference
[f]Differences not significant at 95% confidence level, but are significant at reduced 90% confidence level

Regarding deposition, VD0.5 and VD0.9 values for application treatments generally followed expected manufacturer suggested rankings from coarse to medium to fine droplet sizes. Expected ranking was less apparent for VD0.1 values. Percentage area covered and drops/cm^2 were not statistically different except at top of the plant canopy at the Boone site where air-assist and high-rate applications had greater coverage.

In a separate analysis, all data was pooled (i.e., all three canopy locations) within each site. Percentage area covered and drops/cm^2 were statistically greater at the top of the canopy than at the middle or bottom at both sites. Mean top coverage was 18% at Boone and 17% at Chariton, but ranged from 1 to 8% mean coverage at the bottom or middle canopy positions depending on site and canopy position. At the Boone site percentage area covered and drops/cm^2 were statistically greater at the middle than at the bottom of the canopy.

Efficacy of application treatments and yield

Leaf disease severity immediately before fungicide applications and almost three weeks after application are shown in table 6. Dry environmental conditions during the period were not conducive for the development of soybean foliar diseases. Although brown spot (*Septoria glycines*) and frogeye leaf spot (*Cercospora sojina*) were present at both sites, low disease pressure precluded detecting any differences among application treatments or with the unsprayed check. Perhaps because disease pressure among treatments was low, harvested soybean yields were also statistically equivalent across all application treatments and the unsprayed check (table 7).

Table 6. Soybean leaf disease severity in bottom, middle, and top of leaf canopy before and after spraying[a]

	Before spraying			After spraying		
Site/treatment	Bottom	Middle	Top	Bottom	Middle	Top
Boone						
High-rate	0.97	0.05	0.00	0.58	0.00	0.00
Low-rate	1.28	0.16	0.02	0.64	0.00	0.00
Herbicide-style	0.75	0.00	0.00	0.61	0.23	0.00
Air-assist	0.77	0.09	0.00	0.81	0.03	0.00
No spray	1.05	0.06	0.02	0.75	0.41	0.00
$LSD_{\alpha=0.05}$[b]	NS[c]	NS	NS	NS	NS	NS
McNay						
High-rate	0.78	0.20	0.02	0.92	0.19	0.00
Low-rate	0.97	0.17	0.03	0.64	0.13	0.00
Herbicide-style	1.03	0.16	0.00	0.58	0.09	0.05
Turbo duo	0.50	0.27	0.00	0.84	0.14	0.00
No spray	0.66	0.33	0.00	0.69	0.09	0.00
$LSD_{\alpha=0.05}$	NS	NS	NS	NS	NS	NS

[a]Severity scale:
0 = no disease
0.5 = few spots
1 = <15% of leaf area with disease
2 = 15 – 24% leaf area with disease
[b]Least significant difference at 95% confidence level for a leaf position at a specific location
[c]Differences are not statistically significant

Table 7. Soybean yields (adjusted to 13%) and moisture content at harvest for fungicide application treatments

Location/treatment	Yield, bu/ac	Moisture content, %
Boone		
High-rate	64.9	13.1
Low-rate	61.2	12.9
Herbicide-style	62.4	12.9
Air-assist	62.8	12.9
No spray	62.7	12.9
$LSD_{\alpha=0.05}$[a]	NS[b]	NS
McNay		
High-rate	49.2	15.0
Low-rate	45.0	14.8
Herbicide-style	48.5	15.4
Turbo duo	46.3	15.2
No spray	43.5	14.8
$LSD_{\alpha=0.05}$[b]	NS	NS

[a]Least significant difference at 95% confidence level for a leaf position at a specific location
[b]Differences are not statistically significant

Conclusions

Within the range of conditions encountered at two field sites, data support the following conclusions:

Deposition:

- VD0.5 and VD0.9 values for application treatments generally followed expected manufacturer suggested rankings from coarse to medium to fine droplet sizes. Expected ranking was less apparent for VD0.1 values.
- Percentage area covered and drops/cm^2 were not statistically different among treatments except at top of the plant canopy at the Boone site. When all data was pooled (all canopy locations) within each site, percentage area covered and drops/cm^2 were statistically greater at the top of the canopy (17 - 18% coverage) than at the middle or bottom (1 – 8% coverage) at both sites. At the Boone site percentage area covered and drops/cm^2 were statistically greater at the middle than at the bottom of the canopy.

Foliar disease and yield:

- Foliar disease pressure was light, perhaps due to dry environmental conditions, and no statistical differences were detected in leaf disease severity or soybean yield among the application treatments or unsprayed check.

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