Aerial Application Methods for Increasing Spray Deposition on Wheat Heads

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Abstract. *Fusarium head blight (FHB) is a major disease of wheat and barley in several small grain production areas in the United States and, as such, the development and evaluation of aerial application technologies that enhance the efficacy of fungicides with aerial spray applications, is one of the research priorities of the United States Wheat and Barley Scab Initiative. This research was initiated to assess aerial spray technologies in an effort to increase spray deposits on wheat heads. The experiment was designed as a 2 × 3 factorial treatment arranged in a randomized complete block with three replications at each of three field locations. Multiple sub-samples of wheat heads and artificial samplers were collected and analyzed to assess and describe spray deposits from the specified treatments. Test results indicated that lower spray rates with larger droplet sizes tended to result in greater tracer deposits. The results from this study are expected to provide guidance for aerial fungicide applications for increased deposition.*

Keywords. *Aerial application, Aerial spraying, Spray deposition, Wheat head blight.*

Fusarium head blight (FHB) is a major disease of wheat and barley in several small grain production areas in the United States. By the mid-1990s, cultural practices, resistant cultivars, and fungicides had made only limited impact on managing the disease (Parry et al., 1995). Recent studies on efficacy of fungicide applications focus on fungicide type and not effects of application parameters such as spray pressure, spray rate and associated spray droplet spectrum (Milus and Parsons, 1994; Shaner and Buechley, 1999; Milus et al., 2001; Hershman and Milus, 2002). Halley et al. (1999) evaluated two ground application systems with varying nozzle orientations and water volumes for deposition of fungicide on grain spikes and found that nozzles oriented in alternating front-angled and back-angled positions significantly increased deposition and control. Droplet size of spray was not examined or reported. Both Halley et al. (1999) and Hart et al. (2001) and showed the importance of thorough coverage of the wheat heads as a factor in fungicidal efficacy for FHB suppression emphasizing the need for optimizing application parameters such that maximum deposition is achieved.

Numerous studies have been reported on optimization of aerial application practices for pest control in cotton, corn, weeds, and brush noting that optimum spray rate droplet size combinations are pest specific and vary from one pest or target area to another (Bouse et al., 1992; Hoffmann et al., 1998; Kirk et al., 1989, 1992, 1998, 2001) found that higher spray rates with smaller droplet sizes resulted in increased herbicide deposits on yellow foxtail plants. Bouse et al. (1992) found that overall, increased spray rates and decreased droplet size resulted in increased mortality of honey mesquite. Kirk et al. (1992) found that higher spray rates and larger droplet sizes resulted in increased deposits within the canopy of cotton plants. Hoffmann et al. (1998) found that smaller droplet sizes and lower spray rates resulted in increased levels of control for the targeted insect pest. As these results indicate, it is important to consider the ultimate target when maximizing application equipment set-ups.

Objective

The major objective of this study was to assess and compare deposition (tracer deposits) on wheat heads with treatments comprised of three levels of spray rates and two levels of droplet size in field conditions in an effort to optimize aerial application techniques.

Materials and Methods

Based on experience with aerial application and consultation with FHB researchers, aerial application methods were selected that might offer improved spray deposition on wheat heads. These methodologies were implemented across fields of hard red spring wheat at three different locations. The experimental treatment design at each location was a 3 × 2 factorial structure; spray rate at 19, 47, and 94 L/ha and mean droplet size at 175 and 350 µm. The application treatments and their respective spray rates, $D_{V0.5}$ and DSC, are shown in table 1. The volume median diameter, $D_{V0.5}$, is the diameter

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Table 1. Aerial application treatment operation parameters and settings.

Treatment	Notation[a]	Deflector Angle	Airspeed. km/h (mile/h)	Spray Rate, L/ha (gal/acre)	$D_{V0.5}$, µm	DSC[b]
1	HVF	90°	241 (150)	94 (10)	175	VF
2	HMD	30°	177 (110)	94 (10)	350	M
3	MVF	90°	241 (150)	47 (5)	175	VF
4	MMD	30°	177 (110)	47 (5)	350	M
5	LVF	90°	241 (150)	19 (3)	175	VF
6	LMD	30°	177 (110)	19 (3)	350	M

[a] The notation column denotes the three letter notation that will be use throughout the manuscript, the first letter refers to the spray rate (H − high, 94L/ha; M − middle, 47 L/ha; and L − low, 19 L/ha) and the second letter refers to the droplet size spectrum (VF − very fine; and MD − medium)

[b] Defined by ASAE S572 AUG99 Droplet Spectra Classification; VF − very fine and M − medium. All treatments applied with CP−03 (CP Products Inc., Tempe, Ariz.) with 3.18-mm (0.125-in.) orifice and a spray pressure of 276 kPa (40 psi).

of droplet such that 50% of the total volume of droplets is in droplets of smaller diameter. The $D_{V0.5}$ for each treatment was determined using the Aerial Applicators Spray Nozzle Handbook (USDA-ARS AH-726) and the nozzle and aircraft operating parameters. The treatments were applied with an Air Tractor AT-402B (Air Tractor, Inc., Olney, Tex.).

At each field location, treatments were arranged within the location as a randomized complete block design with three replications, resulting in three blocks each with six plots corresponding to a different treatment. Within field blocking was included to accommodate cooperators post harvest studies and not as a result of any expected sources that would result in varying deposition amounts within the field. Individual treatment plots ranged from 1 to 3 ha depending on application site. Location 1 (Hunter, N.D.) plot sizes were 250 × 75 m (1.9 ha) and were sprayed with five 250- × 15-m swaths. Location 2 (Crookston, Minn.) plot sizes were 250 × 45 m (1.4 ha) and were sprayed with three 250- × 15-m swaths. Location 3 (St. Thomas, N.D.) plot sizes were 400 × 75 m (3 ha) and were sprayed with five 400- × 15-m swaths.

Spray performance variables were documented based on ASAE Standards S327.2 and S572 (2004). These standards define $D_{V0.5}$, Droplet Spectra Classification (DSC), and other pertinent spray parameters. All treatments were applied with CP-03 nozzles (CP Products Company, Tempe, Ariz.) with varying orifice and deflector settings. Water-based spray mixtures contained equal per-hectare rates of the colorimetric tracer, FD&C Blue #1 food grade dye (50 g/ha). Weather parameters were monitored and recorded during all spray applications with a Gill 27005 Anemometer (R. M. Young Company, Traverse City, Mich.), Young 43372VC Relative Humidity and Temperature Probe (R. M. Young Company, Traverse City, Mich.), and a Campbell 21-X data logger (Campbell Scientific, Inc., Logan City, Utah). Recorded meteorological data is reported in table 2 as averages and standard deviations over all three reps of a given treatment within each field.

Data Collection, Processing, and Analysis

As deposition under an aircraft can vary both across the swath and along the flight path as a function of aircraft position and spatial variation in the meteorological conditions, sampling locations in this study were selected to account for this variation as much as possible. The number of samples taken was maximized based on the available manpower, flight-time limitations, physical limitations of sampling equipment, and ability to process samples in a timely manner.

To avoid cross contamination between plots, sampling was done only in the center swath for each plot (i.e. swath #3 for field's 1 and 3 and swath #2 for field 2). Two sampling sites (A & B) (fig. 1) were located 50 m from each edge of each treatment plot. Artificial samplers were placed at each sampling site in five equally spaced sub-stations across the center of the aircraft immediately prior to spray application.

Table 2. Weather conditions for the three field studies.

Field	Treatment	Wind Velocity, Average (m/s)	Wind Velocity, Standard Deviation (m/s)	Temperature, Average (°C)	Temperature, Standard Deviation (°C)	Relative Humidity, Average (%)	Relative Humidity, Standard Deviation (%)
1	1	3.5	0.8	17.4	0.4	71.4	1.4
1	2	4.1	0.9	17.4	0.5	70.0	1.9
1	3	4.9	0.3	18.4	0.3	67.3	1.3
1	4	3.4	0.1	17.4	0.2	70.2	0.8
1	5	3.1	0.6	18.1	0.3	65.8	2.1
1	6	3.0	0.3	19.5	0.9	62.9	1.4
2	1	3.9	0.6	20.1	0.3	66.5	1.2
2	2	3.9	0.9	20.0	0.5	68.0	1.1
2	3	4.1	1.2	19.8	0.4	68.5	1.5
2	4	4.3	1.5	18.5	0.1	70.2	0.9
2	5	4.8	0.2	17.8	0.3	72.3	1.6
2	6	4.8	0.6	17.5	0.2	73.4	1.9
3	1	3.9	0.2	17.1	0.1	79.7	0.7
3	2	4.9	0.4	17.1	0.2	80.7	0.5
3	3	5.0	0.3	18.1	0.1	75.9	0.7
3	4	4.2	0.2	17.9	0.1	75.7	0.5
3	5	3.8	0.4	18.2	0.1	74.6	0.7
3	6	4.3	0.8	18.1	0.1	77.5	0.7

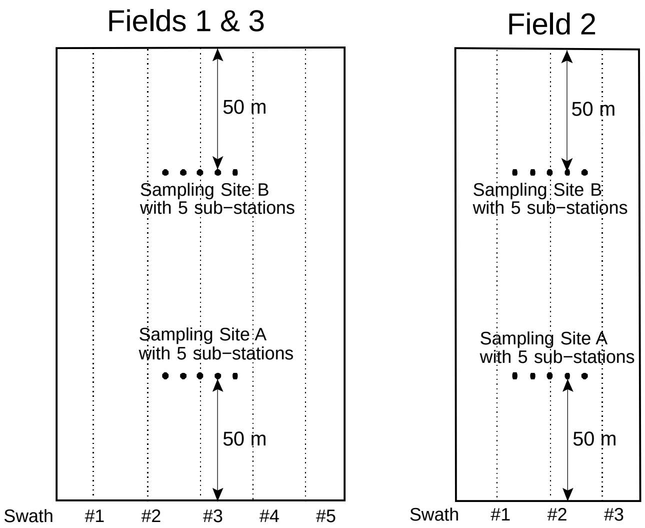

Figure 1. Layout of sampling locations within three different wheat fields.

Artificial samplers at each sub-station consisted of a mylar plate (100 × 100 mm), soda straws (200- × 5-mm diameter), and a water sensitive paper (WSP) (26 × 76 mm). Mylar plate samplers were included to provide a standard measurement at all three field locations (given that wheat head and plants structure, and thus their sampling efficiency varied from field to field) as well as to include a standard sampling method that is used by many researchers to allow for comparisons with any future work. Soda straws samplers were included in an attempt to mimic wheat head sampling performance. At each sub-station, a mylar plate and one WSP was oriented horizontally at the top of the crop canopy and three soda straws were inclined at 45° to vertical and were also placed at the top of the canopy (fig. 2). At two of the sub-stations, a WSP sample, rolled into a cylindrical shape (50- × 7-mm diameter) to simulate a wheat head, was placed vertically at the top of the canopy.

Immediately after spray application the artificial samplers and wheat heads were collected and placed in labeled plastic bags. All soda straws at each sampling site were combined and bagged as one sample. Wheat head samples, comprised of ten randomly chosen heads, were collected at each of the five sub-stations at locations A and B. Mylar samples as each sub-station were collected and bagged individually. For each plot there were two soda straw samples (one each from site A and B), ten mylar samples (five from each site A and B), ten wheat head samples (five from each site A and B), ten horizontal WSP samples (five from each site A and B), and four vertical WSP samples (two from each site A and B). The vertical WSP samples were WSP that had been rolled (longwise) into cylinders, and are here after referred to as vertical WSP. All samples were labeled with location, treatment, replication, sample, and sub-sample information. Samples were placed into insulated coolers immediately after collection for transport to the laboratory for analysis.

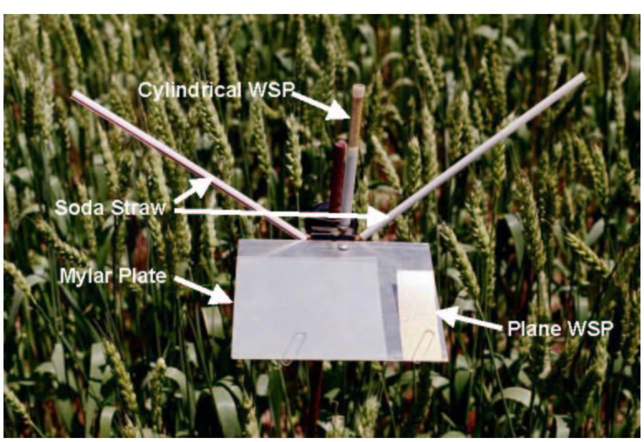

Figure 2. Artificial samplers located at each sampling.

Mylar plate, soda straw, and wheat head samples were washed in 20 to 40 mL of ethanol in the collection bags. Samples were agitated briefly to allow time for dye to dissolve into ethanol solution. Previous testing has shown that this methodology results in near total recovery of dye deposited on samples. A sample portion of the wash effluent was placed in a 12- × 75-mm borosilicate glass culture tube and colorimetric dye concentrations were obtained with a Pharmacia Ultrospec III spectrophotometer (Pharmacia LKB Biochrom Ltd., Cambridge, England). Spray deposits were quantified by comparison with similarly determined dye concentrations from spray tank samples and areas of the respective samples. Following washing, projected areas of the wheat head samples were determined with a LI-3100 Area Meter (LI-COR, Inc., Lincoln, Nebr.). The data quantifications were expressed as quantity of dye (μg) deposited per unit area of the sample (cm^2). It is important to note that throughout the text whenever the terms 'deposits' or 'deposition' are used they refer to mass of dye (which would correspond to amount of active ingredient), not mass of total spray mix, deposited on specified sampling surface.

The WSP samples were processed with computerized image analysis (IMAQ Vision Builder v5, National Instruments, Austin, Tex.) to determine droplet stain density and stain size. Stain size, stain diameter, and minimum stain dimension were determined in two 0.75-cm^2 sample areas on each card. Each stain in the sample area was converted to droplet diameter with an experimentally determined spread factor ($0.54 \times$ stain diameter $- 8.5 \times 10^{-5} \times$ stain diameter^2). The cylindrical WSP cards were flattened and the sample areas were selected from the part of the card with the highest droplet density. Based on observations in the field, this was the upwind side of the vertical WSP. Droplet size was subsequently determined for each WSP card.

Analysis of deposition data on wheat heads, mylar plates, and soda straws was completed in SAS using PROC MIXED (SAS, 2001). Wind speed, temperature, and relative humidity data corresponding to treatments within each field were included as covariates in the analysis. For each set of sampler specific data, analysis of variation in dye deposition was completed with field location, droplet size, spray rate, and droplet size by spray rate interaction as fixed effects. Random effects included replication within location, replication, replication by droplet size by spray rate interaction, sample site within replication, and sub-sample within sample location and replication. The blocks within field were not treated as blocks but as replications, as there were no expected sources of variation within each field location that would contribute to variation in the deposition data. Additionally, droplet size, spray rate, droplet size spray rate interaction were replaced with treatment effect (i.e. treatment 1, treatment 2 ... treatment 6) with each treatment being a combination of spray rate and droplet size as given by table 1. Deposition data for each sampling media were then analyzed by field location with analysis similar to that previously listed. The individual analysis for each field location was performed to benefit the cooperators who had separate follow-up studies at each location.

RESULTS

DEPOSITION ON WATER SENSITIVE PAPER

The major objective of the WSP was assessment of droplet size for treatments at each location. Examining the data over all locations indicates that target conditions were well met (tables 3-6). Treatments based on a $D_{V0.5}$ of 175 µm resulted in overall measured $D_{V0.5}$'s on the horizontally placed WSP ranging from 174 to 215 µm. Treatments based on a $D_{V0.5}$ of 350 µµm, resulted in overall measured $D_{V0.5}$'s on the horizontally placed WSP ranging from 306 to 363 µm. Overall measured $D_{V0.5}$'s on the vertical WSP ranged from 151 to 159 µm for the 175-µm treatments and 245 to 261 µm for the 350-µm treatments. The vertical WSP had lower measured $D_{V0.5}$'s, as compared to the horizontal WSP (seen in previous study by Kirk et al., 2004) as a result of the vertical orientation combined with the narrow cylindrical shape which will collect smaller, suspended droplets by impaction versus horizontal collectors which sample larger settling droplets by deposition. Another visual result from the vertical WSP was that droplet deposition only occurred on the upwind side. This result would also be true for the wheat heads and for the soda straws, though no additional assessments were done. Droplet sizing data from the individual fields follow similar trends. WSP samples from treatment in location 2 were unreadable due to slight precipitation that lasted only a few minutes.

DEPOSITS ON WHEAT HEADS

There was a significant field location effect on deposition (mass of tracer applied at same rate per acre for all treatments not volume of spray) on the wheat head samples (P = 0.0062) [the probability (p) that the association seen in the data would have been seen by chance] while droplet size (P = 0.7854), spray rate (P = 0.8118), and droplet size spray rate interaction (P = 0.6585) effects were non-significant (table 7). Wheat head deposition means for locations 1 and 2 were not significantly different from each other but were significantly less than the wheat head deposition mean from location 3. Location 3 wheat heads had higher deposition amounts as a result of longer awns (approx. 6.5 vs. 4.5 cm) which resulted in greater collection efficiency of the spray droplets without a significant increase in leaf area. The same results hold when size and rate main effects and interactions are replaced by with treatment effect, the treatment effect was non-significant (P = 0.9162) while the field location (P = 0.0062) was significant (table 8).

Examining the deposition on the wheat heads for each separate location shows no significant effects from droplet size (P = 0.6046), spray rate (P = 0.1316), or droplet size by spray rate interaction (P = 0.8938) at location 1 (table 9). Additionally, treatment effects at location 1 were non-significant (P = 0.4218) (table 10). At location 2, droplet size (P < 0.0001), spray rate (P < 0.0001), and droplet size by spray rate interaction (P < 0.0001) were all highly significant (table 11). The interaction effect was significant but graphical analysis did not provide any obvious patterns or practical explanation for the interaction. Examination of the raw field data did not reveal any significant outliers or inconsistencies that would contribute to the interaction significance. This was true for all significant interactions in this study. A $D_{V0.5}$ of 350 µm resulted in greater deposition than a $D_{V0.5}$ of 175 µm, while 47 L/ha resulted in greater deposition than 19 or 94 L/ha. Looking at treatment effects (table 12), which were also highly significant (P < 0.0001), treatments MVF, MMD, and LMD resulted in significantly greater deposits than the others. At location 3, only rate was significant (P = 0.0460) (table 13). Spray rates of 19 and 47 L/ha resulted in the

Table 3. Aerial spray deposit parameters for composite (over all three locations) data for Water Sensitive Paper (WSP) samples horizontally and vertically oriented above canopy.

Treatment	Droplet Size, $D_{V0.5}$, µm	
	Horizontal WSP	Vertical WSP
HVF	174	151
HMD	346	260
MVF	215	159
MMD	306	245
LVF	181	159
LMD	363	261

Table 4. Aerial spray deposit parameters for location 1 (Hunter, N.D.) Water Sensitive Paper (WSP) samples horizontally and vertically oriented above canopy.

Treatment	Droplet Size, $D_{V0.5}$, µm	
	Horizontal WSP	Vertical WSP
HVF	168	156
HMD	340	244
MVF	226	162
MMD	270	216
LVF	166	161
LMD	325	231

Table 5. Aerial spray deposit parameters for location 2 (Crookston, Minn.) Water Sensitive Paper (WSP) samples horizontally and vertically oriented above canopy.

Treatment	Droplet Size, $D_{V0.5}$, µm	
	Horizontal WSP	Vertical WSP
HVF	166	162
HMD	397	264
MVF	186	158
MMD	271	317
LVF	---	---
LMD	294	386

Table 6. Aerial spray deposit parameters for location 3 (St. Thomas, N.D.) Water Sensitive Paper (WSP) samples horizontally and vertically oriented above canopy.

Treatment	Droplet Size, $D_{V0.5}$, µm	
	Horizontal WSP	Vertical WSP
HVF	187	137
HMD	300	268
MVF	231	157
MMD	365	268
LVF	196	157
LMD	409	280

Table 7. Statistical results (P values) from testing for main effects of location, droplet size, spray rate, and droplet size by spray rate interaction for mean deposition on wheat head, mylar, and soda straw samplers.[a]

Src. Var.	Sampler: Wheat Head	Mylar	Soda Straw
Location	** 0.0062 3 2 1	0.1317	0.1425
Size	0.7854	* 0.0145 350 175	0.9823
Rate	0.8118	*** 0.0001 19 47 94	****0.061 19 47 94
Size*Rate	0.6585	0.2438	0.3090

[a] * Significant at the $\alpha = 0.001$ level
** Significant at the $\alpha = 0.01$ level
*** Significant at the $\alpha = 0.05$ level
**** Significant at $\alpha = 0.10$ level.
For significant main effects, factors are listed in order of decreasing dye deposition means. Factor levels joined by underline are not significantly different based on Duncan's multiple range test (p = 0.05) (Harter, 1960).

greatest deposition. Treatment effect was significant at the $\alpha = 0.10$ level (P = 0.0670) with treatments LVF and MMD resulting in the greatest deposits (table 14). Based on the wheat head samples alone, the recommended treatments for maximum deposition are 19 and 47 L/ha with a droplet $D_{V0.5}$ of 350 µm.

Deposits on Mylar Samplers

The mylar and soda straw samplers were included in the experiment as a means of providing consistent data from location to location, as well as providing a check to insure that applications were consistent from location to location, versus the wheat heads which vary in size and structure resulting in significant location effects, as shown earlier. The

Table 8. Statistical results (P values) from testing for main effects of location and treatment for mean deposition on wheat head, mylar, and soda straw samplers.[a]

Src. Var.	Sampler: Wheat Head	Mylar	Soda Straw
Location	**(P = 0.0062) 3 2 1	(P = 0.1317)	(P = 0.1425)
Treatment	(P = 0.9162)	**(P =0.0005) MMD LMD LVF MVF HMD HVF	(P = 0.1644)

[a] Follows same pattern as indicated in footnote for table 7.

Table 9. Statistical results (P values) from testing for main effects of droplet size, spray rate, and droplet size by spray rate interaction for mean deposition on wheat head, mylar, and soda straw samplers at location 1.[a]

Src. Var.	Sampler: Wheat Head	Mylar	Soda Straw
Size	0.6046	0.2490	0.8544
Rate	0.1316	***0.0001 19 47 94	0.9453
Size*Rate	0.8938	0.5375	*0.0406

[a] Follows same pattern as indicated in footnote for table 7.

Table 10. Statistical results (P values) from testing for main effects of treatment for mean deposition on wheat head, mylar, and soda straw samplers at location 1.[a]

Src. Var.	Sampler: Wheat Head	Mylar	Soda Straw
Treatment	0.4218	** 0.0004 LMD LVF MMD MVF HMD HVF	0.1954

[a] Follows same pattern as indicated in footnote for table 7.

Table 11. Statistical results (P values) from testing for main effects of droplet size, spray rate, and droplet size by spray rate interaction for mean deposition on wheat head, mylar, and soda straw samplers at location 2.[a]

Src. Var.	Sampler: Wheat Head	Mylar	Soda Straw
Size	***<0.0001 350 175	**0.0004 350 175	0.2444
Rate	***<0.0001 47 19 94	***0.0001 47 19 94	0.3630
Size*Rate	***<0.0001	* 0.0362	* 0.0426

[a] Follows same pattern as indicated in footnote for table 7.

Table 12. Statistical results (P values) from testing for main effects of treatment for mean deposition on wheat head, mylar, and soda straw samplers at location 2.[a]

Src. Var.	Sampler: Wheat Head	Sampler: Mylar	Sampler: Soda Straw
Treatment	MVF MMD LMD HVF HMD LVF	MMD LMD HVF HMD HVF LVF	LMD MVF MMD HVF HMD LVF

[a] Follows same pattern as indicated in footnote for table 7.

Table 13. Statistical results (P values) from testing for main effects of droplet size, spray rate, and droplet size by spray rate interaction for mean deposition on wheat head, mylar, and soda straw samplers at location 3.[a]

Src. Var.	Sampler: Wheat Head	Sampler: Mylar	Sampler: Soda Straw
Size	0.8689	0.6772	* 0.0435 175 350
Rate	* 0.0460 19 47 94	* 0.0432 19 47 94	** 0.0016 19 47 94
Size*Rate	0.0897	* 0.0201	*** 0.0007

[a] Follows same pattern as indicated in footnote for table 7.

Table 14. Statistical results (P values) from testing for main effects of treatment for mean deposition on wheat head, mylar, and soda straw samplers at location 3.[a]

Src. Var.	Sampler: Wheat Head	Sampler: Mylar	Sampler: Soda Straw
Treatment	****0.0670 LVF MMD LMD HMD MVF HVF	0.3743	*** 0.0001 LVF MMD MVF LMD HMD HVF

[a] Follows same pattern as indicated in footnote for table 7.

location effect (P = 0.1317) was not a significant factor affecting deposition (mass of tracer applied at same rate per acre for all treatments not volume of spray) on the mylar samplers (table 7). For the mylar plate samples, droplet size (P = 0.0145) and spray rate (P = 0.0001) were significant effects, while droplet size spray rate interaction was non-significant (P = 0.2438) (table 7). A $D_{V0.5}$ of 350 µm resulted in significantly more deposition than a $D_{V0.5}$ of 175 µm (which is expected for a flat plate sampler), and spray rates of 19 and 47 L/ha (not sig. dif.) resulted in significantly greater deposition than 94 L/ha. Treatment effect was also significant (P = 0.0005) with treatments MMD, LVF, and LMD resulting in the greatest deposition (table 8).

Though location effect was not significant and a separate analysis of mylar deposits by location is not required, doing so assists cooperators with their individual studies as well as providing further insight. At location 1, only spray rate was significant (P < 0.0001) with 19 L/ha resulting in significantly greater deposits than 47 L/ha which provided significantly greater deposits than 94 L/ha (table 9). Treatment effect was also significant with treatments LMD, LVF, and MMD resulting in the greatest deposition (table 10). At location 2, droplet size (P = 0.0004), spray rate (P = 0.0001), and droplet size spray rate interaction (P = 0.0362) were all significant (table 11). A spray rate of 47 L/ha resulted in significantly greater deposits than 19 or 94 L/ha (which were not significantly different). A $D_{V0.5}$ of 350 µm resulted in significantly greater deposits that a $D_{V0.5}$ of 175 µm. Treatment effect was also significant (P = 0.0003) with treatment MMD resulting in the greatest deposits (table 12). At location 3, spray rate (P = 0.0432) and droplet size spray rate interaction (P = 0.0201) were both significant (table 13). Spray rates of 19 and 47 L/ha (not significantly different) resulted in significantly greater deposits than 94 L/ha. Treatment effect (P = 0.3743) was not significant (table 14). Based on the mylar samples alone the recommended spray treatment would be lower spray rates, 19 to 47 L/ha, with larger droplets, $D_{V0.5}$ of 350 µm.

Deposits on Soda Straw Samplers

The location effect (P = 0.1425) was not a significant effect on deposits on the soda straw samplers (table 7). Overall, (at the α = 0.10 level) only spray rate was a significant factor (P = 0.0610) with spray rates of 19 and 47 L/ha resulting in the greatest deposition (mass of tracer applied at same rate per acre for all treatments not volume of spray) (table 7). Treatment effect was also non-significant (P = 0.1644) (table 8). Like the mylar samples, looking at the individual field locations provides further data for the cooperators individual studies. At location 1, only the droplet size spray rate interaction effect (P = 0.0406) was significant (table 9). Treatment effect at location 1 was non-significant (P = 0.1954) (table 10). At location 2, again only the droplet size spray rate interaction effect (P = 0.0426) was significant (table 11). Treatment effect was significant (at the α = 0.10 level) (P = 0.0861) with treatments LMD, MVF, and MMD resulting the greatest deposition (table 12). At location 3, droplet size (P = 0.0435), spray rate (P = 0.0016) and droplet size spray rate interaction (P = 0.0007) were all significant (table 13). Spray rates of 19 and 47 L/ha (not significantly different) resulted in significantly greater deposits than a rate of 94 L/ha. A $D_{V0.5}$ of 175 µm resulted in significantly greater deposits that a $D_{V0.5}$ of 350 µm. Treatment effect (P = 0.0001) was significant with treatment LVF resulting in the greatest deposition at location 3 (table 14). Based on the soda straw samplers, the recommended treatment would be a spray rate of 47 L/ha with a droplet $D_{V0.5}$ of 175 µm.

DISCUSSION

As noted in the previous discussion of optimization studies, the ultimate spray target must be considered when optimizing application parameters for increased deposition. The results of this study seem to counter what one would expect based on physical laws. One would expect that as spray rate or droplet size increases, total deposition volume under the aircraft (deposition on and in crop canopy and ground surface) would increase, which, while not measured in this study, is true. It should be noted that while spray rate volume increases, the active ingredient or tracer rate (assuming it is mixed at the same per area basis, as in this study) does not increase, and should therefore result in the same total amount of active ingredient or tracer being deposited under the aircraft. The results presented herein are not meant to indicate that lower sprays rates increase total tracer deposits under the aircraft as compared to larger spray rates. This study was aimed at determining the combination of spray rate and drop size that resulted in maximum tracer deposition on the wheat heads. While neither drift nor within canopy and ground deposition were measured, it can be concluded that, for each of the treatments, the portion of spray not intercepted and collected by the wheat heads was collected by remaining the canopy structure and ground interception or was lost to drift.

CONCLUSIONS

This study looked to optimize aerial application technologies to enhance deposition on wheat heads. Six treatments based on three spray rates (19, 47, and 94 L/ha) and two droplet size spectra ($D_{V0.5}$ of 175 and 350 µm) were examined. Wheat heads as well as artificial samplers were used to assess spray tracer deposits. WSP samples, which collected droplet size information, showed that application treatments did in fact meet targeted droplet spectrums. Results from wheat head and mylar samplers indicated that lower spray rates (19 to 47 L/ha) and a larger median droplet size (350 µm) resulted in significantly greater deposits than other treatment combinations. Soda straw sampler results had the greatest deposits as a result of a medium spray rate (47 L/ha) across both sizes (as size effect was only significant in field 3) which was similar to wheat heads.

It is important to note that greater deposition does not always translate to greater efficacy as other factors such as coverage uniformity may play a critical role depending on crop type and targeted pest. Based on the results of this study, the combination of lower spray rates (19 to 47 L/ha) with a mean droplet size of 350 µm resulted in maximum deposition of aerially applied sprays on wheat heads.

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