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A Comparison of an Unhooded and Hooded Sprayer for Pesticide Drift Reduction

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Abstract— **Management of drift from pesticide applications is important for human and environmental health concerns. It is also necessary to ensure adequate dosage of the pesticide meets the target species(s). A variety of factors can affect the drift potential of a pesticide application, including nozzle selection, solution chemistry, and application equipment. In the present study, a comparison of two ground sprayers, one with a hood and one without a hood, is made using three common ground nozzles in the US. The hooded sprayer reduced the drift potential of the pesticide application for all nozzles tested. In addition, higher spray coverage under the boom was measured when using the hooded sprayer. The results of this study indicate that incorporating a hood will lead to reduced drift potential from a pesticide application.**

Index Terms—**Drift reduction technologies, hooded sprayer, pesticide drift**

I. INTRODUCTION

MANAGEMENT of pesticide drift from ground applications is necessary to help reduce risks associated with human and environmental exposure. In the US, pesticides serve as a major component of crop production. In 2012, herbicides, insecticides, and fungicides were applied to 98, 18, and 11 percent of soybean acreage, respectively, with the most commonly applied herbicide being glyphosate [1]. The benefits of pesticide use is well documented in regards to productivity increases; however, the combination of rising input prices [2], weed resistance management [3], and government regulations regarding drift reduction techniques [4] are causing growers to reevaluate pesticide application methods. With respect to pesticide drift, growers are faced with unwanted damage to sensitive species, complaints, legal ramifications, and profit loss [5]. A key aspect of government regulations regarding drift reduction will be field evaluations of the proposed method or technology.

Assessing drift reduction technologies (DRTs) in a field environment is critical for establishing the DRTs potential, labeling requirements, and potential for crop injury. Over the years, the knowledge gained from such studies has been used to develop computer modeling programs for evaluating the potential for pesticide drift, especially those from aerial applications [6]. The use of wind tunnels is another option for drift assessment; however, evaluating the drift from ground based applications in a low speed wind tunnel is an on-going area of development [7]. When the proposed DRT consists of sprayer modification, e.g. hooded sprayer, the upcoming US EPA regulations will most likely require a field evaluation to be performed [8].

Using hooded sprayers during ground applications has the potential to minimize pesticide drift, especially when combined with other DRTs, e.g. drift retardant adjuvants or low drift nozzles. Reference [9] demonstrated the capacity of using a simple hood and curtain to reduce spray drift over a conventional spray boom. For this study, a spray solution of water soluble dye through a single nozzle design reduced downwind drift up to 275% over the open boom design. In a wind tunnel study, two hooded sprayer designs (a double foil and triple foil shield) reduced drift up to 76% when measured using collection cans under the sprayer, and these results were dependent upon nozzle orifice size and spray pressure [10]. A study involving a variety of hooded sprayer designs and nozzle setups further demonstrate the potential for hoods to reduce spray drift [11]. Shielded individual nozzles proved successful for reducing spray drift in wind speeds up to 30 km/h [12], although this approach would limit the user from easily switching nozzles which is important for custom application businesses.

In the current market of increasing input prices and government regulations regarding pesticide applications, growers will need effective methods for drift reduction. While multiple DRTs exist, and combinations thereof will likely provide the greatest drift reducing potential, it is likely growers will look towards efficient approaches that provide consistent performance. With this in mind, the objective of the current research was to evaluate the drift reduction potential of a newly designed hooded sprayer system versus an unhooded system in a field environment. The application procedures were developed to mimic those realized in a normal application scenario, specifically spray solutions, nozzle types, and weather conditions that are common to the Corn Belt of the US. The authors hypothesized that a combination of low-drift nozzles and a hooded sprayer would result in the greatest drift reduction over a flat fan nozzle in an unhooded sprayer. The data from this study can aid sprayer manufacturers and government bodies for developing and testing hooded sprayers for pesticide drift reduction.

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II. MATERIALS AND METHODS

A. *Field Location and Setup*

This experiment was conducted at the Dryland Research Farm in North Platte, NE (41.052342N, -100.746646W) in early fall of 2012 and late summer of 2013. For the trial conducted in 2012, the field site was a wheat stubble field, with stubble height being approximately eight inches. The field was gently sloped uphill towards the west, northwest. An area of 183 meters by 105 meters was designated as the experimental site within this field and encompassed the gentle uphill slope. For the trial conducted in 2013, the field site was a soybean field next to a wheat stubble field with soybean canopy height approximately six inches (growth stage V3) at the time of the experiment. The field was flat with no tall features (trees, buildings, etc.) within 100 meters in any direction. Similar to the 2012 trial, an area of 183 meters by 105 meters was designated as the experimental site within this field.

Prior to the time of the experiment, drift collection stations were placed in the experimental area. Twenty-seven stations were placed downwind of the application zone in three transects, with each transect serving as a replication in analysis of the data. In 2012, the collection media was plastic petri dishes (ø 150mm) placed at the top height of the wheat stubble (Fig. 1). The collection media for 2013 was plastic mylar cards (101 mm by 101 mm) (Fig. 2), and the decision to switch collection media was based on research that demonstrated a higher collection efficiency of mylar cards over petri dishes (unpublished data). The downwind collection stations in 2013 were placed into the adjacent wheat stubble field, and the collection height was set at eight inches. The application zone contained nine collection stations (in-swath stations), and one collection stations were placed upwind of the application zone (Fig. 3).

B. *Sprayer Description and Setup*

In order to discern the drift reduction capabilities of a hooded sprayer, two sprayers (Wilmar Manufacturing, Wilmar, MN) were employed for this study, the only difference being the inclusion of a hood or no hood. These sprayers were 9.1 meters in width and each had a1136 liter polyethylene tank. Spray delivery was accomplished via a hydraulic pump driven by the accompanying tractor. Each sprayer was connected to its own tractor via the three-point hitch system. Nozzle spacing was 51 cm, and the nozzle height was set at 91 cm above the ground level for both sprayers. The wind skirt on the hooded sprayer was set approximately two inches into the wheat or soybean canopy. The height for each sprayer was maintained throughout the study via the sprayers' guide wheels and the tractors' hitch system. The hooded sprayer design used in 2012 is shown in Fig. 4. The hood was constructed of molded, polymer plastic that surrounded the nozzles. The hood sections reached approximately 30.5 cm below the nozzle orifices, and a plastic curtain reached a further 10.2 cm below the plastic hood. During the trial in 2012, it was noticed that the design of the hood interfered with the spray plume of the nozzles, particularly those with an angled exit trajectory, e.g. the TTI nozzle (TeeJet Technologies, Wheaton, IL, USA). For this reason, the hood design was slightly modified for the 2013 trial, to widen the area underneath the nozzle orifices (Fig. 5). No interference of hood and nozzle plume was observed in the 2013 trial.

C. *Application Protocol*

The treatments for this experiment are listed in Table I. The spray solution consisted of Roundup PowerMax (540 g ae/L, Monsanto, St. Louis, MO) at a rate of 2.34 L ha^{-1}, Bronc AMS (Wilbur-Ellis, San Francisco, CA) at 5 % vol/vol, and rhodamine dye (intracid rhodamine WT, Cole Parmer Instrument Company) at 0.25 % vol/vol. The desired application rate was 94 L ha^{-1} for each treatment. Each nozzle was run at 44 psi and travel speed was 12.8 to 14.4 km h^{-1}. The volume median diameter for each spray is listed in Table I, and the data was collected at the University of Nebraska-Lincoln Pesticide Application Technology Laboratory using established techniques [12]. Just prior to an application, the petri dishes or mylar plates were placed on each collection station. The targeted wind velocity was between 8.04 to 24.1 km h^{-1} and +/- 30 ° of being perpendicular to the driveline before applying a treatment. The meteorological conditions were recorded by an on-site weather station with an accompanying data logger set to record temperature, wind speed, wind direction, and relative humidity. When necessary, the driveline and treatment zone was shifted to maintain the +/- 30 ° wind direction target. The weather data for each respective treatment is listed in Table II. A single application along the driveline was made for each treatment, and each treatment was repeated twice. All petri dishes or mylar plates were collected 5 minutes after the end of the application, placed into clean plastic bags, and placed into a container to prevent photodegredation of the dye. In 2013, water sensitive cards (52mm by 72mm, Spraying Systems Co., Wheaton, IL, USA) were placed in the driveline for each treatment to measure spray coverage. The cards were analyzed using DropletScan™ v2.5 (Lonoke, AR,USA).

D. *Collection Media Analysis Using Fluorometry*

The collection media were taken to a laboratory to extract and analyze dye concentration using fluorometry techniques. Reagent alcohol (Fisher Scientific, Fair Lawn, NJ) was diluted with distilled water to a final concentration of 50%. In 2012, 60 mL of this alcohol solution was added to each petri dish, in 20 mL increments, using a bottle top dispenser (Model 60000-BTR, LabSciences, Inc.). The rinsate was then decanted into a sterile polyethelyne bottle, and a 1 mL sample was drawn to fill a glass cuvette. In 2013, 60 milliliters of this alcohol solution was added to bag containing a mylar plate, in 20 mL increments, using the same bottle top dispenser. The bag was vigorously shaken to remove any dye from the mylar plate and 1 mL sample was drawn to fill a glass cuvette. Fluorescence data was collected using a fluorometer (Model T200, Turner

Designs) with a rhodamine/phycoerythrin module installed.

E. Statistical Analysis

The deposition rates were calculated as a percent of the applied rate, which was measured as the amount of spray deposited in the driveline for each treatment. The fluorescence of the 50% alcohol solution was measured and recorded to serve as the background signal for the fluorescence measurements. This value was subtracted from each reading, and the corrected value was used for statistical analysis. All data was subjected to ANOVA using PROC MIXED in SAS [14] with replication set as a random variable. Means were separated using a Tukey adjustment with alpha set to 0.10.

III. RESULTS

A. Pesticide deposition in 2012

The ambient air temperature and relative humidity were uniform throughout the experiment. The wind velocity and direction were within the targeted range, except Treatment 5. During this treatment, the wind velocity reached 37.3 km h^{-1}, the highest recorded wind velocity during the experiment. In addition, the wind direction shifted close to the 30 degree tolerance of being perpendicular to the drivelines which may partially explain the lack of drift reduction observed with the hooded sprayer for this nozzle.

Deposition data is presented in Table III. The sprayers are compared within each nozzle type. The TTI nozzle produced the lowest amount of downwind deposition, overall. This is to be expected because this nozzle produced the largest droplets from the three nozzles tested (Table 1). At all distances downwind, except four and eight meters, measured drift was higher for the hooded sprayer than the unhooded sprayer. This is likely a result of two determining factors. First, the wind velocity reached the highest recorded level for this treatment, and the average wind velocity was approximately 4.8 km h^{-1} higher than for Treatment 6. In addition, during the course of the experiment, it was observed that the spray plume from the TTI nozzle impacted the backside of the hood. While it is not understood why, it seems likely that the increased drift with the hood is due to this interference. The researchers speculate that this may be due to shattering droplets leading to decreased droplet sizes. Based on this observation, the hood's design was altered to accommodate spray nozzles with angled plumes for the 2013 experiment (Fig. 5).

Measured deposition was less than one percent when using the hooded sprayer and AIXR nozzles at all downwind distances. At four, eight, and 32 meters downwind, deposition was less using the hooded sprayer as compared to the unhooded sprayer. At the other distances, no differences between deposition of the hooded and open boom were observed. Wind velocity and the maximum recorded wind velocity were higher during the application using the hooded sprayer with AIXR nozzles than the unhooded sprayer with AIXR nozzles.

The XR nozzle produced the highest levels of downwind deposition in this experiment. At 4 and 8 meters downwind, measured deposition levels were 2.05 and 1.37 percent of the total volume applied, respectively, for the unhooded sprayer utilizing XR nozzles. These were the highest measured values in this experiment in 2012. At all measured downwind distances, deposition amounts for the hooded sprayer were either less than or similar to the open sprayer. When applied with a hooded sprayer, the measured deposition from the XR nozzle was similar to that of the hooded sprayers with the AIXR or TTI nozzles.

B. Pesticide Deposition in 2013

During the course of the experiment, the ambient air temperature rose 5 degrees, reaching a maximum of 27 °C for treatment six. Relative humidity decreased from 72 percent to 46 percent. The wind velocity and direction were within the targeted range for all treatments. The average wind speed was greatest for treatment two at 13.2 km h^{-1} and lowest for treatment 1at 11.2 km h^{-1}. The range of wind speed observed, and the maximum gust speeds, were within appropriate application guidelines for the pesticide label for all treatments.

Deposition data is presented in Table IV. Overall, the applications made using the hooded sprayer had the least amount of downwind deposition, regardless of nozzle type. When using the TTI nozzle, the inclusion of the hood decreased deposition at downwind distances of 45 and 105 meters. At the other distances, the deposition rate was similar to the unhooded sprayer. There was no measured deposition at 4,8, 16, 32, 45, and 105 meters when using the hooded sprayer and TTI nozzles.

Similar to the TTI nozzle, measured deposition was less than one-tenth of a percent when using the hooded sprayer and AIXR nozzles. For the majority of measured distances, deposition was less for the hooded sprayer than the unhooded sprayer. There was no measured drift at 8, 16, 32, 45, and 75 meters with the hooded sprayer and AIXR nozzle setup.

The XR nozzle again produced the highest levels of downwind deposition observed in this experiment in 2013. At the nearest five distances, the deposition rate of the hooded sprayer was less than that of the unhooded sprayer, and the deposition rates were similar between the two sprayers at the four furthest distances. As in 2012, the deposition rates for the hooded sprayer with the XR nozzles were similar to that of the hooded sprayers with the AIXR and TTI nozzles.

Percent coverage of the spray application was measured for each treatment using WSC (Fig. 6). The hooded sprayer had more coverage than the open sprayer, regardless of nozzle type. The treatment with the highest coverage was the hooded sprayer using the XR nozzle, while the treatment with the least coverage was the unhooded sprayer with the XR nozzle.

IV. CONCLUSION

The results of this experiment highlight the potential of utilizing a hooded sprayer design to minimize pesticide drift. From this experiment, the authors conclude:

- A hooded sprayer is capable of reducing pesticide drift, even when making an application with a “fine” spray quality
- The design of a hood should not interfere with the spray plume. If an interference occurs, the drift

potential is markedly increased

- Spray coverage was improved when using a hooded sprayer, as measured by WSC

It should be noted that none of the treatment resulted in zero downwind deposition at all measured distances in this experiment. When compared to an unhooded sprayer with XR nozzles, the percent reduction in deposition for the treatments ranged from 0 to 100 percent in 2012 and 2013; however, there were instances of a percent increase in measured deposition in both years even when using a hooded sprayer (Tables V and VI). This could be due to a number of reasons. It is possible a greater wake effect is produced by the hood leading to unstable air near the sprayer. Any droplets that escape the hood can be influenced by this stable air and pushed downwind. Future work involving different plant canopies and heights, as well as efficacy screens of weed species will help to further advance the potential of a hooded sprayer for use in row crop systems in the US.

V. ACKNOWLEDGMENTS

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Table I. List of treatments used in this experiment for both 2012 and 2013.

Treatment	Nozzle[a]	Boom	VMD[b]	Spray Classification[c]
1	XR11003	Hooded	203	Fine
2		Open		
3	AIXR11003	Hooded	428	Coarse
4		Open		
5	TTI11003	Hooded	704	Ultra Coarse
6		Open		

[a] Spraying Systems, Wheaton, IL

[b] Volume Median Diameter

[c] Spray classifications are defined using ASABE S572.1

Table II. Meteorological data for each treatment. Data was logged by an on-site weather station placed approximately 50 meters southwest of the application zone. The data logger recorded at 15 second intervals and data presented is average over the duration of the each treatment.

Treatment	Air temperature	Relative humidity	Wind speed[a]	Wind direction
	°C	%	Km h^{-1}	°
			2013	
1	22	72	11.2 (14)	17
2	27	47	13.2 (16.7)	25
3	23	65	13 (15.2)	33
4	27	46	12.2 (17.3)	12
5	22	69	13.8 (18.1)	30
6	27	46	11.9 (13.5)	45
			2012	
1	26	19.3	14.9 (20.1)	128
2	26	19.4	13 (18.7)	128
3	26	19.9	16.9 (25.4)	117
4	27	18.9	13 (20.7)	121
5	26	20.0	17.5 (37.3)	94
6	26	22.1	12.4 (26)	113

[a] Numbers listed in parentheses were observed maxima wind speed for each treatment

Table III. Deposition amounts determined as a percent of the applied rate for each nozzle tested in 2012. Differences in a nozzle by boom pair are noted in bold font.

Nozzle	Boom	Distance Downwind								
		4	8	16	32	45	60	75	90	105
		meters								
XR	Hooded	**0.35**	**0.29**	0.68	**0.03**	**0.03**	**0.03**	0.30	0.08	0.13
	Open	**2.05**	**1.37**	0.90	**1.05**	**0.27**	**0.34**	0.42	0.08	0.10
AIXR	Hooded	**0.21**	**0.14**	0.28	**0.08**	0.10	0.09	0.16	0.07	0.11
	Open	**0.66**	**0.74**	0.48	**0.41**	0.13	0.17	0.19	0.07	0.04
TTI	Hooded	0.18	0.07	**0.16**	**0.15**	**0.28**	**0.23**	**0.15**	**0.06**	**0.16**
	Open	0.14	0.10	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**

Table IV. Deposition amounts determined as a percent of the applied rate for each nozzle tested in 2013. Differences in a nozzle by boom pair are noted in bold font.

Nozzle	Boom	Distance Downwind								
		4	8	16	32	45	60	75	90	105
						meters				
XR	Hooded	**0.05**	**0.00**	**0.01**	**0.00**	**0.00**	0.00	0.02	0.00	0.06
	Open	**1.73**	**0.61**	**0.15**	**0.06**	**0.02**	0.04	0.04	0.02	0.05
AIXR	Hooded	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**	0.02	**0.00**	0.02	0.02
	Open	**0.86**	**0.30**	**0.10**	**0.03**	**0.04**	0.05	**0.06**	0.01	0.03
TTI	Hooded	0.00	0.00	0.00	0.00	**0.00**	0.06	0.01	0.02	**0.00**
	Open	0.04	0.02	0.08	0.00	**0.08**	0.08	0.09	0.01	**0.03**

Table V. Percent reduction in drift compared to the XR11003 flat fan nozzle with an open boom in 2012. Negative values represent an increase in drift.

Nozzle	Boom	Distance Downwind								
		4	8	16	32	45	60	75	90	105
						meters				
XR	Hooded	82.9	78.8	24.4	97.1	88.9	91.2	28.6	0.0	-30.0
	Open	0	0	0	0	0	0	0	0	0
AIXR	Hooded	89.8	89.8	68.9	92.4	63.0	73.5	61.9	12.5	-10.0
	Open	67.8	46.0	46.7	61.0	51.9	50.0	54.8	12.5	60.0
TTI	Hooded	91.2	94.9	82.2	85.7	-3.7	32.4	64.3	25.0	-60.0
	Open	93.2	92.7	96.7	100.0	100.0	100.0	100.0	87.5	100.0

Table VI. Percent reduction in drift compared to the XR11003 flat fan nozzle with an open boom in 2013. Negative values represent an increase in drift.

Nozzle	Boom	Distance Downwind								
		4	8	16	32	45	60	75	90	105
						meters				
XR	Hooded	97.1	100.0	93.3	100.0	100.0	100.0	50.0	100.0	-20.0
	Open	0	0	0	0	0	0	0	0	0
AIXR	Hooded	97.7	100.0	100.0	100.0	100.0	50.0	100.0	0.0	60.0
	Open	50.3	50.8	33.3	50.0	-100.0	-25.0	-50.0	50.0	40.0
TTI	Hooded	100.0	100.0	100.0	100.0	100.0	-50.0	75.0	0.0	100.0
	Open	97.7	96.7	46.7	100.0	-300.0	-100.0	-125.0	50.0	40.0

Fig. 1. A drift collection station used for the trial in 2013. A mylar cards is held in place by a paperclip on a metal platform, which is held up by a metal pole and clip. The mylar cards were placed at a level just above the wheat stubble.

Fig. 2. A drift collection station used for the trial in 2012. A petri dish is held in place by tape to a wooden platform, which is held up by a fiberglass pole and clip. The petri dishes were placed at a level just above the wheat stubble.

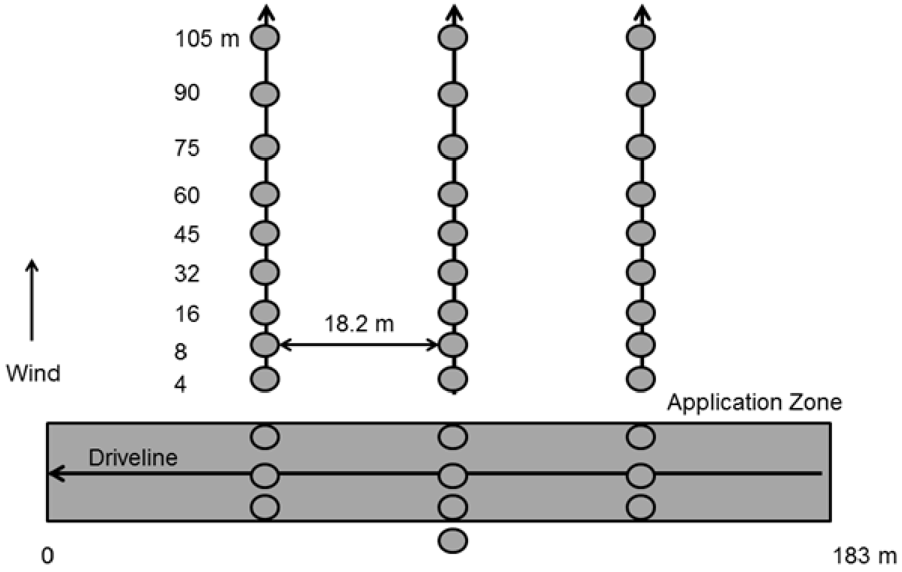

Fig. 3. Field layout used for this experiment. Each dot represents a collection station. Twenty-seven stations were placed downwind from the application zone at the designated distances. Nine stations were placed within the applications zone, and one station were placed upwind of the application zone.

Fig. 4. The hood design used in the 2012 trial. The hood consisted of molded plastic extending approximately 30.5 cm below the nozzle orifices, and the plastic curtain extended approximately 10.2 cm below the hood.

Fig. 5. The hood design used in the 2013 trial. The area under the hood was widened to decrease the chance of interference of the hood with the spray plume.

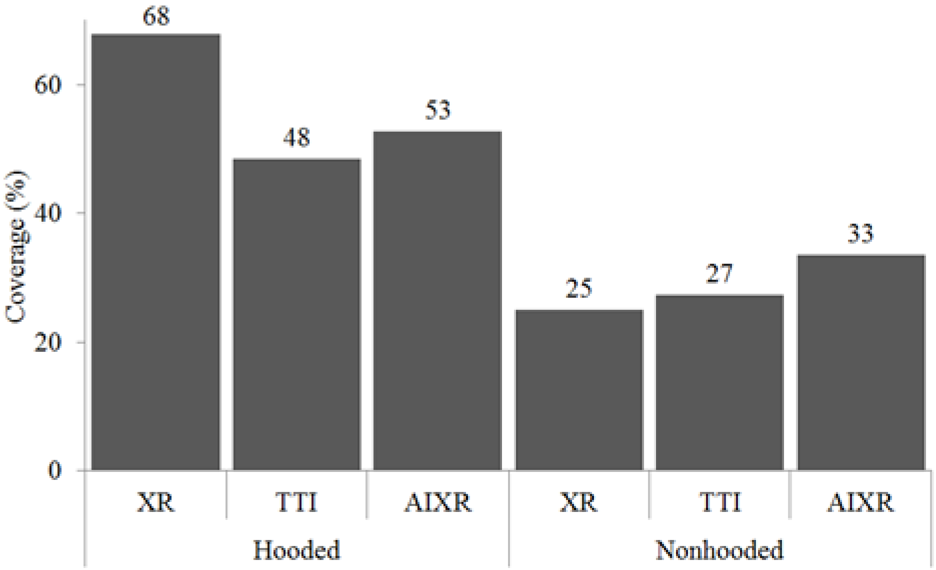

Fig. 6. Percent coverage using water sensitive cards (WSC) placed in swath. Each treatment contained three WSCs and the graphs are the average. The WSCs were evaluated using DropletScan v2.4