Off-target spray particle movement

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Abstract

BACKGROUND:

1 Introduction

Integrate pest management The off-target particle movement

The objective of this stu

2 Materials and Methods

2.1 Field study

Field experiments were conducted in three locations: North Platte, NE (geographic coordinates) on September 11-12/2021; Arlington, WI (geographic coordinates) on September 15-16/2021; and city, MO (geographic coordinates) on September 18-20/2021. Applications were made on bare ground, corn stubble (XX cm height) and ???? in NE, WI, and MO, respectively. The fields were flat and with no surrounding trees. Samples were processed and analyzed at the Pesticide Application Technology Laboratory of the University of Nebraska-Lincoln located in North Platte, Nebraska.

Three factors were evaluated: sprayer type, nozzle type, and spray solution. Each experimental treatment was replicated 10 times. Two sprayers (Manufacturer, city, state) 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 a 1130 L 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 boom height was set at 90 cm above the ground level for both sprayers. The wind skirt on the hooded sprayer was set slightly above the soil surface or corn stubble. The height for each sprayer was maintained throughout the study via the sprayers' guide wheels and the tractors' hitch system. The hood was constructed of molded, polymer plastic that surrounded the nozzles (Manufacturer, city, state). The hood sections reached approximately 30.5 cm below the nozzle orifices, and a plastic curtain reached a further 10 cm below the plastic hood. Nozzles were properly attached to the boom in order to get no interference of hood and nozzle plume.

Nozzle types were TTI11003 and AIXR11003 (Teejet Technologies, Wheaton, IL), and ULD12003 (Pentair, Minneapolis, MN). All nozzles have air inclusion features and the carrier volume was 140 L ha^-1 applied at 276 kPa operating pressure and 2.6 m s-1 application speed.

The spray solutions were prepared at the same day of applications and were water alone and water plus a drift-reducing adjuvant based on polyethylene glycol, choline chloride, and guar gum (IntactTM, Precision Laboratories, LLC, Waukegan, IL) at a rate of 0.5% v v-1. Additionally, a rhodamine fluorescent dye (Red Dye, Cole-Parmer, Vernon Hills, IL) was added to all solutions at a rate of 0.5% v v-1. The volumetric median diameter (VMD) of droplets and volume percentage of droplets finer than 200 µm (V200) were measured at the Pesticide Application Technology Laboratory using a Sympatec Helos-Vario K/R laser diffraction system (Sympatec Inc., Clausthal, Germany), setup with a R7 lens, with a dynamic size range of 9 to 1,800 µm. The distance from the nozzle tip to the laser was 0.3 m. The VMD and V200 for each combination spray solution versus nozzle type are listed in Table 1.

2.1.1 Application and field layout

Prior to the applications, 27 drift collection stations were placed downwind of the sprayed area in three transects (spaced by 7.6 m) and perpendicular to the spray line (Figure 1). For each transect, collectors were positioned at 1, 2, 3, 4, 8, 16, 31, 45, 60 m from the edge of the application zone. Additionally, three drift stations were placed 5 m upwind from the edge of the application zone and four petri dishes (150 mm diameter) were placed in-swath. All collectors were positioned 10 cm above the ground surface. Mylar cards (Grafix Plastics, Cleveland, OH) were used as drift collectors. Cards with dimensions of 10 x 10 cm were placed upwind and up to 31 m downwind, whereas cards with dimensions of 20 x 20 cm were placed at 45 and 60 m downwind.

Each replication was considered as one pass of the sprayer, equivalent to 828 m2 in total area (91 m length x 9.1 m wide). Before each pass, a new set of mylar cards and petri dishes were placed at the sampling points. Five minutes after the end of each application was performed, cards and petri dishes were collected and placed individually into pre-labeled plastic bags. All samples were carefully managed to avoid cross-contamination and stored into dark containers until further analysis in laboratory in order to prevent photodegradation of rhodamine dye. Samples were collected from the furthest to the nearest downwind distance. Different teams were designated to work at downwind, upwind, and in-swath zones, and gloves were changed between application passes.

The targeted wind velocity was between 3.6 to 6.7 m s-1 and ± 30° of being perpendicular to the driveline before applying a treatment. When necessary, the driveline and application zone was shifted to maintain the ± 30° wind direction target. Meteorological conditions (air temperature, and relative humidity, wind speed, wind direction) were collected at 2 m height and 1-min intervals using a HOBO RX3000 Weather Station (Onset Computer Co., Bourne, MA, USA) positioned upwind of the sprayed area. The wind speed and direction data were collected using 2D WindSonic anemometers (Gill Instruments, Lymington, UK). The meteorological data for each respective treatment is listed in Figure 2.

2.1.2 Dye quantification

Samples were taken to the laboratory for dye extraction and quantification using fluorometry technique. Distilled water was used as extraction solution added to each bag using a bottle top dispenser (LabSciences Inc., 60000-BTR, Reno, NV). Samples collected downwind were rinsed with 50 mL of distilled water, whereas samples collected upwind and in-swath were rinsed with 20 mL of distilled water. The samples were agitated for 15 s and then a 1.5 mL aliquot from each sample bag was drawn to fill a glass cuvette. The cuvette was placed in a rhodamine module inside a fluorometer (Trilogy 7200.000, Turner Designs, Sunnyvale, CA) using green light. Serial dilutions were performed upon each tank sample to generate calibration curves, which allowed the conversion of relative fluorescence unit into mg L-1 and further expressing data into ɳL cm-2.

2.2 Greenhouse study

A completely randomized design

2.3 Statistical analyses

The statistical analyses were conducted with R statistical software version 4.1.0.[1] Data analyses were performed with Bayesian inference with “brms” package.[2] Bayesian inference uses Markov chain Monte Carlo algorithms for sampling a probability distribution;[2] and avoids singular fit from frequentist linear models when using complex random effects.

2.3.1 Field study

Solution, sprayer and nozzle factors were grouped as a single fixed effect (herein treatments) due to missing factor water in Missouri. Resulting in a combination of 12 treatments.

2.3.1.1 Spray solution deposition at upwind and inswath Data was fitted to a mixed model using *brm* function. Treatments were the fixed effects and blocks nested within location random effects. Model family was gaussian and prior distribution was set to student-t with mean 0.5, standard deviation 3 and 11 degrees of freedom. The posterior summaries (mean and highest posterior density) were estimated with *emmeans* function from the “emmeans” package. Treatment means were compared using

Bayes Factor (BF).[3,4] In short, if BF > 1 there is evidence for H1 (difference between treatments); whereas, if H0 < 1 there is evidence for H0 (no difference between treatments). If BF = 1, there is no evidence. The level of evidence (anecdotal, moderate, strong, very strong, and extreme) varies as the BF value increases (evidence for H1) or decreases (evidence for H0).

2.3.1.2 Spray solution deposition at downwind Data was fitted to a Bayesian linear mixed model using *brm* function. Spray solution deposition and distance were log-transformed to meet linearity. A single model was fitted to each treatment. For each model, treatments and distance were the fixed effects and blocks nested within location random effects. Model family was gaussian and prior distribution was set to student-t with mean 0.5, standard deviation 3 and 11 degrees of freedom. For clarification, intercepts, slopes were back-transformed with *exponential* function. Moreover, the linear models fitted were used to predict the distance where no spray particle deposition was detected (0 ηL cm^{-2}) for each treatment, which was also back-transformed to m scale.

The area under the curve (AUC) was used to validate the linear models. The spray solution deposition across distances within an experimental unit were used to calculate the absolute AUC value. The AUC was performed with *audps* function from the "agricolae" package. The AUC is commonly used for plant disease progress[5,6] but has been used to calculate herbicide injury.[7] Data was fitted to a mixed model using *brm* function. Treatments were the fixed effects and blocks nested within location random effects. Model family was gaussian and prior distribution was set to student-t with mean 0.5, standard deviation 3 and 11 degrees of freedom. The posterior summaries and treatment means were estimated and compared using Bayes Factor (BF) as above-mentioned.

2.4 Greenouse study

The Dv(10,50,90), RS, and % drifable fines was fitted to a Bayesian linear mixed model using *brm* function. In the models, solution and nozzle were set as fixed effects. Model family was hurdle gamma and prior distribution was set to student-t with mean 0.5, standard deviation 1 and 2 degrees of freedom. For each response variable, two models were fitted: with and without interaction (solution and nozzle). A model comparison was made with **bayesfactor_models** from “bayestestR” package[8] to investigate interaction significance. For all response variables (Dvs, RS and % drifable fines), the best model was with interaction. The posterior summaries and treatment means were estimated and compared using Bayes Factor (BF) as above-mentioned.

3 Results

3.1 Spray solution deposition at inswath and upwind

In general, Open sprayer treatments resulted in a more variable spray particle deposition than Hood treatments (Figure 1). The inclusion of either DRA or Water strongly impacted spray particle deposition inswath for Open sprayer treatments, regardless nozzle type. The top and bottom three treatments contained either DRA or Water, respectively. For example, treatment DRA-Open-ULD resulted in the highest spray particle deposition (1318.5 ηL cm^{-2}, Figure 1). In contrast, 911.2 nL cm^{-2} was the lowest spray solution deposition, which was achieved with Water-Open-ULD treatment. Hood sprayer treatments resulted in a more uniform spray particle deposition. Furthermore, there were less than 0.29 ηL cm^{-2} spray deposition at upwind with strong evidence (BF < 0.25) of no difference between all pairwise treatment contrasts (data not shown).

3.2 Spray solution deposition at downwind

Treatments with highest intercepts, which is the amount of spray particle deposition near the treated area, were Water-Open-AIXR (15.7 ηL cm^{-2}), followed by DRA-Open-AIXR (15.7 ηL cm^{-2}), and Water-Open-ULD (12.0 ηL cm^{-2}; Figure 2). In contrast, DRA-Hood-TTI, DRA-Hood-ULD and DRA-Hood-AIXR treatments resulted in the lowest intercepts (< 2.0 ηL cm^{-2}). In addition, there is evidence that treatments with Hood sprayer provided faster decay of spray particle deposition (slopes; Figure 2). The treatments with highest slope decay were Water-Hood-TTI (-0.50), DRA-Hood-TTI (-0.48), DRA-Hood-ULD (-0.44), Water-Hood-AIXR (-0.43), Water-Hood-ULD (-0.43), and DRA-Hood-AIXR (-0.39).

The predicted distance where no spray particle deposition was detected varied upon treatments (Figure 3A). In general, Open sprayer treatments resulted in spray particle deposition at longest distances. For example, the distance of non-detectable spray particle deposition with Open sprayer treatments varied from 9.9 m (DRA-Open-TTI) to 54.9 m with DRA-Open-AIXR; whereas Hood sprayer treatments varied from 1.4 to 8.2 m with DRA-Hood-TTI and Water-Hood-AIXR, respectively.

Similar trend was observed in AUC. Treatments with Hood or Open sprayer strongly impacted on AUC values (Figure 3B). The highest AUC values were Water-Open-AIXR (87.4), followed by Water-Open-ULD (72.9) and DRA-Open-AIXR (72.6). In contrast, DRA-Hood-TTI (13.9), DRA-Hood-ULD (14.3) and Water-Open-AIXR (21.9) resulted in lowest AUC values. The impact of Open and Hood sprayer is demonstrated in treatments including AIXR nozzles. There is a high difference in AUC (50.7) between DRA-Open-AIXR vs DRA-Hood-AIXR (BF > 100). Moreover, addition of DRA did reduced AUC values when comparing within fixed factors, sprayer (Hood and Open) and nozzle (AIXR, TTI and ULD); however, addition of DRA were not statistically different for some contrasts, including DRA-Hood-TTI vs Water-Hood-TTI (BF = 0.91), DRA-Open-TTI vs Water-Open-TTI (BF = 0.55), and DRA-Open-AIXR vs Water-Open-AIXR (BF = 0.93).

3.3 Dv, Relative Span

4 Discussion

4.1 Spray solution deposition at inswath and upwind

4.2 Spray solution deposition at downwind

5 Conclusion

6 Acknowledgments

7 Conflict of Interest Declaration

8 Tables (each table complete with title and footnotes)

9 Figure Legends

References

1 R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria (2021).

2 Bürkner P-C, **Brms** : An *R* Package for Bayesian Multilevel Models Using *Stan*, *J Stat Soft* **80** (2017).

3 Lee MD and Wagenmakers E-J, Bayesian Cognitive Modeling: A Practical Course, Cambridge University Press (2014).

4 Kass RE and Raftery AE, Bayes Factors, *Journal of the American Statistical Association* **90**:773–795, [American Statistical Association, Taylor & Francis, Ltd.] (1995).

5 Meena PD, Chattopadhyay C, Meena SS, and Kumar A, Area under disease progress curve and apparent infection rate of Alternaria blight disease of Indian mustard (Brassica juncea) at different plant age, *Archives of Phytopathology and Plant Protection* **44**:684–693, Taylor & Francis (2011).

6 Simko I and Piepho H-P, The Area Under the Disease Progress Stairs: Calculation, Advantage, and Application, *Phytopathology®* **102**:381–389, Scientific Societies (2011).

7 Striegel S, Oliveira MC, Arneson N, Conley SP, Stoltenberg DE, and Werle R, Spray solution pH and soybean injury as influenced by synthetic auxin formulation and spray additives, *Weed Technol* **35**:113–127 (2021).

8 Makowski D, Ben-Shachar M, and Lüdecke D, bayestestR: Describing Effects and their Uncertainty, Existence and Significance within the Bayesian Framework, *JOSS* **4**:1541 (2019).