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Large Scale Evaluation of 2,4-D Choline Off-Target Movement and Injury in 2,4-D Susceptible Soybean[1]

Take Home Message

- Herbicide off-target movement via particle and vapor drift is a concern of growers adopting the novel auxin-resistant crops (i.e., Enlist E3, Roundup Ready Xtend).
- No soybean injury was observed at any distance downwind from the treated area, indicating that 2,4-D-susceptible soybean can indeed be considered a compatible crop if 2,4-D choline herbicide is applied according to label requirements.
- Particle drift was the main source of off-target movement (OTM) of 2,4-D choline, as higher 2,4-D concentration was detected by filter papers in the downwind direction, and it was reduced with increasing distance from the edge of the application. Furthermore, air concentrations were low in both upwind and downwind directions suggesting that vapor drift was not a primary source of 2,4-D choline off-target movement in this experiment.

Introduction

Products containing 2,4-D have been commonly utilized for burndown or POST control of more than 200 broadleaf weed species in labeled crops (e.g., corn (Zea mays L.), small grains, pasture, and turf; Aquino et al. 2007). Corteva™ Agriscience's Enlist™ crops are resistant to 2,4-D and glyphosate; the most recent generation of this technology, Enlist E3™, confers additional resistance to glufosinate in soybean (Glycine max [L.] Merr.; Nandula 2019; Wright et al. 2010). A survey conducted in the winter of 2020 with soybean growers and agronomists indicated that 14% of Wisconsin soybean acres managed by survey respondents would be planted with Enlist E3™ in 2020 and more than 80% of those acres would receive a POST application of 2,4-D choline, suggesting rapid adoption of the technology (Arneson and Werle 2020). The 2,4-D choline herbicides, Enlist One® with Colex-D® and Enlist Duo® with Colex-D® are labeled for use PRE without any plant back interval and POST up to full flowering (R2 growth stage) in Enlist E3 soybean. The Enlist One® and Enlist Duo® labels list 2,4-D-susceptible soybean as a compatible crop (Anonymous 2020b), therefore permitting applications of 2,4-D choline in 2,4-D-resistant soybean immediately adjacent to 2,4-D-susceptible soybean, regardless of wind direction.

Field Experiment Overview

In 2019 and 2020 the UW-Madison Cropping Systems Weed Science Lab conducted large-scale drift field experiments evaluating off-target movement of 2,4-D choline and its impact on adjacent 2,4-D-sensitive soybean.

Off-target Movement of Synthetic Auxins

Auxin herbicides can move off target through both particle and vapor drift which are influenced by meteorological conditions (Havens et al. 2018; Strachan et al. 2010). Typically, direct exposure to a sublethal dose of 2,4-D causes distinct soybean injury symptoms (e.g., epinasty and leaf strapping; Egan et al. 2014; Figure 1). Soybean injury from auxin herbicides is highly variable and is dependent on numerous factors, including soybean growth stage, cultivar selection, meteorological conditions, application parameters, active ingredient and the amount of active ingredient the plants are exposed to (Egan et al. 2014; Havens et al. 2018; Solomon and Bradley 2014). While the labels of 2,4-D choline products contain detailed application requirements to mitigate particle drift, including spray nozzles that produce coarse to ultra-coarse droplets ($>$326 mm), low wind speed conditions ($<$15 mi hr^{-1}) and absence of temperature inversion (Anonymous 2020), they don't necessarily address vapor drift. Research on the OTM potential of 2,4-D choline applied according to label requirements under large-scale field conditions is lacking and represents a major topic of interest to growers adopting this novel technology.

Figure 1. Soybean injury following 2,4-D exposure (notice leaf strapping). Photo credit: Marcelo Zimmer, Purdue University.

Objective

- Evaluate off-target movement (OTM) of 2,4-D choline by means of particle deposition during application, 2,4-D concentration in the air (0.5-48 hr following application), and subsequent injury to neighboring 2,4-D susceptible soybean.

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[1] Access the journal publication: https://doi.org/10.1017/wet.2021.62

Materials and Methods (Technical Description)

A large-scale drift experiment was established near Sun Prairie, WI and Arlington, WI in 2019 and 2020, respectively. A 2,4-D choline-resistant soybean variety was planted in the center of the field (7 ac), while the area surrounding (>23 ac) was planted with a 2,4-D choline-susceptible variety (Table 1). Seeding rates varied by variety and site-year where at Sun Prairie, the 2,4-D-resistant variety was seeded at 118,000 seeds ac^{-1} and the 2,4-D susceptible variety was seeded at 154,000 seeds ac^{-1}. At Arlington, both varieties were seeded at 160,000 seeds ac^{-1}. In both years, soybean was planted on 30 in row spacing.

An application of Enlist Duo® with Colex-D® technology (2,4-D choline plus glyphosate) at 3.5 pt ac^{-1} plus AMS at 8.5 lb per 100 gal was completed within the center block at R2 and V6 growth stage on August 1, 2019 and July 3, 2020, respectively. Applications were made with a Demco pull behind tractor sprayer equipped with a 45 ft boom with six Turbo TeeJet Induction TTI11004 nozzles (Spraying Systems Co., Wheaton, IL) on 20-inch spacing, calibrated to deliver 15 gal of spray solution per acre.

Immediately before application, three downwind transects (relative to the area to be treated with 2,4-D choline) and one upwind transect were established on the 2,4-D-susceptible soybean using plastic tarps (10 ft wide by 50 ft long by 5 ft in height) kept above the soybean canopy by polyvinyl pipe frames (similar to methodology adopted by Soltani et al. 2020). Filter papers were placed within (in-swath) and outside of the treated area alongside the upwind transect and three downwind transects to estimate particle deposition. Filter papers were collected 30 min after application, placed in 50-mL centrifuge tubes (Sarstedt AG CO., Numbrecht, Germany), and transported to -4°F cold storage until overnight shipment for analysis. Low volume air samplers consisting of pumps (AirChek 224-52; SKC Inc., Eighty-Four, PA) equipped with polyurethane foam (PUF; catalog no. 226-92; SKC Inc.) and powered by rechargeable batteries (Powercore + 20100 USB-C; Anker Innovations, Shenzhen, Guangdong, China) were affixed horizontally at 2 ft above soybean canopy and ran for the 0.5 to 48 h period following application to estimate 2,4-D air concentration. Filters and polyurethane foam tubes were shipped to Mississippi State Chemical Laboratory for analysis. Injury to 2,4-D choline-susceptible soybean was assessed visually (0 to 100% injury) 21 d after treatment within and adjacent to the aforementioned transects.

Statistical analysis – R 4.0.2 A fixed effect model was fit to the 2,4-D air concentration (ng m^{-3}) dataset from 2020 with sampler location (in-swath, upwind, and downwind) as a fixed effect. Normality and homogeneity of residual variance of the dataset were evaluated using the Shapiro-Wilk test (stats package; R Core Team 2020) and Levene's test (car package 3.0-8; Fox and Weisberg 2019), respectively. The ANOVA was conducted using the car package (Fox and Weisberg 2019) and when the main effect was significant, means were separated using Fisher's protected least significant difference (LSD) using the emmeans package 1.4.7 (Lenth 2020). A three-parameter log-logistic model (drm function) of the drc package 3.0-1 (Ritz et al. 2015) was fitted to the datasets of 2,4-D deposition (ng cm^{-2}) and 2,4-D injury (%) on 2,4-D -susceptible soybean. Model selection criterion of choice was log likelihood (using the mselect function in the drc package). The distance to 50% (D50) and to 90% (D90) reduction in 2,4-D deposition and injury on 2,4-D-susceptible soybean was determined using the ED function of drc package (Ritz et al. 2015).

Table 1: Field background and meterological conditions during 2,4-D choline application at Sun Prairie, WI in 2019 and Arlington, WI in 2020.

Site-year	2,4-D-resistant variety	2,4-D-susceptible variety	Application date (growth stage)[c]
Sun Prairie, 2019	P5011102-02[a]	P18A98X[a]	August 1 (R2)
Arlington, 2020	P20T64E[a]	Stine 19BA23[b]	July 3 (V6)

[a] Pioneer (Johnston, IA), Corteva Agriscience (Wilmington, DE). [b] Stine Seed Company (Adel, IA).

[c] Meterological conditions during application. Sun Prairie, 2019: air temperature (77.7°F), relative humidity (51.9%), wind speed (2.9 mph), wind direction (east/southeast). Arlington, 2020: air temperature (83.7°F), relative humidity (59.5%), wind speed (2.9 mph), wind direction (north/northeast). No temperature inversions were present during application.

Results and Discussion

Temperature inversions were detected following applications in both years, occurred most frequently over the evening and early-morning hours, and were more pronounced in 2019 (data not shown). Average 2,4-D deposition collected in-swath from filter papers was 9,662 (±455) and 5,727 (±179) ng cm^{-2} in 2019 (Sun Prairie) and 2020 (Arlington), respectively (environmental conditions and crop developmental stage at application, concentration in spray solution, and/or laboratorial conditions may help to explain the difference in in-swath deposition in 2019 and 2020). 2,4-D deposition in the downwind direction from application sharply decreased as distance from the 2,4-D choline treated area increased (Figure 2). A three-parameter log-logistic model predicted that 90% of 2,4-D was deposited (D90 parameter) within 0.63 and 0.90 m (2 and 3 ft) from the edge of the treated area in 2019 and 2020, respectively (Figure 2). Higher wind speeds at the time of application would have likely resulted in higher predicted distance to 90% 2,4-D deposition. Spray particle drift is primarily carried to neighboring areas in the downwind direction (Jones et al. 2019; Soltani et al. 2020). Our results indicate that particle drift was the main source of OTM of 2,4-D choline, as higher 2,4-D concentration was detected by filter papers in the downwind direction, and it was reduced with increasing distance from the edge of the application. The nozzles used herein (TTI11004) generate ultra-course spray droplets less prone to drift, partially justifying why most off-target particles deposited within 1 m (3.3 ft) from the edge of the treated area.

Differences were detected ($P<0.05$) in 2,4-D air concentration with low-volume air samplers during the 48 h period following 2,4-D choline application in-swath and outside of the 2,4-D-treated area (Table 2). The concentration of 2,4-D detected by air samplers in-swath ranged from 3.44 to 5.88 ng m^{-3} in 2019, and 3.39 to 4.63 ng m^{-3} in 2020. Air concentration of 2,4-D was reduced 67% and 90% in the south (downwind) and north (upwind) directions, respectively, in comparison with the 2,4-D concentration detected in-swath in 2020. The 2,4-D concentration detected in both upwind and downwind directions were low, suggesting that vapor drift was not a primary source of 2,4-D choline movement in this field experiment. In both years, no injury symptoms were observed in 2,4-D-susceptible soybean in the covered and non-covered areas at various distances upwind and downwind from the treated area 21 DAT (visual injury = 0%; data not shown). **This suggests that a labeled application of 2,4-D choline would be unlikely to result in substantial injury to downwind 2,4-D-susceptible soybean.**

Table 2: Concentration of 2,4-D detected by low-volume air samplers during 48 h period following 2,4-D choline application in-swath and outside of the 2,4-D-treated area at the Arlington Agricultural Research Station near Arlington, WI in 2020.[a,b]

Samplers	**n**	**2,4-D concentration ($\mathrm{ng\ m^{-3}}$)**
In-swath	3	4.01 (3.39-4.63) a
South[c]	3	1.34 (0.72-1.96) b
North[d]	3	0.395 (0.0-1.02) c

[a] Means followed by a different letter are different at $P<0.05$ according to Fisher's Protected Least Significant Difference.

[b] Air samplers at Sun Prairie in 2019 collected 5.88 and 3.44 ng $\mathrm{m^{-3}}$ in-swath (n=2), 0.52 ng $\mathrm{m^{-3}}$ downwind (n=1), and 0.12 ng $\mathrm{m^{-3}}$ upwind (n=1) during 48 h period following 2,4-D choline application.

[c] Samplers southcentral, southeast, and southwest of 2,4-D choline treated area, constituting the downwind direction at application at Arlington in 2020.

[d] Samplers northcentral, northeast, and northwest of 2,4-D choline treated area, constituting the upwind direction at application at Arlington in 2020.

Recommendation for Soybean Growers

No soybean injury was observed at any distance downwind from the treated area, indicating that 2,4-D-susceptible soybean can indeed be considered a compatible crop if 2,4-D choline herbicide is applied according to label requirements. This research indicated that downwind particle drift was the primary source of off target movement (OTM) of 2,4-D choline. Applications of 2,4-D choline using nozzles that produce large droplets during low wind speed conditions could help to mitigate OTM. Risk of 2,4-D choline OTM can be further reduced by completing applications when the wind direction is toward non-sensitive areas (i.e., corn). Lastly, leaving an appropriate buffer zone, paying attention to wind direction at the time of application and potential wind directional shifts following application can protect sensitive buffer areas and susceptible neighboring crops from herbicide OTM.

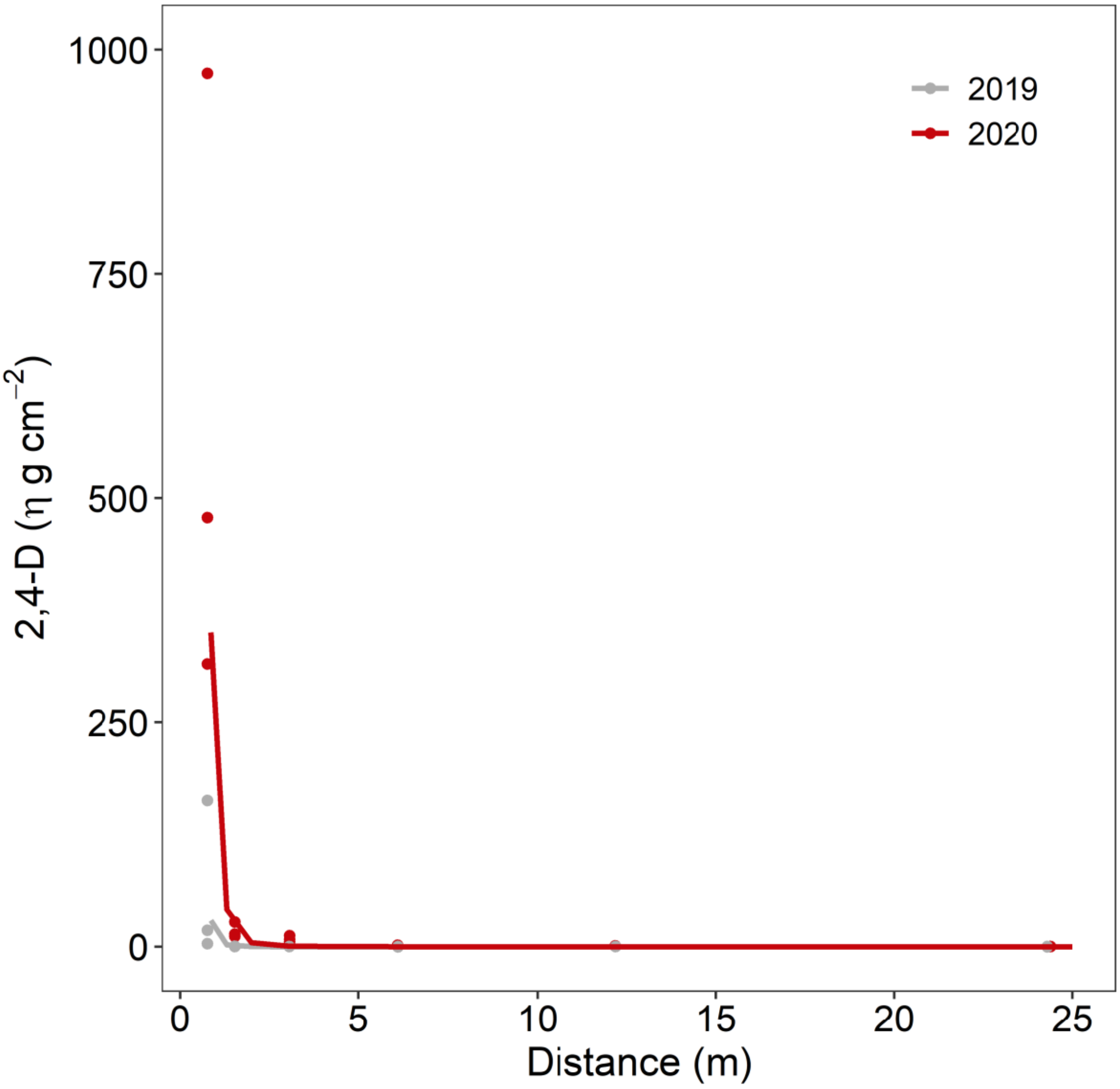

Figure 2. Deposition of 2,4-D at various distances downwind from the 2,4-D choline treated area at a commercial field near Sun Prairie, WI in 2019 and the Arlington Agricultural Research Station near Arlington, WI in 2020.

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Additional Resources

- Enlist E3 Soybean System in 2020: What We Think Applicators Should Know.
- Spray Solution pH and Soybean Injury as Influenced by Dicamba and 2,4-D Herbicide Formulation and Spray Additives.
- 2019 Wisconsin Weed Science Research Report.
- 2020 Wisconsin Weed Science Research Report.
- 2021 Wisconsin Waterhemp Herbicide Resistance Project (2,4-D, dicamba, and glufosinate).
- Differentiating 2,4-D and Dicamba Injury on Soybeans - Purdue Extension.