Field volatility of Dicamba

Report:	MRID 51017502. Brayden, B.H., A.P. Rice, and L.B. Sisco. Off-target Movement Assessment of a Spray Solution Containing MON 76980 + MON 79789 + Intact™ – Illinois. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by Monsanto Company, Chesterfield, Missouri. Stone Study ID: 19-058-A. Monsanto Study ID: STC-2019-0032. Reference No.: MSL0030829. Experiment initiation August 8, 2019 and completion September 5, 2019 (p. 8). Study and Report completion January 9, 2020.
Document No.:	MRID 51017502
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with U.S. EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site observations, slope estimates, pesticide and crop history, soil taxonomy, and study weather data (p. 4). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification statements were provided (pp. 2, 4-6, 9).
Classification:	This study is **acceptable**. Monitoring started after the conclusion of application. An independent laboratory method validation was not conducted. Minimum fetch requirements were not always met for the aerodynamic method, but this is not expected to significantly impact the derivation of the flux rates.
PC Code:	128931
Final EPA Reviewer:	Chuck Peck Senior Fate Scientist Signature: Date: 2020.10.24 19:08:28 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist Signature: Date: 2020.10.25 12:51:10 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Richard Lester Environmental Scientist Signature: Date: 3/24/20
	Joan Gaidos Environmental Scientist Signature: Date: 3/30/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba formulation MON 76980 when tank mixed with glyphosate potassium salt (MON 79789) and Intact™ (polyethylene glycol, choline chloride, and guar gum)

was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in Effingham County, Illinois. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of application (8/8/19) ranged from 18.7-31.0°C (65.7-87.8°F), 20.1-36.8°C (68.8-98.2°F), and 62-98%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 14.9-30.5°C (58.8-86.9°F), 17.8-41.1°C (64.0-106°F), and 44-100%, respectively, 1 to 7 days after application.

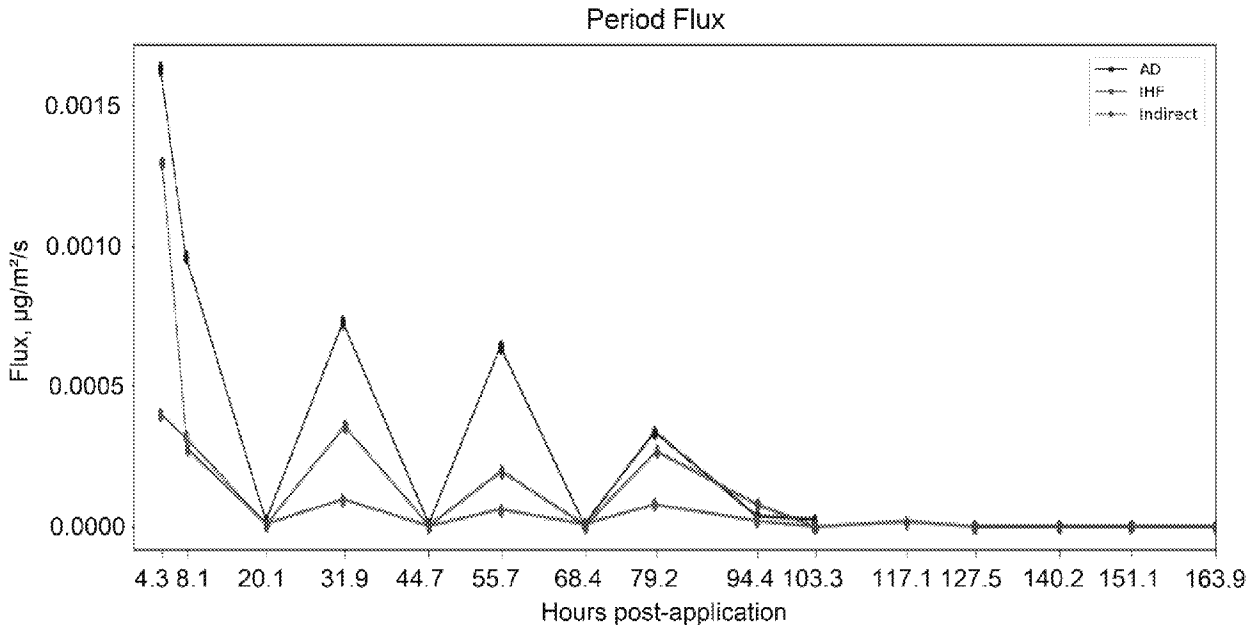
Under field conditions at the test plot, based on calculations using the Indirect method, a peak volatile flux rate of 0.001297 $\mu g/m^2 \cdot s$ was estimated by the reviewer and study authors, accounting for 0.036% of the applied dicamba observed 0.4 to 4.9 hours post-application. By the end of the study, a total of 0.119% of dicamba volatilized and was lost from the field. Peak and secondary peak volatile flux rates occurred during the warm daytime hours in the days after application.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, a peak volatile flux rate of 0.000401 $\mu g/m^2 \cdot s$ was estimated by the reviewer and the study authors, accounting for 0.011% of the applied dicamba observed 0.5 to 4.2 hours post-application. By the end of the study, a total of 0.044% of dicamba volatilized and was lost from the field.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, a peak volatile flux rate of 0.001631 $\mu g/m^2 \cdot s$ was estimated by the reviewer and study authors, accounting for 0.038% of the applied dicamba observed 0.5 to 4.2 hours post-application. By the end of the study, a total of 0.185% of dicamba volatilized and was lost from the field.

Spray drift measurements indicated that dicamba residues were not detected in any of the upwind samples at one hour after application and were detected at a maximum fraction of the amount applied of 0.001943 in downwind samples and 0.000911 in left wind samples. Deposition of dicamba above the no observed adverse effects concentration (NOAEC) was detected in all transects of the downwind and one transect of the left wind direction in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach NOAEC for soybean (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) ranged from <3.0 to 7.1 m in the downwind direction and 8.7 m in the one left wind transect. Reviewer-estimated distances were 4.95 m (3.1 to 6.3 m for the three transects) and 3.83 m (3.0 to 6.0 m in the two transects) in the downwind and left wind directions, respectively.

Figure 1 Volatile flux – Soybean Plot



Plant effects (51017502, EPA Guideline 850.4150; Supporting files in Appendix 2)

The effect of **MON 76980 (a.i. Dicamba diglycolamine (DGA) salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact™** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On day 28 the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury. Notably, this study was conducted late in the summer with plants that were planted in July and final assessment of effects being observed in September. It is unclear how this late season study may relate to potential effects during the (May-July).

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visible signs of injury (VSI) were recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. VSI distances were established based on regression estimated distances to a 10% VSI. For the drift study, three of the downwind transects, two of the left wind transects, and the east diagonal transect showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. Percent of visible symptoms was a maximum of 50% in these fields closest to the treatment field.

Furthest distance to 5% Reduction in Plant Height = 31.3 meters (102.7 feet)
Furthest distance to 10% VSI = 53.3 meters (174.9 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

When compared to the negative control plot, the study author and reviewer found no significant inhibitions in plant height at any distance in any direction in the volatility samples. The percent of visible symptoms were slight (≤10%) and there was no dose response.

Furthest distance to 5% Reduction in Plant Height = < 3 meters (<9 feet)
Furthest distance to 10% VSI = <3 meters (<9 feet)

Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

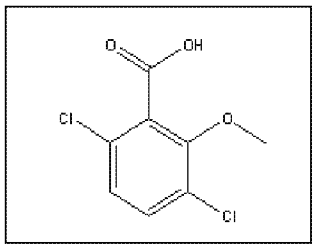
Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	7.0 [e]	21.4 [e]	<3	<3
DWB[a]	19.9 [e]	36.2 [e]	<3	<3
DWC	23.9 [e]	35.0 [e]	<3	<3
LWA	4.2 [e]	15.7 [e]	<3	<3
LWB[a]	31.3 [c]	39.7 [c]	<3	<3
E Diag	27.4 [d]	53.3 [d]	<3	<3
RWA	<3	<3	<3	<3
RWB	<3	<3	<3	<3
N Diag[a]	<3	<3	<3	<3
S Diag[a]	9.1 [e]	22.3 [e]	<3	<3
UWA[a]	NA	NA	<3	<3
UWB[b]	5.3 [e]	>20 [f]	<3	<3

[a] Study authors indicate flooding may have impacted these transects

[b] reported that runoff from the treated field may have impacted transect out to 40 m.
[c] distance estimated with linear regression
[d] distance estimated with polynomial regression
[e] distance estimated with logistic regression
[f] distance estimated visually

I. Materials and Methods

A. Materials



1. Test Material

Product Name: MON 76980 (Appendix B, pp. 88-89) - dicamba
Formulation Type: Liquid
CAS #: 104040-79-1
Lot Number: 11495284
Storage stability: The expiration date of the test substance was May 10, 2020.

Product Name: MON 79789 – glyphosate, potassium salt
Formulation type: Liquid
CAS Number: 70901-12-1
Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 7, 2020.

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Liquid
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was August, 2022.

2. Storage Conditions

The test substance was received on May 9, 2019 and stored at SynTech Research, Inc., Stewardson, Illinois (Appendix B, p. 89). The test substance was sprayed on the test plot on August 8, 2019 (p. 13). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, p. 37).

B. Study Design

1. Site Description

The test site was located in Effingham County, Illinois, *ca.* 1 mile northwest of Shumway, Illinois (Appendix B, pp. 90-91). A single soybean-cropped field, measuring *ca.* 900 ft × 900 ft (274 m × 274 m, ~ 18.6 A) was treated with a mixture of MON 76980 (containing dicamba),

MON 79789 (containing glyphosate potassium salt), and Intact™ (polyethylene glycol, choline chloride, and guar gum). The crop on the plot was a dicamba-tolerant soybean crop (Variety: Asgrow AG36X6) with a 110-ft buffer surrounding the plot planted in non-tolerant soybeans (Variety: Stine PGL3590). Soil characterization indicated the USDA textural class was silt loam (Appendix B, p. 104). Prior to the study, dicamba had not been applied to the test plot within the previous three years (Appendix B, p. 92). Crop history for the three years preceding the study indicated the field had been planted in corn and soybean (Appendix B, pp. 151-152). Terrain was flat with a slope between 0% and 1%. The test plot was surrounded primarily by agricultural land (Appendix B, Figure 1, p. 128). The test plot and surrounding buffer zone were planted with soybean on June 13, 2019 and replanted on July 15, 2019 as a result of seed damage due to significant precipitation and saturated soil conditions during germination (Appendix B, p. 91). The soybean seeds were planted at a density of 140,000 seeds/A on 30-inch row spacing for both plantings.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e./A or 15 GPA (p. 14; Appendix A, p. 38; Appendix B, p. 92). Four application monitoring samples consisting of four filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 97). The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 102). The application rate was assumed to be 100% of the target rate. The actual application rate calculated by a Raven Applied Technology Viper 4+ Field Computer was 103% of the target application rate or 15.5 GPA (Appendix B, Table 1, p. 109).
Irrigation and Water Seal(s):	No irrigation or water seals were reported in the study. Precipitation events occurred on the third (0.05 inches), fourth (1.22 inches), and fifth (0.76 inches) days after application (Appendix B, Table 11, pp. 121-122). A total of 2.03 inches of precipitation were reported during the seven-day field volatility study.
Tarp Applications:	Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (volatility; Appendix A, p. 43).
Application Equipment:	A Rogator 1074 ground sprayer equipped with a 100-ft boom was used for the spray application (Appendix B, p. 92). 60 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 20-inch spacing and the boom height was set at 20 inches above the crop

canopy (20 cm). The sprayer had one spray tank with a volume of 1,100 gallons.

Equipment Calibration Procedures: Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 92). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 29.8 gallons/minute (GPM). The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 300 ft. Speed verification was repeated three times.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	8/8/2019 at 11:35	9.58	18.6	0.515	15.5

Data obtained from Appendix B, p. 93 and Appendix B, Table 1, p. 109 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, p. 106).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3.**

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period[2]
Soybean	18.6	8/8/2019 between 11:35 – 11:51	8/8/2019 between 11:58 – 16:26	Not Applicable	8/8/2019 Between 11:09-12:37

Data obtained from Appendix B, p. 93; Appendix B, Table 2, p. 110; and Appendix B, Table 5, p. 113 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 8/8/2019 between 12:05 – 15:48.
[2] Tarps were placed on select transects to evaluate volatility exposure without spray drift. Note that some tarps remained on the field for approximately 45 minutes after application had stopped (protocol was to remove within 30 minutes).

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.1 (Appendix B, Table 3, p. 111).

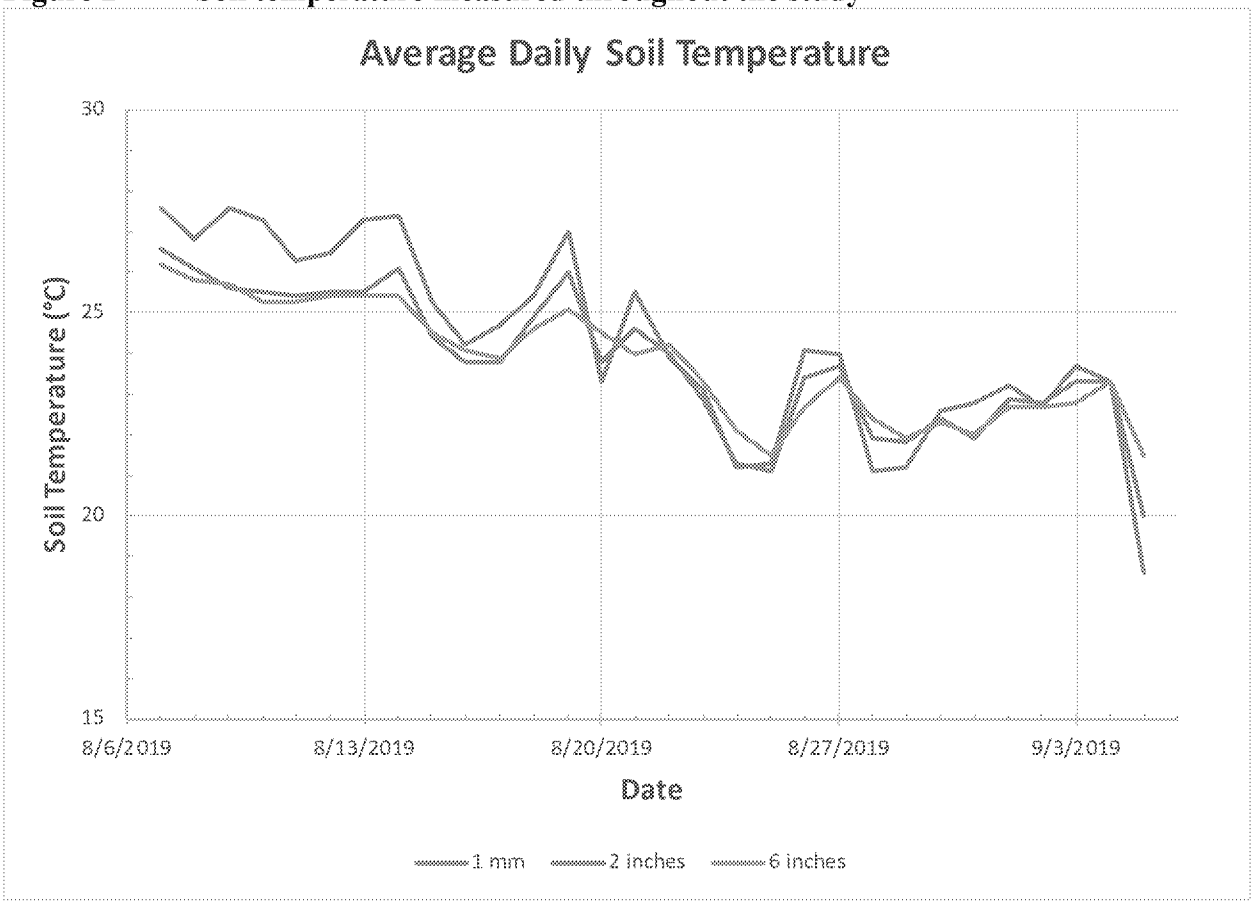
Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean	0-6	Silt Loam	Not Reported	Not Reported	1.07	% Organic Carbon[1] = 1.16% % Sand = 20% % Silt = 64% % Clay = 16%

Data obtained from Appendix B, pp. 95, 104, and Appendix B, Table 3, p. 111 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 2.0%.

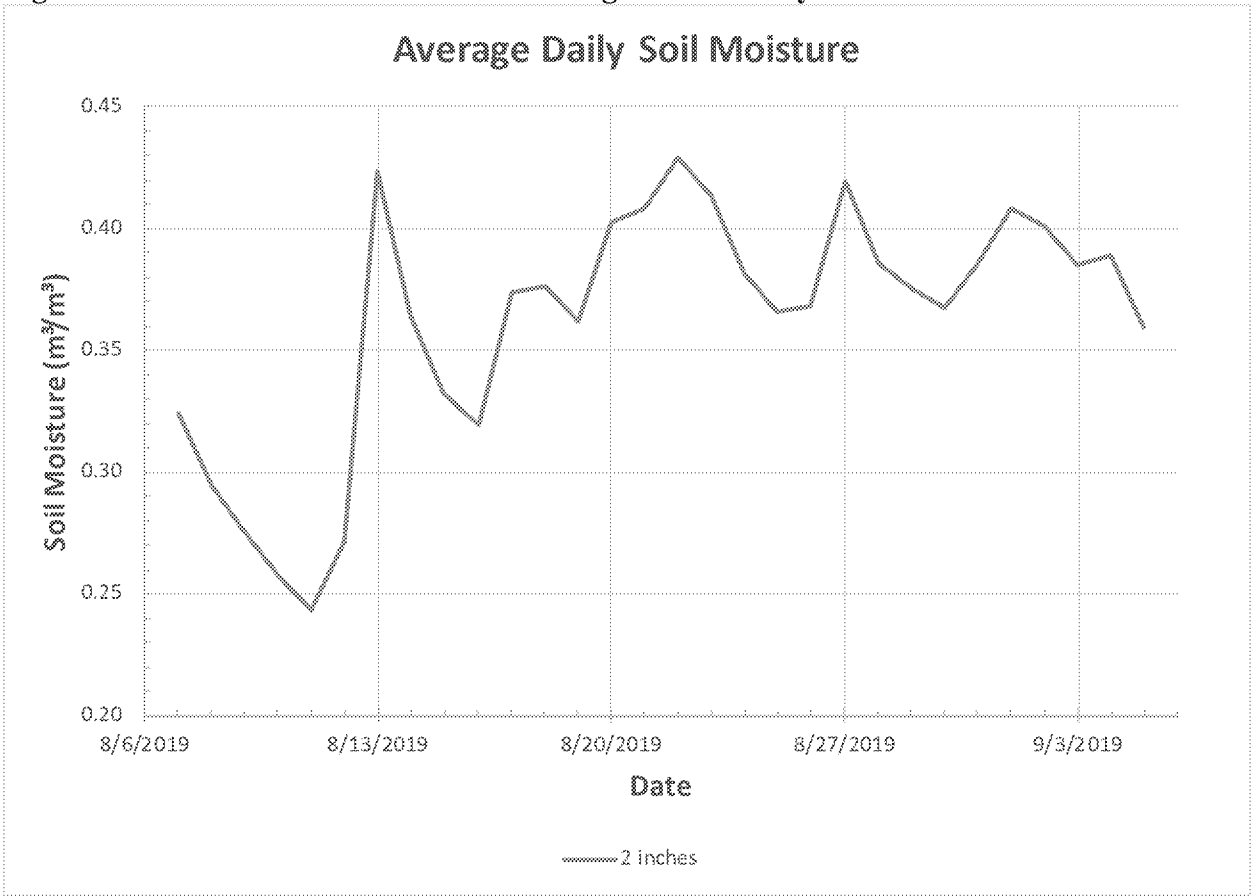
Figures 2 and 3 are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 12, pp. 123-124 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 12, pp. 123-124 of the study report.

4. Source Water

Tank mix water was obtained from well water from South Central FS. The pH of the tank mix water was 7.8 with an alkalinity of 58 mg $CaCO_3$/L and a conductivity of 0.25 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 93).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, p. 94, and Figure 2, p. 129). The system included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. All parameters were reported at heights of 1.7, 5, and 10 m. The station included sensors for monitoring windspeed and direction (3D anemometer at 10 m and 2D anemometers at 1.7 and 5 m), air temperature, and relative humidity.

A boom height anemometer collected wind speed and wind direction data during application at a height just above the crop canopy at about 20 inches above the ground (Appendix B, p. 94). The

anemometer was mistakenly placed 20 inches above the ground instead of at boom height (20 inches above the crop canopy). The anemometer was located *ca.* 3 m downwind of the sprayed area. In lieu of the Boom Height Anemometer, data from the 0.55 m anemometer located on the Secondary Flux Meteorological Station were used for wind direction and speed measurements at boom height.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 94, and Table 12, pp. 123-124). The station included wind speed and direction sensors (1.84 m), a rain gauge sensor (1.5 m), a temperature/relative humidity sensor (1.25 m), a pyranometer to measure solar irradiation (1.5 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to application and was then moved to the center of the plot, remaining there until after the final drift sample was collected on the morning of August 15, 2019 (Appendix B, p. 95). The station included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station was positioned upwind and outside of the sprayed area. A secondary flux meteorological station also recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy (Appendix B, p. 95).

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights (m)	Averaging Period
Soybean Plot 10-Meter Main Met. Station	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute
		Wind speed/wind direction	1.7, 5, and 10	1 minute
Soybean Plot Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.51	Not Reported
Soybean Plot Long Duration Main Met. Station	Not Reported	Precipitation	1.5	1 minute
		Air temperature	1.25	1 minute
		Relative humidity	1.25	1 minute
		Soil temperature	1 mm, 2 inches, 6 inches	1 minute
		Soil moisture	2 inches depth	1 minute
		Solar radiation	1.5	1 minute
		Wind speed/wind direction	1.84	1 minute
Soybean Plot Primary Flux Met. Station	152.89	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute
Soybean Plot	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute

Field	Minimum Fetch (m)	Parameter	Monitoring heights (m)	Averaging Period
Secondary Flux Met. Station		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute

Data obtained from Appendix A, pp. 46-47, 60; Appendix B, pp. 93-95; and Appendix D, Table 8, p. 555 of the study report.
* Denotes height above crop canopy

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop surface at the approximate center of the test plot (Appendix B, pp. 97-98). Samples were collected for *ca.* 6 hours on August 7, 2019 from 10:32 to 16:36.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, p. 98). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and two at 1.5 m above the crop surface. Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 98). Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects (Appendix B, pp. 99-101). Samples were also collected with a control plot, upwind of the spray area. All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 120 m in all three of the downwind transects and one left wind transect. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 5 minutes after spray application was completed. Initial downwind deposition sample collection times ranged from 24 to 33 minutes after the start of application. Deposition samples were collected at intervals of 1, 24, 48, 72, 96, 120, 144, and 168 hours post-application.

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the treated soybean

field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 120 meters (Appendix G, pp. 726-727; Figure 1, p. 736). Height effects and visual symptomology was recorded at 0, 14, and 28 days after spray application of the tank mix. Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, four upwind control areas were identified and evaluated for plant height.

Plant effects from volatility only were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 726-727; Figures 1 and 2, pp. 736-737). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology resulting from volatilization of dicamba. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. The actual time the plants remained covered ranged from 11:09 am to 12:37 pm (approximately 1.5 hrs. total and approximately 45 mins post-application). Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment.

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, p. 96). PUF sorbent tubes and filter papers were placed in pre-labeled conical tubes. Pre-application, application monitoring, deposition filter paper samples, field exposed spikes, transit stability PUF, during application PUF, and post-application PUF, were stored in a -20°C freezer or cooler with dry ice prior to shipment. Spray area (application monitoring) samples were kept separate from other samples and were stored and shipped in a cooler containing dry ice until final transfer to storage at approximately -20°C at the analytical test site. Tank mix samples were stored and shipped in a cooler under ambient conditions. Field spikes and transit stability samples were stored in coolers containing dry ice. All samples were shipped in a freezer truck to the Eurofins laboratory.

All field collected PUF and filter paper samples were extracted within 16 and 13 days, respectively, after collection (Appendix C, p. 419-438). All field exposed QC and transit stability samples were extracted within 15 days after fortification. Stability of dicamba on PUF and filter paper samples was demonstrated for at least 78 and 85 days, respectively, during frozen storage in a stability study (Maher 2016). All PUF and filter paper samples were analyzed within 3 and 6

days, respectively, after extraction, which study authors indicate is within the demonstrated stability (Appendix C, p. 419-438).

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipes (Appendix B, p. 97). SKC AirChek 52 air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 2.950-3.050 L/min. Spray drift deposition collectors consisted of Whatman #1 15 cm diameter filter papers.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 304-327). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean polypropylene plate positioned below the filter plate (Appendix C, pp. 328-329). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 0.150 mL of 25% methanol in water. The sample was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode within the storage time determined during method validation (Appendix C, p. 244).

  The filter paper samples were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 332). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate (Appendix C, pp. 339). The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 332).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 322-326). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation was provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF. For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF

and the LOD was 0.065 ng/PUF (Appendix C, p. 323). During the study, the LOQ was 1.0 ng/PUF (p. 18).

Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix C, pp. 346). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation was provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 µg/filter paper (Appendix C, p. 332). During the study, the LOQ was 0.005 µg/filter paper (p. 18).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 310). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 316 and 369).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix C, p. 337). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted linear curve ($1/x^2$; Appendix C, pp. 342 and 357).

11. Quality Control for Air Sampling

Lab Recovery: 20 of 24 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 372-373). All laboratory spike recoveries are within the range of 89-119%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (12 samples) and 60 ng/PUF (12 samples). Average recoveries were 102% and 100% at 1 ng/PUF and 60 ng/PUF, respectively (Appendix C, p. 373).

Field blanks: Two pre-application samples were collected from the center of the test plot from 10:32 to 16:36 on August 7, 2019, the day before application (Appendix B, pp. 97-98). Dicamba was not detected in either pre-application sample (Appendix B, pp. 104-105).

Six control samples from field spike analyses also contained no detectable dicamba (Appendix B, p. 105 and Appendix C, Table 8, p. 263).

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Most field spike recoveries are within the acceptable range with overall recoveries of 77% to 110% at 3

ng/PUF, 94% to 109% at 10 ng/PUF, and 94% to 102% at 30 ng/PUF (Appendix B, p. 105).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, p. 105). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 101% to 107%.

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 95% to 105% (Appendix C, pp. 372-373). The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 20.8 ng/PUF (Appendix C, pp. 376-385) which is *ca.* 35% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 44 of 60 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 381-382); 13 recoveries spiked at 0.005 µg/filter and 3 recoveries spiked at 50 µg/filter. All laboratory spike recoveries are within the range of 77-119%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (27 samples), 5 µg/filter (27 samples), and 50 µg/filter (6 samples). Average recoveries were 97%, 104%, and 108% at 0.005 µg/filter, 5 µg/filter, and 50 µg/filter, respectively (Appendix C, p. 265).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 µg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 162, 421). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 98% to 99%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area at the crop height, or 20 cm (Appendix B, p. 97). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target was 91%, with a range of 42-120% of the target rate (Appendix B, p. 104; Appendix B, Table 14, p. 126; and Appendix C, p. 359).

Spray application rates were automatically maintained by the sprayer using a variable rate controller (Appendix B, p. 102). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. The actual application rate calculated by a Raven Applied Technology Viper 4+ Field Computer was 103% of the target rate (Appendix B, Table 1, p. 109).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, pp. 96-97).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. Study authors used U.S. EPA's AERMOD model (version 18081) to estimate deposition and the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) to estimate air concentrations (Appendix E, p. 608). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 609). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM2 and the average flux rate and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different, particularly where weighted averaging occurred. However, they did not impact the overall modeling conclusions.

Wet, dry, and total deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, pp. 611). For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, maximum 24-hour average total (dry+wet) deposition ranged from 3.25 to 4.25 $\mu g/m^2$ (Appendix E, Table 7, pp. 623-624). 90th percentile total deposition ranged from 1.48 to 2.12 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 610-611). Modeled 95th percentile 24-hr air concentrations ranged from 5.7 to 9.0 ng/m^3 at 5 m from the edge of the treated field and 4.0 to 6.3 ng/m^3 at 50 m from the edge of the field.

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Air concentration modeling results were slightly higher (8.6-18 ng/m^3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 $g/m^2 \cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, study authors removed the spatial relationship by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, study authors multiplied the ratio of the sum of the measured concentrations to the sum of the modeled concentrations by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1
$$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2
$$Flux = \frac{-(0.42)^2(c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3
$$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + \left(u_{ztop} - u_{zbottom}\right)^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = (1 + 16R_i)^{0.33}$ *and* $\phi_p = 0.885(1 + 34R_i)^{0.4}$

if $R_i < 0$ (for Convective/Unstable IBL)
$\phi_m = (1 - 16R_i)^{-0.33}$ *and* $\phi_p = 0.885(1 - 22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was not satisfied at all times. Given the highest height sampled was 1.70 m (1.5 m above the crop which was 20 cm), the minimum fetch distance is 170 m. Based on wind direction analysis, this requirement was not satisfied at all times. The fetch distance was below 170 m for all but one sample period (Period 4). If the minimum fetch were considered 150 m, the height of the highest sampler above the crop, then the minimum fetch distance would have

been satisfied for all sampling periods. As such, there is some uncertainty in the flux rates derived from this analysis, as the internal boundary layer depth may not have been sufficient. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x}\int_{Z_0}^{Z_p} \overline{c}\,\overline{u}\,dz$$

where P is the volatile flux in units of $\mu g/m^2 \cdot s$, $\overline{c}$ is the average pesticide residue concentration in units of $\mu g/m^3$ at height Z in units of meters, $\overline{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 4 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P} (A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface characteristics of the field consisted of soybeans at 6 inches (15 cm) in height. For most sampling periods, the surface roughness length was equal to or less than 0.08 m, below the required of 0.1 meters for this method to be valid. However, for sampling periods 5 and 7,

both overnight periods, the surface roughness was approximately 0.12 to 0.13, resulting in some uncertainty with regards to the flux estimates derived for these periods.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 4.67 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Notes	Registrant ($\mu g/m^2 \cdot s$)	Notes
1	8/8/19 11:58 – 16:26	4:28	0.001297	Regression	0.001297	A
2	8/8/19 15:48 – 20:18	4:30	0.000276	Regression	0.000276	A
3	8/8/19-8/9/19 19:35 – 8:11	12:36	0.000002	Regression	0.000008	B
4	8/9/19 7:45 – 20:06	12:21	0.000379	Regression, no intercept	0.000357	A
5	8/9/19-8/10/19 19:23 – 8:42	13:19	0.000005	Regression	0.000005	A
6	8/10/19 8:26 – 19:59	11:33	0.000197	Regression	0.000197	A
7	8/10/19-8/11/19 19:10 – 8:30	13:20	0.000008	Regression	0.000004	B
8	8/11/19 8:02 – 19:30	11:28	0.000268	Regression	0.000268	A
9	8/11/19-8/12/19 18:42 – 10:26	15:44	0.000079	Regression	0.000079	A
10	8/12/19 10:10 – 19:26	9:16	0.000000	C	0.000000	B
11	8/12/19-8/13/19 18:53 – 9:06	14:13	0.000000	C	0.000020	B
12	8/13/19 8:48 – 19:40	10:52	0.000000	C	0.000000	B
13	8/13/19-8/14/19 19:02 – 8:15	13:13	0.000000	C	0.000000	B
14	8/14/19 7:57 – 19:13	11:16	0.000000	C	0.000000	B
15	8/14/19-8/15/19 18:45 – 7:48	13:03	0.000000	C	0.000000	B

Data obtained from Appendix B, Table 5, pp. 113-114 and Appendix D, Table 6, p. 553 of the study report.

Notes

A The spatial regression method was used to calculate the flux estimate for the sampling period.

B The ratio method was used to calculate the flux estimate for the sampling period.

C Insufficient number of measured values to conduct regression/analysis. Measured concentrations were < LOD.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	Notes
1	8/8/19 12:05 – 15:48	3:43	0.000401 0.001631	0.000400 0.001632	IHF AD	
2	8/8/19 15:55 – 19:41	3:46	0.000318 0.000961	0.000318 0.000961	IHF AD	
3	8/8/19-8/9/19 19:45 – 7:50	12:05	0.000011 0.000020	0.000011 0.000021	IHF AD	
4	8/9/19 7:53 – 19:29	11:36	0.000097 0.000728	0.000097 0.000727	IHF AD	
5	8/9/19-8/10/19 19:33 – 8:31	12:58	0.000004 0.000011	0.000004 0.000011	IHF AD	
6	8/10/19 8:34 – 19:15	10:41	0.000061 0.000638	0.000061 0.000640	IHF AD	
7	8/10/19-8/11/19 19:32 – 8:05	12:33	0.000010 0.000007	0.000010 0.000007	IHF AD	
8	8/11/19 8:06 – 18:44	10:38	0.000079 0.000338	0.000079 0.000338	IHF AD	
9	8/11/19-8/12/19 18:47 – 10:11	15:24	0.000022 0.000038	0.000022 0.000038	IHF AD	
10	8/12/19 10:12 – 18:54	8:42	NC NC	0.000001 0.000027	IHF AD	A
11	8/12/19-8/13/19 18:58 – 9:44	14:46	NC NC	NC NC	IHF AD	B
12	8/13/19 9:48 – 19:05	9:17	0.000000 0.000000	0.000000 0.000000	IHF AD	C
13	8/13/19-8/14/19 19:08 – 8:02	12:54	0.000000 0.000000	0.000000 0.000000	IHF AD	C
14	8/14/19 8:06 – 18:53	10:47	0.000000 0.000000	0.000000 0.000000	IHF AD	C
15	8/14/19-8/15/19 18:55 – 7:38	12:43	0.000000 0.000000	0.000000 0.000000	IHF AD	C

Data obtained from Appendix B, Table 5, pp. 113-114; Appendix D, Table 8, p. 555; and Appendix D, Table 10, p. 558 of the study report.
NC indicates not calculated.
*Methods legend: ID = Indirect Method, AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes

A All sample residues, except one, collected during this period were ND or <LOD. No flux rate could be estimated, as a concentration profile could not be developed.

B Samples were wet. Flux was not calculated for this period.

C All sample residues collected during these periods were ND or <LOD. Flux was estimated to be 0.000000 $\mu g/m^2/s$.

During Period 10, only one sampler on the central mast detected dicamba, so a flux rate using the integrated horizontal flux or aerodynamic method was not calculated for this period as a concentration profile could not be developed. Samples collected from the central mast during period 11 were wet, so flux was not calculated for period 11 using the integrated horizontal flux or aerodynamic method. All measured concentrations for periods 12 through 15 were non-detect or less than the LOD. Flux rates for these periods were estimated to be 0.000000 $\mu g/m^2 \cdot s$.

The maximum flux rate calculated by all three methods occurred during the initial sampling period after application. Maximum flux rates were 0.001297 $\mu g/m^2 \cdot s$, 0.000401 $\mu g/m^2 \cdot s$, and 0.00163 $\mu g/m^2 \cdot s$ for the indirect, integrated horizontal flux, and aerodynamic methods, respectively (Appendix D, pp. 535-537).

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.552 to 0.998 for periods 1 through 9. The reviewer used the spatial regression method to estimate flux for all periods, except period 4 when spatial regression using an intercept of zero was used. Study authors used spatial regression to estimate flux during periods 1, 2, 4, 5, 6, 8, and 9 and the ratio method for periods 3 and 7. Reviewer and study author flux rates were similar.

R-squared values in log-linear vertical profiles of wind speed were generally high with all R-squared values ≥0.978. R-squared values in log-linear vertical profiles of concentration were low for period 7 (0.551). R-squared values in log-linear vertical profiles of temperature were variable and ranged from 0.05 for period 9 to 0.967 for period 6. In general, r-squared values for log-linear vertical profiles of temperature were below 0.75 for overnight periods, when profiles of temperature no longer increase with height.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.001943 at 3 m from the field within the first hour after application (Appendix F, Table 1, pp. 658-675). Dicamba residues were not detected in any of the upwind or right wind samples within the first hour after application. **Figures 4** and **5** depict the deposition fractions and the reviewer-predicted spray drift curves for the downwind and left wind transects within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was

removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Figure 4 Spray Drift Analysis for Downwind Transects – 1 Hour

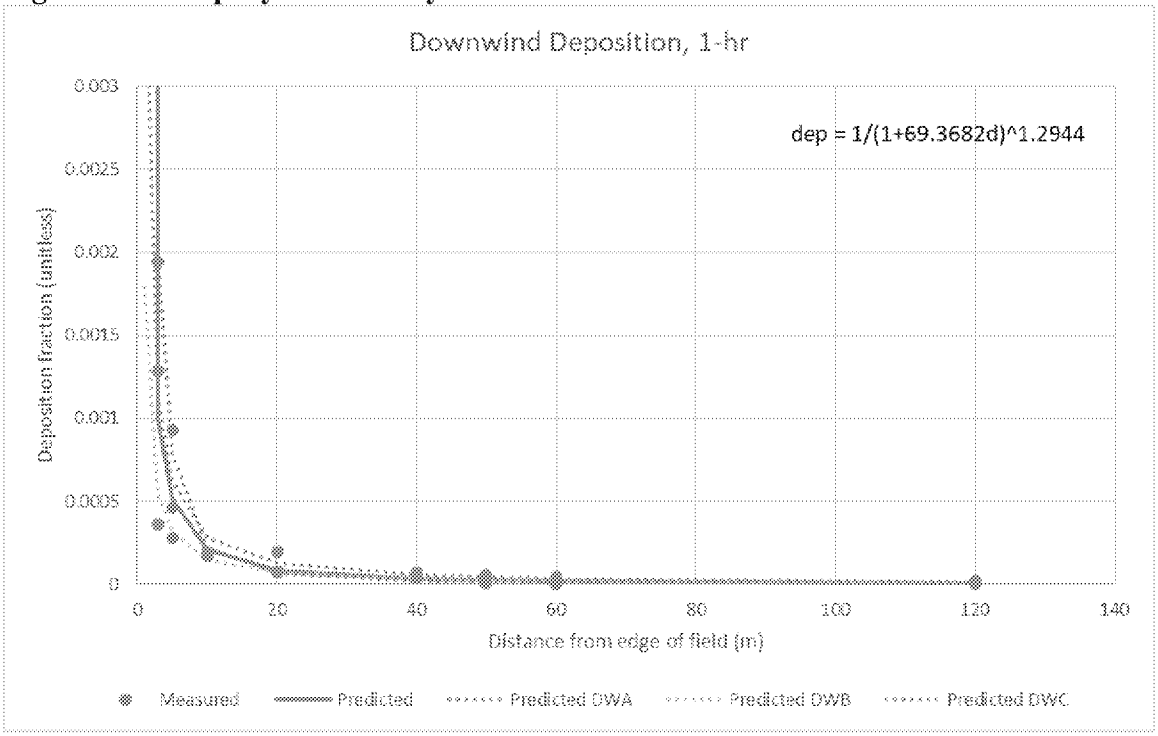
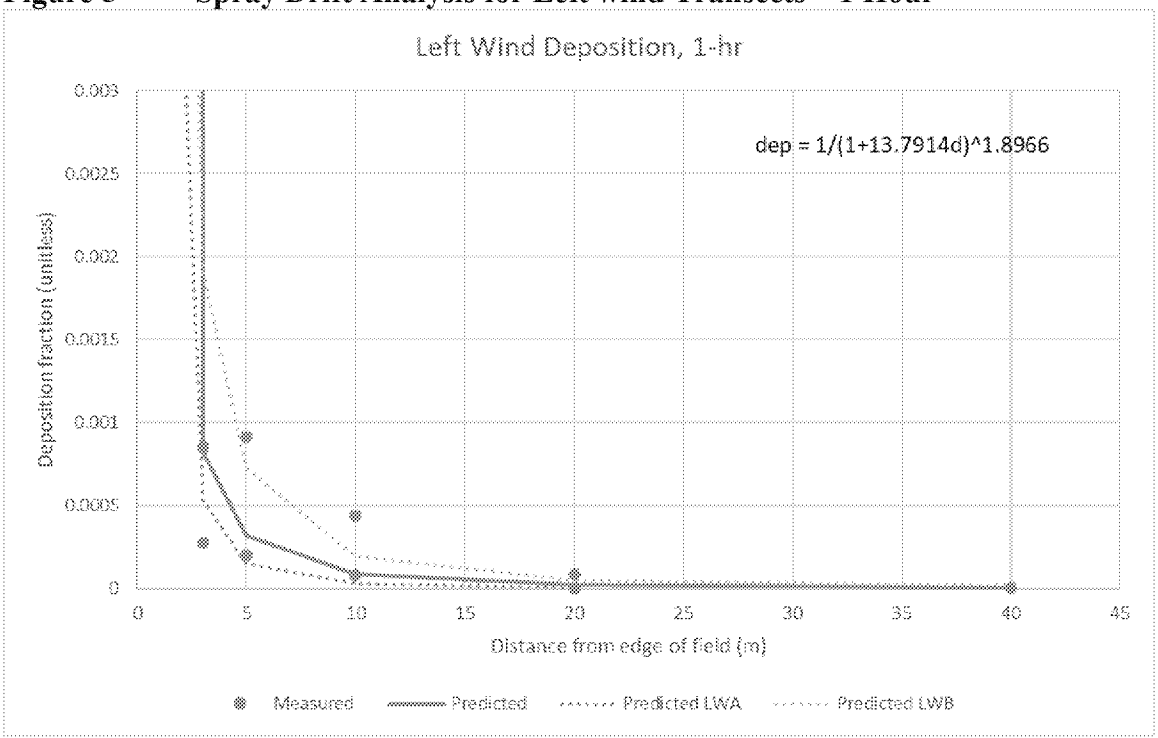


Figure 5 Spray Drift Analysis for Left wind Transects – 1 Hour



Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, p. 653). For samples collected within the first hour of application, the best fit models were the exponential with intercept model (downwind transect A and left wind transects A & B) and the power with coefficient model (downwind transects B & C; Appendix F, Table 2, p. 676). The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) were 4.95 m (3.1 to 6.3 m for the three transects) and 3.83 m (3.0 to 6.0 m in the two transects) in the downwind and left wind directions, respectively, using the reviewer-developed curves and ranged from <3.0 to 7.1 m in the downwind direction and 8.7 m in the left wind direction for the study author developed curves.

D. Plant Effects Results

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height along downwind (DW), left wind (LW) and east diagonal transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8, 10, & 12). The best fit regression (as indicated by the R^2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Table 6b provides the estimated distances to 5% reduction in plant height for each transect. The furthest distances were estimated for transects in the Down Wind, Left Wind, East Diagonal, and South Diagonal transect areas, reaching out to distances of 4.2 to 31 meters (14 to 102 feet).

Flooding and runoff from the treated area was reported to have impacted a few of the transects. The impact of this on plant height effects is uncertain. The reviewer considered the reported impacts on individual transects and plots, and determined that the reduced plant height effects are attributed to the dicamba exposure during application, for those transects used to established distances in Table 6b. Notably, transect UWA was determined to be principally impacted by the runoff and flooding. The central portion of the transect was reported to be a low area and plant heights were greatly reduced in these central portions. Plant heights at the edge of field and at the furthest distances along the transect were not different from the controls. No distance was estimated for this transect.

A major uncertainty in the implementation of this study was that the measurements of plant height were not consistently taken from the same individual plants over the course of the successive sampling events. While the study authors indicate that the initial plot distances were selected to reduce variability in plant height at the start of the study, it is unclear how the transects relate to the rest of the field, and more importantly how other plants in the plot were responding as compared to those that were selected "non-systematically" for measurement of plant height. No discussion was provided to explain how the plants were selected such to prevent

selection of the healthiest looking plants from a plot. This uncertainty may contribute to underestimation of effects and therefore underestimation of off-field distance estimates.

Visual Signs of Injury (VSI)

Visible symptomology was reported, but the specific phytotoxic symptoms were not detailed for the transects. For the drift study, the same transects that showed a dose response relative to the field for the height endpoint, also showed a dose response for VSI (Table 6b). For these transects, linear, logistic and polynomial regression methods in Excel to estimate the distance to the point where 10% VSI would be predicted (Figures 7, 9, 11 & 13). The furthest distances to 10% VSI were consistent with the transects that showed significant effects on plant height and ranged from 15.7 meters to 53.3 meters (51.5 to 174.9 feet; Table 6b). Transect UWB did not show an expected decreasing dose response with distance. The near field observation points were reported to have received runoff from the treated area; therefore, it is unclear if this response is reflective of the dicamba exposure through runoff or exposure through drift.

Volatility Exposure (covered) Transects

Plant height measures and distances estimated with logistic regression, indicate that impacts to plant height were significantly less than observed along the uncovered transects. Plant height and VSI distances were determined to be less than 3 meters based on a lack of observed effect.

Table 6b. Estimated distance to 5% reduction in plant height and visual signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	7.0 [e]	21.4 [e]	<3	<3
DWB[a]	19.9 [e]	36.2 [e]	<3	<3
DWC	23.9 [e]	35.0 [e]	<3	<3
LWA	4.2 [e]	15.7 [e]	<3	<3
LWB[a]	31.3 [c]	39.7 [c]	<3	<3
E Diag	27.4 [d]	53.3 [d]	<3	<3
RWA	<3	<3	<3	<3
RWB	<3	<3	<3	<3
N Diag[a]	<3	<3	<3	<3
S Diag[a]	9.1 [e]	22.3 [e]	<3	<3
UWA[a]	NA	NA	<3	<3
UWB[b]	5.3 [e]	>20 [f]	<3	<3

[a] Study authors indicate flooding may have impacted these transects
[b] reported that runoff from the treated field may have impacted transect out to 40 m.
[c] distance estimated with linear regression
[d] distance estimated with polynomial regression
[e] distance estimated with logistic regression

[f] distance estimated visually

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

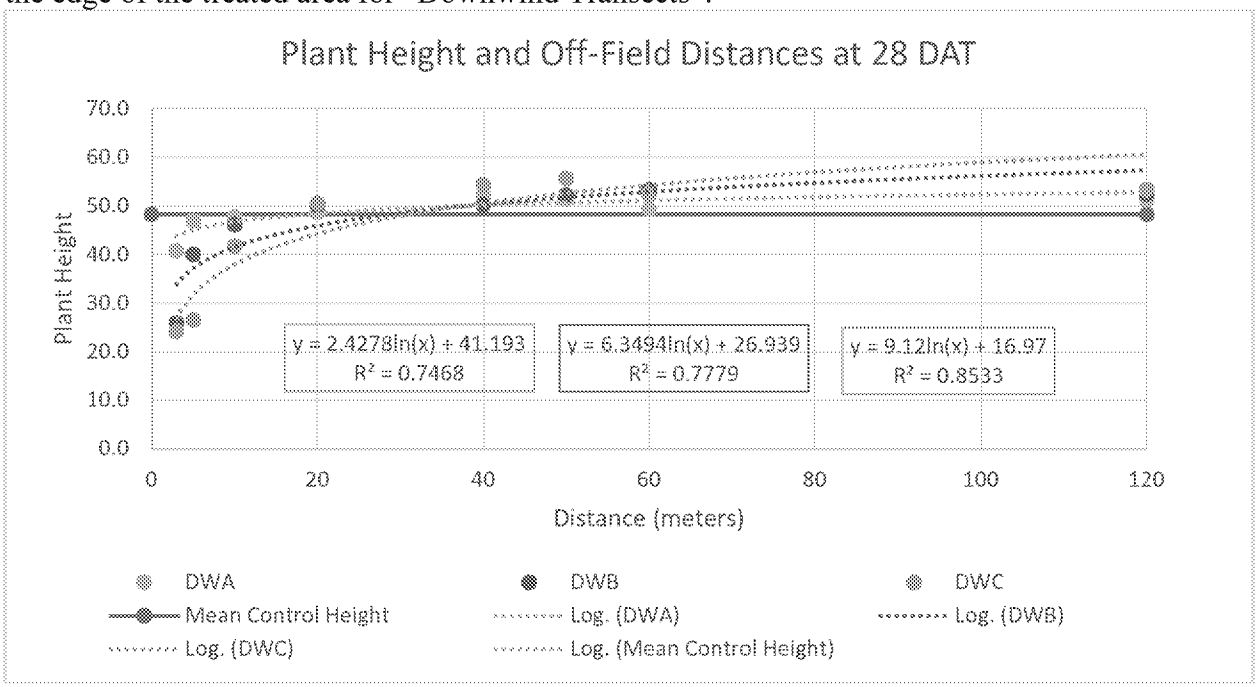


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

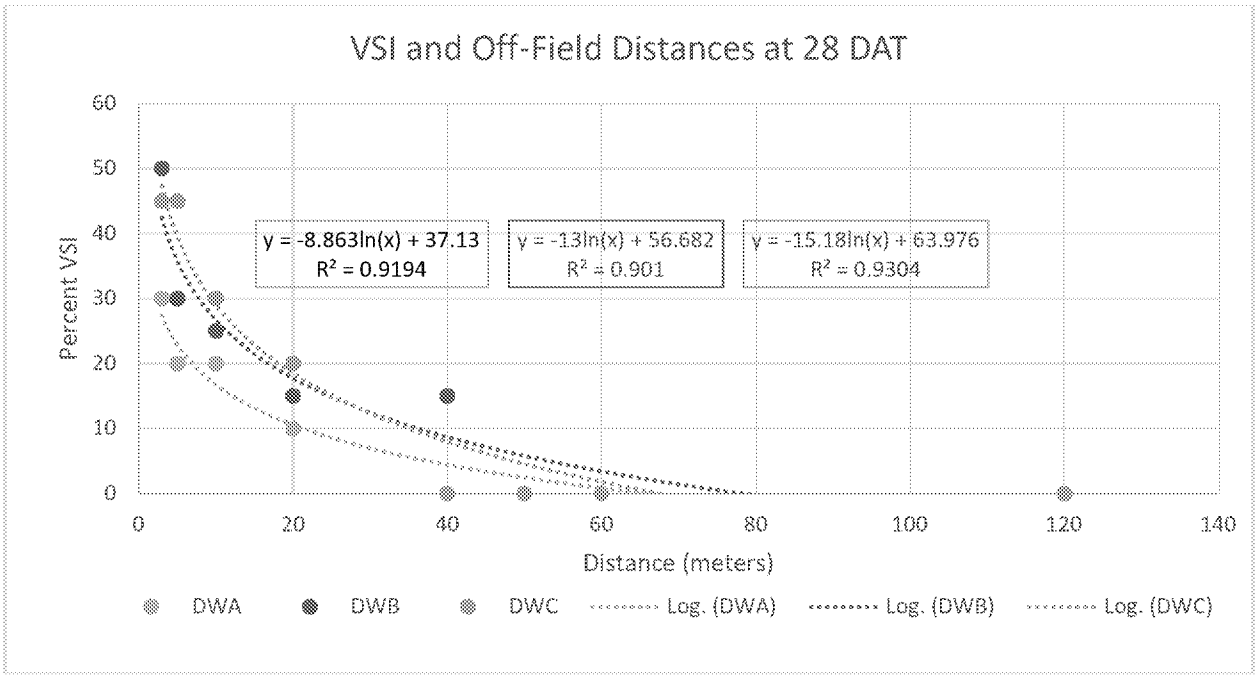


Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from

the edge of the treated area for "Left Wind" and "East" corner transects.

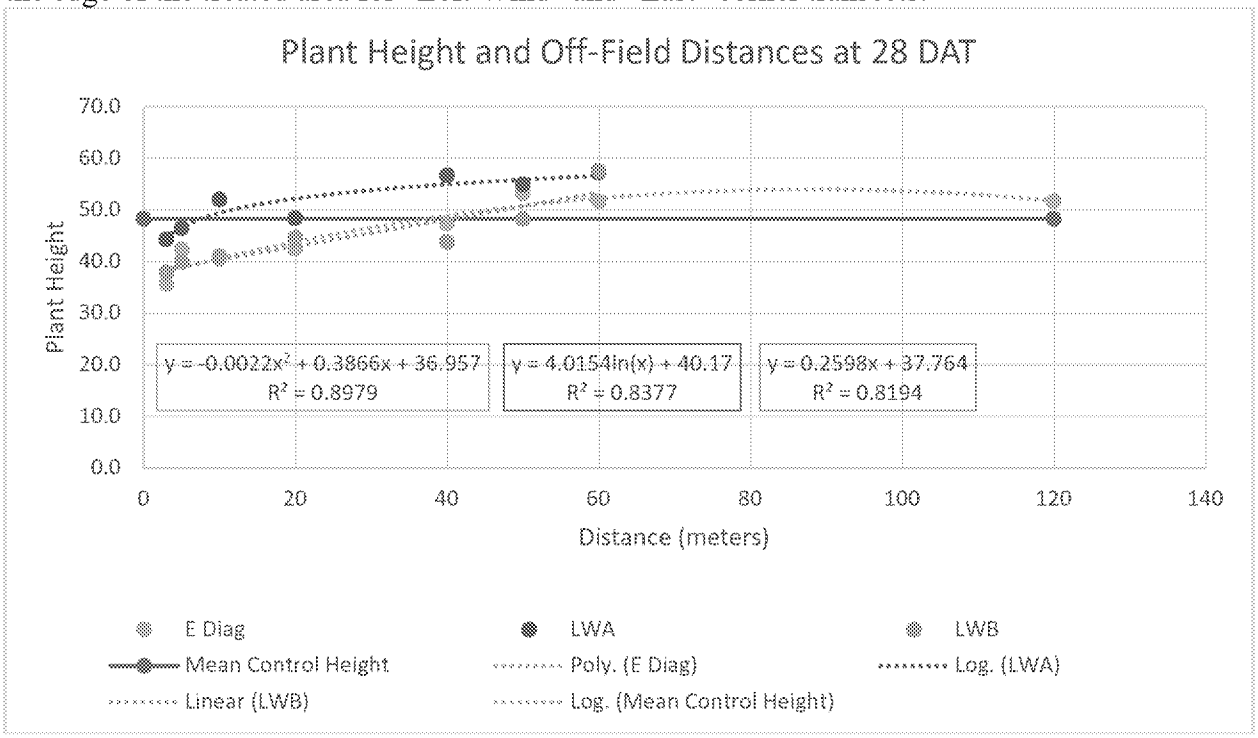


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" and "East" corner transects.

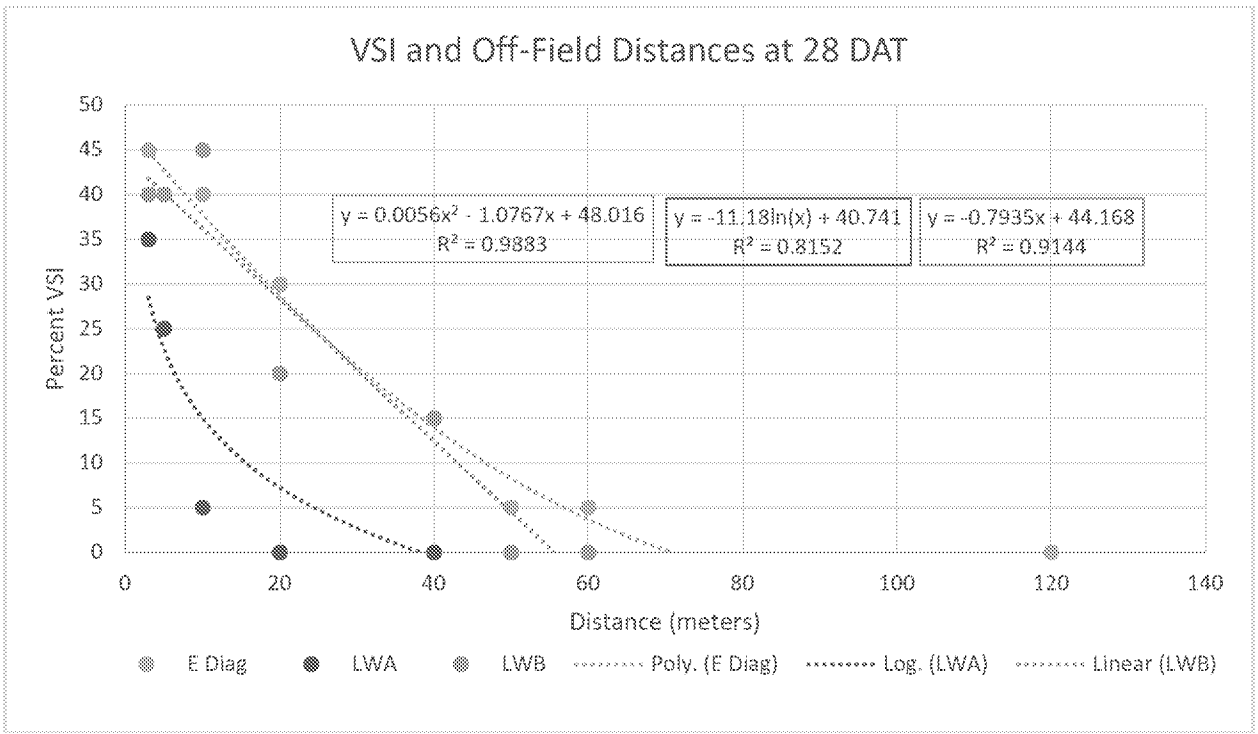


Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from

the edge of the treated area for "Right Wind" and "North" corner transects. Note: transects showed no drift related effects on plant height.

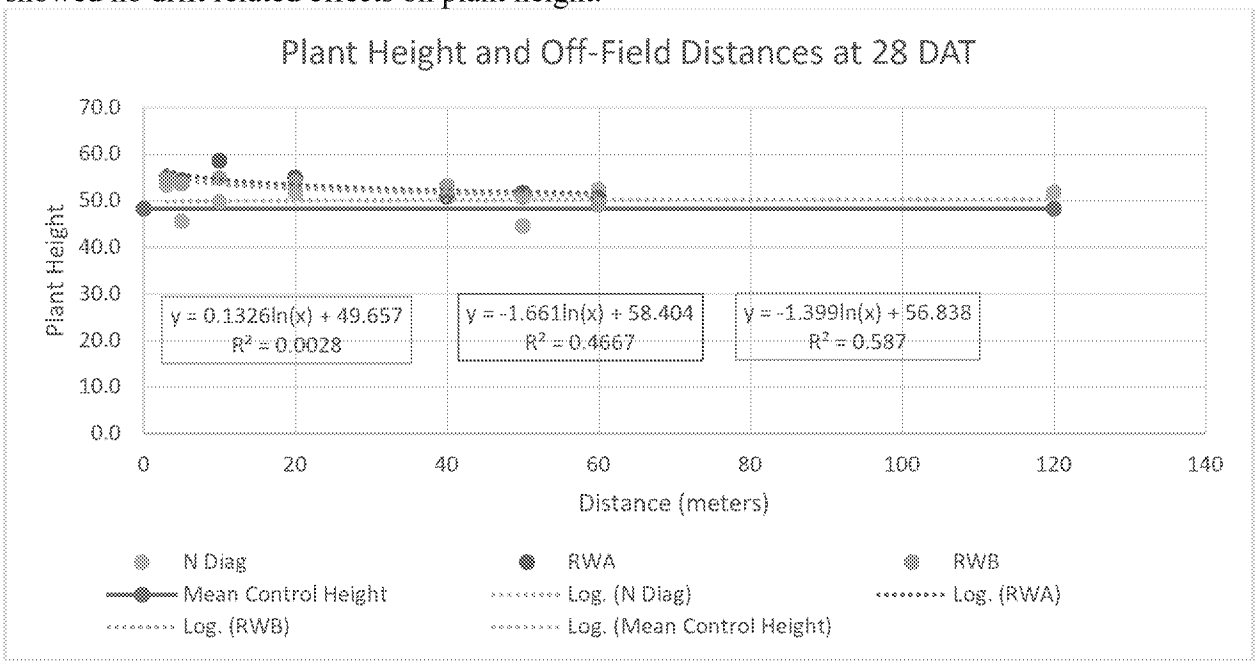


Figure 11: VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Right Wind" and "North" corner transects. Note: transects showed no VSI.

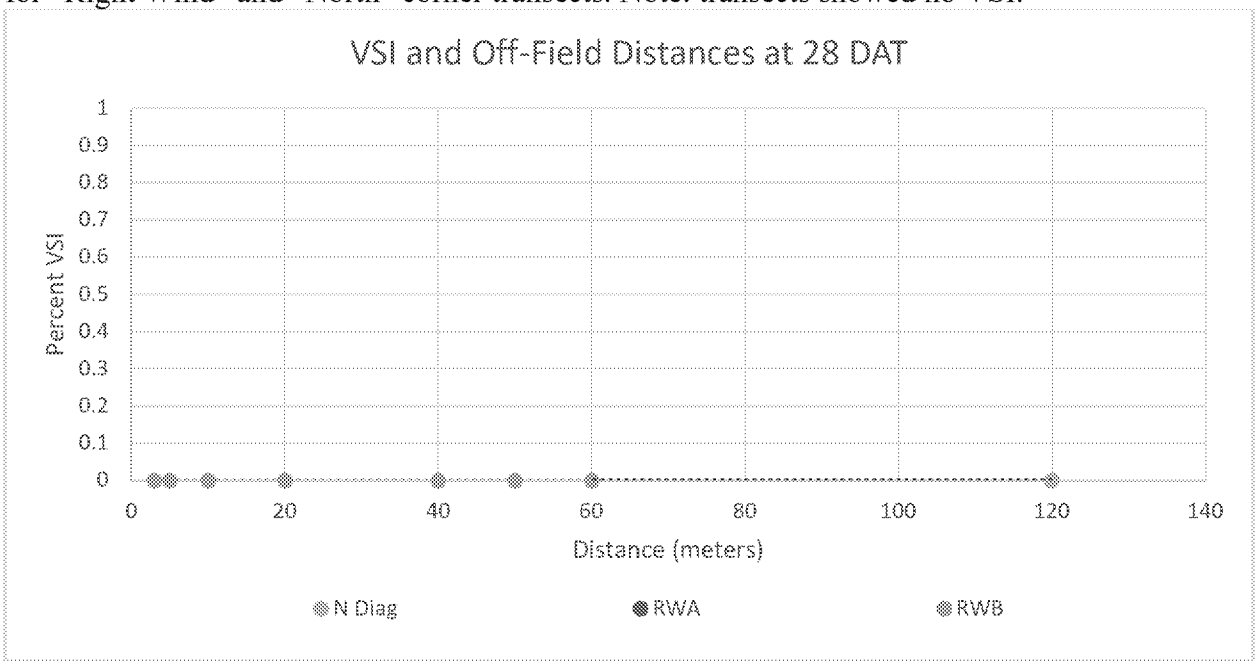


Figure 12: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" and "South" corner transects.

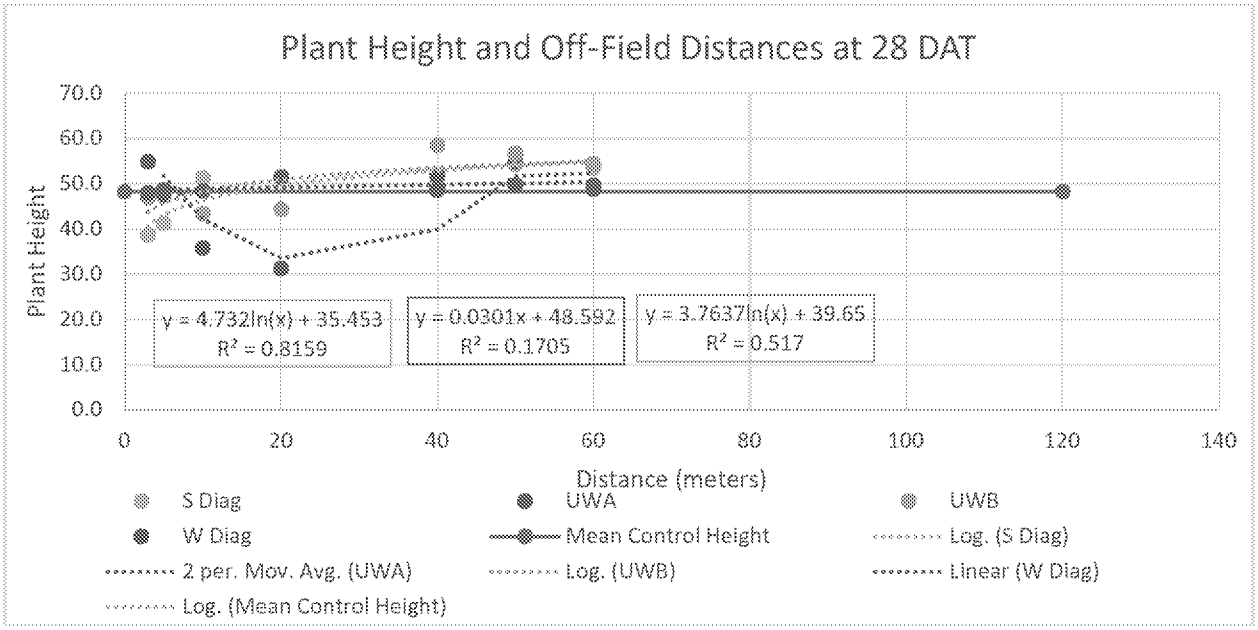
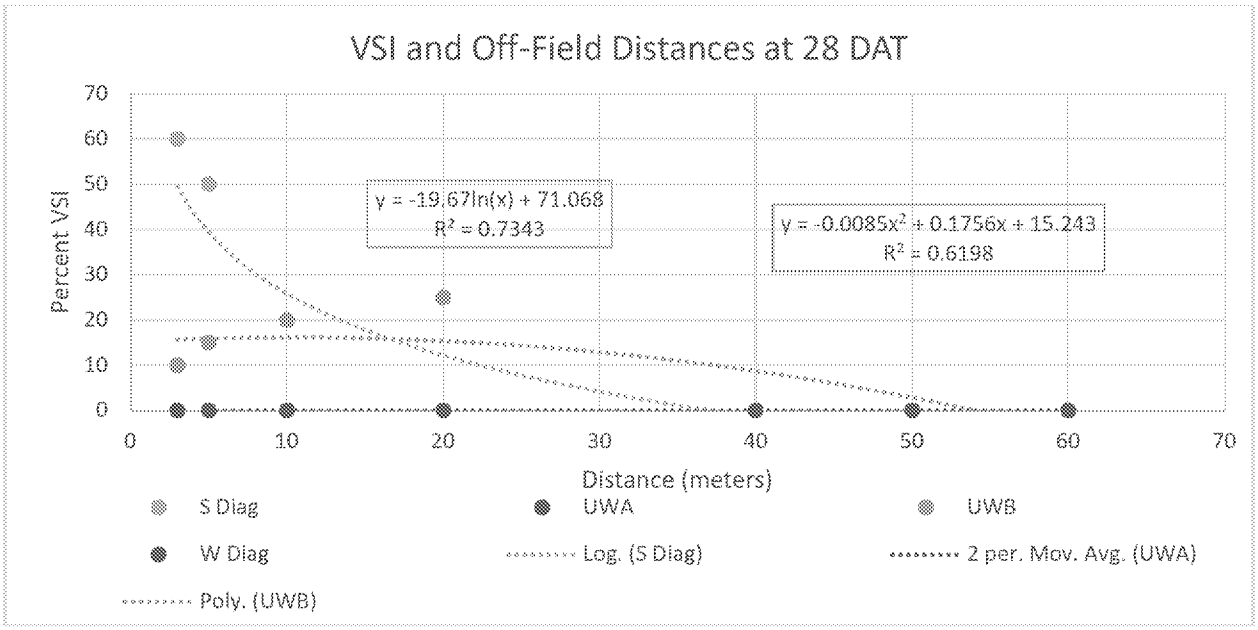


Figure 13: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" and "South" corner transects. Note: W-diag and UWA transects showed no VSI.



III. Study Deficiencies and Reviewer's Comments

1. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 532). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

2. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well and set to half the detection limit when estimating flux rates.

3. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, slope estimates, pesticide and crop history, soil taxonomy, and study weather data (p. 4).

4. The first air monitoring period started after the conclusion of application.

5. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

6. Soil was characterized (Appendix B, pp. 95-96, 104, and Appendix B, Table 3, p. 111), but no taxonomic classification was provided.

7. Soil bulk density and organic matter content were reported at only a single depth of 0-6 inches.

Study Deficiencies: Plant Effects

1. For both the volatility and spray drift portions of the study, the study author measured the height of a varying number of plants along each transect prior to test material application (volatility n=2; drift n=3; Appendix G, Table 1, p. 733). Following application, "At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points" (Appendix G, p. 727).

The variability in plant vigor and stand condition across the site suggested the results of both studies may have been confounded due to a lack of homogeneous field conditions. The method presented by the study author indicates that no effort was made to determine uniform, homogenous, boundary-marked sampling sites at prescribed distances and sampling areas prior to treatment. OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. Although the study author reported that 'plants selected for plant height measurements were selected non-systemically as an unbiased representation for the population", the reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

2. The diagonal transects included one replicate of 10 plants per distance from the treatment field, and due to the lack of sufficient replicates/data, the Dunnett Multiple Comparison test was unable to determine significance of height effects and NOAEDs. The plants in the east diagonal transect (ED) and north diagonal transect (ND) are adjacent to the downwind transects and may be expected to show height effects.

3. Rainfall throughout the study was observed to have pooled in areas of low elevation. Subsequent growth effects due to flooding in some portions of the test fields were reported. The variable impact of the flooding on plant growth may have additionally confounded test results.

4. In certain cases, environmental factors were an important variable influencing plant height. For example, in the north diagonal drift transect (0% symptomology) and left wind B drift transect (15% symptomology), plant height was negatively impacted; however, reduction in plant height was likely attributable to standing water in the field and is not considered treatment related (Figure 7). Using visual symptomology as an assessment endpoint has its limitations due to the subjective nature of the rating; however, it can be valuable as an additional line of evidence to evaluate the likelihood a response in the field is treatment related (p. 729). Based on the information provided for VSI it is not possible to discern dicamba related VSI from other influences. Therefore, the reviewer considered all VSI reported in the study to be a response to dicamba exposure.

5. Transects for spray drift were 60 m long (three upwind sides and two diagonals) and approximately 120 m long (downwind side and the two downwind diagonals) with measurements/symptomology ratings completed at approximately 3, 5, 10, 20, 40, 50, 60, and 120 m from the sprayed area. The study did not report actual distances for each of the height measurements, so NOAED presented by the reviewer are based on nominal distances.

6. The study author determined No-Effect Distance (NOAED) but did not report the field reference point for calculating no-effect distances. As a result, NOAED values, which

include 0 meters and other values reported in Table 2 in the Plant Effects Sub-Report (Appendix G, p. 734, of the study report) should be interpreted with caution.

7. The study author did not provide seed supplier information and historical germination rates for the soybean varieties planted.

8. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported, nor was the specific location within the untreated field as it relates to elevations.

9. The physico-chemical properties of the test material were not reported.

10. The Stine PGL3590 variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

IV. **References**

Johnson, B., Barry, T., and Wofford P. 1999. Workbook for Gaussian Modeling Analysis of Air Concentrations Measurements. State of California, Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA.

Maher, D. 2016. Storage Stability of Dicamba on Polyurethane Foam Air Sampling Traps. Monsanto Technical Report MSL0026782. St. Louis, Missouri.

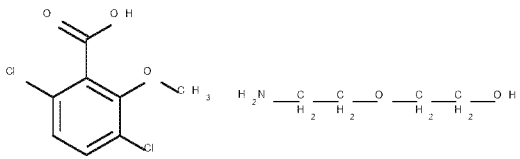
Majewski, M.S., Glotfely, D.E., Paw, K.T., and Seiber, J.N. 1990. A field comparison of several methods for measuring pesticide evaporation rates from Soil. Environmental Science and Technology, 24(10):1490-1497.

Wilson, J.D., and Shum. W.K.N. 1992. A re-examination of the integrated horizontal flux method for estimating volatilisation from circular plots. Agriculture Forest Meteor. Vol 57:281-295.

Yates, S.R., F.F. Ernst, J. Gan, F. Gao, and Yates, M.V. 1996. Methyl Bromide Emissions from a Covered Field: II. Volatilization," Journal of Environmental Quality, 25: 192-202.

Attachment 1: Chemical Names and Structures

Dicamba-diglycolamine and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba-diglycolamine (Diglycolamine salt of dicamba)	IUPAC: 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol CAS: 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid CAS No.: 104040-79-1 Formula: $C_{12}H_{17}Cl_2NO_5$ MW: 326.17 g/mol SMILES: COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		835.8100 Field volatility	51017502	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

128931_51017502_DE
R-FATE_835.8100_3-18

2. Validation spreadsheet for the Indirect Method

128931_51017502_DE
R-FATE_835.8100_4-6-

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

128931_51017502_DE
R-FATE_835.8100_4-6-

4. Validation spreadsheet for the Aerodynamic Method:

128931_51017502_DE
R-FATE_835.8100_4-6-

5. Air modeling files

129831 51017502 air modeling.zip

6. Validation spreadsheet for spray drift calculations

128931_51017502_DE
R-FATE_840.1200_08-2

7. Terrestrial Plants: Regressions for Plant Height and VSI

**MRID51017502_STC
-2019-0032_Plant_Da**

Attachment 3: Field Volatility Study Design and Plot Map

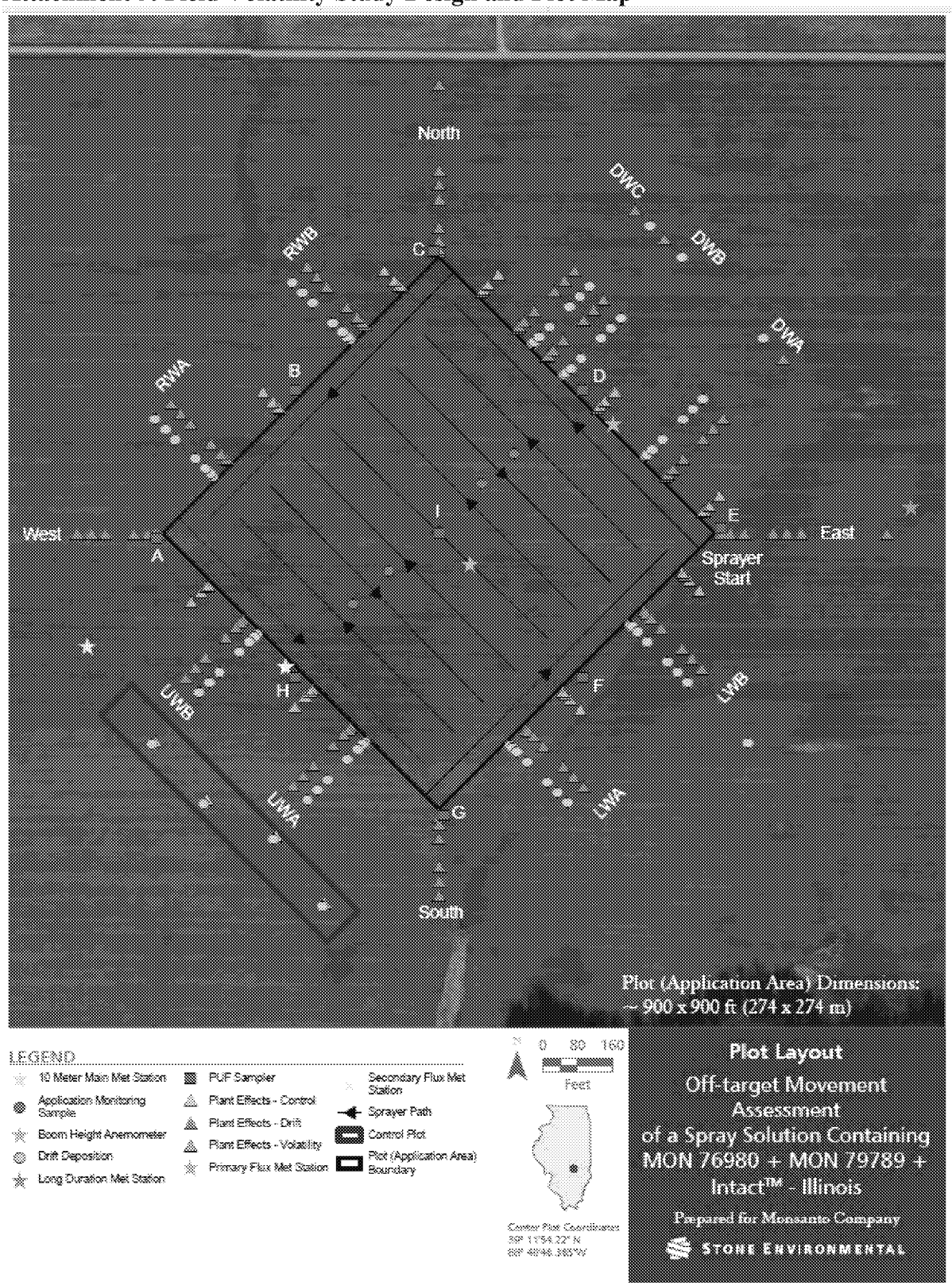


Figure obtained from Appendix B, Figure 2, p. 129 of the study report.