Improved Prediction of the Atmospheric Transport and Fate of Dicamba

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Goals and Objectives

Goal:
The goal of this Rapid Agricultural Response project is to examine the transport and fate of dicamba using a combination of micrometeorological observations, chemical tracers, and concentration footprint analyses using sophisticated numerical model simulations.

Objectives:

1. Estimate the typical concentration source footprint for an agricultural field to establish the potential transport distance for dicamba.

2. Use the concentration source footprint modeling to inform the design of a sampling network for detecting the transport and fate of dicamba under field conditions.

3. Identify the meteorological conditions that inhibit/enhance the transport of dicamba downwind and develop a source footprint climatology to inform best management practices.
Experimental setup: Dicamba application area

Dicamba application area
Traited soybeans and Dicamba Application Plot
10 acres

Non-trailed Soybeans “bio-indicators”
Soybeans planted on May 18, 2018
Dicamba was applied to a 10 acre subplot within a larger 40 acre soybean field at 9:00 am on June 14, 2018 and 10:30 am on June 17, 2019. All specified label requirements for dicamba application were followed.
Canopy Development During Spray Application on June 17, 2019
Dicamba Application

- Farmers Mill and Elevator Inc.
- June 14, 2018 applied at 9:00 am
- Tractor wind speed, 10 mph
- Tractor wind direction, SSE
- Tractor Temp, 72F
- Application rate = 22 oz per acre

- June 17, 2019 applied at 10:30 am
- Tractor wind speed, 4 mph
- Tractor wind direction, S
- Tractor Temp, 67F
- Application rate = 22 oz per acre
Dicamba Application

- Xtendimax with Vapor Grip
- Diglycolamine salt of dicamba (3,6-dichloro-o-anisic acid)
- 22 oz per acre
- 0.56 kg Dicamba per hectare

- Note: In 2019 **Astonish** was added with Xtendimax to reduce drift and volatilization
Atmospheric Sampling
Task 1: Design a sampling network for detecting the transport and fate of dicamba under field conditions.
Sampling scenarios (i.e. South Flow vs Northwest Flow)

X = micromet tower, heat flux, surface temp, turbulence, wind speed
A = TE 1000 air samplers – at intervals of 10 m, 25 m, and 50 m from the dicamba field edge (distance between rows = 50 m)
P = potted soybean plants at 45 degree intervals x 24 hour integrals for up to 7 days at 10 m, 25 m, and 50 m

Six air samplers move according to wind direction.

U, forecast winds for Thursday June 14
Intensive Field Sampling Campaigns in 2018 and 2019
Tisch High volume air samplers

Flow rate: 280 LPM

Air samplers deployed in an array extending out to about 40 meters from the treated soybean subplot that was sprayed. The high volume air samplers were operated continuously for a period of about 1 week following the spray application in both years. All air samples have been archived and are currently being analyzed using accelerated solvent extraction followed by liquid chromatography tandem mass spectrometry.

81 samples collected for analysis
High Volume PUF and Passive Silicon Samples
Dicamba Air PUF Sampling
Liquid Chromatography with Tandem Mass Spectrometry (LC-MS/MS)
Task 2: Identify the meteorological conditions that inhibit/enhance the transport of dicamba downwind and develop a concentration source footprint climatology
Eddy covariance measurements were made within the experimental field to characterize atmospheric turbulence, heat fluxes, stability, air temperature, and humidity.

These observations were used to model the transport of dicamba using backward and forward Lagrangian model simulations.
Mean $T_a = 22.5 \degree C$; Max $T_a = 32.7 \degree C$; min $T_a = 15.0 \degree C$, Total Precipitation = 121 mm

$z/L$ = measure of atmospheric stability (+ stable, - unstable)
Mean $T_a = 18.4 \, ^\circ\text{C}$; Max $T_a = 23.9 \, ^\circ\text{C}$; min $T_a = 10.8 \, ^\circ\text{C}$, Total Precipitation = 24 mm

$z/L$ = measure of atmospheric stability (+ stable, - unstable)
Lagrangian Transport Modeling

First 24 hours following dicamba application June 14, 2018

Ensemble conditions

Ta = 21.3 °C

Wind speed = 4.1 m/s

Wind direction = 144.5 degrees

z/L = -0.025 = unstable atmosphere
Lagrangian simulation tracks particles backward in time based on the recorded eddy covariance and micrometeorological measurements.

Trajectories are influenced by wind direction, speed, stability and stochastic properties of the turbulent flow.

The particles are tracked backward in time from the air samplers.
Lagrangian Modeling of Dicamba Transport

Dicamba flux estimate from 10 acre subplot: 1.32 ng m\(^{-2}\) s\(^{-1}\)

Puf Sample Value
0.18 ug/m3

Dicamba plot
Lagrangian Forward Modeling of Dicamba Transport Based on the Estimated Emission Source Strength

Concentration estimate at 200 m 1.97 ng/m³
Influence of Atmospheric Stability on Downwind transport of Dicamba
Estimating Drift vs Volatization

- Analysis of PUF Sample 1 (first 24 hours) includes drift + volatization
- Analysis of PUF Sample 2-7 (days 2 to 7) represent the volatization
- This work is pending LC-MS/MS analysis
Task 3: Detecting dicamba damage using plant bio-indicators

Dicamba injury symptom rating scale

0  No effect, plant normal.
10 Slight crinkle of leaflets of terminal leaf.
20 Cupping of terminal leaflets, slight crinkle of leaflets of second leaf, growth rate normal.
30 Leaflets of two terminal leaves cupped, expansion of terminal leaf suppressed slightly.
40 Malformation and growth suppression of two terminal leaves, terminal leaf size less than one-half that of control. New axillary leaves developing at a substantially reduced rate.
50 No expansion of terminal leaf, second leaf size one-half that of control.
Axillary leaf buds unable to open and develop.
60 Slight terminal growth, necrosis of terminal leaf, and axillary bud apparent.
Chlorosis and necrosis in axillary leaf clusters.
70 Terminal bud dead, substantial, strongly malformed axillary shoot growth.
80 Limited axillary shoot growth, leaves present at time of treatment chlorotic with slight necrosis.
90 Plant dying, leaves mostly necrotic.
100 Plant dead.
Detecting damage using bio-indicators

These two pictures were taken at the same location and at the same number of Days After Application, but in different years which had different climate conditions.

**2018 North 10m** from edge of dicamba treated beans. This is among the highest damage we saw over the entire campaign. Strong wind out of south and high temperature during 2018 application. Damage = 40

**2019 North 10m** from edge of dicamba treated beans. The wind in 2019 during application was from the north so we wouldn’t expect to see much damage. Damage = 10
Detecting damage using bio-indicators

These two pictures were taken at the same location and at the same number of Days After Application, but in different years which had different climate conditions.

2018 South 10m from edge of dicamba treated beans. The wind during application was out of the south so we would not expect to see damage here.
Damage = 5

2019 South 10m from edge of dicamba treated beans. The wind during application was out of the north so we would expect to see damage here, however, the temperature was lower and the wind speed was less than 2018.
Damage = 5
Damage Assessment June 25, 2018

Traited soybeans and Dicamba Application Plot

10 acres

Damage estimates
June 25 NW 10m damage
June 25 S25 m damage
Drone image analysis of Dicamba Damage, 2018
Impact on Soybean Yield

Traited beans mean yield = 51.65 +/- 6.67
Non-traited beans mean yield = 49.63 +/- 9.57
Task 4: Long-term Climate Parameters Related to Transport
Searching for Air Temperature Inversions to Identify Stable Atmospheric Conditions
Climatological (20 site-years) Analysis of Atmospheric Stability

Stable = Do not spray
Climatological (11 site-years) Analysis of Wind Speed above Crops

Red dashed line = Wind speed threshold of 1.3 to 4.5 m/s or 3.0 to 10.0 mph
Do not spray outside of threshold
Next Steps for Modeling

• Perform transport simulations for all 81 puf observations
• Perform simulation based on known tracer release
• Estimate the emissions for different time periods to examine how volatization changes with time and meteorological conditions.
• Estimate the maximum probable downwind concentration based on emission estimates
• Develop a simple calculator based on our Lagrangian modeling and observations