

Validation Model to Predict Soybean Yield Loss Associated with Dicamba Exposure

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Dicamba-Resistant Soybeans in 2016

- Monsanto, DuPont Pioneer and several other seed companies sold dicamba-resistant soybeans for use in the Roundup Ready Xtend Crop System
- Seed planted on approximately 2 million acres
- Dicamba herbicide was not registered for commercial in-crop use
- Access to dicamba formulations resulted in illegal use



Dicamba-Resistant Soybeans in 2016

- EPA collected reports of crop damage from 10 states: Missouri, Alabama, Arkansas, Illinois, Kentucky, Minnesota, Mississippi, North Carolina, Tennessee, and Texas (Eco Watch, September 2, 2016).
- Dicamba injury complaints were concentrated in Missouri, Tennessee, and Arkansas.
- Estimated that in Missouri and Arkansas over 200,000 acres were illegally sprayed and affected everything from soybeans, peaches, watermelons to tomatoes (Wall Street Journal, August 2, 2016).
- Tennessee estimates that an additional 35,000 acres of soybeans were illegally sprayed (Larry Steckel, University of Tennessee).

Dicamba-Resistant Soybeans in 2016

- Missouri Department of Agriculture received more than 100 pesticide drift complaints (four-county area in southeast MO)
 - The Missouri Department of Agriculture officially pegged the number of Missouri soybean acres damaged by dicamba at 45,000 acres.
 - Injury also reported for cantaloupe, tomato, purple hull peas, watermelon, and peaches.
- Kevin Bradley (University of Missouri Weed Scientist)
 - Walked fields for 124 dicamba-related complaints filed with the Missouri Department of Agriculture.

Objectives

- To quantify the severity of injury for fourteen injury criteria as influenced by dicamba rate and soybean growth stage.
- To determine relationship between severity of injury for each criterion and yield and to develop a model to predict yield loss.



Materials and Methods

Location:

- Central Research Station in 2013, 2014, and 2015
- Soil type: clay loam

Varieties:

- Indeterminate MG 4.8 to 5.1 soybean planted in early May to early June

Herbicide Treatments:

- Dicamba (Clarity diglycolamine salt) at 1/64, 1/32, 1/16, 1/8, 1/4, 1/2, 1, 2, 4, and 8 oz/A; 1/1024 to 1/2 of the use rate of 16 oz/A
- Nonionic surfactant at 0.25% v/v added to all treatments
- CO₂ backpack sprayer used with 15 GPA spray volume @ 30 psi
- Nontreated included for comparison



Materials and Methods

Application Timing:

- V3/V4 (third/fourth node with 2/3 fully expanded trifoliates)
- R1/R2 (open flower at any node on main stem/open flower at one of the two uppermost nodes on main stem)

Plot Size:

- 4 rows (30 inch spacing) x 30 feet;
2 inner rows treated

Experimental Design:

- RCB with factorial arrangement of treatments (dicamba rate x application timing) and four replications



Materials and Methods

Data Collected:

- Fourteen injury criteria identified
- Rated 7 and 15 d after dicamba application (DAA) on a severity scale of 0 to 5 with 0= no injury; 1= slight; 2= slight to moderate (producer concern); 3= moderate; 4= moderate to severe; and 5= severe
- Overall visual assessment of soybean injury and plant height reduction made on 0 to 100% scale and soybean canopy height determined 7 and 15 DAA
- Mature plant height and yield determined

Data Analysis:

- ANOVA and Tukey-Kramer ($P < 0.05$)
- Multiple regression to develop yield prediction model (to be discussed later)



Fourteen Dicamba Injury Criteria

- Upper canopy:

- leaf cupping
- leaf surface crinkling
- pale leaf margins
- leaf rollover/inversion

- Lower leaf soil contact

- Leaf petiole:

- droop
- base swelling

- Terminal leaf:

- cupping
- chlorosis
- necrosis
- epinasty



- Stem epinasty

- Lower stem:

- base swelling
- lesions/cracking






Injury Criteria as Influenced by Soybean Growth Stage - 15 DAA

Dicamba rate (oz/A)	Cupping of upper canopy leaves		Pale leaf margins		Lower leaf soil contact		Lower stem base swelling	
	V3/V4	R1/R2	V3/V4	R1/R2	V3/V4	R1/R2	V3/V4	R1/R2
0	0 f	0 f	0 i	0 i	0 f	0 f	0 e	0 e
1/64 (1/1024 x)	4.7 a-d	0 f	4.1 a-d	0 i	0 f	0 f	0.2 e	0 e
1/32 (1/512 x)	4.8 abc	0 f	4.2 abc	0 i	0 f	0 f	0.4 de	0 e
1/16 (1/256 x)	4.6 a-d	0 f	3.9 bcd	0 i	0 f	0 f	0.7 ed	0 e
1/8 (1/128 x)	4.5 a-d	0 f	3.8 cd	0 i	0 f	0 f	1.2 de	0 e
1/4 (1/64 x)	3.8 d	0 f	2.7 e	0 i	0 f	0 f	1.6 d	0 e
1/2 (1/32 x)	2.6 e	0 f	1.6 fg	0 i	0.3 f	0 f	3.2 c	0 e
1 (1/16 x)	1.8 e	0 f	1.3 gh	0 i	1.9 e	0 f	4.0 abc	0 e
2 (1/8 x)	0.3 f	0 f	0.3 hi	0 i	2.1 de	0 f	3.3 bc	0 e
4 (1/4 x)	0 f	0 f	0 i	0 i	3.0 cde	0 f	3.3 bc	0 e
8 (1/2 x)	0 f	0 f	0 i	0 i	3.3 bcd	0 f	3.3 bc	0 e

Injury severity based on: 0-5 scale with 0= no injury; 1= slight; 2= slight to moderate (producer concern); 3= moderate; 4= moderate to severe; 5= severe

Injury Criteria 15 DAA

V3/V4 Dicamba Application

Dicamba rate (oz/A)	Cupping of upper canopy leaves	Pale leaf margins	Lower leaf soil contact	Lower stem base swelling
0				
1/64 (1/1024 x)				
1/32 (1/512 x)				
1/16 (1/256 x)				
1/8 (1/128 x)				
1/4 (1/64 x)				
1/2 (1/32 x)				
1 (1/16 x)				
2 (1/8 x)				
4 (1/4 x)				
8 (1/2 x)				



Injury Criteria As Influenced by Soybean Growth Stage - 15 DAA

Dicamba rate (oz/A)	Cupping of terminal leaves		Upper canopy leaf rollover/whitish appearance	
	V3/V4	R1/R2	V3/V4	R1/R2
0	0 d	0 d	0 e	0 e
1/64 (1/1024 x)	0 d	4.4 a	0 e	0.5 de
1/32 (1/512 x)	0 d	5.0 a	0 e	0.5 de
1/16 (1/256 x)	0 d	4.5 a	0 e	0.5 de
1/8 (1/128 x)	0 d	4.1 a	0 e	0.5 de
1/4 (1/64 x)	0 d	2.4 b	0 e	0.9 d
1/2 (1/32 x)	0 d	1.4 bc	0 e	1.1 d
1 (1/16 x)	0 d	0.6 cd	0 e	2.4 c
2 (1/8 x)	0 d	0.4 cd	0 e	3.4 b
4 (1/4 x)	0 d	0 d	0 e	2.4 c
8 (1/2 x)	0 d	0d	0 e	0 e

Injury severity based on: 0-5 scale: 0= no injury; 1= slight; 2= slight to moderate (producer concern); 3= moderate; 4= moderate to severe; 5= severe

Injury Criteria 15 DAA

R1/R2 Dicamba Application

Dicamba rate (oz/A)	Cupping of terminal leaves	Upper canopy leaf rollover/whitish appearance
0		
1/64 (1/1024 x)		
1/32 (1/512 x)		
1/16 (1/256 x)		
1/8 (1/128 x)		
1/4 (1/64 x)		
1/2 (1/32 x)		
1 (1/16 x)		
2 (1/8 x)		
4 (1/4 x)		
8 (1/2 x)		

Soybean Yield As Influenced by Soybean Growth Stage

Dicamba rate (oz/A)	3 Year Average Yield (Bu/A)	
	V3/V4	R1/R2
0	64.6	66.6
1/64 (1/1024 x)	61.9 (4%)	56.4 (15%)
1/32 (1/512 x)	60.3 (7%)	56.6 (15%)
1/16 (1/256 x)	57.0 (12%)	54.6 (18%)
1/8 (1/128 x)	55.9 (14%)	50.8 (24%)
1/4 (1/64 x)	52.8 (18%)	46.9 (30%)
1/2 (1/32 x)	49.1 (24%)	20.2 (70%)
1 (1/16 x)	32.5 (50%)	16.2 (76%)
2 (1/8 x)	6.4 (90%)	5.5 (92%)
4 (1/4 x)	0 (100%)	2.1 (97%)
8 (1/2 x)	0 (100%)	0 (100%)



For each dicamba rate, greater yield reduction observed for exposure at R1/R2 vs. V3/V4
 A sizeable change in yield reduction occurred at 1 oz/A for V3/V4 and 0.5 oz/A for R1/R2

Development of Model to Predict Yield

- Multiple regression analysis with a forward selection procedure was used
 - Separate analysis performed for V3/V4 application at 7 and 15 DAA and for R1/R2 application 7 and 15 DAA
 - Variables analyzed to determine their relationship to yield included:
 - 14 injury criteria plus overall visual injury, plant height reduction, and canopy height
- For each application timing and DAA, only six of the seventeen variables were selected for use in the models/regression equations to predict yield.
- By knowing the yield for the nontreated, yield loss can be calculated.

Multiple Regression Analysis

V3/V4 Exposure 15 DAA

Summary of Forward Selection				
Step	Variable Entered	Number Vars In	Model R-Square	Mallow's criteria C(p)
1	Lower stem lesions/cracking	1	0.8326	168.072
2	Percent height reduction	2	0.8583	124.623
3	Terminal leaf epinasty	3	0.8646	115.520
4	Leaf petiole droop	4	0.8967	60.6341
5	Leaf petiole base swelling	5	0.9125	34.8322
6	Stem epinasty	6	0.9201	23.2344
7	Terminal leaf necrosis	7	0.9241	18.2834
8	Lower leaf soil contact	8	0.9274	14.4487
9	Terminal leaf chlorosis	9	0.9307	10.5323
10	Upper canopy leaf surface crinkling	10	0.9324	9.4919
11	Stem base swelling	11	0.9333	10.0136

Prediction Equation: \hat{Y} = Intercept value – 4.08 (lower stem lesions/cracking) – 0.46 (percent height reduction) + 5.38 (terminal leaf epinasty) – 5.92 (leaf petiole droop) + 4.21 (leaf petiole base swelling) – 3.77 (stem epinasty)

Note: Visual assessment of injury not included in model

Multiple Regression Analysis

R1/R2 Exposure 15 DAA

Summary of Forward Selection				
Step	Variable Entered	Number Vars In	Model R-Square	Mallow's criteria C(p)
1	Lower stem lesions/cracking	1	0.8829	91.8446
2	Terminal leaf chlorosis	2	0.9030	63.6752
3	Leaf petiole base swelling	3	0.9190	41.6476
4	Stem epinasty	4	0.9285	29.4470
5	Terminal leaf necrosis	5	0.9304	28.4866
6	Terminal leaf cupping	6	0.9358	22.5014
7	Terminal leaf epinasty	7	0.9422	14.7522
8	Percent height reduction	8	0.9433	15.1065
9	Canopy height	9	0.9493	8.0872
10	Upper canopy leaf surface crinkling	10	0.9503	8.6977
11	Leaf petiole droop	11	0.9506	10.1340

Prediction Equation: \hat{Y} = Intercept value – 10.37 (lower stem lesions/cracking) – 3.92 (terminal leaf chlorosis) – 4.68 (leaf petiole base swelling) + 3.90 (stem epinasty) – 2.46 (terminal leaf necrosis) – 1.70 (terminal leaf cupping)

Note: Visual assessment of injury not included in model



Summary/Conclusions



- Soybean injury criteria and severity of injury associated with dicamba exposure varied depending on rate and growth stage.
 - Upper canopy leaf cupping, upper canopy pale leaf margins, lower leaf soil contact, and lower stem base swelling was observed at V3/V4 exposure but not at R1/R2.
 - Terminal leaf cupping and upper canopy leaf rollover/inversion was observed at R1/R2 but not at V3/V4.
- Yield reduction was greater when soybeans were exposed to dicamba at the reproductive growth stage compared with the vegetative stage.
- Soybean yield loss at a rate of 1/1024th of the use rate (exposure associated with volatility) was 4% for V3/V4 application and 15% for R1/R2 application.
- For dicamba rate associated with spray tank contamination (0.25 to 2%), soybean yield was reduced 7 to 18% for V3/V4 application and 15 to 30% for R1/R2 application.
- Soybean yield loss at a rate of 1 to 10% of the use rate (exposure associated with spray particle drift) was 14 to 50% for V3/V4 application and 24 to 76% for R1/R2 application.
- A multiple regression model was developed to predict soybean yield and yield loss using specific injury variables.

Next Step.....

- Validate the models in the field
- If the models are able to reasonably predict yield reduction, a field diagnostic procedure and software package/App will be developed

Stay tuned for part 2

