Injury Criteria Associated with Soybean Exposure to Dicamba and Potential for Yield Loss Prediction

Matt Foster
Dicamba in 2017

- **Arkansas**: 924 dicamba complaints filed (Arkansas Agricultural Department August 18, 2017)

- **Missouri**: 287 dicamba complaints filed (Missouri Department of Agriculture August 17, 2017)

- **Tennessee**: 118 dicamba complaints under investigation (Bradley August 10, 2017)

- **Mississippi**: 72 dicamba complaints made to the Department of Agriculture and Commerce (Bradley August 10, 2017)

- Complaints also reported in Iowa, Ohio, Illinois, Indiana, Kansas, Kentucky, Minnesota, Nebraska, North Carolina, North Dakota, and South Dakota
Objectives

• To determine the negative effects of dicamba on soybean growth and yield

• To develop a model to predict soybean yield loss following dicamba exposure

• To validate the model and develop a software package/APP for use in yield loss prediction
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; 1/1000 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
- Non-treated 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 visual 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)
- Regression analysis
- Multiple linear 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
Leaf Injuries Criteria

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

Leaf Cupping/Crinkling
Leaf Petiole Drooping
Leaf Soil Contact
Leaf Petiole Base Swelling
Terminal Injury Criteria

**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
Stem Injury Criteria

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

Stem Epinasty

Stem Cracking

Stem Swelling
Soybean Yield as Influenced by Soybean Growth Stage

**Equations:**
- **V3/V4**: \( y = 4249.1064e^{-0.0220x} \), \( R^2 = 0.98 \)
- **R1/R2**: \( y = 4013.7541e^{-0.0412x} \), \( R^2 = 0.97 \)

**Graph:**
- **Y-axis:** Soybean yield (kg ha\(^{-1}\))
- **X-axis:** Dicamba rate (g ae ha\(^{-1}\))
- Data points and trend lines indicating yield decline with increasing Dicamba rate.
Predicted Soybean Yield Loss

• Volatility
  – 0.1% of the use rate (Egan and Mortensen 2012)
  – 1/64 oz/A dicamba
    • V3/V4 (1%) and R1/R2 (2%)

• Spray particle drift
  – 1.0 to 8% of the use rate (Maybank et al. 1978)
  – 1/8 oz/A to 1 oz/A dicamba
    • V3/V4 (9 to 54%) and R1/R2 (17 to 76%)
  – As high as 16% of the use rate (Wolf et al. 1992)
  – 2 oz/A dicamba
    • V3/V4 (79%) and R1/R2 (94%)
Soybean Mature Height as Influenced by Soybean Growth Stage

\[ y = 78.6422e^{-0.0254x}, \quad R^2 = 0.96 \]

\[ y = 72.1160e^{-0.0046x}, \quad R^2 = 0.90 \]
Value of Yield Prediction Models?

• Aid in critical decisions regarding:
  – Replanting of the crop
  – Additional crop inputs
  – Crop insurance claims
  – Liability issues

• “Gut feeling“ currently only method of predicting soybean yield loss
Development of Model to Predict Yield

• Multiple linear regression analysis with a forward/stepwise selection procedure was used to analyze the 2013-2015 data
  – Separate analysis was performed for V3/V4 application at 7 and 15 DAA and for R1/R2 application 7 and 15 DAA
  – 14 injury criteria plus overall visual injury, visual height reduction, and canopy height were analyzed to determine their relationship to soybean yield

• For each application timing and DAA, only six of the seventeen variables were selected for use in the models to predict soybean yield

• By knowing the yield for the non-treated, yield loss can be calculated
## Variables Included in Models

<table>
<thead>
<tr>
<th>V3/V4 exposure</th>
<th>R1/R2 exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7 DAA</strong></td>
<td><strong>15 DAA</strong></td>
</tr>
<tr>
<td>visual height reduction (%)</td>
<td>lower stem base lesions/cracking (0-5)</td>
</tr>
<tr>
<td>lower leaf soil contact (0-5)</td>
<td>visual height reduction (%)</td>
</tr>
<tr>
<td>lower stem base lesions/cracking (0-5)</td>
<td>terminal leaf epinasty (0-5)</td>
</tr>
<tr>
<td>canopy height (cm)</td>
<td>leaf petiole droop (0-5)</td>
</tr>
<tr>
<td>overall visual injury (%)</td>
<td>leaf petiole base swelling (0-5)</td>
</tr>
<tr>
<td>upper canopy leaf surface crinkling (0-5)</td>
<td>stem epinasty (0-5)</td>
</tr>
</tbody>
</table>
Prediction Equations

• **V3/V4**
  
  - **7 DAA:** $\hat{Y} = \text{Intercept value} - 0.30 \text{ (visual height reduction)} - 3.77 \text{ (lower leaf soil contact)} - 4.25 \text{ (lower stem base lesions/cracking)} - 0.76 \text{ (canopy height)} - 0.27 \text{ (overall visual injury)} + 1.71 \text{ (upper canopy leaf surface crinkling)}$
  
  - **15 DAA:** $\hat{Y} = \text{Intercept value} - 4.08 \text{ (lower stem base lesions/cracking)} - 0.46 \text{ (visual height reduction)} + 5.38 \text{ (terminal leaf epinasty)} - 5.92 \text{ (leaf petiole droop)} + 4.21 \text{ (leaf petiole base swelling)} - 3.77 \text{ (stem epinasty)}$

• **R1/R2**
  
  - **7 DAA:** $\hat{Y} = \text{Intercept value} - 0.77 \text{ (visual height reduction)} - 6.93 \text{ (lower stem base lesions/cracking)} - 1.60 \text{ (leaf petiole droop)} + 1.93 \text{ (upper canopy leaf rollover/inversion)} - 2.95 \text{ (leaf petiole base swelling)} + 1.78 \text{ (stem epinasty)}$
  
  - **15 DAA:** $\hat{Y} = \text{Intercept value} - 10.37 \text{ (lower stem base lesions/cracking)} - 3.92 \text{ (terminal leaf chlorosis)} - 4.68 \text{ (leaf petiole base swelling)} + 3.90 \text{ (stem epinasty)} - 2.46 \text{ (terminal leaf necrosis)} - 1.70 \text{ (terminal leaf cupping)}$
Validation of Models

- Experiments conducted in Baton Rouge and St. Joseph, LA in 2016 using ‘Asgrow 4835’, an indeterminate MG 4.8 cultivar
- Dicamba formulation, rates, and application timings same as used to develop the models
  - Clarity (diglycolamine salt) at 1/64 to 8 oz/A (1/1000x to 1/2x) plus 0.25% v/v NIS
  - V3/V4 (third/fourth node with 2/3 fully expanded trifoliates) and R1/R2 (open flower at any node on main stem/open flower at one of the two uppermost nodes on main stem)
Validation of Models (Continued)

• Data were collected for the six variables specified by the model for each application timing and DAA

• Plots harvested to determine yield; nontreated yields of 67 Bu/A at Baton Rouge and 82 Bu/A at St. Joseph
  
  ➢ Percent yield reduction vs. nontreated was calculated for each dicamba rate

• Using the models (equations), yield for each dicamba rate was predicted and percent yield reduction vs. nontreated was calculated

• To test the models, predicted percent yield reduction for each dicamba rate was compared to actual percent yield reduction
## Validation Study Results Averaged Across Locations

### 15 DAA for V3/V4 Application

<table>
<thead>
<tr>
<th>Dicamba rate (oz/A)</th>
<th>Average actual yield (Bu/A) / percent yield reduction</th>
<th>Average predicted percent yield reduction</th>
<th>Difference between predicted and actual yield reduction (percentage points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>74.3 / --</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1/64 (1/1000 x)</td>
<td>66.1 / 11%</td>
<td>12%</td>
<td>+1</td>
</tr>
<tr>
<td>1/32 (1/512 x)</td>
<td>63.1 / 15%</td>
<td>17%</td>
<td>+2</td>
</tr>
<tr>
<td>1/16 (1/256 x)</td>
<td>59.7 / 20%</td>
<td>20%</td>
<td>0</td>
</tr>
<tr>
<td>1/8 (1/128 x)</td>
<td>56.5 / 24%</td>
<td>22%</td>
<td>-2</td>
</tr>
<tr>
<td>1/4 (1/64 x)</td>
<td>52.8 / 29%</td>
<td>37%</td>
<td>+8</td>
</tr>
<tr>
<td>1/2 (1/32 x)</td>
<td>50.4 / 32%</td>
<td>52%</td>
<td>+20</td>
</tr>
<tr>
<td>1 (1/16 x)</td>
<td>41.7 / 44%</td>
<td>72%</td>
<td>+28</td>
</tr>
<tr>
<td>2 (1/8 x)</td>
<td>18.9 / 75%</td>
<td>89%</td>
<td>+14</td>
</tr>
<tr>
<td>4 (1/4 x)</td>
<td>7.6 / 90%</td>
<td>99%</td>
<td>+9</td>
</tr>
<tr>
<td>8 (1/2 x)</td>
<td>0 / 100%</td>
<td>99%</td>
<td>-1</td>
</tr>
</tbody>
</table>

Avg = +1.8

Avg = +21
## Validation Study Results Averaged Across Locations

15 DAA for R1/R2 Application

<table>
<thead>
<tr>
<th>Dicamba rate (oz/A)</th>
<th>Average actual yield (Bu/A) / percent yield reduction</th>
<th>Average predicted percent yield reduction</th>
<th>Difference between predicted and actual yield reduction (percentage points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>73.8</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1/64 (1/1000 x)</td>
<td>64.8/12%</td>
<td>16%</td>
<td>+4</td>
</tr>
<tr>
<td>1/32 (1/512 x)</td>
<td>61.8/16%</td>
<td>18%</td>
<td>+2</td>
</tr>
<tr>
<td>1/16 (1/256 x)</td>
<td>58.7/21%</td>
<td>27%</td>
<td>+6</td>
</tr>
<tr>
<td>1/8 (1/128 x)</td>
<td>54.3/26%</td>
<td>30%</td>
<td>+4</td>
</tr>
<tr>
<td>1/4 (1/64 x)</td>
<td>41.9/43%</td>
<td>36%</td>
<td>-7</td>
</tr>
<tr>
<td>1/2 (1/32 x)</td>
<td>32.6/56%</td>
<td>60%</td>
<td>+4</td>
</tr>
<tr>
<td>1 (1/16 x)</td>
<td>16.3/78%</td>
<td>77%</td>
<td>-1</td>
</tr>
<tr>
<td>2 (1/8 x)</td>
<td>8.9/88%</td>
<td>88%</td>
<td>0</td>
</tr>
<tr>
<td>4 (1/4 x)</td>
<td>4.8/94%</td>
<td>97%</td>
<td>+3</td>
</tr>
<tr>
<td>8 (1/2 x)</td>
<td>0/100%</td>
<td>97%</td>
<td>-3</td>
</tr>
</tbody>
</table>

Avg = + 1.2
Results - Validation Study

- Ability of the models to predict soybean yield loss was greater 15 days after dicamba application compared with 7 days (data not shown)

- **V3/V4 exposure 15 DAA of dicamba at 1/64 to 1/4 oz/A**
  - Average actual yield loss was of 11 to 29%
  - The model underestimated average actual yield reduction by 2 percentage points or overestimated by as much as 8 percentage points
  - Average difference in percentage points between predicted and actual yield was 1.8

- **R1/R2 exposure 15 DAA of dicamba at 1/64 to 8 oz/A**
  - Average actual yield loss was of 12 to 100%
  - The model underestimated average actual yield reduction by as much as 7 percentage points or overestimated by as much as 6 percentage points
  - Average difference in percentage points between predicted and actual yield was 1.2
Summary/Conclusions

- Injury criteria and severity of injury varied (rate and growth stage dependent)
- Greater yield reduction at the reproductive growth stage
- Soybean yield loss at a rate of $1/1000^{th}$ of the use rate (exposure associated with volatility)
  - 1% for V3/V4 application and 2% for R1/R2 application
- Soybean yield loss at a rate of 1 to 8% of the use rate (exposure associated with spray particle drift)
  - 9 to 54% for V3/V4 application and 17 to 76% for R1/R2 application
- Soybeans have the ability to recover even when severe injury symptoms are observed
- A U.S. patent regarding the yield loss prediction model was filed in November of 2017
- Next step – Develop software package/App (In progress)
Questions?