What will 2,4-D and Dicamba Agronomic Crops Mean for Vegetable Producers?

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Current Situation

- Dow AgroSciences and Monsanto are developing agronomic crops with resistance to 2,4-D and dicamba.
- This technology is moving forward
- This talk is to provide background on:
  - the logic for this technology
  - information about the technology and
  - concerns we as vegetable growers should be aware of as this moves forward.
Background on Herbicide Resistant Crops

• Roundup Ready (RUR) Agronomic Crops
  – Revolutionized weed management
  – Increased no-till practices
  – Glyphosate applied postemergent during crop season provided excellent broad-spectrum weed control
  – RUR Crops – soybean, corn, cotton, sugar beet, canola
RUR Weed Management

• Technology has not been perfect
• High selection pressure on weeds
• Multiple applications within years
• Resistant weeds evolved
  – 21 weeds worldwide are resistant
  – 3 major weeds in IN confirmed
    • Marestail, giant ragweed, waterhemp
  – Other suspected
In the last 15 years, it has emerged as one of the most problematic weeds to control in soybeans and corn.

- Documented resistance to triazines, ALS inhibitors, and PPO’s (not as widespread as ALS resistance at the current time).
- Best options for postemergence control in soybean besides PPO’s:
  - Glyphosate
  - Glufosinate (Liberty)
  - Hand removal?
Triple-Stack Corn
- Yield Gard CB
- Yield Gard RW
- Roundup Ready

Triple-Stack Corn
- Herculex I
- Herculex RW
- Liberty Link

Triple-Stack Waterhemp
- ALS resistant
- PPO resistant
- Glyphosate resistant
Giant Ragweed
In Indiana

Sensitive
Noble County

0.75 lb ae/A – 21 DAT
Giant Ragweed
In Indiana

Noble County  Sensitive
3.0 lb ae/A – 21 DAT
Palmer Amaranth in Cotton in GA, we don’t have it, YET!
What does Weed Resistance to Roundup Mean?

• Roundup ready technology imperiled
• Requires use of additional herbicide tools and cultural practices
• Must investigate new control methods and use integrated weed management relying less on the sole use of glyphosate
• Herbicide companies investigating new methods of weed control
Future Weed Management Technology

• New Herbicide mechanisms - limited
• Genetic Engineering to obtain crop plants resistant to other herbicides
• Dow AgroSciences -
  – Enlist Weed Control System with 2,4-D tolerance in corn, soybean and cotton
• Monsanto
  – Roundup Ready Plus with dicamba tolerance in corn, soybean and cotton
Why Herbicide Tolerant Crops?

- Provide an additional tool in the RUR system
- A herbicide management package that would provide a wide spectrum of control without damaging the crop
- Use of multiple mechanisms of action mixtures should slow or prevent further evolution of herbicide resistant weeds
- Maintain sustainability of RUR system
Concerns Regarding this Technology

1. How will this influence weed management in agronomic crops?
2. How will widespread use of 2,4-D and dicamba affect non-target crops if these herbicides move away from the treated field by drift and/or volatility?
   • Our concern as vegetable growers is question 2
Present Knowledge

• 2,4-D and dicamba provide control of many broadleaf weeds that have developed resistance to glyphosate.

• The possibility of injury to non-target plants from drift and/or volatility are well documented.

• Drift of any herbicide can cause problems but is especially problematic for these herbicides as vegetables are quite sensitive to very low doses.

• Volatility has been a problem with certain 2,4-D and dicamba formulations (2,4-D esters, Banvel).

• Must ensure that this technology is thoroughly tested prior to any release.
<table>
<thead>
<tr>
<th>Weed Species</th>
<th>Hard-to-Control</th>
<th>Glyphosate-Resistant</th>
<th>ALS-Resistant</th>
<th>2,4-D-Controlled**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chenopodium album (Common lambsquarters)</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ambrosia artemisiifolia (Common ragweed)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ambrosia trifida (Giant ragweed)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Solanum ptycanthum (Eastern black nightshade)</td>
<td>X</td>
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<td></td>
<td>X</td>
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<tr>
<td>Ipomoea sp. (Morningglory species)</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Amaranthus palmeri* (Palmer amaranth)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Conyza canadensis (Marestail)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sida spinosa (Prickly sida, Teaweed)</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Abutilon theophrasti (Velvetleaf)</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Amaranthus rudis (Tall or common waterhemp)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Requires a broader management plan

**560 to 1,120 g ae/ha rate
Present Status of Enlist Technology

• Enlist System
  – Genes discovered that metabolize 2,4-D and they can be transformed into target crops
  – A better formulation of 2,4-D was necessary
    • Less volatile, less susceptible to drift
  – Colex-D technology developed
    • 2,4-D choline is a quaternary ammonium salt, not an amine or an ester
    • Ultra low volatility
    • Minimized potential for drift
    • Low odor
    • Better handling characteristics
2,4-D Metabolism Gene

Metabolic detoxification of 2,4-D by AAD-12
Glyphosate + 2,4-D DMA tank mix

Premix with Colex-D Technology
Present Status of Enlist Technology

- Corn, soybean and cotton in development
- All crops will contain glyphosate resistance
- Soybean and cotton and some corn will contain glufosinate resistance
- Corn will have resistance to ‘Fop’ herbicides
- Offer an expanded window of application both burndown and later in season
- Target release dates – 2013 for corn, 2014 for soybean, 2015-16 for cotton
Present Status of Roundup Ready Plus Crops

• Roundup Ready Plus
  – Genes for discovered that metabolize dicamba and can be transformed into target crops
  – A better form of dicamba was necessary
    • Less volatile, less susceptible to drift
  – dicamba formulation technology
    • Ultra low volatility
    • Minimized potential for drift
    • Better handling characteristics
Present Status of Roundup Ready Plus Crops

- Soybean, corn and cotton being developed
- Resistance to Roundup, dicamba and in cotton glufosinate
- This technology will provide better weed control, less crop injury and greater flexibility in timing of applications
- Release date in 2015
- BASF and Monsanto working together on herbicide and off-site movement issues
New Herbicide Resistant Crop Technologies

• Will require the use of preemergent herbicides

• Research being conducted on:
  – Appropriate application technology
    • Nozzles
    • Effect of off-site movement by drift and potential for volatility
    • Environmental condition effects
    • Susceptibility of non-target plants
What does this Technology mean for Vegetable Growers?

• Must be aware of this technology
• Will require better communication between neighbors
• Will there be regulations on the use of this technology
• If off-site movement occurs, what should be done?
• What about damage?
Registry of Pesticide-sensitive Areas

\textit{driftwatch\textsuperscript{TM}} is a tool to help protect pesticide-sensitive crops and habitats from the drift that sometimes occurs during spray operations
Drift Watch is a Purdue based Program

- This program provides a base of information to all farmers about the presence of sensitive crops
- Become aware of this site and how to be involved to minimize problems
- Maps of sensitive crops
- Warnings of when crops will be planted or exist
What is the HLA Department doing?

- Developing diagnostic tools and information about vegetable crops response to drift
- What are the symptoms?
- When or if crops recover?
- How much loss might occur?
- Education for applicators on how best to use the new technology
What is the HLA Department doing?

- Determination of crop response
- Determination of nozzles used in application and how far particles move
- Environmental conditions that result in volatility potential
- SCRI grant involvement
- Company cooperation
What Results have been Generated?

- Effects of low-dose 2,4-D and dicamba and combinations with Roundup to:
  - Processing tomato responses
  - Fresh market vegetables response - Tomatoes, peppers, muskmelon, watermelon
Experimental Methods – Processing Tomatoes

• Two Application Timings
  – Small plants / Large plants

• Cultivars
  – 2007: 611
  – 2008: 611 & 311 (IN), 616 & 818 (OH)

• 7 Rates
  – 0, 1/1000, 1/300, 1/100, 1/30, 1/10, & 1/3X rates where X= 0.5 lbs ae/A for dicamba and X= 0.6 lbs/A for glyphosate

• Data collected
  – Crop injury, yield (red and green fruit), and % flower loss

• Analysis
  – Non-linear log logistic modeling in R

• Plot Design
  – 1.5 m x 6 m plots
  – Tomatoes transplanted into raised beds
Commonly Observed Symptoms with Dicamba

5 hours after treatment
3 days after treatment
7 days after treatment
14 days after treatment
28 days after treatment
## Results

<table>
<thead>
<tr>
<th>Flower Loss</th>
<th>Marketable Fruit Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>25%</td>
<td>5%</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50%</td>
<td>10%</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- **Timing 1:** 1/233<sup>rd</sup>
- **Timing 2:** 1/373<sup>rd</sup>
- **Timing 1:** 1/42<sup>nd</sup>
- **Timing 2:** 1/88<sup>th</sup>
- **Timing 1:** 1/15<sup>th</sup>
- **Timing 2:** 1/36<sup>th</sup>

- **Timing 1:** 1/243<sup>rd</sup>
- **Timing 2:** 1/224<sup>th</sup>
- **Timing 1:** 1/124<sup>th</sup>
- **Timing 2:** 1/144<sup>th</sup>

(0.5 lbs ae/A = 1X)
Conclusions

• Low rates of dicamba drift resulted in significant yield loss regardless of timing
• The second timing at flowering caused higher yield loss than the first timing
• Results were similar at both locations and for all cultivars tested
• There is a risk of causing tomato yield loss from dicamba drift
Commonly Observed Symptoms caused by Glyphosate

3 days after treatment

7 days after treatment

21 days after treatment

28 days after treatment
<table>
<thead>
<tr>
<th>Flower Loss</th>
<th>Marketable Fruit Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>– 5 %</strong></td>
<td><strong>– 1 %</strong></td>
</tr>
<tr>
<td>• Timing 1: 1/20&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 1: 1/58&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>• Timing 2: 1/229&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 2: 1/337&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>– 25 %</strong></td>
<td><strong>– 5 %</strong></td>
</tr>
<tr>
<td>• Timing 1: 1/13&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 1: 1/30&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>• Timing 2: 1/85&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 2: 1/164&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>– 50 %</strong></td>
<td><strong>– 10%</strong></td>
</tr>
<tr>
<td>• Timing 1: 1/10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 1: 1/22&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>• Timing 2: 1/47&lt;sup&gt;th&lt;/sup&gt;</td>
<td>• Timing 2: 1/120&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

(0.6 lbs ae/A= 1X)
• Glyphosate drift at the time of fruit set leads to greater fruit loss than at the time of transplanting
• Glyphosate drift delayed fruit ripening
• Both cultivars tested responded similarly to glyphosate drift
• Tomatoes are sensitive to even low rates of glyphosate
Tomato Response to combinations of Glyphosate and Dicamba Drift

Untreated

1/100X glyphosate

1/100X dicamba

1/100+1/100 Gly + dicamba
Tomato Response to combinations of Glyphosate and Dicamba Drift

Untreated

1/30X glyphosate

1/30X dicamba

1/30+1/30 Gly + dicamba
The effects of three different drift rates of dicamba and glyphosate on commercial processing tomatoes.

<table>
<thead>
<tr>
<th>Glyphosate rate</th>
<th>Dicamba rate</th>
<th>Expected results$^1$</th>
<th>Observed results$^2$</th>
<th>Difference in results</th>
<th>Joint activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ lbs ae/A</td>
<td>____________</td>
<td>% Control</td>
<td>____________</td>
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2 WAT

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<thead>
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<th></th>
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<th></th>
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<td>1/300</td>
<td>1/300</td>
<td>26</td>
<td>21</td>
<td>-5</td>
<td>Additive</td>
<td></td>
</tr>
<tr>
<td>1/100</td>
<td>1/100</td>
<td>61</td>
<td>74</td>
<td>13</td>
<td>Synergistic</td>
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<tr>
<td>1/30</td>
<td>1/30</td>
<td>95</td>
<td>94</td>
<td>-1</td>
<td>Additive</td>
<td></td>
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</tbody>
</table>

5 WAT

<table>
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<tr>
<th></th>
<th>+</th>
<th>+</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/300</td>
<td>1/300</td>
<td>40</td>
<td>32</td>
<td>-8</td>
<td>Additive</td>
<td></td>
</tr>
<tr>
<td>1/100</td>
<td>1/100</td>
<td>67</td>
<td>69</td>
<td>2</td>
<td>Additive</td>
<td></td>
</tr>
<tr>
<td>1/30</td>
<td>1/30</td>
<td>95</td>
<td>91</td>
<td>-4</td>
<td>Additive</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

- Drift from combinations of glyphosate and dicamba have an additive effect on causing tomato injury
- $1/30x + 1/30 X$ resulted in $> 90\%$ injury
- Drift from either glyphosate or dicamba causes serious injury
- Drift from a combination of the 2 herbicides causes even greater injury
Methods and Materials

• 2010 and 2011 studies performed at Meigs Horticulture Research Farm in Lafayette, IN.

• Four vegetable crops were used:
  • “Mt. Fresh Plus” tomato
  • “Aristotle” bell pepper
  • “Hales Best Jumbo” cantaloupe
  • “Mardi Gras” watermelon
Cantaloupe Injury, 21 DAT

2,4-D

- Untreated
- 16 g ae ha\(^{-1}\)
- 8 g ae ha\(^{-1}\)
- 8 g ae ha\(^{-1}\) + 8 g ae ha\(^{-1}\) gly
- 4 g ae ha\(^{-1}\)
- 4 g ae ha\(^{-1}\) + 4 g ae ha\(^{-1}\) gly
Cantaloupe Injury, 21 DAT

Dicamba

- Untreated
- 5.6 g ae ha⁻¹ + 8 g ae ha⁻¹ gly
- 11.2 g ae ha⁻¹
- 2.8 g ae ha⁻¹
- 5.6 g ae ha⁻¹
- 2.8 g ae ha⁻¹ + 4 g ae ha⁻¹ gly
Tomato Injury, 21 DAT

2,4-D

Untreated

8 g ae ha\(^{-1}\) + 8 g ae ha\(^{-1}\) gly

16 g ae ha\(^{-1}\)

4 g ae ha\(^{-1}\)

8 g ae ha\(^{-1}\)

4 g ae ha\(^{-1}\) + 4 g ae ha\(^{-1}\) gly
Tomato Injury, 21 DAT

Dicamba

Untreated

5.6 g ae ha\(^{-1}\) + 8 g ae ha\(^{-1}\) gly

11.2 g ae ha\(^{-1}\)

5.6 g ae ha\(^{-1}\)

2.8 g ae ha\(^{-1}\)

2.8 g ae ha\(^{-1}\) + 4 g ae ha\(^{-1}\) gly
Conclusions

Total Harvest

• Cantaloupe
  • Initial delay in fruit maturity
  • 2,4-D treated plants yielded less than untreated.
  • There was no total yield difference between untreated and dicamba-treated plants.

• Tomato
  • Delay in fruit maturity but overall no difference between untreated and treated plants for either 2,4-D or dicamba.
SCRI Research

• Will determine effects of:
  – Wind
  – Formulation
  – Nozzle type
  On herbicide movement

Further, we will:
  – Quantify amounts of herbicide that move
  – Quantify effect on crop injury, crop recovery, time to fruit maturity and crop yield/quality
  – Conducted on major vegetable crops grown in the Midwest U.S.