New Herbicide Resistant Crops and Weeds

Stephen C. Weller
Department of HLA
Purdue University
Overview of Talk

• Situation with weeds resistant to major agronomic herbicides in IN
• Main weeds of concern and levels of resistance to herbicides
• Development of 2,4-D and dicamba resistant crops to allow management of these weeds
• Concerns that horticulture crop producers need to be aware of
Herbicide Resistance

Inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type.
What Causes Herbicide Resistance

• **Selection Pressure**
  – A standard procedure performed by traditional crop breeders
  – The repetitive use of a *single mode of action* over time *under non-ideal conditions*
over time under non-ideal conditions

• Non-ideal Conditions
  – Cut herbicide rates
  – Weed height
  – Weather conditions
  – Tank mixes
  – Adjuvant systems
  – Water quality
  – Spray equipment
## Herbicide Resistance in Indiana

<table>
<thead>
<tr>
<th>Weed Type</th>
<th>Herbicides Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redroot/Smooth Pigweed</td>
<td>Atrazine</td>
</tr>
<tr>
<td>Lambsquarter</td>
<td>Atrazine</td>
</tr>
<tr>
<td>Jimsonweed</td>
<td>Atrazine</td>
</tr>
<tr>
<td>Kochia</td>
<td>Atrazine, cyanazine, metsulfuron-methyl</td>
</tr>
<tr>
<td>Common Ragweed</td>
<td>Cloransulam-methyl, imazethapyr, glyphosate</td>
</tr>
<tr>
<td>Giant Ragweed*</td>
<td>Cloransulam-methyl, imazethapyr, glyphosate</td>
</tr>
<tr>
<td>Horseweed*</td>
<td>Glyphosate, chlorimuron-ethyl, cloransulam-methyl</td>
</tr>
<tr>
<td>Giant Foxtail</td>
<td>Nicosulfuron, rimsulfuron</td>
</tr>
<tr>
<td>Johnsongrass</td>
<td>Nicosulfuron</td>
</tr>
<tr>
<td>Shattercane</td>
<td>Foramsulfuron, nicosulfuron</td>
</tr>
<tr>
<td>Common Waterhemp*</td>
<td>Chlorimuron-ethyl, cloransulam-methyl, imazaquin, imazethapyr, glyphosate, fomesafen, lactofen</td>
</tr>
<tr>
<td>Palmer Amaranth*</td>
<td>Glyphosate, chlorimuron, cloransulam</td>
</tr>
</tbody>
</table>

* Major problem weeds in agronomy in IN
## Amaranth Identification

<table>
<thead>
<tr>
<th>Palmer Amaranth</th>
<th>Common Waterhemp</th>
<th>Redroot/Smooth Pigweed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovate to diamond leaves with apex towards the petiole</td>
<td>Long lanceolate leaves</td>
<td>Round to oval leaves with apex towards the middle</td>
</tr>
<tr>
<td>No hair</td>
<td>No hair</td>
<td>Fine hairs on stem especially towards newest growth</td>
</tr>
<tr>
<td>Long petioles and rosette leaf pattern</td>
<td>Waxy leaf surface</td>
<td>Rough leaf surface</td>
</tr>
</tbody>
</table>
Waterhemp Populations response to Roundup – also resistant to PPOs and ALS herbicides
ALS-resistant Common Waterhemp in Indiana

**All samples tested expressed ALS-resistance. Only the counties shown have been sampled.**
PPO-Resistant Common Waterhemp in Indiana

- Counties with PCR assay confirmed PPO-resistant waterhemp
- Number of fields confirmed for PPO-resistance
Glyphosate-resistant Common Waterhemp in Indiana

Counts with confirmed Glyphosate resistant waterhemp
Evansville, IN Palmer Amaranth
Survived 3.3 and 6.7 gallons/A of glyphosate!
Estimate of Soybean Fields with Palmer amaranth infestations during the growing season (2014)

- No Palmer Incidents Reported
- Palmer incident reported, unknown estimate of soybean fields infested
- Palmer incident previously reported, 0% estimated soybean fields infested

- <1 %
- 1-5 %
- 6-10 %
- 11-20 %
- 21-30%
Estimate of Soybean Fields with Palmer amaranth infestations at Harvest (2014)

- No Palmer Incidents Reported
- Palmer incident reported, unknown estimate of soybean fields infested
- Palmer incident previously reported, 0% estimated soybean fields infested
- <1 %
- 1-5 %
- 6-10 %
- 11-20 %
- 21-30%
Estimate of Soybean Fields with Palmer amaranth infestations at Harvest (2014)

- No Palmer Incidents Reported
- Palmer incident reported, unknown estimate of soybean fields infested
- Palmer incident previously reported, 0% estimated soybean fields infested
- <1 %
- 1-5 %
- 6-10 %
- 11-20 %
- 21-30%

# Approx. number of fields that Palmer amaranth was hand pulled
Palmer in a WC IN Alfalfa Field in October
Palmer Growing out of Hay Bales!
Giant Ragweed
Glyphosate Resistant Giant Ragweed

Indiana Counties with Glyphosate Resistant or Tolerant Giant Ragweed Populations (January 2008)
Rapid Necrosis Phenotype
Glyphosate-Resistant Responses in Giant Ragweed

Treated with 2,520 g ae ha⁻¹ glyphosate

Left: Non rapid necrosis
Center: Susceptible
Right: Rapid necrosis resistant
Counties with Glyphosate-Resistant Giant Ragweed

- **2008**
- **2014 (suspected)**
Current Situation in Agronomic Crops to Address Resistance to Herbicides

- 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
  - 31 weeds worldwide are resistant
  - 15+ major weeds in US
Glyphosate-resistant Palmer amaranth devastates cotton producers, new technology is desperately needed

Slide courtesy of Doohan and Blakeslee, OSU
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 Xtend Crop System with dicamba tolerance in soybean and cotton with Vapor Drip (dicamba, Monsanto), Engenia (BASF)
Enlist™ Weed Control System

Technical Attributes:

New trait conferring 2,4-D tolerance\textsuperscript{1,2}
- Removes planting intervals in burndown applications
- Widens/enables postemergence application window

Upon regulatory approvals, expected to be partnered with glyphosate-tolerant trait technologies
- In corn, will be stacked with SmartStax\textsuperscript{2}
- In soybeans, will be stacked with Roundup Ready\textsuperscript{®} 2 Yield

Additional herbicide tolerances\textsuperscript{1,2},
- Glufosinate tolerance: soybeans/cotton
- Fop tolerance: corn

\textsuperscript{*}4.7 pts./A and N-Pak AMS at 2.5% v/v

Dow AgroSciences

Enlist
Weed Control System
The Roundup Ready® Xtend Crop System - will Address Farmer Needs

Innovative New Traits + Enhanced Chemistry Options = Greater Flexibility, Weed Control and Yield Potential

The Roundup Ready® Xtend Crop System will be a component of Roundup Ready PLUS Weed Management Solutions,

Monsanto Trials – Marion, Arkansas - Glyphosate Resistant Palmer Amaranth

Untreated
Roundup PowerMAX® FB
Roundup PowerMAX

Dicamba+Roundup PowerMAX+Warrant™ FB Liberty®+Warrant

Reflex® FB
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
Timeline of 2,4-D & Dicamba in USA

- 2,4-D introduced shortly after WW II
- Lawsuits for drift damage to grape, cotton and tomato documented in Akesson & Yates (1964)
- Bans in many states
- Dicamba introduced in 1960s
- Drift claims related Banvel use soon after registration
- 1990’s 2,4-D subject of major international toxicology studies
- 2000-2010 Cloning of detoxifying bacterial genes, generation of tolerant crops

Slide courtesy of Doohan and Blakeslee, OSU
Timeline for Introduction

- Enlist Weed Control System – approved by USDA and EPA, requires state approvals however, there will be very limited introductions in 2015 for
  - Corn
  - Soybean
  - 2016 for Cotton

- Roundup Ready Xtend Crop System – deregulated by USDA, pending at EPA, will require state approvals
  - Soybean & Cotton will be introduced in 2015 but no dicamba over the top will be allowed. Full release with dicamba applications anticipated for 2016
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
Figure 1: Recent estimated acreage of crops sprayed with 2,4-D or dicamba
Data from www.24d.org, and D. Pepitone, BASF. Slide courtesy of Doohanan and Blakeslee, OSU
Use will shift to the corn belt
Annual applications will increase from typically 1 to as many as 3
Application rate will increase

Slide courtesy of Doohan and Blakeslee, OSU
Projected Use

- 2,4-D in 2012 ca 50 million acres (pasture, grain, turf)
- 2,4-D tolerant corn, soybean = 160 million acres
- 30% of 160 million acres = 53 million acres for total of 103 million acres treated
- 3 applications/ season
  - More like 300 million acres
- 17000 drift incidents/ year with 50 million acres
  - What will it be with 100-300 million treated acres?

Slide courtesy of Doohan and Blakeslee, OSU
Off Site Movement

• 2,4-D & dicamba, respectively estimated 75X and 100X riskier to terrestrial plants than glyphosate

• 1700 drift incidents reported nationally (AAPCO 2005)
  – Estimated 5-10% actual (SDEN 2012)

• Average of 30 in Ohio
  – 15% confirmed and action taken

• 2,4-D most common pesticide, dicamba in top seven
Volatility

Most commonly associated with volatilization (changing from a liquid to a gas) of pesticides with subsequent movement from the target area.
Enlist Duo – 2,4-D choline

Volatility: a Function of Structure
Dicamba Formulation Advancement
Engenia™ and Vapor Drip Herbicide

- **BASF - Engenia®**
- Chemistry: Dicamba BAPMA
  - BAPMA: N,N-Bis-[aminopropyl]methylamine
  - Tridentate amine provides strong performance

- **Monsanto - Vapor Drip®**
  - Chemistry confidential: 98% reduction claim, proprietary, claim it is better in regards to vapor pressure (volatility) and droplet size (drift avoidance).

- Monsanto and BASF are not working together on these 2 dicamba formulations

Volatility: a Function of Structure
Particle Drift

- The physical movement of spray droplets away from the target site at the time of application
Factors Affecting Drift

**Weather**
- Wind Speed
- Atmospheric Stability
- Air Temperature
- Relative Humidity

**Sprayer Setup**
- Nozzle type
- Pressure
- Travel Speed
- Boom Height

**Human Dimension**
Microdroplet Drift

Glyphosate + 2,4-D DMA tankmix

Premix with Colex-D Technology
TTI Nozzle

- **Applications:**
  - Excellent in herbicides soil applied, excellent in postemergence herbicides, fungicides, and insecticides with systemic activity, and excellent in drift management

- **Features:**
  - 110° wide angle, air induction, tapered flat spray tip pattern based on the patented outlet orifice design of the original Turbo TeeJet nozzle
  - Pressure range 15 to 100 PSI.
  - Best use pressure range 30 to 60 PSI.
  - Drift Management - Excellent

- **Limitations:**
  - Large spray particle size
  - Note difference in orifice sizes between pre-orifice and exit orifice
Weather & The Human Dimension

Calm winds and the inversion result in poor air quality.

1. The winter sun, low in the sky, supplies less warmth to the Earth's surface.
2. Warmer air aloft acts as a lid and holds cold air near the ground.
3. Pollution from wood fires and cars are trapped by the inversion.
4. Mountains can increase the strength of valley inversions.

photo Credit: geneburch.com

Credit: SunValleyONLINE.COM
Auxin & 2,4-D are only Transiently Located on Plant Surfaces

- Auxin/2,4-D lands on a plant leaf or stem
  - Quickly moved to the roots
  - Also metabolized in the plant
    - Broken down into smaller molecules
- Result: 2,4-D is mobilized/broken down within 72 hours post-deposition
  - Problem: By the time 2,4-D damage is observed, it is difficult to detect
## Current Status of Dow and Monsanto Stewardship Plans (2014)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Enlist</th>
<th>RR2 Xtend</th>
<th>HPPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature</td>
<td>Recommendations</td>
<td>Requirements</td>
<td>Future ?</td>
</tr>
<tr>
<td>Herbicide formulations</td>
<td>Low-vol forms required</td>
<td>Low-vol forms required</td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td>10 to 15 GPA</td>
<td>At least 10 GPA</td>
<td></td>
</tr>
<tr>
<td>Nozzle types</td>
<td>Various</td>
<td>Various – 9 types listed, very coarse</td>
<td></td>
</tr>
<tr>
<td>Droplet size (microns)*</td>
<td>250 to 650?</td>
<td>350 to 700?</td>
<td></td>
</tr>
<tr>
<td>Droplet category</td>
<td>Coarse to extremely coarse</td>
<td>Very coarse to ultra-coarse</td>
<td></td>
</tr>
<tr>
<td>Tank mix drift additive</td>
<td>???</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td>&lt;15 mph</td>
<td>3 to 10 mph</td>
<td></td>
</tr>
<tr>
<td>Sprayer speed</td>
<td>???</td>
<td>&lt;15 mph</td>
<td></td>
</tr>
<tr>
<td>Boom height above canopy</td>
<td>20” to 24”</td>
<td>20”</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Maintain buffers</td>
<td>Maintain buffers/ Drift Watch</td>
<td></td>
</tr>
<tr>
<td>Weed size</td>
<td>3-6 3.5-4.75 pts, &gt; 6 4.75 pts</td>
<td>&lt;4”</td>
<td></td>
</tr>
<tr>
<td>Tank rinsing</td>
<td>Triple rinse water</td>
<td>Triple rinse</td>
<td></td>
</tr>
<tr>
<td>Tank cleaner</td>
<td>No</td>
<td>Yes, proprietary</td>
<td></td>
</tr>
</tbody>
</table>

*Specific droplet size has been estimated by author if not specified by company.*
Advocacy Groups Concerned About this Technology

- Save Our Crops Coalition
- Center for Food Safety
- Natural Resources Defense Council
SOCC/ Dow AgroSciences Agreement

• Do not apply under circumstances where drift may occur to food, forage or other plantings

• Do not apply when wind direction favors movement to grape, tomato, cucurbits, other fruiting vegetables.

• Utilize buffer zones when crops other than those labeled are downwind

• Technology agreement will allow only use of Enlist Duo

• Default Buffer of 40 feet
Drift Will Happen – Protection is Needed
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?
What if This Happens to You?

- Register with DriftWatch
- Document, document, document
- Symptoms may be diagnostic
  - Take lots of photos
- Samples may be crucial
  - First 3 days are important
- Look for evidence of a trail of symptoms
  - Wild grape, dogwood, hickory, locust
- Contact Department of Ag & Extension
Registry of Pesticide-sensitive Areas driftwatch\textsuperscript{TM} is a tool to help protect pesticide-sensitive crops and habitats from the drift that sometimes occurs during spray operations.

www.driftwatch.org
Drift Watch was Developed by Purdue University

- Now operated by FieldWatch, Inc, a non-profit company in collaboration with interested agricultural stakeholder groups. For more information, visit www.fieldwatch.com.
- 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
- DriftWatch is not a substitute for any state regulatory requirements
To Do List

• Inform Commercial Applicators & Adjacent Property Owners
  – Annual Exercise
• Prevent Drift & Compromise at Home
• Register with Sensitive Crop Registry
• Keep Excellent Records
• Know symptoms of injury and check crops regularly
  – Act quickly
• Future
  – Detection System being developed by Ohio State
2,4-D- and Dicamba-tolerant Crops — Some Facts to Consider

Johnson, William; Steven Hallett; Travis Legleiter; Fred Whitford; Stephen Weller; Bruce Bordelon; B. Rosie Lerner

ID-453-W
