Herbicide Resistance: These weeds just won’t die!

Daniel Stephenson, Ph.D.
Weed Scientist
LSU AgCenter
What is herbicide resistance?

• Weed Science Society of America definition:
  – The inherited ability of a weed biotype to survive and reproduce despite exposure to a dose of herbicide that was previously effective on an unselected population.

• Biotype = a subset within a population that has a genetically controlled characteristic not common in the population as a whole.
What is weed resistance?
Glyphosate-resistant horseweed (mare’s-tail) in Arkansas

Photo by Dr. Ken Smith
What is weed resistance?

Glyphosate-resistant Palmer amaranth in Georgia

Cotton field following 264 oz/acre of glyphosate

Photo by Dr. Stanley Culpepper
What is weed resistance?
Herbicide-resistant ryegrass in Mississippi

Photo by Dr. Dan Poston
What is weed resistance?

Suspected glyphosate–resistant johnsongrass in Louisiana
What is weed resistance?

Suspected ALS –resistant Palmer amaranth in Louisiana
What is weed resistance?

Suspected glyphosate–resistant Palmer amaranth in Louisiana
Resistance vs. Tolerance

- Tolerance: ability to continue normal growth when exposed to a herbicide
  - Disagreement among scientists as to the difference between tolerance and resistance
  - Typically, weeds never controlled by a herbicide
  - 2,4-D and crabgrass
  - Clethodim and morningglory
  - Morningglory and glyphosate
When it is not herbicide resistance?

• Herbicide misapplications due to:
  – Poor spray coverage, spray tip pattern, or clogged tip

30% overlap

Good boom height

Boom height is high

©Mike Owen
When it is not herbicide resistance?

- Herbicide misapplications due to:
  - Applying less than the recommended label rate; or
  - Treating weeds when they are too large can cause problems.

Some are dead or sick or not injured
When it is not herbicide resistance?

• Adverse environmental conditions;
  – If the temperature is too hot or cold at application.
  – Drought or excessive moisture.
  – Disease, insect, or mechanical damage may cause stress on the weed.
When it is not herbicide resistance?

• Rainfall or irrigation may wash-off postemergence herbicide applications.
  – Postemergence herbicides generally have a rain-fast or rain-free time period on their label.
When it is not herbicide resistance?

• Excessively high weed populations at application.
  – Herbicide spray is intercepted by the larger weeds preventing contact of spray with smaller weeds underneath.
When it is not herbicide resistance?

• New emergence following treatment.
When to suspect resistance!

- The field or area with problem weed(s) has been sprayed repeatedly with the same herbicide or mode of action, AND
When to suspect resistance!

- The patch of weeds occurs in the same spot year after year and is spreading.
When to suspect resistance!

- Other weed species are controlled, but one particular weed species is no longer controlled, AND
When to suspect resistance!

- Surviving plants of the problem weed species may be in a patch where some are dead and/or some show variable injury symptoms, but all are approximately the same age as those that were treated and controlled.
Herbicide Resistance

Year 1

Year 2

Year 3
Herbicide Resistance
Pest Resistance

• Insects first – 1908 – San Jose scale resistant to lime sulfur
  – 2007 - > 500 insects resistance to an insecticide

• 1956 – Idea of herbicide resistance in weeds published by J.L. Harper
  – Not taken seriously
Herbicide Resistance

Distribution of Herbicide Resistant Biotypes

Resistant Weeds by # Biotypes

- 41+ (1)
- 31-40 (3)
- 21-30 (2)
- 16-20 (3)
- 11-15 (5)
- 6-10 (8)
- 2-5 (11)
- 1 (20)
- 0 (164)

Source: Dr. Ian Heap
www.weedscience.com
Herbicide Resistance

- U.S. – Resistance documented in greater than 40 weed species.

- Louisiana
  - Resistance not a severe problem, YET.
  - Barnyardgrass, common cocklebur, itchgrass, & johnsongrass have been documented
  - 2008 suspected sites investigated by LSU AgCenter
    - ALS-inhibitors and glyphosate
      - Johnsongrass
      - Palmer amaranth
      - Waterhemp
Herbicide Resistance

- Recent popular press articles state:
  - Resistance threatens the ability of crop producers to farm profitably
    - Arkansas, Georgia, Mississippi, North Carolina, Tennessee, and other states.

- Glyphosate gets the headlines, but numerous weed species are resistant to many herbicidal modes of action.

“Glyphosate-resistant Palmer amaranth is the most significant threat to agriculture that I have seen in my 30+ years.” Dr. Ken Smith, Extension Weed Scientist, Univ. of Arkansas.
How does a herbicide kill?

• Mode of action
  – The biochemical mechanism by which a herbicide causes growth to cease in target plants.

  – Example: inhibition of ALS (acetolactate synthase), an enzyme involved in synthesis of branched-chain amino acids.

• 16 different herbicidal modes of action
Herbicidal Modes of Action

- ACCase-inhibitors
  - Arrow, Fusliade, Poast, etc.

- ALS-inhibitors
  - Classic, Escort, Outrider, Plateau, etc.

- Photosynthesis-inhibitors
  - Aatrex, Cotoran, Direx, Diuron, Karmex, etc.

- PPO-inhibitors
  - Flexstar, Goal, Ultra Blazer, etc.

- Synthetic auxins
  - 2,4-D, Banvel, Clarity, Paramount, etc.

- EPSP synthase-inhibitor
  - Glyphosate - numerous formulations
What kind of resistance is it?

Cross Resistance

or

Multiple Resistance
Cross Resistance

• Biotype is resistant to two or more herbicides having the same mode of action.

• Example: weeds resistant to imidazolinone herbicides (ALS inhibitors) are often resistant to sulfonylurea herbicides (ALS inhibitors).
Hoelon (an ACCase inhibitor) on Hoelon-resistant biotype

Hoelon (an ACCase inhibitor) on Hoelon-resistant biotype

Axial (an ACCase inhibitor) on Hoelon-resistant biotype

North Carolina

Courtesy of Dr. Alan York
Multiple Resistance

• Biotype is resistant to two or more herbicides having different modes of action.

• Example: weeds resistant to both ALS inhibitors and ACC synthase inhibitors.
Hoelon (an ACCase inhibitor) on Hoelon-susceptible biotype

Hoelon (an ACCase inhibitor) on Hoelon-resistant biotype

Osprey (an ALS inhibitor) on Hoelon-resistant biotype

Courtesy of Dr. Alan York
What has caused us to get into this problem?
What causes herbicide resistance?

• Herbicides do not create resistance!

• Herbicides select for resistant individuals already in the population.

• Dependence on one herbicide exuberates the problem.
Estimated glyphosate-tolerant crops in 2008
## New Herbicide Chemistry

<table>
<thead>
<tr>
<th>Year</th>
<th># New Chem.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946 – 1955</td>
<td>23</td>
</tr>
<tr>
<td>1956 – 1965</td>
<td>62</td>
</tr>
<tr>
<td>1966 – 1975</td>
<td>74</td>
</tr>
<tr>
<td>1976 – 1985</td>
<td>80</td>
</tr>
<tr>
<td>1986 – 1995</td>
<td>96</td>
</tr>
<tr>
<td>1996 – 2006</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>
Not the glyphosate’s fault!

- Roundup Ready crops are excellent tools
- Glyphosate is an excellent herbicide
  - Controls broadleaf and grass weeds
- Roundup Ready crops helped increase the number of acres in conservation tillage
Not the glyphosate’s fault!

- However,
  - Acreage per producer increased dramatically
  - Speed, speed, speed!
  - Only need glyphosate because it is so good
  - Decreased use of residual herbicides
  - Producers not willing to use tillage or herbicide direct-application equipment
Roundup Ready Cotton

<table>
<thead>
<tr>
<th>Timing</th>
<th>App. date</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preplant residual</td>
<td>Mar. 30</td>
<td>none</td>
</tr>
<tr>
<td>Burndown at planting</td>
<td>May 1</td>
<td>glyphosate</td>
</tr>
<tr>
<td>1st POST</td>
<td>May 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>2nd POST</td>
<td>May 30</td>
<td>glyphosate</td>
</tr>
<tr>
<td>3rd POST (DIR)</td>
<td>Jun. 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Layby (DIR)</td>
<td>Jul 1</td>
<td>glyphosate</td>
</tr>
</tbody>
</table>

Herbicide cost/A - $25.35

Provided by Dr. Ken Smith, Univ. of Arkansas
## Roundup Ready Cotton

### Resistance probability vs. Time (years)

<table>
<thead>
<tr>
<th>Timing</th>
<th>App. date</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preplant residual</td>
<td>Mar. 30</td>
<td>none</td>
</tr>
<tr>
<td>Burndown at planting</td>
<td>May 1</td>
<td>glyphosate</td>
</tr>
<tr>
<td>1st POST</td>
<td>May 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>2nd POST</td>
<td>May 30</td>
<td>glyphosate</td>
</tr>
<tr>
<td>3rd POST (DIR)</td>
<td>Jun. 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Layby (DIR)</td>
<td>Jul. 1</td>
<td>glyphosate + Valor</td>
</tr>
</tbody>
</table>

**Herbicide cost/A - $33.93**

Provided by Dr. Ken Smith, Univ. of Arkansas
## Roundup Ready Cotton

### Timing

<table>
<thead>
<tr>
<th>Timing</th>
<th>App. date</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preplant residual</td>
<td>Mar. 30</td>
<td>Reflex®</td>
</tr>
<tr>
<td>Burndown at planting</td>
<td>May 1</td>
<td>None</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; POST</td>
<td>May 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; POST</td>
<td>May 30</td>
<td>glyphosate</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; POST (DIR)</td>
<td>Jun. 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Layby (DIR)</td>
<td>Jul 1</td>
<td>glyphosate</td>
</tr>
</tbody>
</table>

### Herbicide cost/A - $31.46

Provided by Dr. Ken Smith, Univ. of Arkansas
What causes herbicide resistance?

• We caused it!

• Overreliance on a single herbicide or a few herbicides with the same mode of action for weed control
  – Use these herbicides year after year after year!

• Resistance spreads!
Don’t jump to conclusions!
Stewardship of Herbicide-Tolerant Technologies (resistance management)
Stewardship

1. Reduce reliance on one herbicide
   - Competitive crop, good agronomics, cover crop, cultivation

2. Crop rotation with appropriate herbicide selection

3. Diversity of chemistry
   - Multiple modes of action within a crop
     - At least 2 in corn and soybean, 3 in cotton
     - Residual herbicides
     - Use full labeled rates
Roundup Ready Cotton

<table>
<thead>
<tr>
<th>Timing</th>
<th>App. date</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preplant residual</td>
<td>Mar. 30</td>
<td>Reflex®</td>
</tr>
<tr>
<td>Burndown at planting</td>
<td>May 1</td>
<td>None</td>
</tr>
<tr>
<td>1st POST</td>
<td>May 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>2nd POST</td>
<td>May 30</td>
<td>glyphosate</td>
</tr>
<tr>
<td>3rd POST (DIR)</td>
<td>Jun. 15</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Layby (DIR)</td>
<td>Jul 1</td>
<td>glyphosate</td>
</tr>
</tbody>
</table>

Herbicide cost/A - $31.46

Provided by Dr. Ken Smith, Univ. of Arkansas
Residual herbicides:
Control of resistant weeds

Overlay residual herbicides
Residual herbicides: Effect on cotton yield

Seed cotton yield (lb/acre)

- UTC
- PRE only
- POST only
- PRE + POST

2 leaf 5 leaf 8 leaf
Stewardship

- Residual PRE or preplant herbicides have a fit; in addition to reducing selection pressure on glyphosate they offer other benefits:
  - Control species missed by glyphosate
- New chemistry (new MOA’s) coming very slowly
- Stacked HR traits coming in next 5+ years
  Various combinations of:
  - Glyphosate
  - Glufosinate
  - Dicamba
  - 2,4-D
  - Sulfonylureas
  - Others
Herbicide Resistance

• What?
  – Don’t assume resistance! Look for reason for failure.
  – Doesn’t matter how many herbicide TRADE NAMES you use;
  – If herbicides that are used share the same mode of action (kill the same way);
  – Then the potential to create a resistance problem is very possible.
Herbicide Resistance

• Stewardship
  – Roundup Ready crops
  – Clearfield rice
  – Future herbicide-tolerant crops

This is not what we want!
Is this weed resistant?
Want to risk it?