Weed Resistance to Herbicides: An Economic Threat to U.S. Agriculture

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Weed Resistance

Definition: “Inherited ability of a weed population to survive and reproduce after exposure to an herbicide dose (rate) that would control an unselected population”

--- Weed Science Society of America
Herbicide Mechanisms of Action (MOAs)

Definition:
The MOA is the means by which the herbicide controls the weed.

Importance for Resistance:
Weeds will generally be resistant to all herbicides with the same MOA.

There are only 16 MOAs
Current Status of Resistance

Source: [www.weedscience.org](http://www.weedscience.org), Ian Heap, March 2011
## 2011 Cotton Producer Survey - Key Research Issues -

<table>
<thead>
<tr>
<th>% of Respondents Who Ranked Issue in Their Top 5</th>
<th>SE</th>
<th>Mid</th>
<th>SW</th>
<th>FW</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Costs</td>
<td>66</td>
<td>64</td>
<td>73</td>
<td>70</td>
<td>69</td>
</tr>
<tr>
<td>Resistant Weeds</td>
<td>76</td>
<td>73</td>
<td>34</td>
<td>23</td>
<td>54</td>
</tr>
<tr>
<td>Variety Selection</td>
<td>41</td>
<td>36</td>
<td>44</td>
<td>53</td>
<td>42</td>
</tr>
<tr>
<td>Resistant Insects</td>
<td>&lt; 6</td>
<td>12</td>
<td>&lt; 9</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>
# Herbicide-Resistant Weeds

## Loss of Options

<table>
<thead>
<tr>
<th>Herbicide MOAs</th>
<th>Trade Name</th>
<th>Est. Loss of Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALS (in soybeans)</td>
<td>Pursuit, Staple</td>
<td>95 %</td>
</tr>
<tr>
<td>ALS (in cotton)</td>
<td>Staple</td>
<td>60 %</td>
</tr>
<tr>
<td>ACCase</td>
<td>Assure, Fusilade</td>
<td>30 %</td>
</tr>
<tr>
<td>Glycine</td>
<td>Roundup and others</td>
<td>30 %</td>
</tr>
<tr>
<td>Photosystem II</td>
<td>Cotoran, Diuron</td>
<td>5 %</td>
</tr>
<tr>
<td>PPO</td>
<td>Valor, Reflex</td>
<td>3 %</td>
</tr>
<tr>
<td>Auxin Analogs</td>
<td>2,4-D, Clarity (dicamba)</td>
<td>1 %</td>
</tr>
<tr>
<td>Glufosinate</td>
<td>Liberty (Ignite)</td>
<td>&lt; 1 %</td>
</tr>
</tbody>
</table>
Poster Child of Herbicide Resistance.....
Glyphosate-Resistant Palmer Amaranth in Georgia
Counties with Glyphosate-Resistant Palmer Amaranth
Glyphosate-Resistant Italian Ryegrass

- Confirmed glyphosate-resistant
- Suspected glyphosate-resistant

J. Bond et al. 2012
The Challenge of Glyphosate Resistance

Early predictions were that glyphosate resistance would not occur:

– Unique mode of action
– Minimal tolerance in plants
– Difficulty in selecting resistance for GR crops
– Target site alterations lead to less fit plants
The Challenge of Glyphosate Resistance

The prediction did not anticipate, the intense selection pressure placed on glyphosate in agronomic systems

- >90% of cotton and soybean acreage shifted to glyphosate-resistant crop cultivars
- Price reductions of generic glyphosate made it the herbicide of choice
- Reduced rates of glyphosate (likely) common
Number of different herbicides used on $\geq$ 5% of U.S. soybeans

Source: USDA, Young
% of cotton acres applying weed management practice

<table>
<thead>
<tr>
<th>Practice</th>
<th>1996</th>
<th>2000</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetically modified herbicide resistant seed</td>
<td>not reported</td>
<td>58</td>
<td>90</td>
</tr>
<tr>
<td>Field scouted for weeds</td>
<td>71</td>
<td>82</td>
<td>92</td>
</tr>
<tr>
<td>Burndown herbicide used</td>
<td>6</td>
<td>23</td>
<td>41</td>
</tr>
<tr>
<td>Pre-emergence weed control</td>
<td>90</td>
<td>79</td>
<td>73</td>
</tr>
<tr>
<td>Post-emergence weed control</td>
<td>62</td>
<td>76</td>
<td>89</td>
</tr>
<tr>
<td>Cultivated for weed control</td>
<td>89</td>
<td>63</td>
<td>38</td>
</tr>
</tbody>
</table>

Source: USDA, ARMS
Herbicide Innovation: A 30 Year Look at U.S. Patents and New Active Ingredient Introductions

From Gerwick, Sept., 2010, Agrow
No herbicides with new mechanisms of action are in advanced development trials. The last new mechanism of action was introduced over 20 years ago; therefore, we will have to rely on currently available herbicides for the foreseeable future.
U.S. Species with Confirmed Glyphosate Resistance

- Palmer amaranth (*Amaranthus palmeri*)
- Common waterhemp (*Amaranthus rudis*)
- Common ragweed (*Ambrosia artemisiifolia*)
- Giant ragweed (*Ambrosia trifida*)
- Hairy fleabane (*Coryza bonariensis*)
- Horseweed (*Coryza canadensis*)
- Italian ryegrass (*Lolium multiflorum*)
- Rigid ryegrass (*Lolium rigidum*)
- Johnsongrass (*Sorghum halepense*)

**Thirteen species in other countries, but not U.S.**
Weeds with Resistance to More than one Mechanism of Action

The number of weed species with resistance to more than one herbicide mechanism of action has increased drastically since 1990. Currently, 50 weed species with multiple forms of resistance have been confirmed.

Source: www.weedscience.org, Ian Heap, March 2011
Palmer amaranth in GA with resistance to both the ALS and glycine mechanisms of action

Weathermax  88 oz.
Staple LX     10 oz.
Federal Agency Responses

- Environmental Protection Agency – pressure to “do something” has led to questions regarding regulations, or alternatives thereof

- USDA Animal Plant Health Inspection Service – role of resistance management in approving new biotech crops

- USDA Natural Resources Conservation Service – impact of herbicide resistance on conservation systems
Strategic Solution

• National Leadership by the Weed Science Society of America

• Recommendations to Conserve Herbicide Mechanisms of Action

  – Presented at the ‘Weed Resistance Summit’ sponsored by the National Research Council at Washington, D. C., May 10, 2012
Manage Herbicides to Retard Resistance

**Applications:** Use Full Label Rates  
**Within-Season:** Diversify Mechanisms of Action  
**Between-Seasons:** Rotate Traits and Herbicides
Adoption of Best Management Practices Varies More Across Practices than Crops
Current Status of Herbicide Resistance in Weeds

Lesson 1

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Objectives

By the end of this lesson, you will:

- Understand the need for managing herbicide resistance in weeds.
- Know the current status of herbicide resistance in weeds.

Above: Seedling stage of kochia, a weed that is known to be resistant to several herbicides.

*Image number 5361300 at www.invasive.org.*
How Herbicides Work

Lesson 2

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Objectives

By the end of this lesson, you will:

Know the terminology associated with herbicide use, including tolerance, chemistry, efficacy, timing, and placement of applications.

Understand how herbicides are categorized according to their mechanism of action.

Above: Inflorescence of wild oat, a weed that is known to be resistant to several herbicides.

Image number 5404825 at www.invasive.org.
What is Herbicide Resistance?

Lesson 3

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Objectives

By the end of this lesson, you will:

Understand what herbicide resistance is and how it evolves in the field.

Recognize the factors that influence selection for herbicide resistance.

Define the different types of herbicide resistance.

Above: Redroot pigweed in an onion field. Redroot pigweed is a weed that is known to be resistant to several herbicides.

Image number 5362588 at www.invasive.org.
Scouting After a Herbicide Application and Confirming Herbicide Resistance

Lesson 4

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Objectives

By the end of this lesson, you will:

- Understand the importance of scouting for herbicide-resistant weeds.
- Know the factors that can contribute to weeds being present after a herbicide application.
- Know how to identify herbicide resistance in the field.
- Understand when to suspect and test for herbicide resistance in the field.
- Know procedures for confirming herbicide resistance.

Above: Italian ryegrass is a weed that is known to be resistant to several herbicides.
Image number 5387406 at www.invasive.org.
Principles of Managing Herbicide Resistance

Lesson 5

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Objectives

By the end of this lesson, you will:

- Understand that diversity is an important concept in the management of herbicide-resistant weeds.
- Identify the broad strategies and specific tactics for managing herbicide-resistant weeds.
- Compare the value of proactive versus reactive management for herbicide-resistant weeds.

Above: Seedling stage of waterhemp, a weed that is known to be resistant to several herbicides.

Image number K8040-1 at the USDA-ARS online image gallery.
Collaborations/Initiatives

**With EPA**
Development of Herbicide Product Label Language
- Mechanism of Action Group number display
- Text associated with Mechanism of Action Group
- Resistance Management Plans

**With USDA-APHIS**
Reports:
- I Summarizing current state of resistance
- II Best management practices and obstacles to adoption

**With USDA National Resources Conservation Service (NRCS)**
Concerns about impact of Herbicide Resistance on conservation
- Collaborative meetings leading to
- Adoption of best management practices

**With Industry, Commodity Groups**
Resistance Education/Training Modules
The Path Forward….

Continue and increase:

– Emphasis on education and training (deliver a consistent message)
– Emphasis on research (basic and best method)
– Development of new weed control options

Cooperation between all parties is critical for…..SUCCESS