Management of Glyphosate Resistant Palmer Amaranth in Cotton

Dr. Bill McCloskey, Extension Weed Specialist
School of Plant Sciences
University of Arizona Cooperative Extension

- 372 Resistant Biotypes
- 200 species
  - 116 dicots
  - 84 monocots
- Over 570,000 fields

Chronology of Herbicide Resistant Weeds
Plateau in resistance due to glyphosate?

No herbicides with new mechanisms of action are in advanced development trials. The last new mechanism of action was introduced over 20 years ago.

We will have to rely on currently available herbicides for the foreseeable future.

*Chronology of Herbicide Resistant Weeds by Mode of Action*


Bob Nichols - Cotton Incorporated
* Distribution of GR Palmer amaranth

Map credit: R. L. Nichols, 2012

Photographs courtesy of Rebekah D. Wallace, University of Georgia, Bugwood.org

* Palmer Amaranth is dioecious - female and male flowers are on separate plants
Palmer Amaranth - Male flowers with yellow anther sacs

* Palmer Amaranth Flowers

Palmer Amaranth - Female flowers

Red root pigweed root (above)

Palmer amaranth root (left)

Photo above by Jack Kelly Clark
Palmer amaranth seed production - 600,000 to 1.6 million seeds per large plant.

An infestation of 1.6 plants/ft of crop row can produce 600 million seeds per acre.
Palmer Amaranth with leaf chevrons

Palmer Amaranth without chevrons
* Palmer Amaranth competition with cotton

* Palmer Amaranth interference with cotton harvest
- WeatherMax 22 oz, 2 d after application to 16 inch Palmer

* GlyTol Cotton treated with Roundup PowerMAX @ 42 fl oz/A (1.48 lb ae/A)

Photo 5/24/2011, trt 13 - no PREE, 4DAT
Grower had difficulty controlling Palmer amaranth in Roundup Ready Flex cotton in 2011.

After two Roundup applications early this season (2012) failed to control Palmer amaranth, Monsanto hired a custom applicator to apply a third 44 oz/A Roundup application on Wednesday, July 11th.

Although there were a few dead pigweed plants, the majority of plants were not affected on July 17th.
* View looking north
Notice patchy distribution

* Plants sprayed with 5% solution 7/11 by Paul Sawyer; no symptoms 7/17
* Suspect GR Palmer Amaranth sprayed with 5% glyphosate solution August 1, 2012 (picture taken 8/6)

* Severely affected but not dead 9 DAT (picture taken 8/10/2012)
Herbicide resistance should be suspected when ...........

* Other causes of herbicide failure have been ruled out.

* The same herbicide or herbicides with the same mode of action have been used year after year.

* One weed species that is normally controlled is NOT controlled while other weed species are controlled.

* Healthy weeds are mixed with killed weeds (same species)

* A single-species weed patch of uncontrolled plants is spreading.
Progression of Weed Resistance

Weed resistance progresses logarithmically

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>% Resistant Weeds in Population</th>
<th>Weed Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Application</td>
<td>.0001</td>
<td>Excellent</td>
</tr>
<tr>
<td>1</td>
<td>Application</td>
<td>.00143</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>Application</td>
<td>.0205</td>
<td>Excellent</td>
</tr>
<tr>
<td>3</td>
<td>Application</td>
<td>.294</td>
<td>Excellent</td>
</tr>
<tr>
<td>4</td>
<td>Application</td>
<td>4.22</td>
<td>Excellent</td>
</tr>
<tr>
<td>5</td>
<td>Application</td>
<td>60.5</td>
<td>Failure</td>
</tr>
</tbody>
</table>

 Herbicide-resistant biotype

Credit: Mike DeFelice

Seed pool or seed bank in soil

After first application, the herbicide-resistant individual survives to produce more seed
Progression of Weed Resistance

Weed resistance progresses logarithmically

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% Resistant Weeds in Population</th>
<th>Weed Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Application</td>
<td>.0001</td>
<td>Excellent</td>
</tr>
<tr>
<td>1st Application</td>
<td>.00143</td>
<td>Excellent</td>
</tr>
<tr>
<td>2nd Application</td>
<td>.0205</td>
<td>Excellent</td>
</tr>
<tr>
<td>3rd Application</td>
<td>.294</td>
<td>Excellent</td>
</tr>
<tr>
<td>4th Application</td>
<td>4.22</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Herbicide resistance cannot be reversed in a practical time frame. In many cases, the seed pool is unlikely to change back because there is no fitness penalty.

Year 5

Weed plants and seed pool are now mostly herbicide-resistant.

Credit: Mike DeFelice

Gene amplification confers glyphosate resistance in *Amaranthus palmeri*

Todd A. Gaines1, Wenli Zhang1, Dafu Wang1, Bekir Bukum1, Stephen T. Chisholm1, Dale L. Shaner1, Scott J. Nissen1, William L. Patzoldt1, Patrick J. Tranel1, A. Stanley Culpepper1, Timothy L. Grey1, Theodore M. Webster1, William K. Vencill1, R. Douglas Sammons1, Jiming Jiang1, Christopher Presto1, Jan E. Leach1, and Philip Westra2,3

1Department of Bioagricultural Sciences and Pest Management, Colorado State University, Fort Collins, CO 80523; 2Department of Horticulture, University of Wisconsin, Madison, WI 53706; 3Monsanto Company, St. Louis, MO 63167; 4Water Management Research Unit, US Department of Agriculture Agricultural Research Service (USDA-ARS), Fort Collins, CO 80526; 5Department of Crop Sciences, University of Illinois, Urbana, IL 61801; 6Crop and Soil Science Department, University of Georgia, Athens, GA 31602; and 7School of Agriculture, Food and Wine, University of Adelaide, Glen Osmond, SA 5064, Australia

Edited by Charles J. Arntzen, Arizona State University, Tempe, AZ, and approved October 29, 2009 (received for review June 16, 2009)

* Increased gene copy number and enzyme copy number accounts for resistance to glyphosate in Palmer Amaranth, Kochia, and Giant Ragweed
Shikimate - leaf disc assay after treatment with glyphosate.

Gene copy number using quantitative PCR on genomic DNA.

Fig. 1. Increase in genomic copy number of *EPSPS* correlates with reduced shikimate accumulation in 12 individuals each of glyphosate-resistant (filled circles) and -susceptible (open triangles) *A. palmeri* plants. Increase in genomic copy number of *EPSPS* is relative to *ALS* as measured using quantitative PCR on genomic DNA. Shikimate accumulation was measured after incubation in 250 μM glyphosate in an in vitro leaf disk assay.

* Increased levels of *EPSPS* (5-enolpyruvylshikimate-3-phosphate synthase) account for glyphosate resistance in Palmer Amaranth

* Crosses between parents with a range of copy numbers result in various *EPSPS* copy numbers in progeny.

This accounts for varying levels of field resistance to glyphosate.
* Amount of enzyme in leaves is correlated with gene copy number

Fig. 4. EPSPS protein levels in glyphosate-susceptible (S), glyphosate-resistant (R), and pseudo-F$_2$ A. palmeri plants are correlated with relative EPSPS genomic copy number. Top: Regression of normalized EPSPS quantity on increase in relative EPSPS genomic copy number; open circles: S; filled circles: R; open triangles: F$_2$. Bottom: Samples with <20 relative EPSPS copies had 30 μg TSP loaded per lane, and samples with >20 relative EPSPS copies had 15 μg TSP loaded per lane. Increase in relative EPSPS genomic copy number is indicated above each sample lane.