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* Management of Glyphosate Resistant Palmer Amaranth in Cotton

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University of Arizona Cooperative Extension

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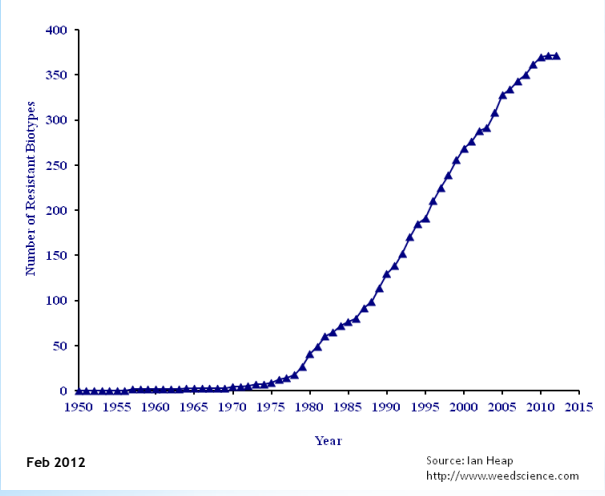

- 372 Resistant Biotypes
- 200 species
  - 116 dicots
  - 84 monocots
- Over 570,000 fields

* Chronology of Herbicide Resistant Weeds

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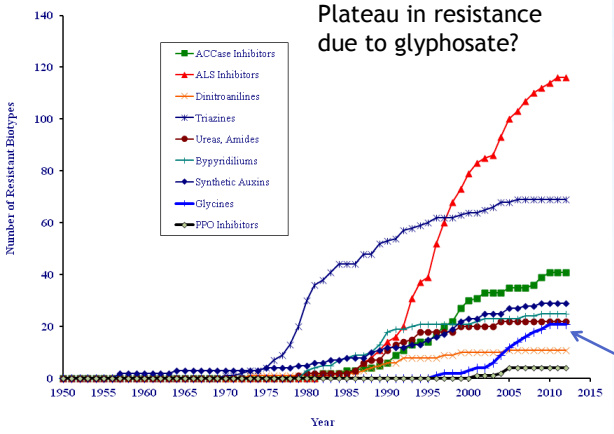

No herbicides with new mechanisms of action are in advanced development trials.

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.

Glyphosate resistance:
21 species, 11 grasses and 10 broadleaves

* Chronology of Herbicide Resistant Weeds by Mode of Action

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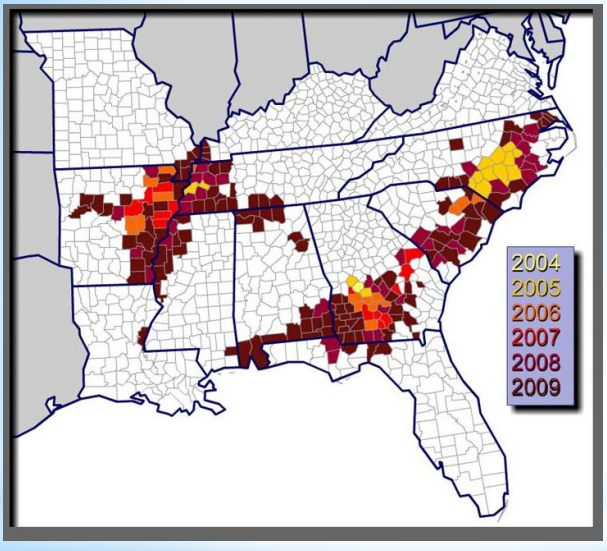
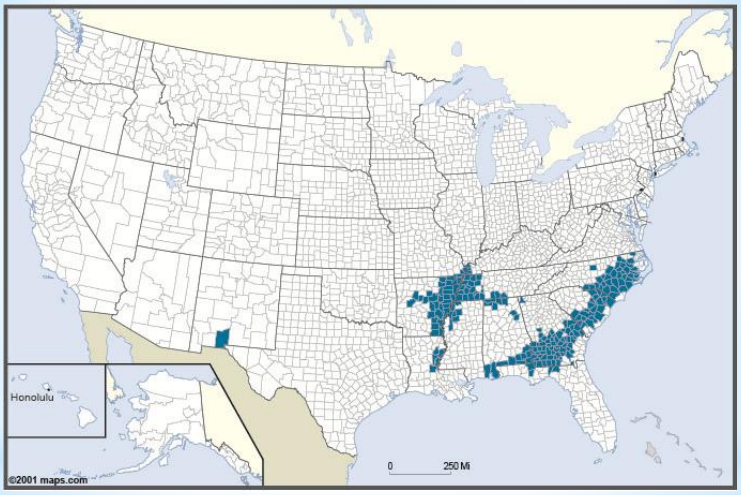


* Growth of Palmer Amaranth Glyphosate Resistance: 2004-2009

Bob Nichols - Cotton Incorporated 4



* Distribution of GR Palmer amaranth

Map credit: R. L. Nichols, 2012

01/19/12

Fig. 55. Palmer amaranth (*Amaranthus palmeri*). Flowering plant and flowering branch. *a*. Basal leaf. *b*. Male flower showing stamens. *c*. Female flower. *d*. Seed.

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

* Palmer Amaranth is dioecious - female and male flowers are on separate plants

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Palmer Amaranth - Male flowers with yellow anther sacs

* Palmer Amaranth Flowers

Palmer Amaranth - Female flowers

Photo above by Jack Kelly Clark

Red root pigweed root (above)

Palmer amaranth root (left)

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.

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* Palmer Amaranth seedlings with ivyleaf morningglory seedling

10

* Palmer Amaranth with leaf chevrons

11

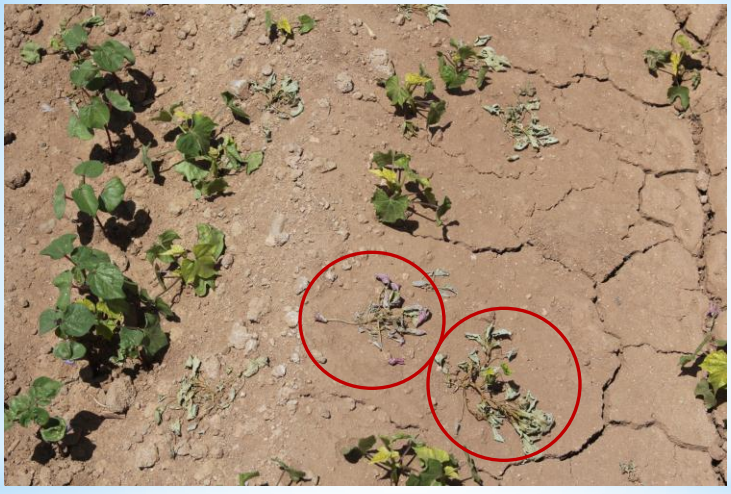
* Palmer Amaranth without chevrons

12

* Palmer Amaranth competition with cotton

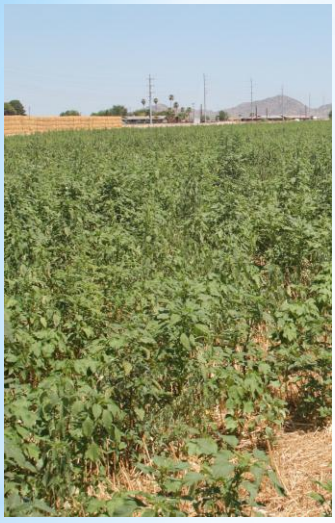
* Palmer Amaranth interference with cotton harvest

•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 16



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.

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* View to Northeast

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* View looking north
Notice patchy distribution

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* Plants sprayed with 5% solution 7/11 by Paul Sawyer; no symptoms 7/17

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* Suspect GR Palmer Amaranth sprayed with 5% glyphosate solution August 1, 2012 (picture taken 8/6)

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* Severely affected but not dead 9 DAT (picture taken 8/10/2012)

* Plants with green leaves, higher EPSPS copy number?

* Herbicide resistance should be suspected when ……..

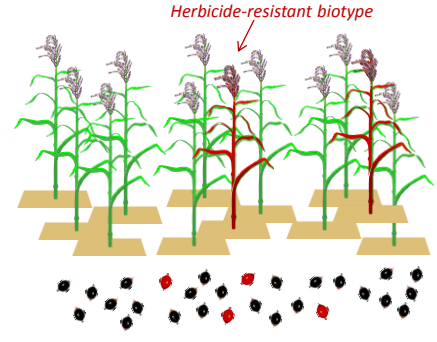
* Other causes of herbicide failure have been ruled out.
* The same herbicide or herbicides with the same mode of action have been used year after year.
* One weed species that is normally controlled is NOT controlled while other weed species are controlled.
* Healthy weeds are mixed with killed weeds (same species)
* A single-species weed patch of uncontrolled plants is spreading.

Progression of Weed Resistance

Weed resistance progresses logarithmically

Treatment	% Resistant Weeds in Population	Weed Control
0 Application	.0001	Excellent
1st Application	.00143	Excellent

Year 0 Credit: Mike DeFelice



After first [illegible] individual survives [illegible] seed

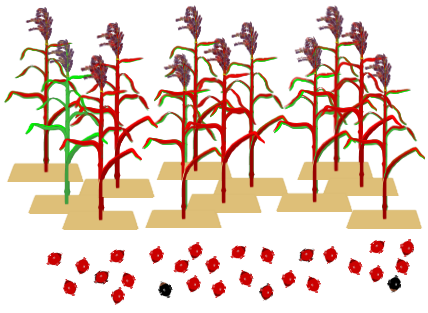
Progression of Weed Resistance

Weed resistance progresses logarithmically

Treatment	% Resistant Weeds in Population	Weed Control
0 Application	.0001	Excellent
1st Application	.00143	Excellent
2nd Application	.0205	Excellent
3rd Application	.294	Excellent
4th Application	4.22	Excellent

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 8 Credit: Mike DeFelice



seed pool or seed bank in soil

Control may still be possible, but the seed pool is almost completely resistant type

Gene amplification confers glyphosate resistance in *Amaranthus palmeri*

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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

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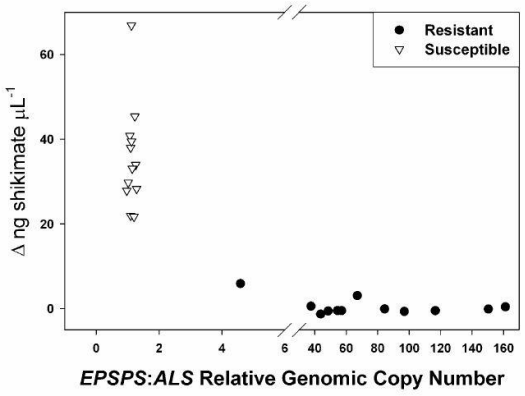

Shikimate – leaf disc assay after treatment with glyphosate.

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 vivo leaf disk assay.

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

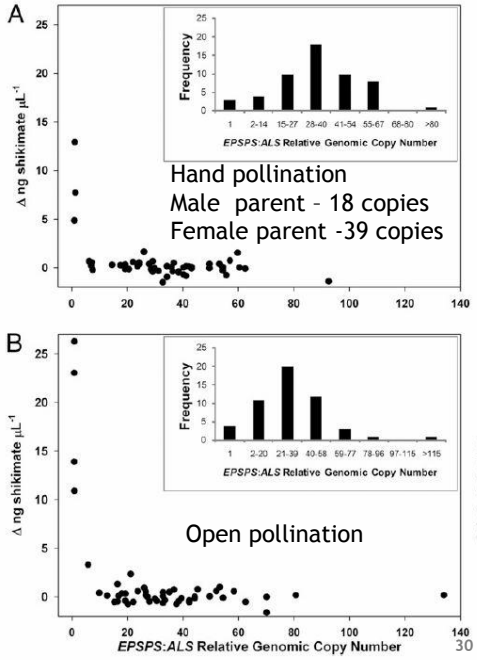

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Fig. 2. *EPSPS* genomic copy number and glyphosate resistance cosegregate

* 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.

Fig. 2. *EPSPS* genomic copy number and glyphosate resistance cosegregate in pseudo-F_2 *A. palmeri* populations. *EPSPS* copy number relative to *ALS* and accumulation of shikimate were determined as described in *Materials and Methods*. *Insets*: Relative copy number histograms in pseudo-F_2 populations generated using (*A*) hand pollination (F_1 male parent 18 relative *EPSPS* copies and F_1 female parent 39 relative *EPSPS* copies) and (*B*) open pollination (parental relative copy number not measured).

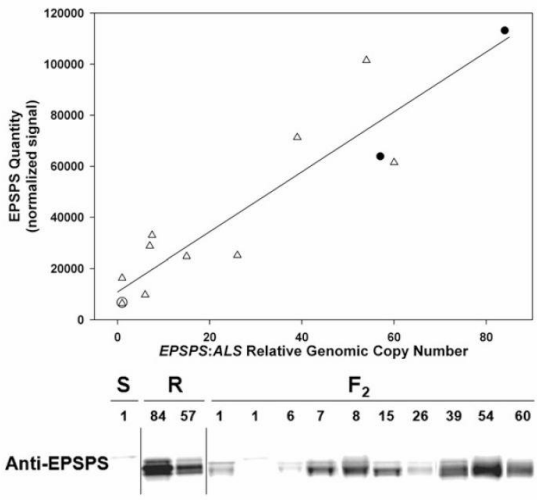

Fig. 4. EPSPS protein levels in glyphosate-susceptible (S), glyphosate-resistant (R), and pseudo-F_2 *A. palmeri* plants are correlated with relative *EPSPS* genomic copy number. *Top:* Regression of normalized EPSPS quantity on increase in relative *EPSPS* genomic copy number; open circles: S; filled 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.

* Amount of enzyme in leaves is correlated with gene copy number