Managing Glyphosate-Resistant Weeds in Glyphosate-Resistant Crops

Dr. Bill McCloskey
Extension Weed Specialist
* RR Flex cotton
* RR alfalfa
* RR Corn
* Tree crops - lemons, pecans, pistachios, etc.
* General farm weed control/sanitation
* Over-reliance on glyphosate?
* Problem of herbicide resistant weeds

* Glyphosate Resistant Weeds?
July 2012: field after 3 sprays of 44 oz/A (1.5 lb ae glyphosate/A). Difficulty controlling Palmer amaranth in 2011; cotton/wheat double crop
* View to Northeast

Resistance to Glyphosate Confirmed in GH
* Suspect GR Palmer Amaranth sprayed with 5% glyphosate solution August 1, 2012 (picture taken 8/6)
Weeds too large when spray by grower

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

GH Study Found NO Glyphosate Resistance
Scouting After a Herbicide Application

Begin scouting 7 to 14 days after each herbicide application, and continue at regular intervals until harvest.

- Move across the field in a scouting pattern covering the area.
- Observe and record:
  - Weed species (proper identification is important)
  - Spatial patterns (if present) of weeds across the field
  - Weed densities
  - Presence of live and dead weeds
  - Herbicide symptomology on live weeds

Above: Example of a scouting pattern in a field.
If Weeds are Present after an Application, Determine the Reason  *Consider the following factors*:

1. Field history
2. Weed biology
3. Environmental factors
4. Crop health
5. Crop cultural practices
6. Herbicide resistance

Investigate and rule out all other factors affecting herbicide performance before suspecting herbicide resistance.
Management Strategies

*Proactive management* is the implementation of tactics before herbicide-resistant weeds are apparent.

*Reactive management* is the implementation of tactics after herbicide resistance has been confirmed in the field.
Progression of Weed Resistance

Weed resistance progresses logarithmically

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After first application, the resistant individual survives the initial population and becomes a seed pool or seed bank in soil.

Credit: Mike DeFelice
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<td>3rd Application</td>
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<td>4th Application</td>
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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.

Control may stop growing in one season, but the seed pool is almost completely resistant to the herbicide type.
Robust annual - reproduces by seed

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.
Male Palmer amaranth - Male flowers with yellow anther sacs

* Palmer amaranth is dioecious - obligate outcrosser

Female Palmer amaranth flowers
* Palmer Amaranth seedlings with ivyleaf morningglory seedling
* Palmer Amaranth competition with cotton (2 leaf) following simultaneous emergence
Male Palmer amaranth - Male flowers with yellow anther sacs

Glyphosate resistance can move in pollen and seed!

Female Palmer amaranth flowers
Diversity of Practices

The best strategies to manage herbicide resistance in weeds are established on the concept of diversity.

Diversity can be achieved by:

- Using mechanical, cultural, and biological practices in addition to herbicides
- Applying several different mechanisms of control (each with a different target within the weeds)

A combination of tactics reduces the selection pressure imposed by any single practice.
* Apply integrated weed management practices including sanitation, tillage and crop rotation.

* Use multiple herbicide modes-of-action with overlapping weed spectrums in rotation, sequences, or mixtures.

* Use the full recommended herbicide rate and proper application timing for the hardest to control weed species present in the field.

* Scout fields after herbicide application to ensure control has been achieved. Avoid allowing weeds to reproduce by seed or to proliferate vegetatively.

* Monitor site and clean equipment between sites.

* General principles of weed resistance management
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* Proactive Management Tactics that may delay or avoid developing herbicide resistant weeds
Proactive Management: Herbicide Tactics

Herbicide choice requires \textit{careful planning} so that products with different mechanisms of action (MOA), or unique group numbers, and activity on the same target weeds, are intentionally combined with each other or other weed control practices.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{sustainable_not_sustainable_diagram}
\caption{Sustainable vs. Not Sustainable Herbicide Application Strategies}
\end{figure}

Repeated annual use of a herbicide with the same MOA in the absence of other MOAs or different management strategies can lead to resistance.

\textit{Note:} For all herbicide applications, it is critical to apply the labeled rate at the correct time. Management strategies based only on a herbicide mechanism of action classification system, or herbicide group number, may not adequately address specific and local needs. Consult product labels and the assistance of your local extension specialist for more information.
Proactive Management: Herbicide Tactics

The main schemes for applying herbicides with different mechanism of action (MOA) to manage herbicide resistance are:

- **Mixture application**: These options can provide the flexibility to choose the best fit or combinations of fit for local agronomic operations.

- **Sequentially throughout season**: MOA #1 and MOA #2

- **Across multiple seasons**: MOA #1 and MOA #2

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Proactive Management: Herbicide Tactics

Tank mixing or the use of pre-mixed products with different mechanisms of action and activity on the same target weed or weeds can be effective at delaying the onset of herbicide-resistant weeds.

Herbicide mixtures contain more than one active ingredient.

Herbicide mixtures may be marketed as prepackaged formulations.

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Need for Full Label Rate

Definitions:

- “Labeled rate” = A rate or range of rates set by herbicide manufacturers to consistently provide effective control of weed species across growth stages and site conditions.
- “Low rate” = A rate applied below the labeled rate that may provide effective control at an individual location, but will not provide consistent control over a wide range of conditions.

Routine exposure to low herbicide rates can allow a portion of the weed population to survive, leading to the evolution of herbicide-resistant populations.

Weeds can be exposed to “low rates” due to:

- Intended use of low rates
- Spraying plants larger than those recommended on the label
- Inadequate coverage of weeds because of size, density and/or crop cover
- Inaccurate sprayer calibration, faulty or ineffective equipment, or mixing errors
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*Proactive Management Tactics that may delay or avoid developing herbicide resistant weeds*
Cotton: NO Prowl H₂O
Cotton: Prowl H₂O (0.95 lb/A) applied PPI (field cultivator, listed, mulched, bed-shaped)
Morningglory & Palmer Amaranth (#/m²)

- **Pend mulch**
- **Trif mulch**
- **Pend flat**
- **Trif flat**
- **Control**

Legend:
- **Palmer A**
- **MG**
Herbicide Resistant Cotton

* Roundup Ready Flex Cotton - glyphosate
* Roundup Ready Flex Pima Cotton
* Liberty Link Cotton - glufosinate
* GlyTol: Glufosinate and Glyphosate resistant cotton
* Dicamba, glyphosate and glufosinate 3-gene stacked cotton varieties
# Cotton Weed Control Operations

<table>
<thead>
<tr>
<th>Preplant</th>
<th>Early POST topical</th>
<th>Mid POST Post-direct</th>
<th>Layby PD broadcast</th>
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<tr>
<td>Tillage</td>
<td>Dual Magnum</td>
<td>Glyphosate</td>
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<tr>
<td>Pendimethalin</td>
<td>Prowl H₂O</td>
<td>Staple LX</td>
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<td>Glyphosate</td>
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<td>Layby Pro*</td>
<td>Layby Pro*</td>
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<td>Goal, GoalTender*</td>
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*Tactics that may delay or avoid developing herbicide resistant weeds*
* Bezzertides Spring Hoe Weeders
* In-row Weeding

Before cultivation

After cultivation
Torsion Bar Weeders
Figure 3. In-row weeders crumble soil and uproot weeds.
Key components:
Disk stabilizers to stop implement drift
Adjust sway blocks to allow implement to run at correct depth. Implement must not rotate with respect to tractor.
Precision Cultivation - Potential Problems

* Cotton must be 12 inches tall with bark on the lower stem to use precision cultivation with in-row weeding. Crop must have a well developed tap root.

* Can close cultivate on smaller row crops without in-row weeding.

* Crop stem damage from moving soil remains a limitation.
* Zero tolerance for Palmer amaranth flower (pollen) and seed production = SANITATION!

* Remove weeds before they produce viable seed.
### Herbicides

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* Proactive Management Tactics that may delay or avoid developing herbicide resistant weeds
* Eliminate weed competition to optimize alfalfa stand

* As a broadcast planted crop, alfalfa is fairly competitive against weeds particularly if the weeds are injured by herbicides

* Herbicide use can stunt or injury alfalfa seedlings

* Weed competition also stunts alfalfa seedlings
* Glyphosate @ 9 Trifoliate Leaf Stage on RR alfalfa
* Palmer amaranth on berms in alfalfa field
* Alfalfa production (RR and conventional varieties)
  
  * Plant in fall (mid-October through November)
  
  * Enables 2,4-DB applications (e.g. Butyrac 200) due to lower temps (temperature cut-off of 90 F)
  
  * Raptor and pursuit alone or tank mix better on winter weeds, possible resistance problem
  
  * Trifluralin granules or water run Prowl H₂O
  
  * Treat berms with residual herbicide or use tillage to keep them clean
  
  * (Roundup where susceptible weed populations occur)

* Managing GR Palmer Amaranth in Alfalfa
* Loss of alfalfa density and 1st harvest problems due to Palmer amaranth escapes following Raptor & Pursuit application in summer planted fields.
* Palmer amaranth on field edge of silage crop
Center pivot irrigation
Row spacing: 30 inch
Plot size: 20 x 30 feet
Herbicides applied at 3 leaf (5 in) and 9 leaf (30 in) growth stages
Second Application - Yukon (4 oz + 4 oz)
Roundup WeatherMAX (32 oz + 32 oz)
* Untreated Control on June 15, 2007
Any weed management program that use soil-applied herbicides followed by postemergence herbicides have less variability in weed control, crop yield, and net return compared with total postemergence programs.
* Herbicide - proactive and reactive
  * Utilize multiple herbicide modes of action, including those with residual effects, before applying glyphosate and/or tank mixing another herbicide with glyphosate.
  * Apply herbicides at the recommended stage of weed growth as stated on the label.
  * Conventional herbicides can and should still be part of the overall weed management system in glyphosate-resistant cropping systems.
  * Since glyphosate resistance may be controlled by more than one gene, it is important to use full label glyphosate rates.

* Resistant Management Strategies and Practices
* Glyphosate-resistant crops are a powerful tool to manage weeds but must be used as part of an integrated pest management (IPM) program.

* IPM principles and practices include field scouting or other detection methods, weed identification, population monitoring, and treatments.

* Weed IPM programs in glyphosate-resistant crops need to consider all available weed management options appropriate to the system.