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The Glyphosate, Weeds, and Crops Series

# Facts About Glyphosate-Resistant Weeds

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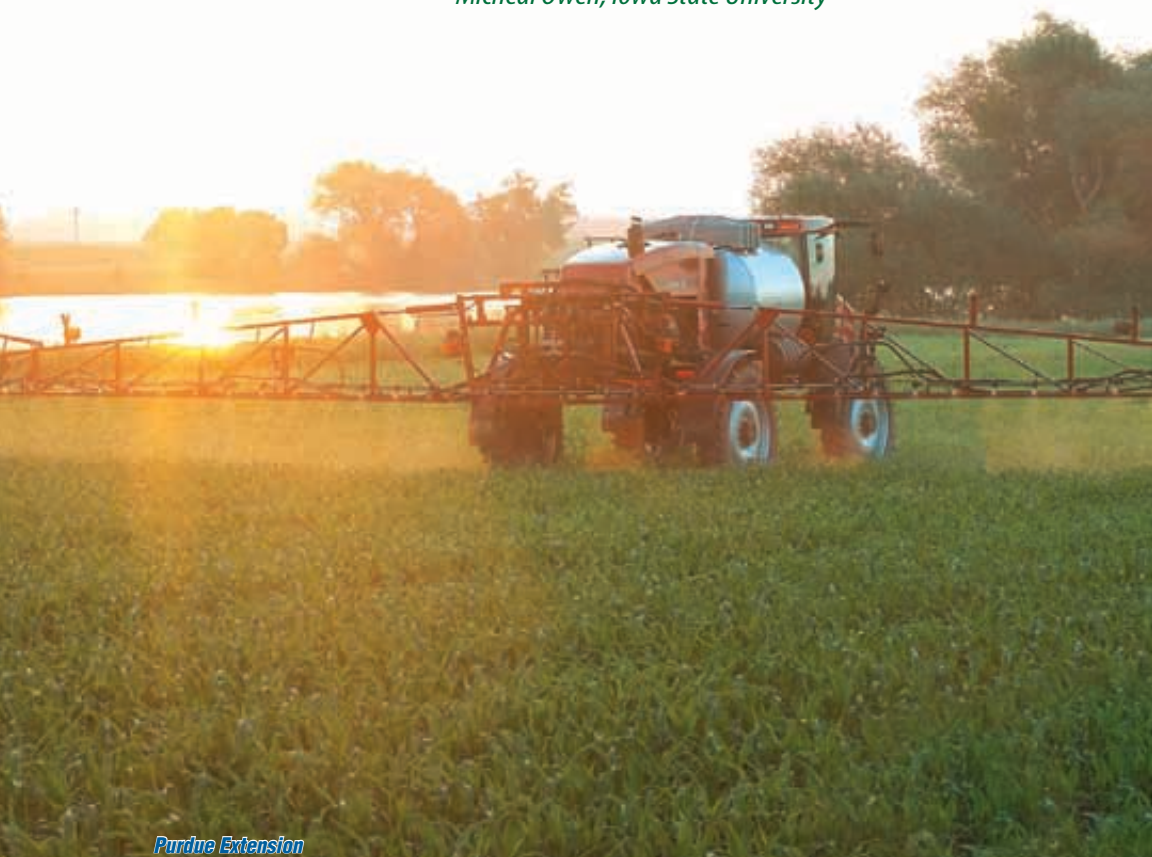

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# The Glyphosate, Weeds, and Crops Series

This publication was reviewed and endorsed by the *Glyphosate, Weeds, and Crops* Group. Members are university weed scientists from major corn and soybean producing states who have been working on weed management in glyphosate-resistant cropping systems.

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Facts About

# Glyphosate-Resistant Weeds

## Glyphosate: A Valuable Tool

Glyphosate (Roundup® and other products) is a valuable herbicide for corn and soybean growers. When applied postemergence to Roundup Ready® soybean varieties and corn hybrids, glyphosate provides broad-spectrum, low-cost weed control with excellent crop safety. It is better than many other herbicides at controlling larger weeds, has no soil activity (allowing for flexible crop rotations), and has low environmental and human health risks. In several respects, glyphosate and Roundup Ready® crops have simplified weed management. Even before Roundup Ready® crops were introduced, glyphosate was (and continues to be) a valuable herbicide in no-till cropping systems, and saves soil, fuel, and labor. No other single herbicide has provided these benefits to U.S. corn and soybean growers.

After glyphosate was introduced in the mid-1970s, it was used primarily for burndown and perennial weed control in corn and soybean. Such uses limited the number of applications and acres sprayed. Generally, glyphosate was also mixed with or followed by other herbicides, a practice that increased herbicide diversity. These practices probably helped prevent glyphosate-resistant weeds from developing in the United States.

Since the introduction of Roundup Ready® crops in 1996 and the dramatic decrease in its price, glyphosate has been widely used for both burndown and in-crop weed control. This significantly increased the number of acres where glyphosate is used (see Figure 1) and greatly increased the potential for selecting glyphosate-resistant weeds.

This publication describes the status and potential consequences of glyphosate-resistant weeds, and the primary factors that increase the risk of glyphosate resistance. This publication also encourages growers to use practices that reduce the selection for glyphosate-resistant weeds.

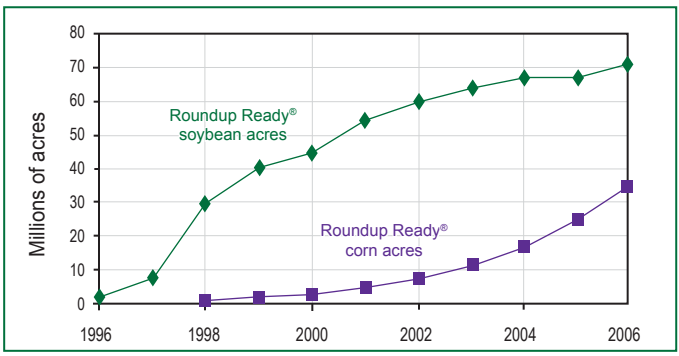


***Figure 1. Increasing Roundup Ready® Crop Acres.*** *This graph shows the steady increase of Roundup Ready® soybean and corn acreage planted since 1996.* *Source: Monsanto, 2006.*

## Increasing Reports of Resistance

The odds of selecting a weed with glyphosate resistance are probably less than the odds for selecting resistance to some other herbicide families. However,

widespread and repeated glyphosate use without diversified weed management has increased the selection of resistant species (see Table 1).

***Table 1. Current Reports of Glyphosate-Resistant Weeds.***

| Weed | Year First Reported | Location of Resistant Populations |
|---|---|---|
| *United States* | | |
| Rigid ryegrass | 1998 | California, other countries |
| Horseweed (marestail) | 2000 | 14 states |
| Italian ryegrass | 2004 | Oregon, other countries |
| Common ragweed | 2004 | Missouri, Arkansas |
| Palmer amaranth | 2005 | Georgia, North Carolina, Tennessee |
| Waterhemp | 2005 | Missouri |
| *World* | | |
| Goosegrass | 1997 | Malaysia |
| Hairy fleabane | 2003 | South Africa, Spain |
| Broadleaf plantain | 2003 | South Africa |
| Johnsongrass | 2005 | Argentina |
| Wild poinsettia | 2005 | Brazil |

*Primary Source: International Survey of Herbicide Resistant Weeds (www.weedscience.org)*

Although the total number of glyphosate-resistant weed species is low, the number of species is increasing at an alarming rate (see Figure 2). This raises two important points. First, glyphosate-resistant weeds can occur even though the gene for resistance is rare. Second, the number and geographic distribution of most glyphosate-resistant weeds is limited.

This means that there is still time to adopt good management practices, limit the selection of additional glyphosate-resistant weeds, and extend the benefits of glyphosate and Roundup Ready® crop technology.

## Consequences of Resistance

Glyphosate-resistant weed species have several negative effects on a farm. For example, horseweed is a common winter annual weed that is best controlled with burndown treatments before no-till corn or soybean. But burndown glyphosate treatments and applications in Roundup Ready® soybean have selected glyphosate-resistant plants that now infest millions of acres from Delaware to Illinois.

In no-till fields, glyphosate-resistant horseweed poses a serious control challenge, so growers have tank mixed additional herbicides with glyphosate. FirstRate® has been a popular tank mix partner, but a significant number of glyphosate-resistant horseweed populations have also developed resistance to FirstRate® and other ALS inhibitors. That's despite the fact that FirstRate® has a different mode of action (ALS inhibitor) than glyphosate (EPSPS inhibitor). When weeds have resistance to herbicides with two or more modes of action, that's called multiple resistance.

Some no-till growers have returned to using spring tillage to control horseweed that has glyphosate resistance or multiple resistances. Glyphosate resistance in this one weed may erode the gains that conservation tillage has made over the past 30 years. And because horseweed seed is easily spread by wind, even no-till growers who have adopted resistance management practices may be affected by this resistant weed.

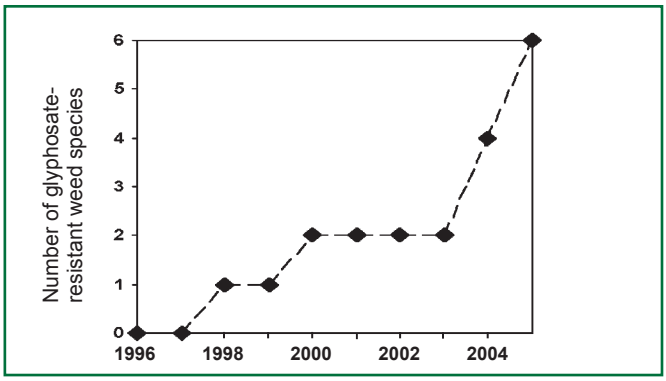


***Figure 2. Glyphosate-Resistant Weed Species in the United States.*** *This graph shows the rising number of known glyphosate-resistant weed species in the United States since 1996.*

Equally troubling, glyphosate-resistant waterhemp was reported in Missouri in 2005 (see Figure 3). Waterhemp infests millions of Midwest corn and soybean acres, and most waterhemp populations are already resistant to ALS-inhibiting herbicides (Raptor®, Pursuit®, and others). There are also waterhemp populations resistant to PPO herbicides (Flexstar®, Cobra®, and others) and triazine herbicides (Sencor®, atrazine, and others). One Illinois farm has a waterhemp population with three-way resistance (ALS, PPO, and triazine). Waterhemp with multiple herbicide resistance that includes glyphosate resistance will be a true challenge to manage with herbicides.

For some weed species, glyphosate resistance may not be as serious because a tank mix partner could control the glyphosate-resistant weed. Even so, adding a second herbicide will be less convenient, increase costs, increase the risk of crop injury, and may limit the window of application.

Some growers may be quick to discount resistance concerns because they believe herbicide manufacturers are developing (or already have) herbicides to solve emerging resistance problems. However, currently there are no known new herbicide modes of action being developed for corn or soybean. The last new mode of action discovered and developed in corn or soybean was pigment inhibitors (Balance®, Callisto®, and others), which were discovered in the 1980s.

## *Principles of Glyphosate Resistance*

A weed's potential for developing glyphosate resistance is primarily guided by three factors: weed biology, intensity of glyphosate use, and glyphosate rate.

### Weed Biology

It is likely that certain weed species have greater genetic diversity, so there is a greater risk that they will develop herbicide resistance. Weed species that have already developed resistance to other herbicides may have a greater probability of developing glyphosate resistance. Species that may be prone to glyphosate resistance based on resistance to other herbicide modes of action include pigweed species (including waterhemp, and Palmer amaranth), common lambsquarters, common and giant ragweed, kochia, and ryegrass. Since the trait for glyphosate resistance can spread by pollen or seed, the spread of resistant populations will be faster for some weed species than others.

### Intensity of Glyphosate Use

Increasing the intensity of glyphosate use (frequency and number of acres treated) increases the probability of selecting an herbicide-resistant plant. With continued glyphosate use, the number of resistant plants will continue to

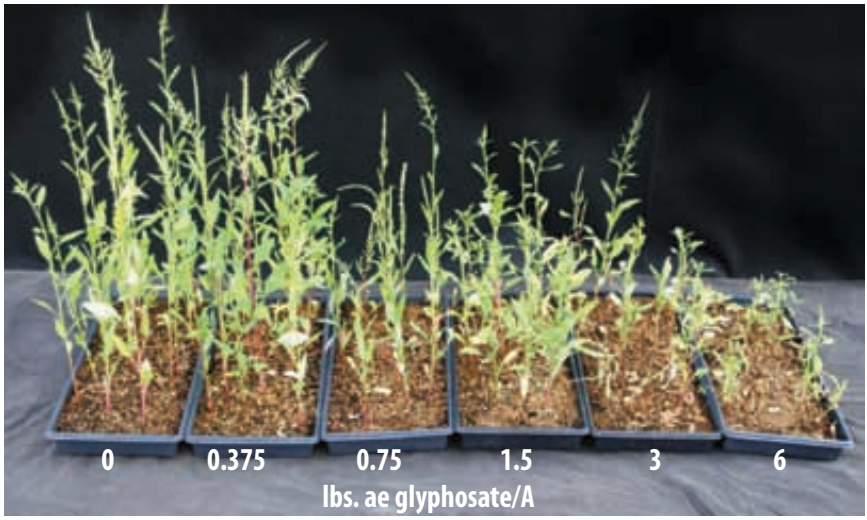


Photo by Kevin Bradley, University of Missouri

***Figure 3.*** *Seedlings from a glyphosate-resistant waterhemp population in Missouri survived the labeled glyphosate rate (0.75 lb. ae/a) and up to eight times the labeled rate (6 lbs. ae/a).*

multiply and create a resistant population. Herbicides do not cause the mutations that result in resistance. Rather, an extremely rare genetic trait that allows a weed to survive glyphosate may exist in the natural population. It is more likely to be found and increase when glyphosate is used frequently.

## Glyphosate Rate

It is less clear how rate affects glyphosate resistance development in weeds. Several known glyphosate-resistant weeds require eight to 10 times more glyphosate to be controlled than the normal, sensitive biotypes. This level of resistance means that labeled glyphosate rates will not control these weeds, and that making applications at labeled rates probably will not prevent resistance.

There are other cases of glyphosate-resistant weeds that appear to have resistance at two to four times greater than normal biotypes. It is unknown if reduced glyphosate rates contributed to these plants becoming resistant, or if resistance would have occurred at labeled rates. Regardless, it is wise to use glyphosate at labeled rates to ensure good control and prevent hard-to-control weeds from increasing in any field.

# Tolerance, Resistance, and Nonperformance

The majority of weed escapes in Roundup Ready® fields are not due to glyphosate resistance. Rather, some escapes can be attributed to certain weed species that are naturally tolerant to glyphosate. Examples include yellow nutsedge, field horsetail, morningglories, prairie cupgrass, wild buckwheat, and dayflower species. Labeled glyphosate rates are less effective against these naturally tolerant species. Also, environmental and application factors can lead to glyphosate performance problems. Factors that may reduce glyphosate performance include:

- Incorrect rate for weed size or species.
- Rain before glyphosate is completely absorbed by the weed.
- Weather-stressed weeds (from drought, cold, etc.).
- Incomplete spray coverage of weeds below the canopy.
- Reduced glyphosate activity with early morning, late evening, or night applications.
- Weeds emerging after the glyphosate application.

If natural weed tolerance or application factors do not explain weed escapes, glyphosate resistance may be possible. If you suspect glyphosate-resistant weeds, use this checklist to determine if glyphosate resistance is possible:

- There were no known application errors and the correct glyphosate rate was added to the tank.
- The environment was favorable for glyphosate performance (unstressed plants).
- Only one species escaped control (escapes may be in patches).
- Glyphosate typically controls the weed species that escaped control.
- The weed shows evidence of being sprayed (glyphosate symptoms).
- Either glyphosate has been used frequently in the past, or glyphosate resistance has been confirmed in the region.

If most of these conditions exist, there is potential for glyphosate resistance. Control glyphosate-resistant weeds with an herbicide that has a different mode of action. Don't attempt to control the resistant weed with another glyphosate application.

## Glyphosate Resistance Management

Although everyone would prefer a simple solution to glyphosate-resistant weeds, adding diversity to our weed management programs is the key. Diverse practices provide additional benefits since many of these practices improve the overall level and consistency of weed control, add flexibility in scheduling applications, and reduce the risks of yield loss. Overall, we must manage the intensity of glyphosate use to reduce the potential for resistance.

These weed management practices avoid the continuous and exclusive use of glyphosate and lessen the potential for developing glyphosate-resistant weeds:

- Rotate between Roundup Ready® and conventional crops or crops with other types of herbicide resistance. Use Roundup Ready® crops and glyphosate in your crop rotation where they have the greatest economic and management value.
- Rotate glyphosate with herbicides that have different modes of action.
- Apply a residual herbicide before glyphosate or tank mix another herbicide with glyphosate.
- Avoid making more than two glyphosate applications to a field over a two-year period.
- If glyphosate is used as a burndown treatment and in-crop in the same year, tank mix the glyphosate applied in the burndown treatment with an herbicide that has a different mode of action. The in-crop glyphosate application should still be rotated with other herbicides in other years.
- Use cultivation and other mechanical weed management practices.

In addition, growers should apply glyphosate at labeled rates and at the correct stage of weed and crop growth to reduce the risk of poor control. Also, scout fields regularly, identify the weeds present, and record their locations on maps to allow a quick response to changes in weed populations.

### *Other Crops Are Also at Risk*

The frequency of glyphosate use is a major concern in corn and soybeans.

The same concern exists in other cropping systems where glyphosate is commonly used. Heavy reliance on glyphosate in Roundup Ready® alfalfa, canola, or other Roundup Ready® crops in the future will also increase the potential for glyphosate-resistant weeds in those systems.

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