

## Comparing glyphosate resistance in Palmer amaranth and marestail

Lowell Sandell, Deana Namuth-Covert, Greg Kruger, and Mark Bernards

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### Introduction:

The simplicity and effectiveness of weed control in glyphosate-resistant (GR) corn, soybean, cotton and sugarbeets have led to extensive adoption of this technology in the US. However, relying primarily on a single herbicide has resulted in the selection of GR populations for a number of important weed species.

Weed species with populations resistant to glyphosate in the Midwest include marestail, waterhemp, common ragweed, giant ragweed, and kochia. In the southern US, GR Palmer amaranth populations are wide spread and GR Johnsongrass populations have also been confirmed. All of these species are present in Nebraska, although Johnsongrass is not common in production fields. Resistant populations of these species are likely to develop in Nebraska where producers rely primarily on glyphosate for weed control.

What's at stake if additional GR weed populations develop in Nebraska? The first is greater yield loss due to weed competition. Second, is the subsequent cost of additional herbicides needed to achieve adequate control. Third, is a potential reduction in no-till acres, since successful no-till is predicated upon effective weed control using herbicides. Fourth, is an increased pesticide load in the environment resulting from the use of additional herbicides necessary to control GR weed populations. The following sections outline how glyphosate kills plants, mechanisms by which Palmer amaranth and marestail have evolved glyphosate resistance, and management to avoid glyphosate resistant weed development.

### Glyphosate action in plants:

Glyphosate controls plants by disrupting essential amino acid synthesis ([Link](#) to animated demonstration). Glyphosate binds to, and disables EPSP synthase. EPSPS is an enzyme that catalyzes reactions in the shikimate pathway which forms three amino acids. When a susceptible plant is sprayed, glyphosate is absorbed by the plant, translocated to actively growing tissues and inhibits necessary aromatic amino acid synthesis. In a susceptible plant, shikimate levels start to increase after application, thus indicating that glyphosate is working as it should. The plant undergoes a relatively slow death over the following 10-20 days.

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## **Glyphosate resistance in Palmer amaranth:**

Palmer amaranth is an economically important weed species in row crop production, especially in the Southern US. In 2006, Culpepper et al. reported the first GR Palmer amaranth population in Georgia. More recently published work describes a genetic basis for glyphosate resistance in Palmer amaranth. In susceptible plants, there is a low gene copy number that encode for production of EPSP synthase (1 gene copy). Gaines et al. (2010) showed that GR Palmer amaranth have an extraordinarily high copy number of the EPSPS gene (5 to more than 160 copies), relative to a glyphosate-susceptible population. A high EPSPS copy number means the plant can produce enough EPSPS to support necessary amino acid production even in the presence of glyphosate. Shikimate does not build up, and amino acid synthesis occurs in spite of the uptake and translocation of glyphosate.

While individual plants of a weed species may look similar (phenotypically similar), there can be a tremendous amount of genetic variability within a population. Because of this broad genetic variability, there is a chance of selecting for a resistant individual under persistent, high selection pressure (e.g. multiple applications of glyphosate alone). In a situation of high selection pressure, resistant plants can come to dominate a field population in only four to five generations (years in the case of most weeds) once plant genetics are selected that confer resistance to that selection pressure (Jasieniuk et al. 1996).

Movement of the resistant individuals can occur in multiple ways once a resistant weed population has evolved. Seed can be moved by tillage and harvesting equipment, by animals, or wind and water. Another method of movement is via pollen (genetic exchange). Palmer amaranth is a dioecious species, meaning plants are either male or female. This means the plants are obligate out-crossers (cross-pollinators), resulting in the exchange of genetic traits each year. Gaines et al. (2010) demonstrated that the increased EPSPS gene copy number is a heritable trait when plants are cross-bred. The concern for producers is that this genetic basis for glyphosate resistance can spread over any distance that the pollen can travel. Sonoskie et al. (2011) have reported movement of resistance traits via pollen up to 1000 feet from a known resistant male plant to susceptible female plants.

## **Glyphosate resistance in marestail:**

Currently, marestail is the species presenting the largest GR weed management problem in Nebraska. The mechanism of glyphosate resistance is not the same in all resistant weed species. In contrast to Palmer amaranth, glyphosate resistance in marestail is likely due to reduced or altered translocation of glyphosate (Feng, et al, 2004. Koger and Reddy, 2005). The glyphosate is sequestered in part of the plant,

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allowing unaffected plant parts to continue to grow and produce seed. This process is thought to be controlled by a single dominant or semi-dominant gene (Zelaya, et al, 2004). Because marestail is capable of both self or cross pollination, passing on resistance traits (from pollen movement) can occur rapidly in a population.

These examples illustrate the complexity of evolved glyphosate resistance in weed species. While both of these cases would be considered non-target site resistance, the physiological methods by which these species avoid death by glyphosate are different.

### **Summary:**

Because the movement of glyphosate resistant traits (via pollen or seed movement) in weed populations cares nothing about property ownership, fence lines, or man-made boundaries, resistance management should be considered the responsibility of the entire ag community. This underscores the necessity of knowing the weeds present in your fields and then implementing weed management programs that are both economically effective and reduce the potential for glyphosate resistance development.

Producers in Nebraska have not experienced production problems with GR Palmer amaranth like producers in southern states. However, if there is over-reliance on glyphosate for weed control, it is likely that resistance will evolve in local populations. Palmer amaranth is present in the southern tiers of Nebraska counties, and becomes more prevalent as you move west.

Proper resistance management is a proactive approach to managing weeds. In fields infested by Palmer amaranth or any of the weed species mentioned at the start of this article, managing to prevent herbicide resistance development is a desirable goal. This can be achieved by using at least one PRE herbicide that is effective on all the weeds present in the field, followed by a POST application, if warranted, of a second herbicide that is effective on the same weeds. Herbicide resistance management principles apply to all cropping systems, including Roudup Ready, Liberty Link, conventional crops, and each of the herbicide resistant technologies that will be commercialized in the future. Using multiple herbicide resistance traits in your crop rotation to “change-up” your herbicide program will result in delayed evolution of herbicide resistant weed population and greater value and longevity of the weed control tools currently available to producers.

### **Take home:**

- Glyphosate resistance in at least one Palmer amaranth population is due to elevated EPSPS production from an increased EPSPS gene copy number in resistant individuals.

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- Glyphosate resistance in marestail is likely due to reduced or altered glyphosate translocation.
- Use at least two different herbicides that are effective on Palmer amaranth each year. Make sure the herbicides have different mechanisms of action. Do not use the same two herbicides every year. This strategy also applies to fields with marestail, kochia, ragweeds, and waterhemp.

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