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Update 2005 on Herbicide Resistant Weeds and Weed Population Shifts

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**Introduction**

Given that +90% of the soybeans in Iowa are glyphosate-resistant varieties with the concomitant use of glyphosate products, and that recent interest in glyphosate-resistant corn is likely to result in an increasing number of crop acres where glyphosate will follow glyphosate, it is important to understand the level of selection pressure from this weed management plan that will be imposed upon the weed community. Changes in agroecosystems attributable to glyphosate-based systems are already being observed. Notably, recent announcements of glyphosate-resistant weeds suggest that weed populations are reacting to the selection pressure more quickly than anticipated. Local changes include problems with common lambsquarters, common waterhemp, and Asiatic dayflower. The implications of current glyphosate-based production systems on weed communities, and resultant economics need to be understood if sound management systems are to be developed and this important technology preserved.

**Understanding selection pressure**

Selection pressure is the sum of all crop production practices that are imparted on a field. Decisions such as planting date, tillage, crop rotation, fertilization, weed management program, and crop variety or hybrid are directly or indirectly a component of the overall selection pressure that influences the ecological balance of organisms that exist within an agroecosystem. With regard to weeds, all of the aforementioned factors influence the weed community, but the primary factors that impact selection pressure are tillage and herbicide program.

Weed communities adapt to the tillage regime. For example, prior to the wide-spread adoption of conservation tillage programs, larger seeded annual broadleaf weeds such as velvetleaf and common cocklebur were the predominant problems. However, conservation tillage "selected" for weeds that can germinate early and from shallow depths. Thus, common lambsquarters and common waterhemp became the predominant problems.

Similarly, herbicides select for weeds that are not effectively controlled. The evolution of ALS resistant biotypes of common waterhemp became wide spread due to the repeated and pervasive use of ALS inhibiting herbicides. Note, however, that the herbicide does not "cause" the trait to occur in the unselected weed population. The trait for herbicide resistance is there due to the natural genetic variability within weed populations.

The frequency of the genetic trait within the weed population depends on a number of factors. If the trait confers a "fitness" penalty on the individual plant, that trait is less likely to exist naturally within the weed population. If the genetic trait is "fitness neutral" or perhaps imparts an ecological advantage, the trait is likely to occur at a high level of frequency. The relative frequency of the trait in population influences how quickly a resistant population will evolve when the selection pressure is applied. For example, the occurrence of the trait that confers ALS resistance occurs naturally very frequently in a weed population. Thus, ALS resistant weed
populations evolved rapidly. Resistance to triazine herbicides, however, imparts a negative fitness penalty on plants and thus exists within populations at very low levels. It took much longer and greater selection pressure for a triazine resistant weed population to evolve.

However, weeds do not have to evolve herbicide resistance to become an economic problem. Weed population shifts are a slower and more complicated example of a response to selection pressure. For example, woolly cupgrass has become a major problem throughout the Midwest over the last 10 to 15 years, but herbicide resistant populations have not yet been identified. The reason is that woolly cupgrass demonstrates considerable tolerance to most soil-applied herbicides, is extremely well adapted to conservation tillage, has a high level of seed production, and is more competitive than most other weeds. Thus, given the overall ecological advantage that woolly cupgrass demonstrates, a population will eventually become the dominant weed in the community without the need for evolved herbicide resistance.

The key to managing a weed community reflects an understanding of the selection pressure that is imparted on a field. The better the management practices, the greater the selection pressure that is imparted. Essentially, the better the weed control and the narrower the focus of the weed control tactics (i.e. the singular use of one herbicide repeatedly over time), the greater the likelihood that a change in the weed community, either evolved herbicide resistance or weed population shifts, will occur. These changes are inevitable unless due consideration is given the developing a diverse weed management program.

**Herbicide resistant pigweeds**

Pigweeds have evolved resistance to many different classes of herbicides world-wide. There are populations of pigweeds resistant to triazines (i.e. atrazine), PPO inhibitors (i.e. Cobra), DNA herbicides (i.e. Treflan), ALS inhibiting herbicides (i.e. Pursuit), and others. There are examples of pigweed populations that are resistant to a number of different herbicide families with different mechanisms of action (multiple resistance) and different herbicides families that have the same mechanism of action (cross resistance). Two pigweeds currently represent potential problems for current production systems.

**Common waterhemp and ALS resistance**

Common waterhemp quickly evolved resistant to ALS inhibiting herbicides across Iowa. Generally, a common waterhemp population is more likely to be ALS resistant than not. Typically, populations are cross resistant to different ALS families and the level of resistance if quite high. The genetic trait is a single dominant gene and the trait does not impart any fitness penalty on the resistant biotype. Thus, the frequency of the trait within populations was relatively high prior to the selection pressure imparted upon the agroecosystem by the widespread adoption of ALS inhibiting herbicides in Iowa.

**Common waterhemp and glyphosate resistance**

A recent press release announced that isolated populations of common waterhemp in Missouri had evolved resistance to glyphosate. While the data to support the announcement is not complete and based primarily on greenhouse efficacy data, the announcement comes as no surprise. In discussions with the University of Missouri personnel, the situation they describe is not unlike that which is relatively common in Iowa. The difference in Missouri is the relative selection pressure on the two fields that were included in the press release. These fields have
been in continuous soybean production for a number of years, and have undergone nine years of glyphosate selection pressure. The level of resistance is similar to what we have reported, although our data was collected from populations that experienced 1 generation of glyphosate selection in the field and subsequently had 3 recurrent selection cycles in the laboratory. Our published data (Zelaya and Owen, 2005, Pest Manag Sci 61:936-950) demonstrated clearly that the genetically heritable trait for glyphosate resistance exists with common waterhemp populations but at a very low frequency. Given the selection pressure that is anticipated with the consistent use of glyphosate on glyphosate-resistant soybean and corn rotations, the frequency of glyphosate-resistant waterhemp will likely increase dramatically in Iowa unless diversity of weed management tactics is employed.

Palmer amaranth and herbicide resistance
Other press releases this Fall, three issued almost simultaneously from Georgia, North Carolina and Tennessee, described Palmer amaranth populations that evolved resistance to glyphosate. Again, the data is not complete and heritability studies have only begun, but given the history of evolved herbicide resistance in Palmer amaranth populations, the announcements come as no great surprise. While Palmer amaranth is not a common weed in Iowa, the significance of the information is that evolved resistance to glyphosate is being discovered frequently and over a broad geographic and crop production range. Palmer amaranth is described as the most aggressive and competitive of the pigweed species. Palmer pigweed populations are increasing in Illinois, Missouri and Kansas and have been reported to demonstrate resistance to ALS and PPO inhibiting herbicides. It is clear that the populations described are simultaneous founding events that evolved glyphosate resistance independently. Also, introgression of genetic traits between Palmer pigweed and common waterhemp is a possibility. Thus, producers in Iowa should be aware of this impending weed problem.

Common ragweed resistant to glyphosate
The University of Missouri announced a population of common ragweed that evolved resistance to glyphosate. This announcement has subsequently been supported by information from Monsanto. However, the glyphosate-resistant common ragweed population is very much different than any other weed population that has evolved herbicide resistance. As detailed, the glyphosate-resistant common ragweed population is in one isolated soybean field, and limited to specific areas within the field. There is little published data that describes the genetic heritability or biochemical mechanisms of the alleged glyphosate-resistant common ragweed biotype. It is unlikely, based on the cursory information available, that glyphosate-resistant common ragweed will become a serious agronomic problem in Iowa.

Horseweed resistant to glyphosate
Evolved glyphosate resistance to horseweed (also commonly known as marestail) has spread widely and rapidly across the eastern Corn Belt. Multiple founding events clearly have occurred and glyphosate-resistant represents a significant economic issue in soybean and cotton production. The first population of glyphosate-resistant horseweed was identified three years after the adoption of glyphosate-resistant soybean and the concomitant use of glyphosate as the sole herbicide. This narrow focus using only glyphosate resulted in considerable selection pressure and the resistance evolved rapidly. Recent research published by the Agronomy Department at Iowa State University (Zelaya et al., 2004, Theor. Appl. Genet. 110:58-70)
elucidated why the distribution of glyphosate-resistant horseweed was so great so quickly. Our data demonstrate that the genetic trait for glyphosate resistance is controlled by a single semi-dominant gene. Given the incredibly high seed production, the fact that the seeds are wind-dispersed, and the adaptation of horseweed to conservation tillage programs, it is obvious why glyphosate-resistant horseweed is a major concern for agriculture. While no glyphosate-resistant horseweed populations have been identified in Iowa, there is no reason to believe they do not exist and will likely increase in the near future.

**Herbicide resistant giant ragweed**

Giant ragweed populations in Iowa and throughout the Midwest have evolved resistance to ALS inhibiting herbicides. Furthermore, there is anecdotal evidence to suggest that glyphosate resistance may be evolving in Ohio and Indiana. However, the existence of glyphosate-resistant giant ragweed has not been confirmed. Be aware that giant ragweed is difficult to manage consistently regardless of whether or not glyphosate-resistant populations evolve.

**Shattercane resistant to ALS inhibitor herbicides**

Shattercane populations that have evolved cross resistance to ALS inhibiting herbicides have been identified in Iowa (Zelaya and Owen, 2004, Weed Sci. 52:588-548), Nebraska and elsewhere. The occurrence of ALS resistant shattercane populations is not widespread and given the adoption of glyphosate technology, does not represent a major management problem for Iowa producers.

**Common lambsquarters resistance to glyphosate**

The importance of common lambsquarters as an economic problem has increased considerably during the last 10 years. Resistance to triazine and ALS inhibiting herbicides is widely distributed. Recent adoption of glyphosate technology has resulted in suspect populations of common lambsquarters in Indiana, Ohio, and elsewhere that may have evolved resistance to glyphosate. Common lambsquarters is difficult to control with glyphosate regardless of the existence of resistance. Thus, multiple tactics should be employed for the most consistent management of common lambsquarters infestations.

**Common sunflowers resistant to ALS inhibitor herbicides**

Common sunflower populations that have evolved cross resistance to ALS inhibiting herbicides have been reported in Iowa and elsewhere.

**Morning glory resistance to glyphosate**

While annual morning glories are not major problems throughout Iowa, populations are increasing in Southern and Eastern Iowa. Morning glories demonstrate heritable tolerance to glyphosate and are suspected to evolve resistance to glyphosate in the southern soybean belt.

**Weed population shifts**

As indicated, weed population shifts is a long-term response to selection pressure imparted on the agroecosystem. However, the selective factors are more complex than illustrated in the evolution of herbicide resistant biotypes, and the speed at which population shifts occur is typically slower than the change that occurs when herbicide resistant populations evolve. To that end, when a weed population shift occurs, it may require more changes in management practice than the changes required for an evolved herbicide resistant weed population. A recent,
albeit relatively isolated, weed population shift that has surfaced in response to the adoption of glyphosate technology is occurrence of Asiatic dayflower. Asiatic dayflower is naturally tolerant to glyphosate, almost irrespective to the application rate. While this weed is indigenous to Iowa, until the selection pressure imparted by growers who have adopted glyphosate technology occurred, only rare infestations were of economic importance. Due to the wide spread adoption of glyphosate technology, Asiatic dayflower problems are increasing in Iowa and elsewhere in the Midwest. While not yet of serious proportion, the infestations appear to be increasing at an increasing rate. It is clear that increased diversity in weed management tactics must be implemented to keep this weed as a rare and scattered problem.

**Conclusions**

It is clear that while rare, evolved glyphosate resistance in several different weed species has become more common and is problematic at an increasing rate. Given the wide spread adoption of glyphosate-resistant soybean and cotton, and the anticipated increase in glyphosate-resistant corn, glyphosate will be applied consistently on fields every year. The level of selection pressure imparted on a field by this management strategy will inevitably result in weeds that are not managed effectively by glyphosate.