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HERBICIDE RESISTANCE UPDATE

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Introduction

Although herbicides have been an important component of Iowa crop production for more than 30 years, the degree of reliance on these ag chemicals has increased significantly in the past decade. The primary cause of this increased reliance is the decrease in the use of tillage as a weed management tool. While this has benefits in terms of protecting soil from erosion and decreasing energy use, it does increase the potential for selection of herbicide resistant weeds. Herbicide resistance is defined as the inherited ability of a weed to survive a herbicide dose that kills the native population of that species. The two important points of this definition are 1) the ability to survive the herbicide is genetic and passed along to progeny, and 2) the native population is controlled by the herbicide. It is likely that herbicides will remain the primary weed management tool used in crop production for the foreseeable future, thus it is critical that they be used in a manner that preserves there utility. This paper will address the following questions concerning herbicide resistance: 1) How does resistance develop? 2) How widespread is resistance? 3) How long will resistance persist once it occurs? 4) How do you prevent resistance? and 5) Will weeds develop resistance to Roundup?

How does Resistance Develop?

Weed shifts are an inevitable consequence of weed control. All control strategies select for weeds that are able to survive that tactic. Plants that survive a control tactic produce seed and therefore increase in population, whereas plants that are killed fail to produce seed resulting in a reduction in the population. In the past, the primary weed shifts we observed involved weed species. For example, in the 1960's and 1970's soybean weed management programs relied heavily on Treflan and metribuzin (Sencor/Lexone). These herbicides were very effective on foxtail, pigweed and lambsquarter, and therefore these weeds became less of a problem. Velvetleaf and cocklebur rapidly increased in severity due to the ineffectiveness of these herbicides on large-seeded broadleaf weeds. Another example of weed species shifts would be the increase in lambsquarter and venice mallow populations following the use of Pursuit, or increases in black nightshade following Classic or Reliance. Weed shifts are not limited to chemical control, but occur to all control strategies. The prevalence of thistles in pastures is due to selective grazing by cattle – they leave the thistles alone because they don’t like a mouth full of spines, therefore allowing the thistles to thrive.

Herbicide resistance involves shifts in weed biotypes rather than shifts in weed species. A biotype is a group of individuals within a species that has characteristics that are not common to the population as a whole. For example, a specific variety of soybean would be a biotype of Glycine max. Herbicides select for individuals within a species that possess some mechanism that allows them to survive. Some have questioned whether herbicide resistance is any different or of any greater concern than the traditional shift in weed species that has always occurred with weed control. In my view resistance is of greater concern because it means we lose a herbicide for controlling a species that initially it was effective against. Traditional weed species shifts will occur with any herbicide and reduce its value somewhat. If shifts in weed biotypes also occur, the value of the herbicide will be diminished even further.

There are two primary mechanisms that result in herbicide resistance: altered sites of action and enhanced herbicide metabolism. The specific location within a plant with which the herbicide interacts is referred
to as the site of action. When a herbicide binds to the site of action, some physiological process is disrupted that results in plant death. Some plants achieve resistance through an alteration in the site of action that prevents the herbicide from binding. This is the most common mechanism of resistance, and is the mechanism of ALS resistance in water hemp. The second common form of resistance is an enhanced ability of a plant to metabolize the herbicide to non-toxic compounds. These plants are able to detoxify the chemical before it reaches the site of action in toxic concentrations. A velvetleaf biotype in Wisconsin achieves resistance to atrazine through enhanced metabolism.

Two other terms that are used in discussing resistance are cross-resistance and multiple resistance. A cross-resistant weed biotype possesses resistance to several herbicides through a single resistance mechanism. ALS-resistant water hemp is cross-resistant to Pursuit, Pinnacle, Python and other commonly used herbicides with this site of action. An altered site of action does not necessarily provide cross-resistance to all herbicides with the same site of action. A weed biotype with multiple resistance possesses two or more distinct resistance mechanisms. A water hemp biotype has been identified in Iowa that has altered binding sites for both the triazine and ALS herbicides. This is the first documented case of multiple resistance in the state.

**How Widespread is Resistance?**

The first case of herbicide resistance was reported in 1957, and involved spreading dayflower and wild carrot biotypes resistant to the growth regulator herbicides. As of 1997, 210 resistant biotypes have been reported worldwide to 15 classes of herbicides. Triazine herbicides have the largest number of resistant species (64), whereas the ALS herbicides are the second leading family with 50 resistant species. Since the 1980's, about nine new resistant species have been reported annually. The U.S. leads the world in the number of resistant species (60), followed by Australia (26) and then Canada and France with 24 resistant species.

Iowa has ten weed species with confirmed resistant biotypes. Resistance is most common to the triazine herbicides, with resistance confirmed in common lambsquarter, smooth pigweed, water hemp, kochia, and Pennsylvania smartweed. Resistance in these species is isolated to individual fields and has not created major problems for most growers. ALS resistant biotypes of water hemp, cocklebur, kochia and sunflower have been confirmed. Water hemp is the only species in which resistance is widespread, and the first resistant species to create major problems for Iowa growers. Both the triazine and ALS resistant biotypes of kochia are believed to have developed on railroad right-of-ways and then moved into agricultural fields. Finally, Iowa has a giant foxtail biotype resistant to the ACC-ase inhibitors (Poast, Assure, etc.). It is isolated to one field where soybeans were grown continuously for several years and the ACC-ase herbicides were used as the sole means of controlling grasses. There may be other resistant species present in the state that we are unaware of.

**How long will resistance persist once it occurs?**

A question that farmers and agronomists frequently ask is how long a herbicide resistant biotype will remain in a field after it has been selected? For example, assume repeated applications of ALS herbicides selected ALS-resistant cocklebur in a field. How long would the farmer need to wait before he could use ALS herbicides again to control cocklebur? Although there have been few long term studies looking at this, experience with antibiotic, fungicide and insecticide resistance suggest that resistance will remain at high proportions for the near future.

One of the few studies involving herbicide resistance investigated the stability of resistance in green foxtail to Treflan in southwestern Manitoba. The resistance appeared following repeated applications of Treflan in wheat fields. The researchers collected foxtail seed samples in 1995 from 17 fields where
Treflan resistance was first reported in 1988. Since 1988, six of these fields had not been treated with dinitroaniline (DNA) herbicides, whereas the other fields had been treated at least once with a DNA product. The proportions of resistant (R) and susceptible (S) biotypes in the foxtail populations were determined and compared to the field history. Two of the fields that had not been treated with Treflan or other DNA herbicides since 1988 contained >99% R foxtail, the other fields ranged from 40 to 83% R biotypes. Among the four fields treated once with DNA herbicides, two fields had >99% R foxtail, and the other two contained 59 and 67% R individuals. Five of the seven fields treated two or more times contained >97% R, and the other two fields contained 89 and 68% R biotypes. The authors concluded that the potential exists for resistance to render some chemicals useless for the foreseeable future. They stated that the emphasis for managing resistant weeds should be on prevention of resistance and the incorporation of integrated weed management techniques.

**Can we prevent resistance?**

Any time a herbicide is used in a field it is placing selection pressure on the weed population and increasing the frequency of resistant weed biotypes. The only way to eliminate the risk of resistance is to stop using the herbicide, which obviously isn’t a desirable option. Therefore, we must look for ways of managing the risk of resistance. The key to managing resistance is to evaluate the selection pressure of individual herbicides relative to other weed management strategies. Basically, the greater the reliance on a specific herbicide or herbicides with similar sites of action, the greater the selection pressure on the weed population, and the sooner resistance will appear in a weed population.

For most growers, managing resistance will primarily involve herbicide selection. The two main considerations for herbicide selection are rotation of herbicides and the use of alternative modes of action. Repeated use of herbicides with the same site of action places continual selection pressure on weed populations. The simplest and most effective method of managing herbicide resistance is to rotate herbicide sites of action annually.

The use of herbicides with multiple sites of action, applied either as tank mixes, premix formulations, or sequential applications, may provide some benefit in managing resistance. A second herbicide will only reduce selection pressure if it is effective on the same weed species as the first product. For example, Bicep contains two herbicides with two different sites of action, Dual and atrazine. This combination should be effective at reducing selection pressure on pigweed since both Dual and atrazine are active on this species. This combination would be less likely at reducing the potential for Dual resistance in foxtail since the rate of atrazine found in Bicep provides little control of foxtail. Thus, when using multiple sites of action, it is critical to evaluate how much overlap in activity among the herbicides being used is present. In most situations there will be several species in which only one of the herbicides is placing selection pressure on the population, and therefore selecting for resistant biotypes.

Incorporating other management strategies into the weed management program will lessen the risk of selecting resistant weed biotypes. Row cultivation is one practice that is widely available to Iowa producers. Including crops other than corn or soybeans in the rotation would also reduce selection pressure, but is not an option for most growers. In the absence of alternatives to herbicides, it is important to consider herbicide selection pressure in the herbicide selection process.

One factor that complicates resistance management is that it isn’t known which species is most likely to develop resistance to a specific herbicide. For instance, when people attempted to predict the species that would first develop resistance to the ALS herbicides in Iowa, waterhemp was not among the species chosen. All fields in Iowa have at least 15 to 20 weed species present, any one of which might possess resistant biotypes to a specific herbicide. If we knew what species was most likely to develop resistance
to a specific herbicide, it would be much easier to develop herbicide programs that would effectively reduce selection pressure on that species and therefore delay appearance of resistance.

Although we can’t predict which species will develop resistance and when resistance will appear, we usually have a fairly good idea of the relative risk for resistance among different classes of herbicides. We know that ALS herbicides are more prone to resistance than Roundup or the amide herbicides. Our understanding of risk for resistance usually is gained from past experience with the herbicides. For instance, ALS-resistant weeds appeared within a few years of introduction of these products. On the other hand, Roundup was used for over 20 years without resistance appearing. Thus, it is apparent that there is a greater risk for resistance with ALS herbicides than with Roundup.

Some herbicide classes are at less risk for resistance because they have multiple sites of action. The likelihood of a biotype having two altered sites of action is much less than of a biotype having a single altered site of action. It is believed that the amide herbicides (Dual, Harness, Surpass, etc.) have multiple sites of action, and this has limited the development of resistant weeds to these herbicides. Other herbicides may have a low risk of resistance because changes in the site of action that prevent herbicide attachment may interfere with the activity of the enzyme. In this situation, most mutations that provide herbicide resistance result in death of the plant since the enzyme is non-functional, even in the absence of the herbicide.

**What is the Potential for Roundup Resistant Weeds?**

There has been considerable discussion concerning the risk of weeds developing resistance to Roundup. Some people stated that it was extremely unlikely that Roundup resistance would appear, but shortly after these statements were made Roundup resistant biotypes of rigid ryegrass appeared in Australia. One resistant biotype was identified in an orchard near Orange, New South Wales, Australia. The site had intensive selection pressure, with two or three applications per year of Roundup (2 to 4 qt/A) for 15 years. The resistant population was found to be between 7 and 11-fold resistant to Roundup compared to the susceptible population. A second resistant rigid ryegrass biotype has been identified from an agronomic site that received less intensive selection pressure. While these cases are not indicative of an impending threat for widespread resistance to Roundup, it should remind users that resistance management should be a consideration with any herbicide, including Roundup.

**Summary**

When resistance to a herbicide occurs, the herbicide loses some of its value to the producer. Although the herbicide still provides control of species that have not developed resistance, other strategies must be implemented to control the resistant biotype. The change may involve switching herbicides, using an additional herbicide to control the resistant species, or implementing alternative strategies, such as cultivation. These changes have a cost, either in the form of expense, effectiveness, or convenience.

Herbicides are an integral component of today’s cropping systems. Changes in herbicide use patterns and tillage systems in Iowa have increased the potential for herbicide resistant biotypes to develop. Managers should consider herbicides a resource to be preserved. Evaluating long-term weed management programs for selection pressure placed on weeds should be an important component of crop management planning.