THE EVOLUTION OF HERBICIDE RESISTANT WEEDS IN IOWA

Micheal D. K. Owen
Professor of Agronomy and Weed Science
Agronomy Department
Iowa State University
Ames, IA 50011

Introduction

The evolution of herbicide resistant weed populations is an inevitable consequence of the selection pressure imposed on the weed community by the use of weed management tactics that focus on herbicides. Weed populations typically demonstrate variability in response to herbicides. Some individuals of the weed populations are extremely sensitive to a specific herbicide while other individuals require considerably more herbicide for control. Herbicides that have a single place (gene loci) in the plant in which the toxic response is elicited (mechanism of action) are more likely to quickly evolve resistant weed populations. However, it is possible, given the genetic diversity in weed populations, polygenically controlled resistance can ultimately evolve over time.

Herbicides have been an important, if not singular tactic used for weed management. Herbicides are used on virtually all of the corn and soybean acres in Iowa. Growers have extremely high (and likely unrealistic) expectations for herbicidal weed control and view weed community eradication as the goal of herbicide use. This goal has been inappropriately promoted and supported by the agrochemical industry. Importantly, there has been no indication that any weeds have been eliminated from the agroecosystem despite more than 50 years of herbicide use. Given the high use of herbicides in Iowa corn and soybeans, the degeneration of diversity in weed management systems, and the selection pressure imposed on weed populations by herbicides, herbicide resistant weed populations have evolved in Iowa. The objective of this paper is to review the evolution of herbicide resistance in Iowa weed communities and discuss the implications of those resistant populations.

Overview of herbicide resistance

Midwest growers are concerned about many weeds such as velvetleaf, foxtail spp., and common lambsquarters. Also included in the top ten weeds are pigweed spp., common cocklebur, giant ragweed, and shattercane. Each of these species has herbicide resistant populations to at least one herbicide mechanism of action. The United States currently has 79 reported herbicide resistant biotypes. Through the 1980s, triazine resistance, primarily to atrazine, was widely reported. However, when acetolactate synthase (ALS) inhibitor herbicides were introduced and adopted for corn and soybean weed control, herbicide resistant weed populations rapidly evolved and became prevalent across the United States. Currently herbicide resistant weed populations to triazines, ALS inhibitor herbicides, acetyl coenzyme A carboxylase (ACCase) inhibitor herbicides, dinitroanilines, and glyphosate have been reported in various agroecosystems.

Triazine herbicide resistance in Iowa

While resistance to triazine herbicides was first reported in Iowa several decades ago and has been widely documented historically across the United, the occurrence of new triazine resistant populations has not been as rapid during the last decade. Triazine resistant populations of common lambsquarters were also discovered in Iowa despite the use of chloroacetamide herbicides in combination with atrazine. Triazine resistant populations of redroot pigweed, common waterhemp, and Pennsylvania smartweed have also been reported in Iowa.

Most of the triazine resistant weed populations have a target-site mutation that confers resistance. The target-site mutation results in a fitness penalty for the resistant population when compared to the susceptible population; the triazine resistant weeds do not grow as well, are not as competitive, or reproduce as well as the triazine susceptible populations. Thus, without significant selection pressure from triazine herbicides, triazine resistant weed populations will not be a problem. Given that triazine herbicides are used typically used in combination with other herbicides and the current use rates of triazine herbicides are not high enough to impose the selection pressure exemplified by historic use rates, it is not likely that triazine resistant weed populations will be problems in Iowa for the future. However, metabolism-based triazine resistance was recently reported in velvetleaf populations in Wisconsin and likely could exist in Iowa. Despite this, it is unlikely, given the changes in triazine herbicide use in corn and soybean that triazine resistance will escalate as a problem.

Acetolactate synthase inhibitor herbicide resistance in Iowa

The introduction of herbicides that inhibit ALS in the 1980's and the rapid adoption of those herbicides, initially in soybeans but later in corn, resulted in the widespread evolution of ALS resistance in many species across Iowa. Given the diversity of weed spectrums that ALS inhibitor herbicides can control, the many application strategies, types of crops for which ALS herbicides are registered, the residual and soil characteristics, and the very specific mechanism of action, it is not surprising that wide spread resistance evolved in many different weed populations.

ALS resistance evolves due to a single amino acid change on the ALS gene. Typically this modification is a dominant trait resulting in all progeny from the cross of an ALS resistant plant and an ALS sensitive plant being resistant. Also contributing to the evolution of resistant populations was the fact that at one time, an estimated 85% or more of the soybean acres and an estimated 60% of the corn acres in Iowa were treated with ALS inhibitor herbicides. In many instances in soybeans, ALS herbicides were applied several times during a single growing season, thus creating significant pressure to select the ALS resistant plants in the weed population. Despites a number of different ALS inhibitor chemical families that are commercially available, the mechanism of action is the same and the specific site on the ALS gene similar thus resulting in some weed populations that are cross-resistant to a number of different ALS inhibitor herbicides.

Generally, ALS inhibitor resistance does not cause a fitness penalty in the resistant population. Thus, the frequency of resistant plants in the unselected weed population is very high and under

the appropriate selection pressure, the population will shift rapidly from sensitive to resistant. The weeds in Iowa that have reported or suspected resistance to one or more ALS inhibitor herbicides include common waterhemp, giant ragweed, common cocklebur, kochia, woolly cupgrass and common sunflower. However, it is very likely that this list is incomplete. Generally, growers who use ALS inhibitor herbicides should recognize that it is not "if" ALS resistance will develop, but rather "when" it will develop.

Common waterhemp populations that demonstrate resistance to ALS inhibitor herbicides are extremely common. Importantly, population of common waterhemp typically will demonstrate cross-resistance to several ALS herbicide families. The most common cross-resistance is to imidazolinone and sulfonylurea herbicides. Iowa populations of common cocklebur were found to be cross-resistant to Pursuit and Scepter, but not to Classic. Iowa common sunflower populations demonstrate cross-resistance to Pursuit and Classic.

Acetolactate synthase inhibitor herbicide resistance was also reported for in shattercane and woolly cupgrass in Iowa. The resistance in woolly cupgrass has not been confirmed. Numerous giant ragweed populations in Eastern Iowa have recently been reported resistant to ALS inhibitor herbicides. Generally, acetolactate synthase inhibitor herbicide resistant weed populations were discovered within five years of the initial use of acetolactate synthase inhibitor herbicides. As ALS inhibitor herbicides are still widely used, it is likely that resistant populations will continue to evolve.

Acetyl coenzyme A carboxylase inhibitor herbicide resistance in Iowa

Populations of giant foxtail have been reported resistant to ACCase inhibitor herbicides in Iowa. Cross-resistance to cyclohexanedione and aryloxyphenoxypropionate herbicides has been typical in other giant foxtail populations but has not been confirmed in Iowa populations. Resistant populations of giant foxtail did not demonstrate any fitness penalty when compared to susceptible populations in Wisconsin and a similar characteristic is presumed for Iowa populations. The mechanism for resistance was an alteration of the target enzyme, ACCase. While there were no reported effects on growth characteristics for the Iowa resistant giant foxtail populations, populations of ryegrass that were resistant to Hoelon demonstrated a greater degree of dormancy compared to susceptible populations. Giant foxtail resistance to ACCase herbicides is not a major problem in Iowa, or future evolution of resistant populations likely to escalate.

Glyphosate herbicide resistance in Iowa

There have been a number of indications that suggested resistance to glyphosate could evolve despite the historic perspective that this was an unlikely consequence of glyphosate use. Glyphosate resistance was also reported in Australian populations of rigid ryegrass after 15 years of use. No specific mechanism to explain the glyphosate resistance in this species has been published. However, glyphosate resistance in Malaysian goosegrass populations was attributed to an altered EPSPS target site.

However, None of these examples of glyphosate resistant weeds are likely to become important problems in Iowa agroecosystems. However, there are numerous recent reports that suggest that

resistance to glyphosate can develop in corn and soybean. Horseweed (marestail) populations in Delaware demonstrate 13 folds of resistance to glyphosate when compared to sensitive populations. While soybeans in Delaware have historically been grown under no tillage production systems and glyphosate has been used as a burndown herbicide treatment, the resistant horseweed populations developed quickly after the introduction of Roundup Ready soybeans and the in-crop applications of glyphosate.

Common waterhemp has become a serious weed problem throughout Iowa within the last decade. Importantly, common waterhemp is dioecious and thus has considerable potential for genetic diversity. Iowa growers reported difficulties controlling common waterhemp in Roundup Ready soybeans, even with multiple applications of glyphosate. Similar reports occur in Minnesota, Missouri, Kansas, and Illinois.

Samples were collected from an Iowa field and evaluated for shikimate accumulation. Shikimate is a component of the pathway inhibited by glyphosate; when shikimate accumulates in the plant, glyphosate is blocking the target site enzyme and the plant will eventually die. The suspected resistant plants accumulated at least five times less shikimate than suspected susceptible plants suggesting differences in the EPSPS target site for glyphosate may have accounted for the different responses. Seedling assays of different common waterhemp populations revealed considerable variation within populations for glyphosate response. The variation for GR_{50} (growth reduction by 50%) ranged from 0.3 mM glyphosate to 8.01 mM glyphosate, or approximately a 27-fold difference. Recurrent selection has resulted in relatively stable glyphosate resistant plant line. Given the widespread use of glyphosate, the ability for common waterhemp to exhibit differential response to glyphosate, and the widespread distribution of this weed, glyphosate resistance may become an issue in Iowa corn and soybean agroecosystems in the near future. It is unknown as to how quickly the shift in resistant populations will occur, but it is not suggested to be as quickly as experienced with ALS resistance.

Conclusions

The occurrence of herbicide resistant weed populations in Iowa is not uncommon. Resistance to ALS inhibitor herbicides, particularly in common waterhemp are widespread and pervasive. There appears to be reasonable evidence that resistance to glyphosate can evolve; the most likely weed candidate for this occurrence in Iowa is common waterhemp, although horseweed populations in Iowa may be increasing given current tillage and herbicide use practices. The important question is whether or not the occurrence of herbicide resistant weed populations is of economic importance. It is the opinion of the author that the answer to this question is yes and no.

Yes, because the evolution of herbicide resistant weed populations represents a problem in the overall weed management system. Iowa growers, not unlike most Midwestern growers, focus primarily, if not solely on herbicides for weed control. The use of alternative strategies is limited and thus there is considerable selection pressure on the agroecosystems from the herbicides used. While it is convenient to use simple, herbicide-base weed control tactics, there is an ecological cost to this convenience. Herbicides can and will cause a rapid shift in weed communities and

weed populations. If alternative weed management strategies are properly employed, the diversity in management tactics will slow weed shifts and minimize or slow the evolution of herbicide resistant weed populations.

No, because the evolution of herbicide resistant weed populations, particularly glyphosate resistance does not appear to be an immediate problem. The possible exception to this is the occurrence of ALS resistant weed populations that is wide spread. However, currently available tactics will provide control of the resistant weed populations with minimal impact on economics. Changes in weed management systems that are thought to provide proactive management of anticipated shifts in weed populations may not be justified economically. Furthermore, some of these tactics may require that the grower incur more risk. Given that herbicide resistance cannot be evaluated as to the economic cost to the grower, proactive management is difficult to recommend if there is added cost due to the change in strategies.