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HERBICIDE RESISTANCE IN CROPS AND WEEDS

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Introduction

Herbicide resistance, whether as a potential problem in weeds, or as a potentially important agronomic tool, has become an extremely volatile issue in agriculture. Documents such as Biotechnology's Bitter Harvest suggest that herbicide resistance in crops will be a major environmental and economic disaster. Industry representatives suggest that herbicide resistant crops will be excellent tools for growers and actually improve the environmental safety of herbicide use. Agronomists voice concerns about the appearance of weed biotypes that demonstrate herbicide resistance. This paper will provide an objective review of herbicide resistance in crops and weeds and suggest possible results of herbicide resistance specifically for Iowa agriculture.

Herbicide Resistance in Weeds

A number of weeds have developed resistant populations to many different herbicides. Most widely researched and understood is triazine resistance. Currently, there are at least 29 plant species that have developed triazine resistance. Several of the weed species are in the same families of important crops. Thus, there is potential movement of genetic material from the resistant weed to the crop. This has been done in the development of triazine resistant rape.

Many other herbicides have had resistant populations of weeds develop. These herbicides include members of the sulfonylurea family, paraquat, 2,4-D, trifluralin, and others. The list of weeds that have developed resistance is quite diverse and includes annuals, perennials, grasses, and broadleaf weeds. The mechanisms by which weeds have developed resistance are also somewhat varied, although they can be classified generally in 2 categories. Weeds have developed resistance by a modification at the specific site of action that does not allow the attachment of the herbicide or eliminates the activity, or by increasing the ability to metabolize the herbicide into non-efficacious metabolites. The latter can result in a weed species that demonstrates cross resistance to a number of herbicides. Lolium species have developed broad resistance to a number of herbicides in several families.
There are a number of factors that influence the development of a resistant weed population. These can be somewhat different for each specific situation, but are generally common. It is important to note that the resistance trait exists normally in the weed population. However, the frequency of the trait is usually quite low. The reason that the trait never becomes a major component of the natural weed community is that generally the resistant individual is not as "fit" as the sensitive individuals. Thus, there is no general advantage for the resistant members of the weed population and the sensitive weeds assume a greater portion of the community. Resistant individuals generally demonstrate a level of fitness that is usually 0.5 to 0.8 of the sensitive individual.

Another consideration is the life of the seed in the soil reservoir. Seed reservoirs serve as a buffer and generally slows the development of any specific trait. The longer the seed remains viable in the soil, the longer the time required for the population to assume a resistant component. Weeds that do not have seeds that remain alive in the soil for a long period of time can have resistant populations develop relatively quickly.

The frequency that the resistant trait occurs naturally is another important factor influencing the development of a resistant population. Generally, herbicide resistance occurs at a frequency of $10^{-6}$ to $10^{-10}$. While this would seem to be a very low probability of occurrence, considering the number of seeds in the soil reservoir, the chance of finding a resistant individual is actually quite high.

The last and most important factor in the development of a resistant population if the selection pressure that a herbicide places on the system. If a herbicide has a very specific mechanism of action, is used frequently, has a long soil life, and is highly effective, there is a good likelihood that a resistant weed population will develop. It is also important to consider that the use of herbicides with similar mechanisms of action, even though they may be in different families, can increase the selection pressure for a resistant weed population.

**Herbicide Resistance in crops**

The development of biotechnological techniques have allowed the manipulation the crop genetics that is quicker and more dramatic than demonstrated by general crop breeding techniques. Thus developing crop varieties that demonstrate much greater levels of herbicide tolerance than normally included in typical varieties has become feasible. Concerns for herbicide selectivity have always been a major consideration in crop breeding. This would cease to be a problem with the development of a herbicide resistant variety.
Also there are few weed management options in many high value crops. Because of limited selectivity demonstrated by available herbicides, a limited market, and the high value and resultant liability risk, the herbicide industry has been reluctant to register herbicides in vegetables and ornamental crops. As a result, growers are forced to use non-registered herbicides and use expensive hand labor to manage weeds. If herbicide resistant varieties were developed, these problems would not exist.

Several currently popular herbicides represent potential environmental problems. Public perception is that all herbicides represent serious hazards. While these perceptions are not scientifically valid, these concerns have resulted in political actions that can potentially change the economic efficiency of agriculture. If resistance to "environmentally friendly" herbicides could be developed in crops, these perceived problems would be resolved.

Last, there are a number of weeds that are not effectively controlled by available herbicides. This problem is usually crop specific. For example, shattercane and Johnsongrass are extremely difficult to control in corn and sorghum. While control options do exist, they provide inconsistent and marginal results. The development of resistance in these crops to herbicides that control these weeds would be extremely beneficial to growers.

There are a number potential problems associated with the development of herbicide resistant crops. It is likely that many of the problems listed will not be important, but should be mentioned. Several environmental groups are concerned that the development of herbicide resistant crops will result in more herbicide use thus impacting the environment. Others suggest that the resistant trait will move from the crop into the weed genome. This will not likely occur unless the crop and weeds are taxonomically similar. However, the use of herbicide resistant crops could increase the potential for the selection of a herbicide resistant weed population. Another concern is that the use of herbicide resistant crops will result in food of lesser quality. Last, there is a concern that the development of herbicide resistant crops will cause many growers who can not afford, or choose not to use this technology, to go out of business.

Many of these concerns do not have significant merit. However, it must be assumed that the industry will make environmentally sound decisions when selecting potential herbicide candidates for resistant crops. Further, it must be assumed that the herbicide industry recognizes the problems and markets the herbicides in a manner that will not contribute to occurrence of significant problems.
The concern about herbicide resistance increasing herbicide use is not likely a factor. Currently, most crop acres already receive a herbicide application. The newer herbicides, and presumably "environmentally friendly", are efficacious at significantly lower rates when compared to older products. Thus, it is unlikely that herbicide resistance will result in greater herbicide loading of the environment, rather the opposite is more likely to occur. However, it is possible that the herbicide resistant trait could result in more applications of a herbicide, particularly if the herbicide did not demonstrate residual characteristics.

The concern that herbicide resistant crops could possibly result in lesser food quality is a valid concern. There are a number of possible problems including metabolism of the herbicide by the resistant crop resulting in previously unidentified metabolites, a crop that has a number of previously unseen secondary plant metabolites, or a crop that is nutritionally different. It must be assumed that these concerns will be resolved through research and the registration process.

The concern about herbicide resistant technology causing economic problems for specific growers is possible although unlikely. There is some need for research in this area.

A valid concern and probable result of herbicide resistant technology is the selection for naturally occurring resistance in weeds. This has not been demonstrated in the field but is predictable. Notably, herbicide resistant weed populations have developed within 3 to 5 years in response to specific sulfonylurea herbicides. Given the mechanism of action and residual activity that the herbicide demonstrates, this was an anticipated result. However, the general traits that the herbicide demonstrates are also those that would make similar herbicides excellent candidates for herbicide resistant crops.

These herbicides may be selective for use in soybeans and used on herbicide resistant corn. The result, if marketed aggressively on both crops, would be the development of a herbicide resistant weed population. While there are many management strategies that will minimize the development of weed resistance, if growers choose to misuse the herbicide resistant crop (by repeated applications of the herbicide), herbicide resistant weeds will result. A major factor influencing whether growers will misuse the important herbicide resistant crop "tool" will be corporate policy. If a company does not demonstrate ethical marketing strategies, looking only to short-term profits, herbicide resistant weeds will become a problem in Iowa.
Conclusion

The likelihood of developing a major herbicide resistant weed problem in Iowa is good. A number of new, highly effective, and environmentally favorable herbicides have been developed. Many of these herbicides have similar mechanisms of action. Further, the herbicides are registered for corn and soybeans. Thus, considerable selection pressure will be placed on the weed population and herbicide resistant individuals will become dominant. It is critical to recognize this potential and include alternative management strategies thus minimizing the opportunities for the resistant individuals to develop.

Herbicide resistant crops will not likely be a major environmental or economic problem in Iowa. Further, if used properly, herbicide resistant crops could improve weed management in corn and soybeans. Just as likely, however, is the possibility that herbicide resistant crops will contribute to the occurrence of herbicide resistant weed populations. A major factor affecting whether herbicide resistant crops represent an important agronomic tool or a potential agronomic problem will be the manner in which the seed industry positions the crop and the herbicide industry markets the herbicide.