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Effectiveness of using multiple sites of action to battle herbicide resistance

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Introduction

The 'Age of Convenient Weed Control' is coming to an end. Some say it is already over. While glyphosate resistance has garnered the headlines, it is important to realize that the problem facing agriculture is herbicide resistance in general. Weeds such as waterhemp have 'quietly' evolved resistance to other herbicides such as the PPO and HPPD inhibitors. Less fanfare has been given to these developments since these products do not dominate the market in the way glyphosate has for the past 16 years. However, since these herbicide classes are needed to fight glyphosate resistance, the significance of the spread of resistance to them should not be overlooked. Now is the time to change our attitude towards weed management to insure that we have a diverse range of tools available to battle weeds in the future.

Both industry and universities have developed lists of weed management strategies for managing resistance. Many of these tactics are traditional stewardship practices often overlooked in an era of highly effective herbicides. An example would be providing the crop an even start with weeds. The current corn-soybean system limits the opportunities to incorporate many of the cultural or mechanical tactics that are the backbone of more diverse cropping systems. Thus, the manner in which herbicides are used is a key component of herbicide resistance management programs in Iowa. This paper will describe a process in which a herbicide program's effectiveness in battling herbicide resistance can be objectively evaluated.

Herbicide mode and site of action

The terms mode and site of action are used to describe how herbicides kill plant. They often are used interchangeably, but they are different and it is important to understand these differences when managing resistance. Mode of action refers to the physiological process that a herbicide disrupts. Examples of modes of action are inhibition of photosynthesis or inhibition of amino acid synthesis. Herbicides inhibit these processes by binding to a specific protein and inhibiting that protein's function. This protein is referred to as a herbicide's site of action. For a few herbicides, the specific site of action has not been identified.

Managing resistance with herbicides involves using herbicides that kill plants in different ways. Differentiating between the mode and site of action is is important since there often is more than one way to inibit a physiological process. Thus, herbicides with the same mode of action may have different sites of action, whereas all herbicides with the same site of action have the same mode of action. Resistance management requires using herbicides with different sites of action.

A numbering system has been developed that makes it easier for persons involved in weed management to determine a herbicide's site of action. A Herbicide Group number is assigned to each unique site of action. The Group Number of herbicides commonly used in corn and soybean production are listed in Table 1. The Herbicide Group number (site of action) is prominently displayed on the first page of most herbicide labels.

Table 1. Herbicide Group numbers and sites of action of herbicides used in corn and soybean production.

Group No.	Site of Action	Mode of Action
1	ACC-ase	Membrane integrity via lipid synthesis
2	ALS	Branched change amino acid synthesis
3	Tubulin	Cell division inhibition
4	Auxin binding site	Mimic activity of auxin
5	D1 protein	Photosynthesis via electron transfer in PS II
6	D1 protein	Photosynthesis via electron transfer in PS II
9	EPSPS	Inhibition of shikimic acid pathway
10	Glutamine synthetase	Photosynthesis via ammonium incorporation
13	DPX synthase	Photosynthesis via carotene synthesis
14	PPO	Photosynthesis via chlorophyll synthesis
15	Unknown	Very long chain fatty acid synthesis
19	Unknown	Auxin transport
22	Photosystem I	Photosynthesis via electron transfer in PS I
27	HPPD	Photosynthesis via carotene synthesis

Herbicide management

The current production system of Iowa is based on herbicidal control of weeds. To preserve the effectiveness of these production tools, they must be used in a different manner than they have been used in recent decades. The days of selecting the least cost, or most convenient, program that provides effective weed control are over. In addition to achieving effective weed control, herbicide programs should be selected based on their ability to manage herbicide resistance. This involves including multiple Herbicide Groups that are effective against specific, problem weeds in the field.

Agronomic fields have diverse weed communities typically consisting of 20 or more weed species. In most fields, these communities are dominated by a few species - the dominant weeds are those best adapted to the current production system. When developing herbicide programs that minimize risks associated with herbicide resistance, the focus should be on the weeds that are prone to evolving resistance. In Iowa, the number one concern is waterhemp. Other resistant-prone weeds include giant ragweed and horseweed/marestail.

A useful exercise is evaluating programs to determine the number of Herbicide Groups that place effective selection pressure on individual weed species. A herbicide is considered to place selection pressure on a weed if that herbicide would provide acceptable control of the weed if it were applied by itself at the rate and timing that it is used in the herbicide program.

A herbicide program recommended by a local coop for no-till corn is presented below. This program includes active ingredients from six different Herbicide Groups (2, 4, 5, 9, 19 and 27). Each active ingredient in this program contributes significantly to overall weed control, but how many of these products would place significant selection pressure on waterhemp in the manner they are used in this program?

Table 2. Example of a typical corn herbicide program used in Iowa.

Preplant		Postemergence	
Product	**Group No.**	**Product**	**Group No.**
1.7 oz Prequel	2 and 27	28 oz Roundup WeatherMax	9
+ 0.75 lb atrazine	5	+ 2.5 oz Status	4 and 19
+ 0.5 pt 2,4-D	4		
Total number of sites of action (herbicide groups)		6	
Number of effective sites of action on waterhemp		1, 2, 3, 4, 5 or 6?	

Analysis of the activity of individual components on waterhemp (using Table 2 example)

Prequel: Premix of rimsulfuron (Group 2) and isoxaflutole (Group 27). Label rate is 1.66 - 2.5 oz/A.

Rimsulfuron: Almost all waterhemp is resistant to Group 2 herbicides, so rimsulfuron would not contribute to waterhemp control.

Isoxaflutole: Active on waterhemp, but 1.7 oz Prequel provides the equivalent of 1 oz of Balance Pro. The label rate of Balance Pro is 1.5-3.0 oz/A. The amount of isoxaflutole in the Prequel is not likely to provide full-season waterhemp control.

Atrazine (Group 5): 0.75 lb/A is too low of a rate to provide full-season waterhemp control. In addition, triazine resistant waterhemp populations occur throughout Iowa.

2,4-D (Group 4): Included to control weeds present prior to planting; little waterhemp will have emerged at the time of the preplant application, thus 2,4-D places little selection pressure on waterhemp.

Roundup WeatherMax (Group 9): 28 oz should provide effective control of susceptible waterhemp.

Status: Premix of dicamba (Group 4) and diflufenzopyr (Group 19). Label rate is 5-10 oz/A when applied alone.

Dicamba: Effective on waterhemp, but this is a reduced rate (equivalent to 2 oz Clarity) that is unlikely to provide effective control of waterhemp.

Diflufenzopyr: Primary role is to enhance activity of dicamba, so alone will not control waterhemp.

Whether a herbicide provides effective control of waterhemp, or another weed of concern, is dependent upon the rate used, application timing, presence of resistant biotypes, environment, and other factors. The decision on whether to give a specific herbicide credit for controlling a particular species is subjective. Based on the analysis above, only glyphosate would place significant selection on the waterhemp population. Other herbicides included in the program (isoxaflutole, atrazine, 2,4-D, dicamba) have activity on waterhemp, but in this program they are used in a manner that limits their effectiveness. Some people might argue that the Prequel provides sufficient isoxaflutole to be considered effective on waterhemp, whereas others would make the case that 2.5 oz of Status is sufficient to control waterhemp (5-10 oz is the recommended rate). The process of evaluating herbicide programs is more important than the individual decisions on the effectiveness of each component of the program.

How many effective Herbicide Groups are needed each year to manage herbicide resistance? There is no correct answer to this, but we know that two sites of action are better than one, and three are better than two. It also is important to evaluate programs over time to make sure the same sites of action are not being relied on year after year.

Conclusions

Herbicides are valuable resources that need to be conserved. While new herbicides are continually introduced, it has been more than 20 years since a new Herbicide Group was discovered. During the first 50 years of the chemical era of weed management, the dominant weeds found in our fields were species adapted to mechanical weed control (foxtails, velvetleaf, cocklebur, etc.). In the past 20 years, weeds adapted to chemical forms of weed control have become the main problems. These include waterhemp, giant ragweed and horseweed. To sustain the current production system, we must develop more complex approaches to weed management.

Managing herbicides efficiently will be the first step in reducing herbicide resistance problems for most growers. Not only is it important to incorporate multiple Herbicide Groups into a program, but individual herbicides must be used in a way that insures they place significant selection pressure on the weeds of concern. This involves considering the herbicide rate, timing of application, and application variables (spray volume and pressure, and spray additives).

Due to a limited number of Herbicide Groups, it is unlikely that efficient herbicide use alone will be sufficient to stop the spread of herbicide resistance. Growers must determine which cultural and mechanical tactics are appropriate for their production systems, and incorporate these whenever possible. Iowa has several advantages (soils, climate, etc.) compared to the southeast U.S. where Palmer amaranth has devastated cotton production. It would be a shame to squander these advantages due to complacency.