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A Contemporary, Color-Enhanced Herbicide Site of Action Bulletin

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A Contemporary, Color-Enhanced Herbicide Site of Action Bulletin

Abstract
Incidences of herbicide-resistant weed biotypes continue to increase throughout the Midwest. Management approaches to reduce the selection of herbicide-resistant weed biotypes include rotating herbicides based on modes or sites of action. The University of Illinois Extension bulletin, "Utilizing Herbicide Site of Action to Combat Weed Resistance to Herbicides," establishes a classification based on 14 sites of action with each individual site of action coded with a distinct "primary" color. This bulletin is intended to enhance the ability of growers to rotate herbicides based on site of action to slow further development of herbicide-resistant weed biotypes.

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Introduction

Herbicides are an integral part of many weed management systems in Midwestern states. Repeated use of herbicides that act in a similar manner within the target weed has resulted in the selection of weed biotypes that are resistant to these herbicides. The Weed Science Society of America (WSSA) defines herbicide resistance as the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. The number of herbicide-resistant weed biotypes continues to increase in the United States and worldwide. Heap (2001) reports 252 herbicide-resistant weed biotypes occur in 47 countries worldwide.

Herbicide Classification by Site of Action

The WSSA has developed a herbicide classification based on herbicide site of action. Terminology used to describe herbicide site of action is often cumbersome for growers to comprehend, so we have adapted it into a color-enhanced system where herbicides with similar target sites have similar colors. Herbicide premixes are also classified by target site(s), with identical or different colors where appropriate. This color-coded system is adapted from the site of action classification outlined by Retzinger and Mallory-Smith (1997).

The University of Illinois Extension bulletin, "Utilizing Herbicide Site of Action to Combat Weed Resistance to Herbicides," establishes a color-coded herbicide site of action classification system based on 14 sites of action. This three-page bulletin is intended to enhance the ability of growers to rotate herbicides based on site of action to slow further selection for herbicide-resistant weed biotypes.

The front cover explains the importance of using a site of action classification for herbicide resistance management. The inner table (Figure 1) separates herbicide sites of action into 14 "primary" colors. Herbicide chemical families sharing a particular site of action are coded in shades of the respective site of action family "primary" color.

Figure 1.
A Color-Coded Table of "Utilizing Herbicide Site of Action to Combat Weed Resistance to Herbicides"

HERBICIDE CLASSIFICATION BY SITE OF ACTION

SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT	HERBICIDE
Inhibitors of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy propionate	fenoxaprop fluazifop quizalofop	Option II Fusilade DX Assure II
	Cyclohexanedione	clethodim sethoxydim	Select Poast, Poast Plus
Inhibitors of acetolactate synthase (ALS)	Sulfonylurea	chlorimuron chlorsulfuron halosulfuron nicosulfuron primisulfuron prosulfuron rimsulfuron sulfometuron thifensulfuron tribenuron	Classic Telar Permit Accent Beacon Peak Oust Pinnacle Express
	Imidazolinone	imazamox imazapyr imazaquin imazethapyr	Raptor Arsenal Scepter Pursuit
	Triazolopyrimidine	flumetsulam cloransulam	Python FirstRate
Inhibitors of microtubule assembly	Dinitroaniline	benefin pendimethalin trifluralin	Balan Prowl, Pendimax Treflan, others
Synthetic auxins - *Specific Site Unknown*	Phenoxy	2,4-D MCPA MCPP	Weedone, others various various
	Benzoic acid	dicamba	Banvel, Clarity
	Carboxylic acid	clopyralid fluroxypyr picloram triclopyr	Stinger Starane Tordon Garlon
Inhibitors of photosynthesis at photosystem II	Triazine	atrazine ametryn prometon simazine	AAtrex, others Evik Pramitol Princep
	Triazinone	hexazinone metribuzin	Velpar Sencor
	Uracil	bromacil terbacil	Hyvar Sinbar
Inhibitors of photosynthesis at photosystem II - *same site different binding behavior*	Nitrile	bromoxynil	Buctril, Connect
	Benzothiadiazole	bentazon	Basagran
	Phenyl-pyridazine	pyridate	Tough
	Urea	diuron linuron tebuthiuron	Karmex Lorox Spike
Photosystem I - *electron diversion*	Bipyridilium	paraquat diquat	Gramoxone Extra Diquat
Inhibition of EPSP synthase	None accepted	glyphosate	Roundup, Touchdown, others
Inhibition of glutamine synthetase	None accepted	glufosinate	Liberty
Inhibition of lipid biosynthesis - *not via inhibition of ACCase*	Thiocarbamate	butylate EPTC	Sutan+ Eradicane
Bleaching: Inhibition of diterpene synthesis	Isoxazolidinone	clomazone	Command
Bleaching: Inhibition of 4-HPPD	Isoxazole	isoxaflutole	Balance
	Callistemone	mesotrione	Callisto
Inhibition of protoporphyrinogen oxidase (PPO)	Diphenylether	acifluorfen fomesafen lactofen	Blazer Flexstar, Reflex Cobra
	N-phenylphthalimide	flumiclorac	Resource
	Aryltriazinone	sulfentrazone carfentrazone	Authority Aim
Unknown	Chloroacetamide	acetochlor alachlor metolachlor propachlor dimethenamid	Harness, TopNotch, Degree Lasso, Micro-Tech, Partner Dual Magnum, Dual II Magnum Ramrod Frontier, Outlook
	Oxyacetamide	flufenacet	

The bulletin also includes common and trade names of many herbicides used in Midwest agronomic production systems. The back page of this bulletin includes corn and soybean herbicide premixes, with individual premix components coded with the appropriate color based on their respective site of action.

Rationale

The development of herbicide resistance in weed populations can result in significant economic losses for growers. Growers, however, frequently continue to use a successful herbicide program until it fails instead of proactively implementing herbicide resistance management strategies.

Peterson (1999) suggested the greatest economic loss producers face due to selection of herbicide-resistant biotypes likely occurs during the first year of poor weed control. Shaner (1995) suggested that the long-term economic consequences of herbicide resistance include loss of herbicide performance and shifts in weed populations. Orson (1999) argued that preventing the selection of herbicide-resistant weed biotypes can often cost a producer significantly less than the costs incurred dealing with resistance once it has developed.

Extension and private industry have proposed numerous management strategies to retard the selection for herbicide-resistant weed biotypes, including utilizing nonchemical weed management options (such as mechanical cultivation), crop scouting and rotation, herbicide tank-mixtures, and rotation of herbicides that act in dissimilar fashions (Shaner 1995). Labels of herbicides registered for use in the United States generally do not enumerate the herbicide site of action. If growers elect to implement herbicide rotation or tank-mixtures as a resistance management strategy, information is needed to identify which herbicides act in a similar manner.

Herbicides are frequently categorized into families according to various similarities. Examples of herbicide classification categories include mode of action, application timing, and chemical structure. Herbicide mode of action describes the metabolic or physiological plant process impaired or inhibited by the herbicide. Essentially, mode of action refers to how the herbicide acts to inhibit plant growth. Herbicide site of action describes the specific location(s) within the plant where the herbicide binds. Site of action thus identifies the herbicide target site within the plant. The most common herbicide classification schemes utilize mode of action; however, much ambiguity exists with respect to herbicide classification based on mode of action.

While an understanding of herbicide mode of action is beneficial, classifying herbicides by site of action may be a more useful system from a resistance management standpoint. Herbicide resistance in plants is often due to an alteration of the binding site in the target plant. Rotating herbicides based on these different binding site(s) or site(s) of action may provide a more reliable classification system. As previously mentioned, classifications based on herbicide mode of action are rather ambiguous. For example, classification systems based on mode of action include anywhere from seven to 13 different categories. Some of these systems describe mode of action categories as "cell membrane disruptors," "seedling growth inhibitors," and "amino acid synthesis inhibitors." Rotating herbicides based on these categories could cause confusion among growers.

For example, the mode of action category "amino acid synthesis inhibitors" would place the herbicides Pursuit (imazethapyr) and Roundup (glyphosate) in the same family, whereas classification by site of action would place these two herbicides into two distinctly different families, allowing growers to more accurately rotate herbicides for resistance management.

Conclusion

Each year the frequency of herbicide-resistant weed biotypes continues to increase in the Midwest. This, coupled with the decreased development of herbicides with new active ingredients, has made it extremely important to manage current herbicides through integrated management practices. Without the proper strategies in place to delay the selection of herbicide-resistant weeds, growers in the Midwest will likely be faced with fewer weed management options and long-term economic consequences. This bulletin could be considered in an overall herbicide resistance integrated management approach to prevent proliferation of herbicide resistant weeds.

To obtain a copy of the bulletin "Utilizing Herbicide Site of Action to Combat Weed Resistance to Herbicides," contact: Information and Technology Communication Services, University of Illinois, Marketing and Distribution, 1917 South Wright Street, 61820, 1-800-345-6087, acespubs@uiuc.edu.

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