Turfgrass Herbicides: Mechanisms of Action and Resistance Management[1]

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Target Audience

The present document is a tool for turfgrass professionals, sod growers, landscape managers, and extension specialists to develop herbicide programs that reduce the risk of herbicide resistance (HR) evolution in turfgrass systems.

Introduction

Herbicides are the most common and effective tool for weed control in turfgrass. However, weed species are capable of adapting, and now almost all herbicide groups have confirmed cases of weed species with resistance. Although HR is always a concern, this problem is particularly serious in turfgrass because typical HR management practices such as crop rotation, tillage and cultivation, cover cropping, and fallow periods are generally not an option in turfgrass production. More importantly, there are considerably fewer products that can be used for herbicide rotation in turfgrass than there are for other agricultural systems.

Reducing the Risk of HR

There are several things that can delay and perhaps prevent HR. The most practical and effective strategy is to rotate herbicides with different mechanisms of action (MOA). The MOA is the way the herbicide disrupts the metabolism of the weed, ultimately causing the weed's death. Table 1 provides a comprehensive list of herbicides that are registered for use in turfgrass and their respective MOA and classification according to the Weed Science Society of America (WSSA) and the Herbicide Resistance Action Committee (HRAC). Many herbicide labels include the herbicide group number (Figure 1) to help the user design herbicide rotations. Simply put, if two herbicides have the same MOA number or code, regardless of whether they have different names or active ingredients, they affect weeds in the same way. Thus, the frequent and repeated use of herbicides with the same MOA will increase the risk of weeds becoming resistant. Conversely, using a diverse herbicide program that either rotates or combines herbicides with different MOAs will help delay the appearance of resistant weeds.

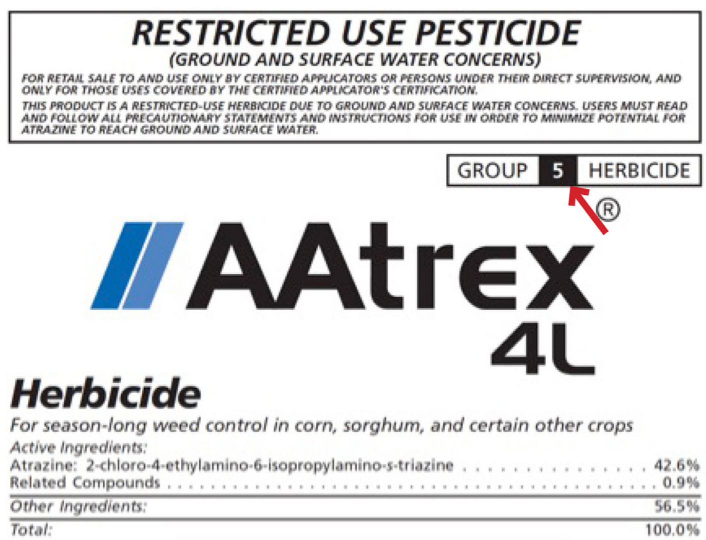

Figure 1. Example of a label indicating the MOA group number (red arrow).

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MOA rotation helps delay HR because changing the MOA reduces the chances of survival and reproduction of HR weeds. In simple terms, if a weed survives an herbicide application with one MOA because it is resistant, the problem can be controlled if the surviving weed is treated with a herbicide with a different MOA to which it has not become resistant.

As shown in Table 1, most herbicides for preemergence (PRE) control are mitosis inhibitors (Groups 3 and 15), while postemergence herbicides are predominantly ALS-inhibitors (Group 2). Although many turfgrass professionals base their herbicide programs solely on Group 3 and Group 2, it is critical that herbicides from other MOAs are included in herbicide programs. To ensure that the most frequently used herbicides in turfgrass will continue being effective for a long time, herbicides with different MOAs should be included in weed management programs even if they are not as effective or require repeat applications to provide the desired level of control.

Groups that are useful for MOA rotation in PRE programs in turfgrass:

- Cellulose inhibitors (Group 21)
- Fatty acid and lipid biosynthesis inhibitors (Groups 8 and 16)
- PPO inhibitors (Group 14)

Groups that are useful for MOA rotation in POST programs in turfgrass:

- Carotenoid biosynthesis inhibitors (Group 28)
- Lipid biosynthesis inhibitors (Group 16)
- Photosystem II inhibitors (Group 5)
- PPO inhibitors (Group 14)
- Synthetic auxins (Group 4)

There are two ways to rotate herbicides in turfgrass. The first way is to change the MOA from year to year (Figure 2). For example, one could use a Group 3 herbicide in the fall of year 1 and change to Group 21 in the fall of year 2. The second way is to rotate herbicides within a season. In this case, MOAs are rotated to control escapes from the previous application. For example, if a Group 16 herbicide was used as PRE or POST and some plants escaped, a Group 14 herbicide can be applied to kill the escapes. This is called the "double-knock down" strategy because weed control is based on two consecutive actions. Ideally, both approaches should be used within the same weed management program.

Another strategy to delay HR is to apply herbicides with different MOA simultaneously. This can be done by tank-mixing herbicides with different MOAs or by using pre-mixed products with two or more herbicides with different MOAs. For this option to work for HR management, the herbicides with different MOA have to be effective when applied alone to control the target weed species.

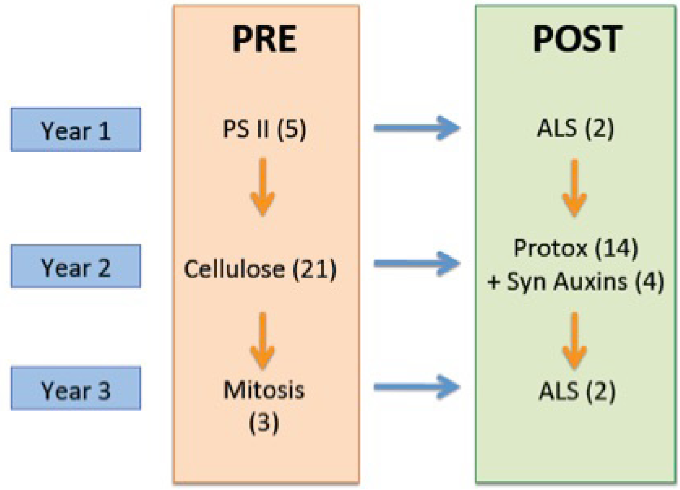

Figure 2. Example of MOA rotation within season and across years. MOAs change from the preemergence (PRE) to postemergence (POST) applications, and each year the MOAs of the PRE and POST herbicides change. MOA groups are specified within parentheses.

Table 1. Mechanism of action (MOA) classification according to the Weed Science Society of America (WSSA) and the Herbicide Resistance Action Committee (HRAC) for preemergence (PRE) and postemergence (POST) herbicides registered for use in turfgrass.

MOA	Common Name	WSSA Code	HRAC Code	PRE/POST	Trade Name Examples
Acetolactate Synthase (ALS) Inhibitors					
	bispyribac-sodium	2	B	POST	Velocity
	flazasulfuron	2	B	POST	Katana
	florasulam	2	B	POST	Defendor
	foramsulfuron	2	B	POST	Revolver
	halosulfuron	2	B	POST	SedgeHammer
	imazaquin	2	B	PRE/POST	Image
	metsulfuron	2	B	POST	Manor, Blade
	rimsulfuron	2	B	POST	TranXit
	sulfometuron	2	B	POST	Oust
	sulfosulfuron	2	B	POST	Outrider, Certainty
	trifloxysulfuron	2	B	POST	Monument
Acetyl CoA Carboxylase (ACCase) Inhibitors					
	clethodim	1	A	POST	Envoy
	diclofop-methyl	1	A	POST	Illoxan
	fenoxaprop	1	A	POST	Acclaim
	fluazifop	1	A	POST	Fusilade
	sethoxydim	1	A	POST	Segment
4-hydroxyphenyl-pyruvatedioxygenase (4-HPPD) inhibitors					
	mesotrione	27	F2	PRE/POST	Tenacity
	topramezone	27	F2	POST	Pylex
Cellulose Inhibitors					
	indaziflam	21	L	PRE	Specticle
	isoxaben	21	L	PRE	Gallery
Fatty Acid and Lipid Biosynthesis Inhibitors					
	bensulide	8	N	PRE	Betasan, Bensumec, Pro-San
	ethofumesate	16	N	PRE/POST	Prograss
Mitosis Inhibitors					
	benefin	3	K1	PRE	Balan, Benefin
	DCPA	3	K1	PRE	Dacthal
	dimethenamid-P	15	K3	PRE	Tower
	dithiopyr	3	K1	PRE	Dimension
	napropamide	15	K3	PRE	Devrinol
	oryzalin	3	K1	PRE	Surflan
	pendimethalin	3	K1	PRE	Pendulum
	prodiamine	3	K1	PRE	Barricade
	pronamide	3	K1	PRE/POST	Kerb
	S-metolachlor	15	K3	PRE	Pennant Magnum

MOA	Common Name	WSSA Code	HRAC Code	PRE/POST	Trade Name Examples
Photosystem II Inhibitors					
	amicarbazone	5	C1	PRE/POST	Xonerate
	atrazine	5	C1	PRE/POST	Aatrex
	bromoxynil	6	C3	POST	Buctril
	hexazinone	5	C1	POST	Velpar
	metribuzin	5	C1	POST	Sencor
	simazine	5	C1	PRE/POST	Princep
Protoporphyrinogen Oxidase (Protox) Inhibitors					
	carfentrazone	14	E	POST	Quick Silver
	oxadiazon	14	E	PRE	Ronstar
	pyraflufen-ethyl	14	E	POST	Octane
	sulfentrazone	14	E	POST	Dismiss
Synthetic Auxins					
	2,4-D amine	4	O	POST	2,4-D amine
	clopyralid	4	O	POST	Lontrel, Confront
	dicamba	4	O	POST	Banvel
	fluroxypyr	4	O	POST	Spotlight
	MCPA	4	O	POST	MCPA-amine, MCPA-ester, Rhonox, Shredder, Solve
	MCPP	4	O	POST	Mecoprop-p, MCPP-p 4 amine
	quinclorac	4	O	POST	Drive
	triclopyr	4	O	POST	Confront
Dihydropteroate Synthetase Inhibitors					
	asulam	18	I	POST	Asulox