UF | IFAS Extension
UNIVERSITY of FLORIDA

SS-AGR-394

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

Pawel Petelewicz, J. Bryan Unruh, and Ramon G. Leon[2]

Target Audience

This document is a tool for turfgrass professionals, sod producers, golf course superintendents, athletic and sports fields managers, landscape managers, and extension specialists to help develop herbicide programs that reduce the risk of herbicide resistant weeds in turfgrass systems.

Introduction

Herbicides are the most efficacious tool for weed control in turfgrass. Many common and/or troublesome weeds are not adequately controlled for various reasons such as lack of access to efficacious active ingredients (AIs) and use restrictions to selected turf species. Weed species are also capable of adapting where these poorly controlled become more common. If not successfully controlled, these weeds can spread creating a cascade of environmental, management and economic issues. In addition, certain weeds have a high potential for developing resistant populations. One such weed is goosegrass [*Eleusine inidica* (L.) Gaertn.] which is a difficult to control annual grassy weed in most Florida turfgrass systems. Populations resistant to current industry standard herbicides such as prodiamine, oxadiazon, and metribuzin have been confirmed in various turfgrass settings.

For turfgrass managers, resistant populations lead to a further limitation of reliable control options. This may force managers to employ less efficacious chemistries, or overuse options still capable of providing satisfactory control, directly resulting in increased management costs. Alternative products can be significantly more expensive while less efficacious products often require more applications to achieve desired weed control. These strategies can also pose an elevated risk of turfgrass damage. While herbicide safeners and/or safening strategies could reduce the potential for turfgrass injury, they generate additional logistic issues and/or expenses and effects may be inconsistent.

Successfully preventing resistance problems requires a complete understanding of what *herbicide resistance* is, how it develops, and effective strategies for mitigation. To achieve this, it is also crucial to understand the general nature of herbicidal activity within a plant.

Herbicide Mechanism of Action and Herbicide Resistance Explained

The term *mode of action* (MoA) refers to the entire sequence of events occurring within the plant treated with an herbicide (including its uptake, translocation, and metabolism), from first contact until the death of the susceptible plant. The term *mechanism of action* (MOA) is more specific and applies to a particular chain of biophysical

1. This document is SS-AGR-394, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date August 2015. Revised February 2023. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

2. Pawel Petelewicz, assistant professor, Agronomy Department; J. Bryan Unruh, professor and associate center Director, Environmental Horticulture Department, UF/IFAS West Florida Research and Education Center; and Ramon G. Leon, professor, courtesy faculty, Agronomy Department, North Carolina State University, Department of Crop and Soil Sciences, Raleigh, NC; UF/IFAS Extension, Gainesville, FL 32611.

(e.g., electron flow inhibition, cell division disruption, protein binding) or biochemical (e.g., enzyme inhibition) processes which herbicide disrupts (e.g., by inhibition or over-stimulation). Although some herbicides may function via several MoAs, only one is considered principal, and is used to describe the herbicide's effect on plant. There is also a term *site of action* which refers to a particular location within a cell where these processes occur (e.g., chloroplasts or particular photosystems in the case of photosynthesis, mitochondria in the case of respiration, nuclei in the case of mitosis, specific binding sites on a protein in the case of enzymes). Some confusion may arise as sometimes those three terms are incorrectly considered as interchangeable by individuals referring to the MoA, which is also used as one of the characteristics for herbicide classification. Being fundamental to proper herbicide resistance management, it is the MoA which is further discussed in this publication.

Herbicide resistance is commonly defined as "the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type". A more current weed-specific definition describes herbicide resistance as "the evolved capacity of a previously herbicide-susceptible weed population to withstand an herbicide and complete its life cycle when the herbicide is used at its normal rate in an agricultural situation". In both cases herbicide resistance, is distinct from *herbicide tolerance* which is described as the "ability of a plant to remain uninjured by a dose of an herbicide normally lethal to other plant species".

Overall, while HR results from over-reliance on herbicides as a sole mean for weed control, herbicides do not induce any gene mutations resulting in herbicide resistance. Those occur naturally and spontaneously. Subsequently, herbicide resistance can be transferred between generations via sexual reproduction in plants producing seeds. Such risk is higher in weeds with an annual life cycle compared to perennial plants that do not rely completely on seed production (i.e., sexual reproduction) for persistence across multiple seasons.

Herbicide resistance usually develops where an individual herbicide or herbicides with the same MoA are used excessively. This occurs during continuous and repeated applications over extended periods of time (e.g., multiple seasons) as the primary control of particular weed species. Such an approach creates a high selection pressure on the targeted weed populations. In most cases, herbicide resistance is already present at very low levels (often <0.0001%). While susceptible plants are removed by the herbicide, the herbicide resistant individuals grow and reproduce and eventually become dominant. Also, weeds may evolve herbicide resistance to other herbicides within the same MoA. However, this is not the case with all MoAs.

Monoculture settings of perennial crops, such as turfgrass, additionally favor the development of herbicide resistant populations. In these situations, crop rotation does not occur, eliminating herbicide options with differing MoAs that would be used in rotational crops. Moreover, proven agronomic management practices that alleviate the risk for herbicide resistance development such as tillage and cultivation, cover cropping, and fallow periods cannot be employed in established turfgrass settings. Therefore, the use of herbicides to control weeds in turfgrass settings becomes a necessity.

Strategies for Reduction of HR Development Risk

Entities such as Weed Science Society of America (WSSA) and the Herbicide Resistance Action Committee (HRAC) have developed MoA-based herbicide classification systems to help end users better address arising herbicide resistance issues. In the past, there were differences between these individual systems (e.g., numerical coding in WSSA's system, alphabetical coding in HRAC's system). In 2020, the HRAC updated their classification system to capture new active ingredients and to reflect the current state of knowledge. Also, the classification was harmonized, and a transition was made from alphabetical (now referred to as 'HRAC Legacy') to numerical codes to ensure global sustainability of the system. A summary of MoA and their classification according to WSSA and HRAC is provided in Table 1, while a comprehensive list of herbicides that are registered for use in turfgrass and their respective MoA WSSA/HRAC groups is provided in Table 2. Alphabetical codes are no longer used in the U.S., thus are not included in this publication. Moreover, in effort to adopt responsible resistance management practices, CropLife International members have voluntarily committed to include MoA icons and WSSA/HRAC groups on all herbicide product labels (Figure 1).

There are several strategies designed to delay or prevent herbicide resistance development in weeds. The most practical and effective tactic is to rotate the use of herbicides with different MoAs. Simply put, if two herbicides have the same MoA number or code, regardless of different names or active ingredients, they affect weeds in the same way. As previously explained, frequent and repeated use of herbicides with the same MoA will increase the risk

of herbicide resistance development. Conversely, using a diverse herbicide program that either rotates or combines herbicides with different MoAs will help delay the development of resistant weeds.

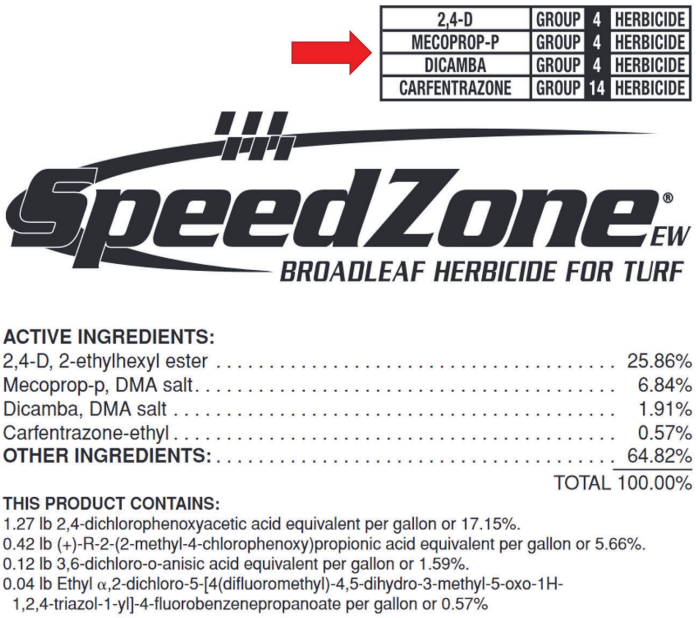

Figure 1. Example of an herbicide product label with an icon indicating the herbicides' mechanism of action (MoA) classification in Weed Science Society of America (WSSA) and Herbicide Resistance Action Committee (HRAC) harmonized system.
Credits: undefined

MoA rotation helps delay herbicide resistance because changing the MoA reduces the chances of survival and reproduction of herbicide resistant 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 an herbicide with a different MoA to which it has not become resistant.

As shown in Table 2, most herbicides for preemergence (PRE) control are inhibitors of microtubule assembly (Group 3) and mitosis inhibitors (Group 15), while postemergence herbicides are predominantly acetolactate synthase (ALS) inhibitors (Group 2). Although many turfgrass professionals base their weed management programs solely on Groups 3 and 2, it is critical that herbicides from other MoA groups be included also. 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.

Example of groups that are useful for MoA rotation with microtubule assembly inhibitors (Group 3) and mitosis inhibitors (Group 15) in PRE programs in turfgrass:

- Group 21 – inhibitors of cell wall synthesis at site B
- Group 29 – inhibitors of cell wall synthesis at site C
- Group 8 – inhibitors of lipid synthesis other than Acetyl CoA Carboxylase (ACCase) inhibitors
- Group 14 (specific active ingredients) – oxadiazole family of protoporphyrinogen oxidase (Protox, PPO) inhibitors

Example of groups that are useful for MoA rotation with ALS-inhibitors (Group 2) in POST programs in turfgrass:

- Group 27 – inhibitors of 4-hydroxyphenyl-pyruvatedioxygenase (4-HPPD)
- Group 5 – inhibitors of photosynthesis at photosystem II (PSII) site A
- Group 14 (specific active ingredients) – triazolinones family of PPO inhibitors
- Group 4 – synthetic auxins
- Group 6 – inhibitors of PSII site B

Example of groups which, due to their dual activity, could be considered for rotation in both PRE and POST programs in turf

- Group 5 (specific active ingredients) – triazine family of PSII site A-inhibitors
- Group 8 (specific active ingredients) – benzofuran family of inhibitors of lipid synthesis other than Acetyl CoA Carboxylase (ACCase) inhibitors
- Group 3 (specific active ingredients) – benzamide family of microtubule assembly inhibitors
- Group 14 (specific active ingredients) – N-phenylphthalimide family of PPO inhibitors
- Group 30 – tyrosine aminotransferase inhibitors

There are two ways to rotate herbicides in turfgrass settings. The first is to rotate herbicide MoAs from year to year (Figure 2). For example, one could use a Group 21 PRE herbicide in the fall of year 1 and change to Group 3 PRE herbicide in the fall of year 2. Conversely, one could use Group 2 POST herbicide in year 1 and then switch to Groups 4 and 14 POST herbicides in year 2.

The second way is to rotate herbicides within a season (Figure 2). In this approach, the rotation cycle may apply to either individual applications or their entire sequences (i.e., initial application followed by supplemental applications as prescribed on the herbicide label). Overall, there are three possible scenarios applicable to this approach. In all of them, the tactic is to change the herbicide MoA to eradicate plants surviving previous application(s) which are often

referred to as "escapes". This approach is called the "double-knock down" strategy because weed control is based on two consecutive actions.

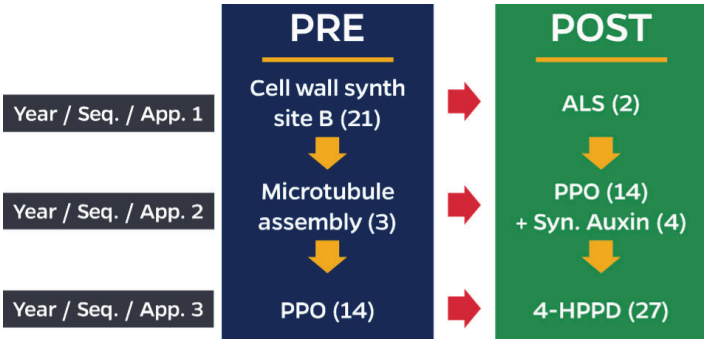

Figure 2. Example of mechanism of action (MoA) rotation within individual season and across years. MoA change from the preemergence (PRE) to postemergence (POST) applications as well as both PRE and POST herbicide MoA change from year to year.
Credits: undefined

In the first scenario, one could apply a Group 21 PRE herbicide at the beginning of the season and switch to a Group 2 POST herbicide to kill plants that may still be emerging and were not prevented by the initial PRE application.

The second and third scenarios are similar to each other and often apply to environments with extended growing seasons, such as Florida's. For example, one could use a Group 21 PRE herbicide prior to expected germination of a target weed and then perform a sequential, follow-up application. However, when residual efficacy of those treatments is expected to diminish, then one could switch to a Group 3 PRE herbicide to ensure no germination occurs later in the season. Similarly, when applying POST herbicides, MoAs should be rotated between 2 POST applications/sequences within same season to target the escapes from the initial application.

Another strategy is to use either tank-mixes or pre-mixes of various active ingredients containing different MoAs. There are also many pre-mix options available in the market, however, most contain 1 to 3 active ingredients from the same MoA group, which is not beneficial from an herbicide resistance management standpoint. The addition of certain active ingredients or even MoAs will broaden their efficacy on additional groups/species of weeds; however, they will not boost the efficacy on the target weed. Therefore, from an herbicide resistance management perspective, it is important that all components of either a tank-mix and/or a rotation program have the capacity to control the target weed.

Lastly, the turf's own ability to outcompete other species is the key to both successful weed control and reduced herbicide resistance risk. A healthy, dense turfgrass enhances competitiveness against weeds and reduces their encroachment. To ensure successful weed control and to minimize herbicide resistant weed development, all of the strategies discussed should be combined with practices aimed to provide the best possible growing conditions for turfgrass along with proper sanitation practices to avoid reintroduction of problematic plants.

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

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
Single MoA Compounds				
Acetyl CoA Carboxylase (ACCase) Inhibitors				
Standalones				
1	Aryloxyphenoxy-propionates ('FOPs')	fenoxaprop-P	POST	Acclaim Extra
		fluazifop-P-butyl	POST	Fusilade II, Ornamec 170, Ornamec Over-The-Top
	Cyclohexanedione ('DIMs')	sethoxydim	POST	Segment, Segment II
	Phenylpyrazoline ('DEN')	pinoxaden	POST	Manuscript
Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) Inhibitors				
Standalones				
2	Imidazolinones	imazapic	POST	Plateau
		imazaquin	POST	Scepter T&O 70 WDG
	Pyrimidinyl(thio) benzoates	bispyribac-sodium	POST	Velocity SG
		pyrimisulfan	POST	Vexis
	Sulfonylureas	flazasulfuron	POST	Katana
		foramsulfuron	POST	Revolver
		halosulfuron-methyl	POST	Halo 5WDG Select, Halo 75WDG Prime, Halo 75WDG Select, Halomax 75, Profine 75, Prosedge, Sandea, SedgeHammer, SedgeHammer+
		imazosulfuron	POST	Celero
		metsulfuron-methyl (MSM)	POST	Manor, MSM 250D, MSM 60, Omni Brand MSM 60 DF, Quali-Pro MSM Turf, Tide MSM 60 DF
		rimsulfuron	POST	Rimsulfuron 25DF
		sulfometuron-methyl	POST	Oust XP
		sulfosulfuron	POST	Certainty, Creedent 75WDG
		trifloxysulfuron-sodium	POST	Monument 75WG, Revolution
	Triazolopyrimidines	florasulam	POST	Defendor
		penoxsulam	POST	LockUp, Sapphire
Premixes				
2	Sulfonylureas	metsulfuron-methyl (MSM)+ rimsulfuron	POST	Negate 37WG
			POST	
	Sulfonylureas	sulfometuron-methyl+ metsulfuron-methyl (MSM)	POST	Oust XTRA
			POST	
	Sulfonylaminocarbonyl-triazolinone+ sulfonylureas	thiencarbazone-methyl + foramsulfuron + halosulfuron-methyl	POST	Tribute Total
			POST	
			POST	
	Sulfonylaminocarbonyl-triazolinone+ sulfonylureas	thiencarbazone-methyl + iodosulfuron-methyl-sodium + halosulfuron-methyl	POST	Celsius XTRA
			POST	
			POST	

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
Inhibitors of Microtubule Assembly				
Standalones				
3	Benzamide	pronamide	PRE/POST	Kerb 50-W, Kerb 50WP, Kerb SC T&O
	Benzoic acid	DCPA	PRE	Dacthal Flowable, Dacthal W-75
	Dinitroanilines	benefin	PRE	Balan 2.5G, Balan DF, Crabgrass Preventer
		oryzalin	PRE	Dinitroaniline Surflan WDG, Harrier 4L, Oryzalin 4 A.S., Surflan AS Specialty
		pendimethalin	PRE	Pendulum 2G, Pendulum 3.3 EC, Pendulum AquaCap, PRE-M 3.3 EC
		prodiamine	PRE	Barricade 4FL
	Pyridine	dithiopyr	PRE	Dimension 2EW, Dimension EC, Dimension Ultra 40WP
Premixes				
3	Dinitroanilines	benefin+ oryzalin	PRE	Surflan A.S., Surflan XL 2G, XL 2G
			PRE	
	Dinitroanilines	benefin+ trifluralin	PRE	Crabgrass Control 2% Team, Team 2G, Team Pro
			PRE	
Synthetic Auxins				
Standalones				
4	Benzoic acid	dicamba	POST	Banvel, Banvel 4S, Clash, Cruise Control, Diablo, Sterling Blue, Vanquish, Vision
	Phenoxy carboxylic acids	2,4-D	POST	2,4-D Amine, 2,4-D LV 6, Barrage HF, Clean Amine, Hardball, Opti-Amine, Saber, Shredder 2,4-D LV4, Shredder 2,4-D LV6, Shredder Amine 4, Shredder E-99, Weedar 64, WEEDestroy AM40, Weedone LV4 EC
		MCPA	POST	MCPA-4 Amine, MCPA ester 4
		mecoprop-P (MCPP)	POST	MCPP-p 4 Amine, Mecomec 2.5
	Pyridine carboxylic acids	clopyralid	POST	Lontrel T&O
		fluroxypyr	POST	Vista XRT
		triclopyr	POST	Triclopyr 4, Trycera, Turflon Ester, Turflon Ester Ultra
	Quinoline carboxylic acid	quinclorac	POST	Drive 75DF, Drive XLR8, Eject 75DF, Quinclorac, Quinclorac 75DF, Quinclorac SPC 75DF, QuinPro Herbicide, Quintessential, Rook 4L
Two-way Premixes				
4	Phenoxy carboxylic acids	2,4-D+ aminopyralid	POST	NativeKlean
			POST	
	Phenoxy carboxylic acid + benzoic acid	2,4-D + dicamba	POST	On Deck
			POST	
	Phenoxy carboxylic acid	2,4-D + dichlorprop (2,4-DP)	POST	Patron 170, Turf Weed & Brush Control
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid	2,4-D + triclopyr	POST	Aquasweep, Chaser, Chaser 2 Amine, Crossroad, Everett, Turflon II Amine
			POST	

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
	Pyridine carboxylic acid	fluroxypyr + triclopyr	POST	Tailspin
			POST	
	Pyridine carboxylic acid	triclopyr + clopyralid	POST	Confront, 2-D
			POST	
Three-way Premixes				
4	Phenoxy carboxylic acid + benzoic acid + phenoxy carboxylic acid	2,4-D + dicamba + dichlorprop (2,4-DP)	POST	Brushmaster, Super Trimec
			POST	
			POST	
	Phenoxy carboxylic acid + benzoic acid + pyridine carboxylic acid	2,4-D + dicamba + clopyralid	POST	Millenium Ultra 2,
			POST	
			POST	
	Phenoxy carboxylic acid + benzoic acid + quinoline carboxylic acid	2,4-D + dicamba + quinclorac	POST	2DQ, Gordon's Trimec Crabgrass Plus Lawn Weed Killer, Momentum Q, Quincept
			POST	
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid	2,4-D + fluroxypyr + dicamba	POST	Elliptical, Escalade 2
			POST	
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	2,4-D + fluroxypyr + halauxifen-methyl	POST	GameOn
			POST	
			POST	
	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	2,4-D + mecoprop-P (MCPP) + dicamba	POST	3-D, Eliminate LO, Eliminate-D, EndRun, MEC Amine-D, Strike-3, Threesome, Three-Way, Trimec 1000, Trimec 899, Trimec 992, Trimec Bentgrass Formula, Trimec Classic, Triplet Low Odor, Triplet Selective, Triplet SF, TruPower2
			POST	
			POST	
	Phenoxy carboxylic acids	2,4-D + mecoprop-P (MCPP) + dichlorprop (2,4-DP)	POST	Spoiler, Triamine
			POST	
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	2,4-D + triclopyr + fluroxypyr	POST	Momentum FX2
			POST	
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid	MCPA + fluroxypyr + dicamba	POST	Change Up
			POST	
			POST	
	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	MCPA + fluroxypyr + triclopyr	POST	Battleship III
			POST	
			POST	
	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	MCPA + mecoprop-P (MCPP) + dicamba	POST	Trimec Encore, Tri-Power
			POST	
			POST	
	Phenoxy carboxylic acids	MCPA + mecoprop-P (MCPP) + dichlorprop (2,4-DP)	POST	Triamine II
			POST	
			POST	

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
	Phenoxy carboxylic acid + pyridine carboxylic acid + phenoxy carboxylic acid	MCPA + triclopyr + dicamba	POST	Cool Power, Eliminate, Horsepower, Spurge Power, Three-Way Ester II
			POST	
			POST	
	Phenoxy carboxylic acid + benzoic acid + quinoline carboxylic acid	quinclorac + dicamba + MCPP	POST	Onetime Herbicie
			POST	
			POST	
Inhibitors of photosynthesis at photosystem II site A				
Standalones				
5	Triazine	atrazine	PRE/POST	AAtrex 4L, AAtrex Nine-O, Atrazine 4L, Atrazine 90DF
		simazine	PRE/POST	Princep 4L, Princep Liquid, Simazine 4L, Simazine 90DF, Sim-Trol 4L, Sim-Trol 90DF
	Triazinone	metribuzin	POST	Sencor 75%
		hexazinone	POST	Velpar 2L
	Triazolinone	amicarbazone	POST	Xonerate, Xonerate 2SC
Inhibitors of photosynthesis at photosystem II site B				
Standalones				
6	Benzothiadiazinone	bentazon	POST	Basagran T&O
	Nitrile	bromoxynil	POST	Broclean, Buctril, Buctril 2L, Buctril 4EC, Maestro 2EC, Maestro 4EC, MOXY 2E
Inhibitors of lipid synthesis; not ACCase inhibition				
Standalones				
8	Benzofuran	ethofumesate	PRE/POST	PoaConstrictor, Prograss, Prograss SC, Thrasher
	Phosphorodithioate	bensulide	PRE	Bensumec 4LF, Betasan 3.6G, Pre-San 7G, Pre-San Granular 12.5G, ProTurf Weedgrass Preventer 8.5G, Weedgrass Preventer
Inhibitors of protoporphyrinogen oxidase (Protox, PPO)				
Standalones				
14	N-phenylphthalimide	flumioxazin	PRE/POST	SureGuard SC
	Phenylpyrazole	pyraflufen-ethyl	POST	Octane 2% SC
	Triazolinones	carfentrazone-ethyl	POST	Quicksilver T&O
		sulfentrazone	POST	Aquesta 4F, Dismiss, Dismiss CA, Dismiss CA Turf, Dismiss Turf, Loyalty 75WDG, Spartan 4F
	Oxadiazole	oxadiazon	PRE	Ronstar FLO, Ronstar G
Premixes				
14	Triazolinones	carfentrazone-ethyl + sulfentrazone	POST	Dismiss NXT, Spartan Charge
			POST	
Mitosis Inhibitors				
Standalones				
15	Acetamide	napropamide	PRE	Devrinol 2G, Devrinol 50 WP, Ornamental Herb. 5G,
	Chloroacetamides	dimethenamid-P	PRE	Tower
		S-metolachlor	PRE	Pennant Magnum

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
Inhibitors of cell wall synthesis site B				
Standalones				
21	Benzamide	isoxaben	PRE	Gallery 75 Dry Flowable, Gallery S.C., Isoxaben 75WG
Inhibitors of 4-hydroxyphenyl-pyruvatedioxygenase (4-HPPD)				
Standalones				
27	Triketone	mesotrione	PRE/POST	Tenacity
	Pyrazolone	topramezone	POST	Pylex
Inhibitors of cell wall synthesis site C				
Standalones				
29	Alkylazine	indaziflam	PRE	Specticle FLO, Specticle G
Tyrosine Aminotransferase				
Standalones				
30	*unspecified*	methiozolin	PRE/POST	PoaCure SC
Unknown MoA				
Standalones				
0	Organoarsenical	DSMA	POST	Ansar 8100, DSMA Liquid
		MSMA	POST	MSMA 6 Plus, MSMA 6.6, TARGET 6 Plus, TARGET 6.6, Weed-Hoe
Multiple MoA Premixes				
Groups 1 + 4				
1	Aryloxyphenoxy-propionate ('FOP') + pyridine carboxylic acid + benzoic acid	fenoxaprop-P + fluroxypyr + dicamba	POST	Last Call
4			POST	
4			POST	
Groups 2 + 3 + 5				
3	Dinitroaniline + imidazolinone + triazine	prodiamine + imazaquin + simazine	PRE	Coastal
2			POST	
5			PRE/POST	
Groups 2 + 4				
2	Sulfonylaminocarbonyl-triazolinone + sulfonylurea + benzoic acid	thiencarbazone-methyl + iodosulfuron-methyl-sodium + dicamba	POST	Celsius WG
2			POST	
4			POST	
2	Sulfonylurea + benzoic acid	halosulfuron-methyl + dicamba	POST	Yukon
4			POST	
Groups 2 + 4 + 14				
2	Triazolopyrimidine + phenoxy carboxylic acid + benzoic acid + triazolinone	penoxsulam + 2,4-D + dicamba + sulfentrazone	POST	Avenue South
4			POST	
4			POST	
14			PRE/POST	
Groups 2 + 14				
2	Imidazolinone + triazolinone	imazethapyr + sulfentrazone	POST	Dismiss South, Sulfen Southern
14			PRE/POST	

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
14	Triazolinone + sulfonylureas	sulfentrazone + metsulfuron-methyl (MSM)	PRE/POST	Blindside
2			POST	
Groups 3 + 4				
3	Dinitroaniline + quinoline carboxylic acid	prodiamine + quinclorac	PRE	Cavalcade PQ, LESCO Stonewall PQ
14			POST	
Groups 3 + 14				
3	Dinitroaniline + triazolinone	prodiamine + sulfentrazone	PRE	Echelon 4SC, various fertilizers with Echelon
14			PRE/POST	
14	Oxadiazole + dinitroaniline	oxadiazon + prodiamine	PRE	Regalstar II, Regalstar G
3			PRE	
Groups 3 + 15				
3	Dinitroaniline + chloroacetamide	pendimethalin + dimethenamid-P	PRE	FreeHand 1.75G
15			PRE	
Groups 3 + 21				
3	Pyridine + benzamide	dithiopyr + isoxaben	PRE	Crew
21			PRE	
3	Dinitroaniline + benzamide	trifluralin + isoxaben	PRE	Snapshot 2.5 TG, Snapshot DG
21			PRE	
Groups 4 + 6				
4	Phenoxy carboxylic acid + nitrile	2,4-D + bromoxynil	POST	Maestro D
6			POST	
4	Phenoxy carboxylic acid + nitrile	MCPA + bromoxynil	POST	Maestro Advanced, Maestro MA
6			POST	
Groups 4 + 14				
4	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid + triazolinone	2,4-D + mecoprop-P (MCPP) + dicamba + pyraflufen-ethyl	POST	RedZone 2
4			POST	
4			POST	
14			POST	
4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid + phenylpyrazole	2,4-D + triclopyr + dicamba + pyraflufen-ethyl	POST	4-Speed XT
4			POST	
4			POST	
14			POST	
4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid + phenoxy carboxylic acid	2,4-D + triclopyr + dicamba + MCPA	POST	Triad T Select
4			POST	
4			POST	
14			POST	
4	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid + triazolinone	2,4-D + dichlorprop (2,4-DP) + dicamba + carfentrazone ethyl	POST	SpeedZone Southern EW
4			POST	
4			POST	
14			POST	

HRAC WSSA MOA Group	Chemical Family	Common Name[Active Ingredient(s)]	Activity	Example Product Trade Name(s)
14	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	carfentrazone ethyl + 2,4-D + mecoprop-P (MCPP) + dicamba	POST	SpeedZone, SpeedZone EW, SpeedZone Lawn Weed Killer, SpeedZone Southern
4			POST	
4			POST	
4			POST	
14	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	carfentrazone ethyl + MCPA + mecoprop-P (MCPP) + dicamba	POST	PowerZone, SpeedZone Ready-To-Use Lawn Weed Killer
4			POST	
4			POST	
4			POST	
14	Triazolinone + quinoline carboxylic acid	carfentrazone + quinclorac	POST	SquareOne
4			POST	
4	Quinoline carboxylic acid + triazolinone + phenoxy carboxylic acid + benzoic acid	quinclorac + sulfentrazone + 2,4-D + dicamba	POST	Q4 Plus
14			PRE/POST	
4			POST	
4			POST	
14	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	sulfentrazone + 2,4-D + mecoprop-P (MCPP) + dicamba	PRE/POST	SureZone, Surge
4			POST	
4			POST	
4			POST	
14	Triazolinone + quinoline carboxylic acid	sulfentrazone + quinclorac	PRE/POST	Solitare, Solitare WSL
4			POST	
4	Pyridine carboxylic acid + triazolinone + phenoxy carboxylic acid + benzoic acid	triclopyr + sulfentrazone + 2,4-D + dicamba	POST	TZONE SE
14			PRE/POST	
4			POST	
4			POST	
Groups 4 + 27				
4	Phenoxy carboxylic acid + benzoic acid + triketone	triclopyr + dicamba + mesotrione	POST	Sublime
4			POST	
27			POST	
Groups 5 + 14				
14	Triazolinone + triazinone	sulfentrazone + metribuzin	PRE/POST	Sulfencore
5			POST	
Groups 8 + 14				
8	Phosphorodithioate + oxadiazole	bensulide + oxadiazon	PRE	Goosegrass/Crabgrass Control
14			PRE	