

Turfgrass Herbicides: Mode of Action and Resistance Management¹

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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 Mode 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 a 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

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(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 overstimulation). 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 a 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 a 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 (Figure 1). 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.

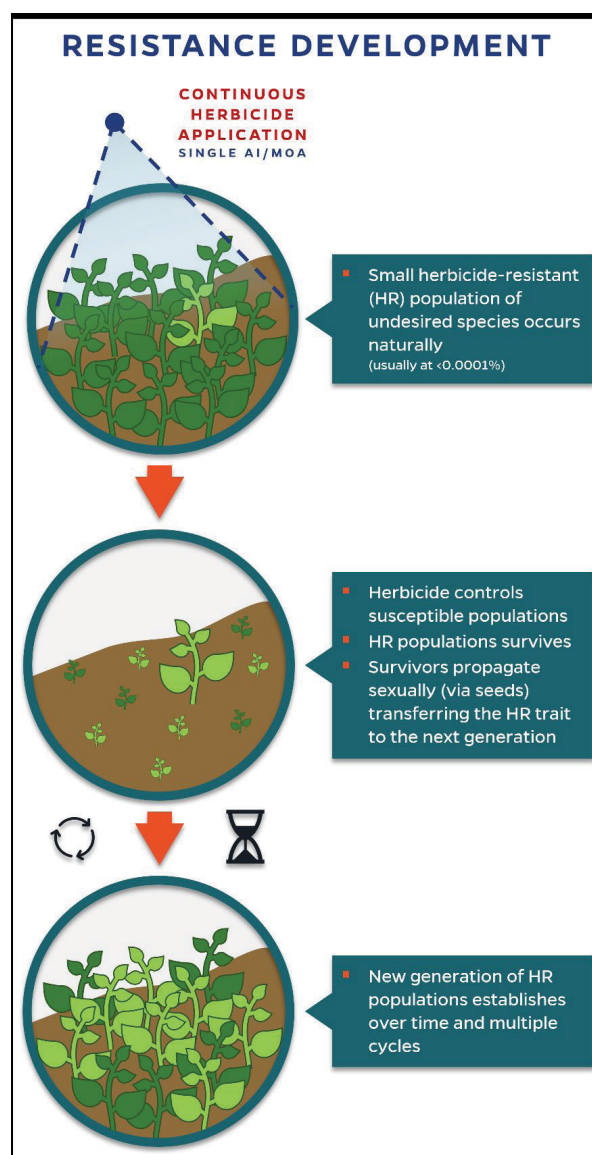
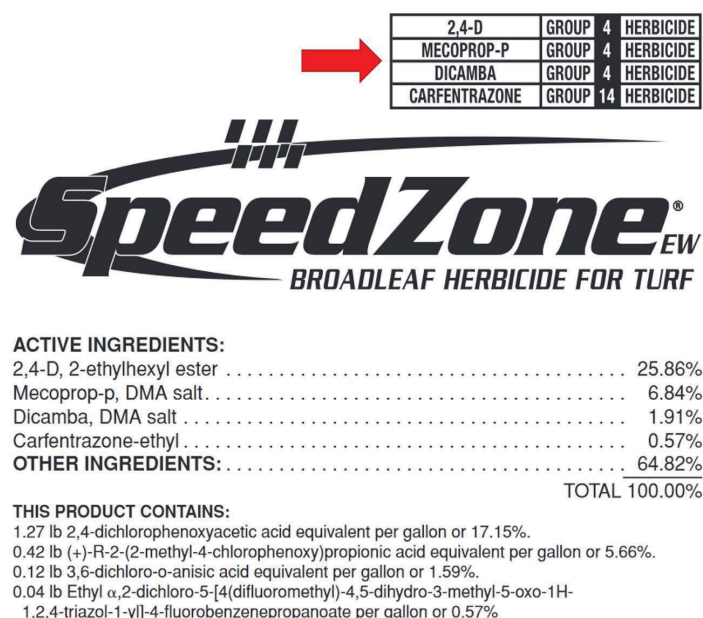


Figure 1. Development of herbicide resistance in weeds due to the continuous use of a single mode of action (MOA) or active ingredient (AI).

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 MOAs and their classifications according to the WSSA and HRAC, along with a comprehensive list of herbicide active ingredients registered for use in turfgrass (including their chemical families) and their respective WSSA/HRAC MOA groups, is provided in Table 1. Additionally, Table 2 summarizes turfgrass tolerance (based on label information) for the most prevalent turfgrasses managed in Florida. Alphabetical codes are no longer used in the U.S., thus are not included in this publication. Moreover, in an 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 2).



2,4-D	GROUP	4	HERBICIDE
MECOPROP-P	GROUP	4	HERBICIDE
DICAMBA	GROUP	4	HERBICIDE
CARFENTRAZONE	GROUP	14	HERBICIDE

SpeedZone^{EW}
BROADLEAF HERBICIDE FOR TURF

ACTIVE INGREDIENTS:

2,4-D, 2-ethylhexyl ester	25.86%
Mecoprop-p, DMA salt	6.84%
Dicamba, DMA salt	1.91%
Carfentrazone-ethyl	0.57%
OTHER INGREDIENTS:	64.82%
TOTAL	100.00%

THIS PRODUCT CONTAINS:

1.27 lb 2,4-dichlorophenoxyacetic acid equivalent per gallon or 17.15%.
0.42 lb (+)-R-2-(2-methyl-4-chlorophenoxy)propionic acid equivalent per gallon or 5.66%.
0.12 lb 3,6-dichloro-o-anisic acid equivalent per gallon or 1.59%.
0.04 lb Ethyl α,2-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]-4-fluorobenzenepropanoate per gallon or 0.57%

Figure 2. Example of a herbicide product label with an icon indicating the herbicides' mode of action (MOA) classification in Weed Science Society of America (WSSA) and Herbicide Resistance Action Committee (HRAC) harmonized system.

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.

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 a herbicide application with one MOA because it is resistant, the problem can be controlled if the surviving weed is treated with 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 3). 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.

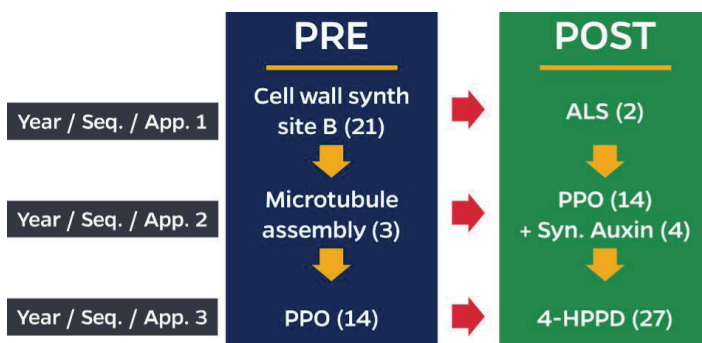


Figure 3. Example of mode of action (MOA) rotation within individual season and across years. MOA change from the preemergence (PRE) to postemergence (POST) applications as well as both PRE and POST herbicide MOA change from year to year.

The second way is to rotate herbicides within a season (Figure 3). 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.

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 premixes of various active ingredients containing different MOAs. There are also many premix options available in the market; however, most contain 1 to 3 active ingredients from the same MOA group, which is not beneficial from a 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 a 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. Mode 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.

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Single MOA Compounds				
Acetyl CoA Carboxylase (ACCase) Inhibitors				
Standalones				
1	Aryloxyphenoxy-propionate ('FOP')	Fenoxaprop-P	POST ^b	Acclaim Extra
1	Aryloxyphenoxy-propionate ('FOP')	Fluazifop-P-butyl	POST	Fusilade II, Ornamec 170, Ornamec Over-The-Top
1	Phenylpyrazoline ('DEN')	Pinoxaden	POST	Manuscript
1	Cyclohexanedione ('DIM')	Sethoxydim	POST	Segment, Segment II
Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) Inhibitors				
Standalones				
2	Imidazolinone	Imazapic	PRE ^b + POST	Plateau
2	Imidazolinone	Imazaquin	POST	Scepter T&O 70 WDG
2	Pyrimidinyl(thio)benzoate	Bispyribac-sodium	POST	Velocity PM
2	Pyrimidinyl(thio)benzoate	Pyrimisulfan	POST	Arkon, Vexis
2	Sulfonylurea	Flazasulfuron	PRE + POST	Katana
2	Sulfonylurea	Foramsulfuron	POST	Revolver
2	Sulfonylurea	Halosulfuron-methyl	POST	Avalaire Halo 75 WDG, Halo 5WDG Select, Halo 75WDG Select, Profine 75, Prosedge, Sandea, SedgeHammer, SedgeHammer+
2	Sulfonylurea	Imazosulfuron	POST	Celero
2	Sulfonylurea	Metsulfuron-methyl (MSM)	POST	Equil Pasture and Turf MSM, Manor, Mansion, MSM 250D, MSM 60, Omni Brand MSM 60 DF, Quali-Pro MSM Turf, Rometsol, Tide MSM 60 DF
2	Sulfonylurea	Rimsulfuron	PRE + POST	Rimsulfuron 25DF, TranXit
2	Sulfonylurea	Sulfometuron-methyl	PRE + POST	Oust XP, LPI Sulfometuron Methyl, Sulfometuron Methyl 75
2	Sulfonylurea	Sulfosulfuron	POST	Certainty
2	Sulfonylurea	Trifloxysulfuron-sodium	POST	Monument 75WG
2	Triazolopyrimidine	Florasulam	POST	Defendor
2	Triazolopyrimidine	Penoxsulam	POST	LockUp on fert., Sapphire
Two-way Premixes				
2 + 2	Pyrimidinyl(thio)benzoate + triazolopyrimidine	Pyrimisulfan + penoxsulam	POST	Aethon
2 + 2	Sulfonylurea + sulfonylurea	Metsulfuron-methyl (MSM) + rimsulfuron	POST	Negate 37WG
2 + 2	Sulfonylurea + sulfonylurea	Sulfometuron-methyl + metsulfuron-methyl (MSM)	PRE + POST	Oust EXTRA
Three-way Premixes				
2 + 2 + 2	Sulfonylaminocarbonyl-triazolinone + sulfonylurea + sulfonylurea	Thiencarbazone-methyl + foramsulfuron + halosulfuron-methyl	POST	Tribute Total
2 + 2 + 2	Sulfonylaminocarbonyl-triazolinone + sulfonylurea + sulfonylurea	Thiencarbazone-methyl + iodosulfuron-methyl-sodium + halosulfuron-methyl	POST	Celsius XTRA

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Special Premixes				
2 + S	Sulfonylurea + <i>safener</i>	Trifloxysulfuron-sodium + <i>metcamifen</i>	POST	Recognition
Inhibitors of Microtubule Assembly				
Standalones				
3	Benzamide	Pronamide	PRE	Kerb 50WP, Kerb SC T&O
3	Dinitroaniline	Benefin	PRE	Balan 2.5G, Balan DF
3	Dinitroaniline	Oryzalin	PRE	Harrier 4L, Oryzalin 4, Surflan AS Specialty
3	Dinitroaniline	Pendimethalin	PRE	1.71% Pendimethalin DG Pro, Corral 2.68G, Pendulum 2G, Pendulum 3.3 EC, Pendulum AquaCap, PRE-M 3.3 EC
3	Dinitroaniline	Prodiamine	PRE	Barricade 4FL, Barricade 65WG, ProClipse 65 WDG, Prodiamine 4L, Prodiamine 65 WDG, RegalKade 50
3	Pyridine	Dithiopyr	PRE + EPOST ^b	Dimension 2EW, Dimension EC, Dimension Ultra 40WP
Two-way Premixes				
3 + 3	Dinitroaniline + dinitroaniline	Benefin + oryzalin	PRE	Surflan XL 2G, XL 2G
3 + 3	Dinitroaniline + dinitroaniline	Benefin + trifluralin	PRE	2% Team on DG Pro, Team 2G, Team Pro MU
Synthetic Auxins				
Standalones				
4	Benzoic acid	Dicamba	POST	Banvel, Banvel 480, Clash, Cruise Control, Diablo, Sterling Blue, Vanquish, Vision
4	Phenoxy carboxylic acid	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
4	Phenoxy carboxylic acid	MCPA	POST	MCPA-4 Amine, MCPA Ester 4
4	Phenoxy carboxylic acid	Mecoprop-P (MCP)	POST	MCP-p 4 Amine, Mecomec 4
4	Pyridine carboxylic acid	Clopyralid	POST	Lontrel T&O
4	Pyridine carboxylic acid	Fluroxypyr	POST	Vista XRT
4	Pyridine carboxylic acid	Triclopyr	POST	Triclopyr 4, Trycera, Turflon Ester, Turflon Ester Ultra
4	Quinoline carboxylic acid	Quinclorac	POST	Acclaim Accelerate, Drive XLR8, Q-Ball, Quinclorac, Quinclorac 75DF, Quinclorac 75DF Select, QuinPro Herbicide, Quintessential, Rook 4L
Two-way Premixes				
4 + 4	Phenoxy carboxylic acid + phenoxy carboxylic acid	2,4-D + dichlorprop (2,4-DP)	POST	Patron 170
4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid	2,4-D + triclopyr	POST	AquaSweep, Chaser, Chaser 2 Amine, Crossroad
4 + 4	Pyridine carboxylic acid + pyridine carboxylic acid	Fluroxypyr + triclopyr	POST	Tailspin

HRAC WSSA Group^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
4 + 4	Pyridine carboxylic acid + pyridine carboxylic acid	Triclopyr + clopyralid	POST	2-D, Confront
Three-way Premixes				
4 + 4 + 4	Phenoxy carboxylic acid + benzoic acid + phenoxy carboxylic acid	2,4-D + dicamba + dichlorprop (2,4-DP)	POST	Brushmaster, Super Trimec
4 + 4 + 4	Phenoxy carboxylic acid + benzoic acid + pyridine carboxylic acid	2,4-D + dicamba + clopyralid	POST	Millennium Ultra 2
4 + 4 + 4	Phenoxy carboxylic acid + benzoic acid + quinoline carboxylic acid	2,4-D + dicamba + quinclorac	POST	2DQ, Terradex Crabgrass & Broadleaf, Triad QC Select, Trimec Crabgrass Plus Lawn Weed Killer, Momentum Q, Quincept
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid	2,4-D + fluroxypyr + dicamba	POST	Escalade 2
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	2,4-D + fluroxypyr + halauxifen-methyl	POST	GameOn
4 + 4 + 4	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	2,4-D + mecoprop-P (MCP) + dicamba	POST	3-D, Eliminate LO, Eliminate-D, EndRun, MEC Amine-D, Strike-3, Threesome, Three-Way, Trimec 1000, Trimec 992, Trimec Bentgrass Formula, Trimec Classic, Trimec Southern, Triplet Low Odor, Triplet SF
4 + 4 + 4	Phenoxy carboxylic acid + phenoxy carboxylic acid + phenoxy carboxylic acid	2,4-D + mecoprop-P (MCP) + dichlorprop (2,4-DP)	POST	Spoiler, Triamine
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	2,4-D + triclopyr + fluroxypyr	POST	Momentum FX2
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid	MCPA + fluroxypyr + dichlorprop (2,4-DP)	POST	Chaser Ultra 2
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid	MCPA + fluroxypyr + dicamba	POST	Change Up
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid	MCPA + fluroxypyr + triclopyr	POST	Battleship III
4 + 4 + 4	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	MCPA + mecoprop-P (MCP) + dicamba	POST	Trimec Encore, Tri-Power
4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + phenoxy carboxylic acid	MCPA + triclopyr + dicamba	POST	Cool Power, Eliminate, Horsepower, Spurge Power, Three-Way Ester II
4 + 4 + 4	Quinoline carboxylic acid + phenoxy carboxylic acid + benzoic acid	Quinclorac + mecoprop-P (MCP) + dicamba	POST	Onetime
Four-way Premixes				
4 + 4 + 4 + 4	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid + phenoxy carboxylic acid	2,4-D + triclopyr + dicamba + MCPA	POST	Terradex Power Premix

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Inhibitors of Photosynthesis at Photosystem II Site A				
Standalones				
5	Triazine	Atrazine	PRE + POST	AAtrex 4L, AAtrex Nine-O, Atrazine 4L, Atrazine 90DF
5	Triazine	Simazine	PRE + POST	Princep Liquid, Simazine 4L, Simazine 90DF, Sim-Trol 4L, Sim-Trol 90DF
5	Triazinone	Metribuzin	POST	Sencor 75%
5	Triazinone	Hexazinone	POST	Velpar DF VU
5	Triazolinone	Amicarbazone	POST	Xonerate 2SC
Inhibitors of Photosynthesis at Photosystem II Site B				
Standalones				
6	Benzothiadiazinone	Bentazon	POST	Basagran T&O
6	Nitrile	Bromoxynil	POST	Broclean, Brox 2EC, Buctril, Buctril 4EC, Maestro 2EC, Maestro 4EC, MOXY 2E
Inhibitors of Lipid Synthesis; Not ACCase Inhibition				
Standalones				
8	Benzofuran	Ethofumesate	PRE + POST	Etho 4SC, Ethofumesate 4SC, PoaConstrictor, Prograss EC, Prograss SC
8	Phosphorodithioate	Bensulide	PRE	Bensumec 4LF
Inhibitors of 5-enolpyruvyl-shikimate-3-phosphate Synthase (EPSPS)				
Standalones				
9	Glycine	Glyphosate	NS (TOTAL) ^b	Accord Concentrate, Accord XRT, Accord XRT II, Aquamaster, Aqua Neat, Aqua Star, Buccaneer, Buccaneer Plus, Buccaneer K, Cinco, Clearout 5 Extra, Cornerstone Plus, Credit 41 Extra, Credit 5.4 Extra, Credit Xtreme, CropSmart Glyphosate 41% Extra, Duplicator 6, Four Power Plus, Gly Star 5 Extra, Gly Star K-Plus, Gly Star Original, Gly Star Plus, Glyphomate 41, Glyphosate 5.4, Glyphosate Plus, Honcho Plus, Imitator Aquatic, Imitator DA, Imitator Plus, KleenUp Pro, Mad Dog, Mad Dog 5.4, Mad Dog Plus, Makaze, Pronto Big N'Tuf, Prosecutor Pro, Ranger Pro, Razor, Razor Pro, Razor Xtreme, Rodeo, Roundup Custom, Roundup Pro, Roundup Pro Concentrate, Roundup PROMAX, Showdown, Shypho-AQ Aquatic & VM, Signature Glyphosate 5.4#, Sunphosate 41%, Sunphosate 5 Plus, Tomahawk 4, Top Dog Glycel 41% Plus Herbicide, Top Dog Glycel Super Max Herbicide, Top Dog Glycel Ultra Max, Willowood Glypho 6, Touchdown Pro

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Inhibitors of Glutamine Synthetase				
Standalones				
10	Phosphinic acid	Glufosinate-ammonium	NS (TOTAL)	Axill Solutions Glufosinate 280SL, Cheetah Pro, Finale, Finale VU, Finale XL T&O, GroSpurt Royce 280 SL, Interline, Opportunity, Reckon 280SL, Surmise, Surmise 5, Surmise Pro, Total, Total 2.3, Total SL, Total TNV, Wynca USA Glufosinate 280 SL
Inhibitors of Protoporphyrinogen Oxidase (Protox, PPO)				
Standalones				
14	N-phenylphthalimide	Flumioxazin	PRE + POST	SureGuard SC, StayGuard on fert., Flumioxazin 51% WDG, Flumishield SC
14	Phenylpyrazole	Pyraflufen-ethyl	POST	Octane 2% SC
14	Triazolinone	Carfentrazone-ethyl	POST	Quicksilver T&O
14	Triazolinone	Sulfentrazone	PRE + POST	Anatares Pro, Aquesta 4F, Dismiss, Expel, Spartan 4F, Surepyc
14	Oxadiazole	Oxadiazon	PRE	Oxadiazon 2G, Oxa-Pro G, Ronstar FLO
Two-way Premixes				
14 + 14	Triazolinone + triazolinone	Carfentrazone-ethyl + sulfentrazone	PRE + POST	Dismiss NXT, Spartan Charge
Mitosis Inhibitors				
Standalones				
15	Acetamide	Napropamide	PRE	Devrinol 2-XT, Devrinol DF-XT
15	Chloroacetamide	Dimethenamid-P	PRE	Tower
15	Chloroacetamide	Pethoxamid	PRE	StriCore
15	Chloroacetamide	S-metolachlor	PRE	Pennant Magnum
Inhibitors of 7,8-dihydro-preroate Synthetase (DHP)				
Standalones				
18	Carbamate	Asulam	PRE	Asulox
Inhibitors of Cell Wall Synthesis Site B				
Standalones				
21	Benzamide	Isoxaben	PRE	Gallery 75 Dry Flowable, Gallery SC, Isoxaben 75 WG
Photosystem I Electron Diverters				
Standalones				
22	Bipyridylum	Diquat	NS (TOTAL)	Dessicash L&A, Diquash, Diquat, Diquat 2 L AG, Diquat SPC 2 L, Reward, Tribune, Tsunami DQ, Verdure-X
Inhibitors of 4-hydroxyphenyl-pyruvatedioxygenase (4-HPPD)				
Standalones				
27	Triketone	Mesotrione	PRE + POST	Tenacity, Lucto
27	Pyrazolone	Topramezone	POST	Pylex
Inhibitors of Cell Wall Synthesis Site C				
Standalones				
29	Alkylazine	Indaziflam	PRE	Specticle FLO, Specticle G

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Inhibitors of Tyrosine Aminotransferase				
Standalones				
30	Unspecified	Methiozolin	PRE + POST	PoaCure SC
Unknown MOA				
Standalones				
0	Carboxylic acid	Pelargonic acid	NS (TOTAL)	Scythe
Multiple MOA Compounds				
Groups 2 + 3 + 5				
Three-way Premixes				
3 + 2 + 5	Dinitroaniline + imidazolinone + triazine	Prodiamine + imazaquin + simazine	PRE + POST	Coastal
Groups 2 + 4				
Two-way Premixes				
2 + 4	Sulfonylurea + benzoic acid	Halosulfuron-methyl + dicamba	POST	Yukon
2 + 4	Sulfonylurea + benzoic acid	Metsulfuron-methyl (MSM) + dicamba	POST	Fahrenheit
Three-way Premixes				
2 + 2 + 4	Sulfonylaminocarbonyl-triazolinone + sulfonylurea + benzoic acid	Thiencarbazone-methyl + iodosulfuron-methyl-sodium + dicamba	POST	Celsius WG
Groups 2 + 4 + 14				
Four-way Premixes				
2 + 4 + 4 + 14	Triazolopyrimidine + phenoxy carboxylic acid + benzoic acid + triazolinone	Penoxsulam + 2,4-D + dicamba + sulfentrazone	POST	Avenue South
Groups 2 + 14				
Two-way Premixes				
2 + 14	Imidazolinone + triazolinone	Imazethapyr + sulfentrazone	POST	Dismiss South, Sulfen Southern
2 + 14	Imidazolinone + triazolinone	Imazaquin + sulfentrazone	POST	Surepyc IQ
14 + 2	Triazolinone + sulfonylurea	Sulfentrazone + metsulfuron-methyl (MSM)	POST	Blindside
Groups 3 + 4				
Two-way Premixes				
3 + 4	Dinitroaniline + quinoline carboxylic acid	Prodiamine + quinclorac	PRE + POST	Cavalcade PQ, LESCO Stonewall PQ
Groups 3 + 14				
Two-way Premixes				
3 + 14	Dinitroaniline + triazolinone	Prodiamine + sulfentrazone	PRE + POST	Echelon 4SC, Echelon on fert.
14 + 3	Oxadiazole + dinitroaniline	Oxadiazon + prodiamine	PRE	Regalstar II, Regalstar G

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
Groups 3 + 15				
Two-way Premixes				
3 + 15	Dinitroaniline + chloroacetamide	Pendimethalin + dimethenamid-P	PRE	FreeHand 1.75G
Groups 3 + 21				
Two-way Premixes				
3 + 21	Pyridine + benzamide	Dithiopyr + isoxaben	PRE	Crew, Fortress
3 + 21	Dinitroaniline + benzamide	Prodiamine + isoxaben	PRE	Gemini, Gemini Granular, Prodoxaben 3.7 SC, Prodoxaben G
Groups 4 + 6				
Two-way Premixes				
4 + 6	Phenoxy carboxylic acid + nitrile	MCPA + bromoxynil	POST	Maestro Advanced, Maestro MA
Groups 4 + 14				
Two-way Premixes				
14 + 4	Triazolinone + quinoline carboxylic acid	Sulfentrazone + quinclorac	POST	Solitare, Solitare WSL
Four-way Premixes				
4 + 4 + 4 + 14	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid + triazolinone	2,4-D + MCPA + dicamba + sulfentrazone	POST	Terradex Quick Strike, Triad SFZ Select
4 + 4 + 4 + 14	Phenoxy carboxylic acid + pyridine carboxylic acid + benzoic acid + phenylpyrazole	2,4-D + triclopyr + dicamba + pyraflufen-ethyl	POST	4-Speed XT
4 + 4 + 4 + 14	Phenoxy carboxylic acid + pyridine carboxylic acid + pyridine carboxylic acid + N-phenylphthalimide	2,4-D + triclopyr + fluroxypyr + flumioxazin	POST	Sure Power
4 + 4 + 4 + 14	Phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid + triazolinone	2,4-D + dichlorprop (2,4-DP) + dicamba + carfentrazone-ethyl	POST	SpeedZone Southern EW
14 + 4 + 4 + 4	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	Carfentrazone-ethyl + 2,4-D + mecoprop-P (MCP) + dicamba	POST	SpeedZone EW
14 + 4 + 4 + 4	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	Carfentrazone-ethyl + MCPA + mecoprop-P (MCP) + dicamba	POST	PowerZone
4 + 4 + 14 + 4	Pyridine carboxylic acid + pyridine carboxylic acid + triazolinone + phenoxy carboxylic acid	Fluroxypyr + triclopyr + sulfentrazone + 2,4-D	POST	Momentum 4-Score
4 + 14 + 4 + 4	Quinoline carboxylic acid + triazolinone + phenoxy carboxylic acid + benzoic acid	Quinclorac + sulfentrazone + 2,4-D + dicamba	POST	Q4 Plus

HRAC WSSA Group ^a	Chemical Family	Common Name [Active Ingredient(s)]	Primary Activity	Commercial Product Example(s)
14 + 4 + 4 + 4	Triazolinone + phenoxy carboxylic acid + phenoxy carboxylic acid + benzoic acid	Sulfentrazone + 2,4-D + mecoprop-P (MCPP) + dicamba	POST	SureZone, Surge
4 + 14 + 4 + 4	Pyridine carboxylic acid + triazolinone + phenoxy carboxylic acid + benzoic acid	Triclopyr + sulfentrazone + 2,4-D + dicamba	POST	TZone SE, Triad TZ Select
Groups 5 + 14				
Two-way Premixes				
5 + 14	Triazinone + triazolinone	Metribuzin + sulfentrazone	POST	Sulfencore
Groups 8 + 14				
Two-way Premixes				
8 + 14	Phosphorodithioate + oxadiazole	Bensulide + oxadiazon	PRE	Goosegrass/Crabgrass Control
Groups 9 + 22				
Two-way Premixes				
9 + 22	Glycine + bipyridylum	Glyphosate + diquat	NS (TOTAL)	QuickPro, Razor Burn

^a HRAC=Herbicide Resistance Action Committee; WSSA=Weed Science Society of America; Group=Herbicide mode of action (MOA) group as classified by HRAC and WSSA.

^b PRE=preemergence; POST=postemergence; EPOST=early postemergence; NS (TOTAL)=non-selective/total.

Mention of a commercial or herbicide brand name or chemical does not constitute a recommendation or warranty of the product by the authors or UF/IFAS, nor does it imply approval of the product to the exclusion of other products that may also be suitable.

Professional-grade herbicides should be handled by trained and licensed/certified personnel and applied using calibrated equipment. Always refer to the label for specific uses, application rates, turfgrass tolerance, and handler and environment safety. Always check for specific precautions and restrictions.

Table 2. Turfgrass tolerance (based on label information) to professional-grade preemergence (PRE) and postemergence (POST) herbicides, organized by mode of action (MOA) classification as defined by the Weed Science Society of America (WSSA) and the Herbicide Resistance Action Committee (HRAC).

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Single MOA Compounds										
Acetyl CoA Carboxylase (ACCase) Inhibitors										
Standalones										
1	Fenoxaprop	D ^c	NI	D	NI	NI	NI	T	T	Acclaim Extra
1	Fluazifop	NI	NI	NI	NI	NI	NI	T	NI	Fusilade II, Ornamec 170, Ornamec Over-The-Top
1	Pinoxaden	T	R	D	NI	T	D	T	NI	Manuscript
1	Sethoxydim	D	NI	D	NI	T	NI	NI	D	Segment, Segment II
Acetolactate Synthase (ALS) or Acetohydroxy Acid Synthase (AHAS) Inhibitors										
Standalones										
2	Imazapic	R	NI	R	NI	T	NI	NI	D	Plateau
2	Imazaquin	T	T	D	D	T	D	T	D	Scepter T&O 70 WDG
2	Bispyribac	R	NI	NI	NI	NI	NI	NI	T	Velocity PM
2	Pyrimisulfan	T	T	T	D	T	T	T	T	Arkon, Vexis
2	Flazasulfuron	T	D	D	D	R	R	T	D	Katana
2	Foramsulfuron	T	NI	NI	NI	NI	NI	T	D	Revolver
2	Halosulfuron	NI	NI	NI	NI	NI	NI	NI	NI	Avalaire Halo 75WDG, Halo 75WDG Select, Profine 75, Prosedge, Sandea
		T	T	T	NI	T	T	T	T	Halo 5WDG Select, SedgeHammer, SedgeHammer+
2	Imazosulfuron	T	T	NI	NI	T	NI	T	T	Celero
2	Metsulfuron	R	R	D	NI	R	NI	R	D	Equil Pasture and Turf MSM, Manor, Mansion, MSM 25OD, Omni Brand MSM 60 DF, Quali-Pro MSM Turf, Tide MSM 60 DF
		R	NI	D	NI	NI	NI	NI	D	MSM 60, Rometsol
2	Rimsulfuron	R	NI	NI	NI	R	NI	R	D	Rimsulfuron 25DF, TranXit
2	Sulfometuron	R	NI	R	NI	R	NI	NI	D	Oust XP, LPI Sulfometuron Methyl, Sulfometuron Methyl 75
2	Sulfosulfuron	T	R	T	NI	T	R	T	D	Certainty
2	Trifloxysulfuron	T	R	D	NI	NI	NI	T	D	Monument 75WG
2	Florasulam	T	T	T	NI	T	NI	T	T	Defendor
2	Penoxsulam	NI	NI	NI	NI	NI	NI	NI	NI	LockUp on fert.
		T	NI	D	D	NI	NI	T	R	Sapphire
Two-way Premixes										
2	Pyrimisulfan + penoxsulam	T	T	NI	D	T	T	T	D	Aethon
2	Metsulfuron + rimsulfuron	R	NI	D	NI	NI	NI	R	D	Negate 37WG
2	Sulfometuron + metsulfuron	R	NI	D	NI	R	NI	NI	D	Oust EXTRA

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Three-way Premixes										
2	Thiencarbazone + foramsulfuron + halosulfuron	T	D	D	NI	D	D	T	D	Tribute Total
2	Thiencarbazone + iodosulfuron + halosulfuron	T	T	D	NI	T	D	T	D	Celsius XTRA
Special Premixes										
2	Trifloxysulfuron + <i>metcamifen</i>	T	T	D	NI	NI	NI	T	D	Recognition
Inhibitors of Microtubule Assembly										
Standalones										
3	Pronamide	T	T	NI	NI	T	NI	T	D	Kerb 50WP
		T	T	NI	NI	T	T	T	D	Kerb SC T&O
3	Benefin	T	T	T	NI	T	NI	T	T	Balan 2.5G
		NI	NI	NI	NI	NI	NI	NI	NI	Balan DF
3	Oryzalin	T	T	T	NI	T	NI	T	NI	Harrier 4L, Oryzalin 4, Surflan AS Specialty
3	Pendimethalin	NI	NI	NI	NI	NI	NI	NI	NI	1.71% Pendimethalin DG Pro
		T	T	T	NI	T	NI	T	NI	Corral 2.68G
		T	T	T	NI	T	T	T	T	Pendulum 2G, Pendulum 3.3 EC, Pendulum AquaCap, PRE-M 3.3 EC
3	Prodiamine	T	T	T	NI	T	T	T	T	Barricade 4FL, Barricade 65WG, ProClipse 65 WDG, Prodiamine 4L, Prodiamine 65 WDG, RegalKade 50
3	Dithiopyr	R	T	T	T	T	T	T	T	Dimension 2EW, Dimension EC, Dimension Ultra 40WP
Two-way Premixes										
3 + 3	Benefin + oryzalin	T	T	T	NI	T	NI	T	D	Surflan XL 2G, XL 2G
3 + 3	Benefin + trifluralin	T	T	T	NI	T	NI	T	T	2% Team on DG Pro, Team 2G, Team Pro MU
Synthetic Auxins										
Standalones										
4	Dicamba	T	R	NI	R	NI	NI	NI	T	Banvel, Banvel 480, Cruise Control, Diablo
		NI	R	NI	R	NI	NI	NI	NI	Clash, Sterling Blue, Vanquish, Vision
4	2,4-D	T	D	NI	NI	NI	NI	NI	NI	2,4-D Amine, Shredder E-99, Weedar 64, Weedone LV4 EC
		NI	D	NI	NI	NI	NI	NI	NI	2,4-D LV 6, Opti-Amine, Shredder 2,4-D LV4, Shredder 2,4-D LV6, Shredder Amine 4, WEEDestroy AM40
		NI	D	NI	D	D	NI	NI	T	Barrage HF, Saber
		NI	NI	NI	NI	NI	NI	NI	NI	Clean Amine
		R	D	R	D	R	NI	R	T	Hardball
		T	R	NI	R	R	NI	NI	T	MCPA-4 Amine
4	MCPA	NI	R	NI	R	NI	NI	NI	NI	MCPA Ester 4
4	MCPP	NI	D	NI	NI	D	NI	NI	NI	MCPP-p 4 Amine, Mecomec 4
4	Clopyralid	T	T	T	NI	T	T	T	T	Lontrel T&O
4	Fluroxypyr	R	R	T	NI	T	NI	T	T	Vista XRT

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
4	Triclopyr	D	D	D	NI	D	NI	D	T	Triclopyr 4, Trycera, Turflon Ester, Turflon Ester Ultra
4	Quinclorac	R	D	D	NI	D	R	T	T	Acclaim Accelerate, Q-Ball, Quinclorac, Quinclorac 75DF, Quinclorac 75DF Select, Quintessential
		R	D	D	D	D	R	T	T	Drive XLR8
		R	D	D	NI	D	NI	T	T	QuinPro Herbicide, Rook 4L
Two-way Premixes										
4 + 4	2,4-D + 2,4-DP	NI	D	NI	D	D	NI	NI	NI	Patron 170
4 + 4	2,4-D + triclopyr	D	D	D	D	D	D	D	T	AquaSweep, Chaser, Chaser 2 Amine, Crossroad
4 + 4	Fluroxypyr + triclopyr	D	D	D	D	D	D	D	T	Tailspin
4 + 4	Triclopyr + clopyralid	R	NI	T	NI	T	NI	R	NI	2-D, Confront
Three-way Premixes										
4 + 4 + 4	2,4-D + dicamba + 2,4-DP	NI	D	NI	D	NI	NI	NI	NI	Brushmaster, Super Trimec
4 + 4 + 4	2,4-D + dicamba + clopyralid	R	D	T	R	D	NI	T	T	Millennium Ultra 2
4 + 4 + 4	2,4-D + dicamba + quinclorac	R	T	T	NI	T	NI	T	T	2DQ
		R	D	D	D	D	D	R	T	Terradex Crabgrass & Broadleaf, Triad QC Select, Momentum Q, Quincept
		R	D	D	D	D	D	T	T	Trimec Crabgrass Plus Lawn Weed Killer
4 + 4 + 4	2,4-D + fluroxypyr + dicamba	T	D	T	R	D	NI	T	T	Escalade 2
4 + 4 + 4	2,4-D + fluroxypyr + halauxifen	R	D	NI	NI	D	NI	T	T	GameOn
4 + 4 + 4	2,4-D + MCPP + dicamba	R	R	R	D	R	NI	R	T	3-D, Eliminate LO, Strike-3, Threesome, Three-Way, Triplet Low Odor, Triplet SF
		T	R	T	D	R	NI	T	T	Eliminate-D
		R	D	R	D	NI	NI	R	T	EndRun, Trimec 992, Trimec 1000
		R	R	R	NI	R	NI	R	T	MEC Amine-D
		NI	R	NI	D	R	NI	NI	NI	Trimec Bentgrass Formula
		R	R	T	D	R	NI	T	T	Trimec Classic
		R	R	NI	NI	R	R	T	NI	Trimec Southern
4 + 4 + 4	2,4-D + MCPP + 2,4-DP	R	NI	T	D	NI	NI	T	T	Spoiler
		R	R	R	D	R	NI	R	T	Triamine
4 + 4 + 4	2,4-D + triclopyr + fluroxypyr	R	NI	R	NI	R	NI	R	T	Momentum FX2
4 + 4 + 4	MCPA + fluroxypyr + 2,4-DP	T	D	T	D	D	NI	T	T	Chaser Ultra 2

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
4 +4 +4	MCPA + fluroxypyr + dicamba	T	T	T	T	T	NI	T	T	Change Up
4 +4 +4	MCPA + fluroxypyr + triclopyr	R	NI	R	NI	R	NI	R	T	Battleship III
4 +4 +4	MCPA + MCPP + dicamba	R	R	T	D	R	NI	R	T	Trimec Encore
		T	D	D	D	D	NI	T	T	Tri-Power
4 +4 +4	MCPA + triclopyr + dicamba	R	R	R	D	R	NI	R	T	Cool Power
		T	R	T	D	R	NI	T	T	Eliminate, Horsepower, Spurge Power, Three-Way Ester II
4 +4 +4	Quinclorac + MCPP + dicamba	R	D	D	D	D	R	T	T	Onetime
Four-way Premixes										
4 +4 +4 +4	2,4-D + triclopyr + dicamba + MCPA	R	R	R	R	R	NI	R	T	Terradex Power Premix
Inhibitors of Photosynthesis at Photosystem II Site A										
Standalones										
5	Atrazine	R	T	NI	NI	T	NI	T	NI	AAtrex 4L, AAtrex Nine-O, Atrazine 4L, Atrazine 90DF
5	Simazine	R	T	NI	NI	T	NI	R	D	Princep Liquid, Simazine 4L, Simazine 90DF, Sim-Trol 4L, Sim-Trol 90DF
5	Metribuzin	T	NI	NI	NI	NI	NI	NI	NI	Sencor 75%
5	Hexazinone	R	NI	R	NI	NI	NI	NI	D	Velpar DF VU
5	Amicarbazone	T	T	T	NI	T	T	T	T	Xonerate 2SC
Inhibitors of Photosynthesis at Photosystem II Site B										
Standalones										
6	Bentazon	T	T	T	T	T	T	T	R	Basagran T&O
6	Bromoxynil	T	T	R	R	R	NI	T	T	Broclean, Brox 2EC, Buctril, Buctril 4EC, Maestro 2EC, Maestro 4EC, MOXY 2E
Inhibitors of Lipid Synthesis; Not ACCase Inhibition										
Standalones										
8	Ethofumesate	R	T	NI	NI	NI	T	D	T	Etho 4 SC, Prograss EC, Prograss SC
		R	T	NI	NI	NI	NI	D	T	Ethofumesate 4SC, PoaConstrictor
8	Bensulide	T	T	T	NI	T	NI	T	T	Bensumec 4LF

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Inhibitors of 5-enolpyruvyl-shikimate-3-phosphate Synthase (EPSPS)										
Standalones										
9	Glycine	R	NI	R	NI	NI	NI	NI	D	Accord Concentrate, Accord XRT, Accord XRT II, Aquamaster, Aqua Neat, Aqua Star, Buccaneer, Buccaneer K, Buccaneer Plus, Cinco, Clearout 5 Extra, Cornerstone Plus, Credit 41 Extra, Credit 5.4 Extra, Credit Xtreme, CropSmart Glyphosate 41% Extra, Duplicator 6, Four Power Plus, Gly Star 5 Extra, Gly Star K-Plus, Gly Star Original, Gly Star Plus, Glyphomate 41, Glyphosate 5.4, Glyphosate Plus, Honcho Plus, Imitator Aquatic, Imitator DA, Imitator Plus, KleenUp Pro, Mad Dog, Mad Dog 5.4, Mad Dog Plus, Makaze, Pronto Big N’Tuf, Prosecutor Pro, Ranger Pro, Razor, Razor Pro, Razor Xtreme, Rodeo, Roundup Custom, Roundup Pro, Roundup Pro Concentrate, Roundup PROMAX, Showdown, Shypho-AQ Aquatic & VM, Signature Glyphosate 5.4#, Sunphosate 41%, Sunphosate 5 Plus, Tomahawk 4, Top Dog Glycel 41% Plus Herbicide, Top Dog Glycel Super Max Herbicide, Top Dog Glycel Ultra Max, Willowood Glypho 6, Touchdown Pro
Inhibitors of Glutamine Synthetase										
Standalones										
10	Glufosinate	R	NI	NI	NI	NI	NI	NI	D	Axill Solutions Glufosinate 280SL, Finale VU, GroSpurt Royce 280 SL, Interline, Opportunity, Reckon 280SL, Surmise, Surmise 5, Surmise Pro, Total, Total 2.3, Total SL, Total TNV, Wynca USA Glufosinate 280 SL
		R	NI	R	NI	NI	NI	NI	D	Cheetah Pro, Finale
		R	NI	R	NI	R	NI	NI	D	Finale XL T&O
Inhibitors of Protoporphyrinogen Oxidase (Protox, PPO)										
Standalones										
14	Flumioxazin	R	NI	NI	NI	NI	NI	NI	D	SureGuard SC, Flumishield SC
		T	NI	NI	NI	D	NI	NI	NI	StayGuard on fert.
		R	R	NI	NI	R	R	R	D	Flumioxazin 51% WDG
14	Pyraflufen	T	T	T	D	R	NI	T	T	Octane 2% SC
14	Carfentrazone	T	T	T	D	T	T	T	T	Quicksilver T&O
14	Sulfentrazone	T	R	R	T	T	T	R	T	Anatares Pro, Dismiss, Expel
		NI	NI	NI	NI	NI	NI	NI	NI	Aquesta 4F
		T	T	T	T	T	T	T	T	Spartan 4F, Surepyc
14	Oxadiazon	R	R	NI	D	D	NI	T	T	Oxadiazon 2G
		R	R	NI	D	D	R	T	T	Oxa-Pro G
		R	R	NI	D	NI	NI	R	NI	Ronstar FLO
Two-way Premixes										
14 + 14	Carfentrazone + sulfentrazone	T	R	R	T	T	T	R	T	Dismiss NXT
		T	T	T	T	T	T	T	T	Spartan Charge

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Mitosis Inhibitors										
Standalones										
15	Napropamide	T	T	T	NI	T	NI	NI	D	Devrinol 2-XT, Devrinol DF-XT
15	Dimethenamid-P	T	T	R	NI	T	T	T	R	Tower
15	Pethoxamid	T	T	T	T	T	T	T	T	StriCore
15	S-metolachlor	T	T	T	NI	T	NI	T	NI	Pennant Magnum
Inhibitors of 7,8-dihydro-preroate Synthetase (DHP)										
Standalones										
18	Asulam	R	R	NI	NI	NI	NI	NI	NI	Asulox
Inhibitors of Cell Wall Synthesis Site B										
Standalones										
21	Isoxaben	T	T	T	NI	T	NI	T	T	Gallery 75 Dry Flowable, Isoxaben 75 WG
		T	T	T	NI	T	T	T	T	Gallery SC
Photosystem I Electron Diverters										
Standalones										
22	Diquat	R	NI	NI	NI	NI	NI	R	NI	Dessicash L&A, Diquash, Diquat, Diquat 2 L AG, Diquat SPC 2 L, Reward, Tribune, Tsunami DQ, Verdure-X
Inhibitors of 4-hydroxyphenyl-pyruvatedioxygenase (4-HPPD)										
Standalones										
27	Mesotrione	R	R	NI	NI	T	D	D	R	Tenacity, Lucto
27	Topramezone	R	D	D	D	T	R	D	T	Pylex
Inhibitors of Cell Wall Synthesis Site C										
Standalones										
29	Indaziflam	R	R	T	NI	R	T	T	D	Specticle FLO, Specticle G
Inhibitors of Tyrosine Aminotransferase										
Standalones										
30	Methiozolin	T	NI	NI	NI	NI	T	T	T	PoaCure SC
Unknown MOA										
Standalones										
0	Pelargonic acid	NI	NI	NI	NI	NI	NI	NI	D	Scythe
Multiple MOA Compounds										
Groups 2 + 3 + 5										
Three-way Premixes										
3 + 2 + 5	Prodiamine + imazaquin + simazine	T	T	D	NI	T	NI	T	D	Coastal
Groups 2 + 4										
Two-way Premixes										
2 + 4	Halosulfuron + dicamba	NI	NI	NI	NI	NI	NI	NI	NI	Yukon
2 + 4	Metsulfuron + dicamba	R	R	D	NI	R	NI	R	NI	Fahrenheit

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Three-way Premixes										
2 + 2 + 4	Thiencarbazon + iodosulfuron + dicamba	T	T	D	D	T	D	T	D	Celsius WG
Groups 2 + 4 + 14										
Four-way Premixes										
2 + 4 + 4 + 14	Penoxsulam + 2,4-D + dicamba + sulfentrazone	T	T	T	D	T	T	T	T	Avenue South
Groups 2 + 14										
Two-way Premixes										
2 + 14	Imazethapyr + sulfentrazone	R	D	R	NI	R	D	R	R	Dismiss South
		T	R	R	NI	T	NI	R	R	Sulfen Southern
2 + 14	Imazaquin + sulfentrazone	T	R	D	NI	T	NI	T	D	Surepyc IQ
14 + 2	Sulfentrazone + metsulfuron	T	T	NI	NI	R	NI	R	NI	Blindside
Groups 3 + 4										
Two-way Premixes										
3 + 4	Prodiamine + quinclorac	T	D	D	D	D	T	T	R	Cavalcade PQ, LESCO Stonewall PQ
Groups 3 + 14										
Two-way Premixes										
3 + 14	Prodiamine + sulfentrazone	T	R	T	T	T	T	R	T	Echelon 4SC, Echelon on fert.
14 + 3	Oxadiazon + prodiamine	T	NI	NI	NI	NI	NI	NI	T	Regalstar II
		T	T	NI	NI	NI	T	T	T	Regalstar G
Groups 3 + 15										
Two-way Premixes										
3 + 15	Pendimethalin + dimethenamid-P	T	T	T	NI	T	T	T	D	FreeHand 1.75G
Groups 3 + 21										
Two-way Premixes										
3 + 21	Dithiopyr + isoxaben	T	T	T	T	T	T	T	T	Crew
		NI	NI	NI	NI	NI	NI	NI	NI	Fortress
3 + 21	Prodiamine + isoxaben	T	R	T	NI	T	T	T	T	Gemini
		NI	NI	NI	NI	NI	NI	NI	NI	Gemini Granular
		R	R	T	NI	T	T	T	T	Prodoxaben 3.7 SC
		T	T	T	NI	T	T	T	T	Prodoxaben G
Groups 4 + 6										
Two-way Premixes										
4 + 6	MCPA + bromoxynil	T	T	T	NI	NI	NI	T	T	Maestro Advanced, Maestro MA

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Groups 4 + 14										
Two-way Premixes										
14 + 4	Sulfentrazone + quinclorac	R	NI	NI	NI	T	T	R	T	Solitare, Solitare WSL
Four-way Premixes										
4 + 4 + 4 + 14	2,4-D + MCPA + dicamba + sulfentrazone	R	D	T	D	R	NI	T	T	Terradex Quick Strike, Triad SFZ Select
4 + 4 + 4 + 14	2,4-D + triclopyr + dicamba + pyraflufen	R	NI	T	D	NI	NI	T	T	4-Speed XT
4 + 4 + 4 + 14	2,4-D + triclopyr + fluroxypyr + flumioxazin	NI	D	NI	D	D	NI	NI	T	Sure Power
4 + 4 + 4 + 14	2,4-D + 2,4-DP + dicamba + carfentrazone	T	R	T	D	T	T	T	T	SpeedZone Southern EW
14 + 4 + 4 + 4	Carfentrazone + 2,4-D + MCPP + dicamba	T	D	D	D	D	D	T	T	SpeedZone EW
14 + 4 + 4 + 4	Carfentrazone + MCPA + MCPP + dicamba	R	R	NI	D	NI	NI	T	T	PowerZone
4 + 4 + 14 + 4	Fluroxypyr + triclopyr + sulfentrazone + 2,4-D	D	D	D	D	D	D	D	T	Momentum 4-Score
4 + 14 + 4 + 4	Quinclorac + sulfentrazone + 2,4-D + dicamba	R	D	D	D	D	NI	R	T	Q4 Plus
14 + 4 + 4 + 4	Sulfentrazone + 2,4-D + MCPP + dicamba	R	D	T	D	R	NI	T	T	SureZone, Surge
4 + 14 + 4 + 4	Triclopyr + sulfentrazone + 2,4-D + dicamba	R	D	R	D	NI	NI	R	T	TZone SE, Triad TZ Select
Groups 5 + 14										
Two-way Premixes										
5 + 14	Metribuzin + sulfentrazone	T	NI	NI	NI	NI	NI	NI	NI	Sulfencore
Groups 8 + 14										
Two-way Premixes										
8 + 14	Bensulide + oxadiazon	T	NI	NI	NI	NI	NI	T	T	Goosegrass/Crabgrass Control

HRAC WSSA Group ^a	Active Ingredient(s) (simplified)	Turfgrass Species								Commercial Product Example(s)
		BER ^b	STA	BAHI	CARP	CENT	PASP	ZOYS	RYE	
Groups 9 + 22										
Two-way Premixes										
9 + 22	Glyphosate + diquat	R	NI	R	NI	NI	NI	NI	D	QuickPro, Razor Burn

^a HRAC=Herbicide Resistance Action Committee; WSSA=Weed Science Society of America; Group=herbicide mode of action (MOA) group as classified by HRAC and WSSA.

^b BER=Bermudagrass; STA=St. Augustinegrass; BAH=Bahiagrass; CARP=Carpetgrass; CENT=Centipedegrass; PASP=Seashore paspalum; ZOYS=Zoysiagrass; RYE=Perennial ryegrass.

^c T=tolerant at labeled rates on well-established (mature, dense turf having a well-anchored root system and healthy, vigorous top growth), healthy turf when applied in optimal conditions; R=some injury may occur, and/or may cause some minor damage to mature, healthy turf, and/or specific restrictions may apply, and/or crop safety may differ between certain products; D=potentially damaging – do not use; NI=no information provided on the label or not registered for use on this species – use not recommended.

Mention of a commercial or herbicide brand name or chemical does not constitute a recommendation or warranty of the product by the authors or UF/IFAS, nor does it imply approval of the product to the exclusion of other products that may also be suitable.

Professional-grade herbicides should be handled by trained and licensed/certified personnel and applied using calibrated equipment. Always refer to the label for specific uses, application rates, turfgrass tolerance, and handler and environment safety. Always check for specific precautions and restrictions.