

TURFGRASS SCIENCE

at the UT Institute of Agriculture

Understanding How Turfgrass Herbicides Work

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Herbicides are chemicals that inhibit normal plant growth processes resulting in death of susceptible weeds. The processes by which herbicides kill weeds are called modes of action while the location where these effects occur at the cellular level is termed the site of action or the mechanism of action. The Weed Science Society of America (WSSA) uses a numerical system to group herbicides by mechanism of action. A more detailed description of this numerical system is presented in Table 1.

Continual reliance on herbicides that employ the same mechanism of action has led to the evolution of herbicide-resistant weeds in turfgrass, as well as in

other agricultural systems. Developing weed management programs utilizing herbicides that employ different mechanisms of action is critical to both preventing and managing herbicide resistant weeds. It is recommended to rotate herbicides that employ different mechanisms of action as often as possible, as well as implementing cultural practices that maximize turf competition and limit weed encroachment. Table 2 lists single active ingredient herbicides used in turfgrass by mechanisms of action group number. These WSSA group numbers can also be found on most herbicide labels as well (Figure 1).

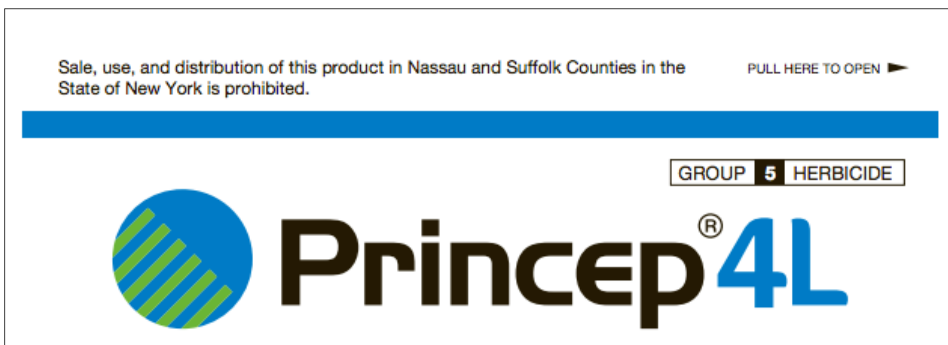


Figure 1. The Weed Society of America (WSSA) uses a numerical system to group herbicides by mechanism of action. The WSSA group number can be found on most herbicide labels.

Table 1. Mechanisms for action of herbicides used to control weeds in turfgrass.

WSSA Action Group	Mechanism of Action	Description
1	Acetyl CoA Carboxylase (ACCase) Inhibitor	Inhibit synthesis of fatty acids required for building new cell membranes
2	Acetolactate Synthase (ALS) Inhibitor	Inhibit the acetolactate synthase (ALS) enzyme involved in synthesizing branch chain amino acids such as isoleucine, leucine and valine
3	Microtubule Inhibitor	Inhibit microtubule structure and function during cell division
4	Synthetic Auxin	Act similar to endogenous auxin (IAA) causing uncontrolled cell division and growth that damages vascular tissue
5, 6 & 7	Photosystem II Inhibitor	Inhibit proper electron flow during the light reactions of photosynthesis (i.e., photosystem II)
8 & 16	Lipid Biosynthesis Inhibitor	Inhibit synthesis of fatty acids and lipids
9	EPSP Synthase Inhibitor	Inhibit production of aromatic amino acids (tryptophan, tyrosine and phenylalanine) required for protein synthesis
10	Glutamine Synthetase Inhibitor	Inhibits conversion of glutamate and ammonia to glutamine
14	Protoporphyrinogen Oxidase (PPO) Inhibitor	Inhibit the PPO enzyme involved in chlorophyll and heme synthesis
15	Long Chain Fatty Acid Inhibitor	Inhibit very long chain fatty acid synthesis
17	Specific Site Unknown	The mechanism of action for these herbicides remains unknown, but could potentially be nucleic acid inhibitors
21 & 29	Cellulose biosynthesis inhibitor (CBI)	Inhibit cell wall synthesis
22	Photosystem I Inhibitor	Herbicides accept electrons from photosystem I leading to oxidative stress that damages cellular structures
26	Specific Site Unknown	The mechanism of action for these herbicides remains unknown
27	Carotenoid Biosynthesis Inhibitor	Inhibit synthesis of carotenoid pigments that protect chlorophyll from oxidative stress

Table 2. Single herbicide active ingredients labeled for use in turfgrass.

Mode of Action	Mechanism of Action	WSSA Action Group	Chemical Family	Active Ingredient	Ex. Trade Names
Lipid Biosynthesis Inhibitor	Acetyl CoA Carboxylase (ACCase) Inhibitor	1	Aryloxyphenoxy-propionate (FOPs)	fenoxaprop	Acclaim Extra
				fluazifop	Fusilade II
			Cyclohexanedione (DIMs)	sethoxydim	Segment
Amino Acid Synthesis Inhibitor	Acetolactate Synthase (ALS) Inhibitor	2	Sulfonylurea	chlorsulfuron	Corsair
				flazasulfuron	Katana
				foramsulfuron	Revolver
				halosulfuron	SedgeHammer
				imazosulfuron	Celero
				iodosulfuron	*NA
				metsulfuron	Manor
				rimsulfuron	TranXit
				sulfosulfuron	Certainty
				trifloxysulfuron	Monument
			Sulfonylaminocarbonyltriazolinone	thiencarbazone	*NA
			Imidazolinone	imazaquin	Image
				imazapic	Plateau
Triazolopyrimidine	florasulam	Defendor			
	penoxsulam	Lockup			
Pyrimidinyl(thio)benzoate	bispyribac-sodium	Velocity			
Root Growth Inhibitor	Microtubule Inhibitor	3	Dinitroaniline	benefin	Balan
				oryzalin	Surflan
				pendimethalin	Pendulum
				prodiamine	Barricade
				trifluralin	Treflan
			Pyridine	dithiopyr	Dimension
			Benzamide	pronamide	Kerb
			Phthalic Acid	DCPA	*NA

Mode of Action	Mechanism of Action	WSSA Action Group	Chemical Family	Active Ingredient	Ex. Trade Names
Synthetic Auxin	Not Well Understood	4	Phenoxy	2,4-D	Various
				MCPP	
				MCPA	
				2,4-DB	
		Benzoic Acid	dicamba	Banvel	
		Pyridine Carboxylic Acid	clopyralid	Lontrel	
			fluroxypyr	*NA	
triclopyr	Garlon				
		4 & 26**	Quinoline Carboxylic Acid	quinclorac	Drive XLR8
Photosynthesis Inhibitor	Photosystem II Inhibitor	5	Triazine	atrazine	AAtrex
				simazine	Princep
			Triazinone	metribuzin	Sencor
			Triazolinone	amicarbizone	Xonerate
Photosynthesis Inhibitor	Photosystem II Inhibitor	6	Nitrile	bromoxynil	Buctril
			Benzothiadiazinone	bentazon	Basagran
Photosynthesis Inhibitor	Photosystem II Inhibitor	7	Urea	siduron	Tupersan
Lipid Biosynthesis Inhibitor	Not Well Understood	8	Phosphorodithioate	bensulide	Bensumec
Amino Acid Synthesis Inhibitor	EPSP Synthase Inhibitor	9	Glycine	glyphosate	Roundup Pro
Nitrogen Metabolism	Glutamine Synthetase Inhibitor	10	Phosphinic Acid	glufosinate-ammonium	Finale
Cell Membrane Disrupter	Protoporphyrinogen Oxidase (PPO) Inhibitor	14	Aryl Triazinone	carfentrazone	Quicksilver
				sulfentrazone	Dismiss
			N-phenylphthalimide	flumioxazin	Sureguard
			Oxadiazole	oxadiazon	Ronstar
			Pyrazole	pyraflufen-ethyl	Octane
Shoot Growth Inhibitor	Long Chain Fatty Acid Inhibitor	15	Chloroacetamide	dimethenamid	Tower
				metolachlor	Pennant

Mode of Action	Mechanism of Action	WSSA Action Group	Chemical Family	Active Ingredient	Ex. Trade Names
Lipid Biosynthesis Inhibitor	Not Well Understood	16	Benzofuran	ethofumesate	Prograss
Not Well Understood	Not Well Understood	17	Organic Arsenical	monosodium methanearsonate (MSMA)	Various
Dihydropter-oate (DHP) Synthase Inhibitor	Not Well Understood	18	Carbamate	asulam	Asulox
Cellulose Biosynthesis Inhibitor (CBI)	Cell Wall Biosynthesis Inhibitor	21	Benzamide	isoxaben	Gallery
Cell Membrane Disrupter	Photosystem I Inhibitor	22	Bipyridilium	diquat	Reward
Not Well Understood	Not Well Understood	26 & 4**	Quinoline Carboxylic Acid	quinclorac	Drive XLR8
		26	Dithiocarbamate	dazomet	Basamid
Carotenoid Biosynthesis Inhibitor	4-Hydroxyphenyl-Pyruvate-Dioxygenase (HPPD) Inhibitor	27	Triketone	mesotrione	Tenacity
			Pyrazolone	topramezone	Pylex
Cellulose Biosynthesis Inhibitor (CBI)	Cellulose Biosynthesis Inhibitor	29	Alkylazine	indaziflam	Specticle

*NA = Not available alone, but can be found in numerous mixtures.

**Quinclorac WSSA action groups are 4 for dicots and 26 for monocots.

In turfgrass, multiple active ingredients are often sold commercially as pre-packaged mixtures to broaden the spectrum of weeds controlled by a single herbicide application. While these products are very useful tools for weed control, they do not replace the need to rotate to herbicides with other mechanisms of action because active ingredients in these mixtures are often included at rates lower than what would be

recommended when these materials are applied alone (i.e., not in a mixture). Table 3 lists example herbicides labeled for use in turfgrass that contain multiple active ingredients and the corresponding WSSA group number for each. Figure 2 is an example of how these groups may be represented on the product label.



Figure 2. Some herbicides labeled for use in turfgrass contain multiple active ingredients from various WSSA groups, as shown on the above label.

Table 3. Select herbicides labeled for use in turfgrass that contain multiple active ingredients.

Trade Name(s)	Active Ingredients	WSSA Action Groups
2DQ	2,4-D + dicamba + quinclorac	4 + 4 + (26 or 4)
4-Speed XT	2,4-D + triclopyr + dicamba + pyraflufen-ethyl	4 + 4 + 4 + 14
Anderson's Goosegrass/Crabgrass	oxadiazon + dithiopyr	14 + 3
Blindside	sulfentrazone + metsulfuron	14 + 2
Brushmaster	2,4-D + 2,4-DB + dicamba	4 + 4 + 4
Celsius	thiencarbazone + iodosulfuron + dicamba	2 + 2 + 4
ChangeUp	MCPA + fluroxypyr + dicamba	4 + 4 + 4
Confront, 2D	triclopyr + clopyralid	4 + 4
Coolpower, Horsepower, Eliminate	MCPA + triclopyr + dicamba	4 + 4 + 4
Dismiss South	sulfentrazone + imazethapyr	14 + 2
Echelon	sulfentrazone + prodiamine	14 + 3
Escalade 2	2,4-D + fluroxypyr + dicamba	4 + 4 + 4
Freehand	dimethenamid + pendimethalin	15 + 3
Last Call	fenoxaprop + fluroxypyr + dicamba	1 + 4 + 4
Millennium Ultra 2	2,4-D + clopyralid + dicamba	4 + 4 + 4
Momentum FX2	2,4-D + triclopyr + fluroxypyr	4 + 4 + 4
Negate	metsulfuron + rimsulfuron	2 + 2
Powerzone	carfentrazone + MCPA + MCPP + dicamba	14 + 4 + 4 + 4
ProDeuce	glyphosate + prodiamine	9 + 3

Trade Name(s)	Active Ingredients	WSSA Action Groups
Q-4 Plus	quinclorac + sulfentrazone + 2,4-D + dicamba	(26 or 4) + 14 + 4 + 4
QuickPro	glyphosate + diquat	9 + 22
Solitare	sulfentrazone + quinclorac	14 + (26 or 4)
Specticle Total	indaziflam + glyphosate + diquat	29 + 9 + 22
Speedzone	carfentrazone + 2,4-D + MCPP + dicamba	14 + 4 + 4 + 4
Squareone	carfentrazone + quinclorac	14 + (26 or 4)
Surge, Surezone	sulfentrazone + 2,4-D + MCPP + dicamba	14 + 4 + 4 + 4
Tribute Total	thiencarbazon + foramsulfuron + halosulfuron	2 + 2 + 2
Trimec Classic, Three Way, Others	2,4-D + MCPP + dicamba	4 + 4 + 4
Trimec Encore	MCPA + MCPP + dicamba	4 + 4 + 4
Trimec Plus	MSMA + 2,4-D + MCPP + dicamba	17 + 4 + 4 + 4
T-Zone	triclopyr + sulfentrazone + 2,4-D + dicamba	4 + 14 + 4 + 4

For more information on herbicide resistance and herbicide selection please visit the following sites:

- www.tennesseeturfgrassweeds.org/Pages/Herbicide-Resistance.aspx
- www.tennesseeturfgrassweeds.org/Pages/Herbicide-Selection-Tool.aspx
- www.mobileweedmanual.com

If you suspect that a weed might be resistant to a herbicide, it is important to report cases to University of Tennessee Extension Specialists focused on weed

management. Reporting allows specialists to not only track spread across the state of Tennessee but also to conduct tests to diagnose resistance in weeds of interest and provide alternative recommendations for control. For more information about reporting a resistance case or conducting diagnostic tests to confirm resistance in a particular weed species, please visit the UT Weed Diagnostics Center (www.weeddiagnostics.org).



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