

# Herbicide-Resistant Weeds and Their Management

*When planning a herbicide program to prevent resistance, do not use herbicides from the same group more than once within three years.*

## Herbicide-Resistance Basics

Herbicide resistance is the inherited ability of a plant to survive a herbicide application to which the wild-type is susceptible. Resistant plants occur naturally within a population. They differ slightly in genetic makeup from the wild-type, but they remain reproductively compatible with them.

Herbicide-resistant plants initially are present in a weed population in extremely small numbers (about 1 in 100,000 to more than 1 in 1,000,000). The repeated use of one herbicide, or of herbicides that kill the plants the same way (same site of action or same herbicide group), allows these few plants to survive and reproduce. The number of resistant plants then increases in the population until the herbicide no longer effectively controls it.

Resistant weed populations may persist in infested fields for many years, even without any additional selection pressure from the herbicide. There is no evidence that herbicides cause the genetic mutations that lead to herbicide resistance.

## Types of resistance

Herbicides are organized into groups based on their site of action. Herbicides in the same group all kill plants the same way.

Weed populations may be resistant to herbicides in different chemical families if those families share the same site of action. For example, kochia populations in southern Idaho are resistant to imidazolinone and sulfonyleurea herbicides, which are both in herbicide group 2. This is called cross-resistance.

Resistance to herbicides with different sites of action can also occur. For example, an Italian ryegrass biotype (a group of organisms having the same genotype) in Idaho is resistant to herbicides in at least three different groups: 1, 2, and 15. This is called multiple resistance.

Herbicide resistance should not be confused with the natural herbicide tolerance that some species have. For example, wheat is tolerant to Puma because it rapidly deactivates the herbicide. Wild oat can only slowly deactivate Puma, so Puma can be used to remove wild oat from a wheat field.

## Herbicide resistance in the Pacific Northwest and worldwide

The first identified herbicide-resistant weed biotype, spreading dayflower (*Commelina diffusa*), which is resistant to 2,4-D, was identified in 1957 in a Hawaii sugarcane field. Since then, more than 300 weed biotypes resistant to one or more herbicides have been identified worldwide. Current information on the status of herbicide-resistant weeds can be found at <http://weeds science.org/>

A number of herbicide-resistant weed biotypes are now common in the Pacific Northwest:

- Kochia, prickly lettuce, Russian thistle, and many other broadleaf weeds are resistant to sulfonyleurea (group 2) herbicides (e.g., Glean, Amber, Ally).
- Wild oat and Italian ryegrass are resistant to Discover and other ACCase inhibitor (group 1) herbicides.
- Powell amaranth and other pigweed species are resistant to triazines and other group 5 herbicides.
- Yellow starthistle is resistant to Tordon (group 4).
- Wild oat is resistant to Far-Go (group 8) and Avenge (group 26).

This publication contains the  
**Guide for Herbicide Rotation**  
 reference poster

## Planning Your Herbicide Program

The development of herbicide-resistant weed populations is strongly linked to repeated use of the same herbicide or of herbicides with the same site of action in monoculture cropping systems and in noncrop areas such as railway or road rights-of-way. However, herbicides with the same site of action can also be used in different crops grown in a rotation. Therefore, knowing the chemical family and site-of-action group in which a herbicide belongs and knowing which other herbicides have the same site of action are critical for creating a plan to prevent or delay development of herbicide-resistant weed populations.

The herbicide rotation table inside this publication lists herbicides by site-of-action group and gives a number and color code to each group to help in distinguishing among them. The table also gives each herbicide's chemical family, common name, and trade name and gives examples of confirmed resistant weed populations by state.

When planning a herbicide program to prevent or delay resistance, do not use herbicides from the same site-of-action group more than once within three years!

### *Preventing or delaying herbicide resistance*

Multiple management practices can be used in an integrated plan to prevent or delay the development of herbicide-resistant weed populations. Use the following practices along with the herbicide-rotation table to form an effective herbicide resistance management strategy.

**Rotating herbicides**—Avoid year-after-year use of the same herbicide or of herbicides with the same site of action. Remember that herbicides belonging to different chemical families may have the same site of action. For example, Maverick is a sulfonylurea herbicide and Pursuit is an imidazolinone herbicide, but both are group 2 herbicides.

**Rotating crops**—Crops differ in their competitiveness against weeds based on life cycle, growth habit, maturity length, etc., so rotating to different crops can help prevent some weed species from becoming dominant in a given field. In addition, because different crops may require different types of herbicides, rotating crops can enable herbicide rotation.

However, some herbicide groups include many different herbicides available for use in many different crops, the imidazolinones and sulfonylureas in group 2, for example. In these cases, crop rotation alone may not be enough to avoid resistance development. In addition, avoid using herbicides with the same site of action in both fallow years and in the crop(s) planted within 3 years.

**Using short-residual herbicides**—Using herbicides that do not persist in soil for long time periods and not apply-

ing them repeatedly within a growing season reduces the selection of herbicide-resistant weed biotypes. However, repeated applications within a single growing season of paraquat, a herbicide with no soil activity, has resulted in the development of paraquat-resistant weed populations. Similar situations have occurred with glyphosate.

**Cultivating**—Cultivation in row crops can eliminate weed escapes, which may be resistant biotypes. Fallow tillage can control herbicide-resistant and herbicide-susceptible weed populations equally as long as seedlings of the two biotypes emerge at about the same time.

**Accurate record keeping**—You must know which herbicides and herbicide sites of action have been used in the past, at what rates, and how often. Also keep track of the weed species that have been present in a given field and of how well particular herbicides have controlled them.

**Planting clean seed**—Plant certified seed to greatly minimize the introduction of weed seeds from herbicide-resistant biotypes. (Certified seed may contain some weed seeds, but not those of noxious weeds.)

**Practicing integrated weed management**—Integration of many control practices is important for effective control of all weeds, not just for herbicide-resistance management. Integrated weed management uses all the tools available to control weeds, including cultural, mechanical, and chemical methods. An integrated approach to weed management, whether in crop or noncrop land, is an important environmental and economic consideration.

### *Dealing with herbicide resistance*

**Monitoring fields for weed escapes**—Weed escapes may or may not be resistant biotypes. A resistance problem may not become visible until 30 percent or more of the weed population is no longer controlled. Check to see if the escapes are of one species or a mixture of species. If a mixture, the problem is more likely related to the environment or the herbicide application. If only one species was not controlled, the problem is more apt to be resistance, especially if the species was controlled by the herbicide in the past and if the same herbicide has been used repeatedly in the field.

**Preventing weed spread**—Prevent weeds in a herbicide-resistant population from flowering and producing seed if possible. Thoroughly clean machinery used in fields or areas with known or suspected infestations of herbicide-resistant weed populations before moving the machinery to other fields or areas. Always plant certified crop seed, free of weed seeds.

Rotating crops and tillage systems—Rotating crops and using differing tillage practices and timings can affect weed populations. Alternating spring and winter crops, for example, means that a field will be tilled and sometimes sprayed with herbicides at different times in the different crops. Resistant as well as susceptible weed biotypes that survive in one type of crop with its associated application and tillage timings could be killed in the other type of crop.

Changing herbicide program—If weed resistance occurs, herbicides with other sites of action and other weed management practices must be used in an integrated management strategy.

### ***Recognizing herbicide resistance***

Irregularly shaped patches of a single weed species in a field are an indicator of herbicide resistance, especially when

- There are no other apparent application problems.
- Other weed species are controlled adequately.
- No or minimal herbicide symptoms appear on the single uncontrolled weed species.
- There has been a previous failure to control the same species in the same field with the same herbicide or with herbicides with the same site of action.
- Records show repeated use of one herbicide or of herbicides with the same site of action.

### ***What to do if you suspect herbicide resistance***

- Do not respray the field with the same herbicide or with herbicides with the same site of action.
- Report your suspicion to a university researcher or extension specialist or to the extension educator in your county.
- If possible, collect plants or seed that can be used to confirm resistance has developed. However, controlling weed escapes and preventing production of viable seeds are of prime importance.

### ***Managing herbicide-resistant crops***

Herbicide-resistant crops have recently been developed for use in weed control. These crops are resistant to herbicides that are lethal to susceptible varieties of the same crop.

Crops resistant to specific herbicides have been developed both through genetic engineering and through traditional selective breeding. Examples include Clearfield wheat, which was selected for resistance to imazamox, and Roundup Ready canola, field corn, and sugarbeets, which were genetically engineered to be glyphosate-resistant.

Used properly, herbicide-resistant crops can be valuable tools for managing difficult-to-control weeds. They also have two inherent risks that need to be considered prior to planting: (1) the emergence of herbicide-resistant volunteers in subsequent growing seasons and (2) the potential for herbicide-resistant crops to cross with weedy relatives. Also, they provide a potential use for the same herbicide several times a year and season after season.

Volunteer herbicide-resistant crops as weeds—Consider whether the herbicide-resistant crop typically occurs as a volunteer crop in subsequent growing seasons, and, if so, whether effective control options are available in the crop rotation to remove herbicide-resistant volunteers. For example, glyphosate, the active ingredient in Roundup, is commonly used to control volunteer crops prior to planting a rotational crop. Glyphosate will not effectively control Roundup Ready crops, however, so some other herbicide or nonchemical control measure will be required to control the glyphosate-resistant volunteers.

Evaluate the impacts on your operation of using these other herbicides or nonchemical control measures against the impacts of not using the herbicide-resistant crop. Impacts could be increased cost, increased soil erosion, moisture loss due to increased tillage, or other factors.

Volunteer crops are usually considered to be a problem largely within one year of harvest. However, certain species have extended dormancy, which could result in multiple years of a herbicide-resistant volunteer crop problem even without seed production by the volunteer plants.

Gene-flow from herbicide-resistant crops to weedy relatives—In rare instances, the trait conferring herbicide resistance in a crop moves into weedy relatives through cross-pollination, resulting in a herbicide-resistant weed. Consider weedy and native relatives of the herbicide-resistant crop in the surrounding area as well as their propensity to cross-pollinate. Self-pollinating crops, such as soybean, are considered low risk in terms of gene flow to weeds or other crops. Roundup Ready, Clearfield, or Liberty Link canola, in contrast, could pollinate nearby herbicide-susceptible canola as well as weedy canola relatives, resulting in volunteer canola plants and weeds that may be resistant to several herbicide families.

Herbicide-resistant cropping systems at risk for gene flow or volunteer management problems may have some or all of the following traits:

- The crop cross-pollinates with other nearby crops or with relatives that are problem weeds.
- The crop seed shatters at or before harvest, as with canola, or leaves vegetative propagules in the ground after harvest, as with potatoes, resulting in volunteer crops in subsequent years.

- Herbicides available for managing volunteer crops are limited to the same herbicide site-of-action group to which the crop is resistant.
- Crop seed remains viable in the soil for several cropping seasons.

Use of a herbicide-resistant crop can increase your reliance on a herbicide within a site-of-action group. The same herbicide may be applied multiple times per season and/or several times during a cropping system rotation.

### *Tank-mixing in resistance management*

Tank-mixing herbicides with different sites of action is not always an effective resistance management strategy. Weed control spectrums of the different herbicides in the mixture must overlap so that weed biotypes resistant to one site of action are controlled by a herbicide with a different site of action. If not, then resistant biotypes can survive and eventually dominate the population.

In addition, if the herbicides in the tank mixture have different soil residual characteristics, resistant weed biotypes can still be selected. For example, Glean and 2,4-D have different sites of action; however, Glean is a long-residual herbicide and 2,4-D is a short-residual herbicide. When tank-mixed, both herbicides control some of the same broadleaf weed species shortly after application. However, Glean will continue to control weeds long after the 2,4-D has stopped providing control, and selection for weed biotypes resistant to Glean could therefore be occurring.

Unless the control spectrum overlaps and the residual length is similar, avoid repeated use of a herbicide or of a herbicide site of action even in tank mixtures with other site-of-action herbicides. Exceptions can be made when a specific herbicide combination is required to control the weed spectrum present or when tank-mixing will result in reduced herbicide use rates. Tank-mixing for other reasons is not economically or ecologically sound.

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**Add this publication to your Pacific Northwest Conservation Tillage Handbook in chapter 5, “Weed Control Strategies,” as series #18.**

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# Guide for Herbicide Rotation in the Pacific Northwest

To avoid selecting for herbicide-resistant weeds, do not use herbicides from the same color group more than once within three years. Rather, rotate to a different group every year of the production system.

Herbicide group number and site of action	Herbicide chemical family	Herbicide common name	Herbicide trade names	Resistant weeds in the PNW	States with resistant weeds	
<b>Group 1</b> Acetyl CoA carboxylase (ACCase) inhibitors	cyclohexane-diones	clethodim	Select Max, Envoy, several others	Italian ryegrass	ID	
		sethoxydim	Poast, several others	Italian ryegrass	ID	
		tralkoxydim	Achieve	Italian ryegrass	ID	
		aryloxyphenoxy-propanoates	clodinafop	Discover NG	Italian ryegrass Wild oat	ID ID
			diclofop	Hoelon	Wild oat Italian ryegrass	ID, OR, WA ID, OR, WA
			fenoxaprop	Puma, Acclaim	Wild oat	ID, OR
		fluazifop	Fusilade DX	Downy brome	OR	
	quizalofop	Assure II, Targa	Italian ryegrass	ID		
	phenylpyrazoline	pinoxaden	Axial	Italian ryegrass	ID, OR	
	<b>Group 2</b> Acetolactate synthase (ALS) inhibitors	imidazolinones	*imazamox	Raptor, Beyond, Clearmax (Beyond + MCPA)	Downy brome Spiny sowthistle	OR WA
*imazapic			Plateau			
*imazapyr			Arsenal, Chopper, several others			
*imazethapyr			Pursuit	Prickly lettuce Kochia Spiny sowthistle Black mustard Mayweed chamomile	ID ID ID ID ID	
sulfonyleureas			*chlorsulfuron	Glean, Telar	Prickly lettuce Kochia Russian thistle Italian ryegrass Mayweed chamomile Smallseed falseflax	ID, OR, WA ID, OR, WA ID, OR, WA OR ID, WA OR
			*chlorsulfuron/metsulfuron	Finesse	Smallseed falseflax	OR
			*ethametsulfuron	Muster		
			*halosulfuron	Sandea		
			mesosulfuron	Osprey	Italian ryegrass	ID
			mesosulfuron/propoxycarbazone	Olympus Flex		
			*metsulfuron	Ally, Escort, Cimarron	Prickly lettuce Kochia Russian thistle Smallseed falseflax	ID, OR OR OR OR
			*nicosulfuron	Accent		
			*primisulfuron	Beacon	Downy brome	OR
		*prosulfuron	Peak			
		*rimsulfuron	Matrix			
		*sulfometuron	Oust, Spyder			
		*sulfosulfuron	Maverick, Outrider, Certainty	Downy brome	OR	
		thifensulfuron	Harmony	Spiny sowthistle Prickly lettuce Mayweed chamomile	WA ID ID	
		thifensulfuron/tribenuron	Harmony Extra, Affinity			
*thifensulfuron/tribenuron/metsulfuron		Canvas				
*triasulfuron		Amber	Prickly lettuce Kochia Russian thistle Italian ryegrass	ID, OR OR OR ID		
tribenuron		Express	Prickly lettuce Mayweed chamomile	ID ID		
*triflurosulfuron		UpBeet				
sulfonylamino-carbonyl-triazolinones		flucarbazone	Everest	Italian ryegrass	ID	
		propoxycarbazone	Olympus			
triazolo-pyrimidines		florasulam	Orion (contains MCPA) - Registration pending			
<b>Group 3</b> Microtubule assembly inhibitors		dinitroanilines	*benefin	Balan		
			*ethalfluralin	Sonalan, Curbit		
	*oryzalin		Surflan			
	*pendimethalin		Prowl H <sub>2</sub> O, Pendulum, several others			
	*prodiamine		Barricade, Endurance, several others			
	*trifluralin	Treflan, Trust				
benzamides	*pronamide	Kerb	Wild oat	OR		
<b>Group 4</b> Synthetic auxins	phenoxyacetic acids	2,4-D	several			
		2,4-DB	several			
		MCP	several			
		mecoprop (MCPP)	several			
	benzoic acids	*dicamba	Banvel, Clarity, several others	Kochia	ID	
	pyridines	*aminopyralid	Milestone			
		*clopyralid	Stinger, Transline, ClopyrAg			
		*fluroxypyr	Starane, Vista, Spotlight			

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Herbicide group number and site of action	Herbicide chemical family	Herbicide common name	Herbicide trade names	Resistant weeds in the PNW	States with resistant weeds
<b>Group 4, continued</b>	pyridines, cont.	*picloram	Tordon K, Tordon 22K	Yellow starthistle	WA
		*triclopyr	Garlon, Remedy, Renovate		
	quinoline carboxylic acids	*quinclorac	Paramount, Drive		
<b>Group 5</b> Photosystem II inhibitors	triazines	*atrazine	AAtrex	Common lambsquarters Pigweed spp. Common groundsel Annual bluegrass Kochia	ID, OR, WA ID OR, WA OR ID
		*simazine	Princep, Simazine	Common groundsel	WA
		*hexazinone	Velpar, Pronone		
		*metribuzin	Sencor, Metri DF		
		*bromacil	Hyvar X, Hyvar X-L	Common groundsel Pigweed spp. Common lambsquarters	OR OR, WA OR
	triazinones	*terbacil	Sinbar		
	uracils				
	<b>Group 6</b> Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	benzothia-diazoles	bentazon	Basagran	
nitriles		bromoxynil	Buctril, Bromox, Bronate (contains MCPA), several others	Common groundsel	OR
<b>Group 7</b> Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)	ureas	*diuron	Karmex, Direx	Common lambsquarters Annual bluegrass	OR OR
		*linuron	Lorox, Linex		
		*tebuthiuron	Spike		
<b>Group 8</b> Lipid synthesis inhibitors but not ACCase inhibitors	thiocarbamates	butylate	Sutan, Sutan+ (contains safener)		
		cycloate	Ro-Neet		
		EPTC	Eptam		
		EPTC + safener	Eradicane		
		triallate	Far-Go	Wild oat	ID
<b>Group 9</b> EPSP synthase inhibitors	glycines	glyphosate	Roundup, several others	Italian ryegrass	OR
<b>Group 10</b> Glutamine synthase inhibitors	phosphinic acids	glufosinate	Rely, Liberty, several others		
<b>Group 14</b> Inhibitors of protoporphyrinogen oxidase (Protox)	diphenylethers	*oxyfluorfen	Goal, several others		
		N-phenyl-phthalimides	flumiclorac	Resource	
		*flumioxazin	Chateau, Valor, SureGuard		
	triazinones	carfentrazone	Aim, several others		
		*sulfentrazone	Spartan, Portfolio		
phenylpyrazole	pyraflufen	ET, Edict			
<b>Group 15</b> Inhibitors of very-long-chain fatty acid synthesis	chloroacet-amides	acetochlor	Harness, Surpass, several others		
		alachlor	MicroTech, several others		
		dimethenamid(-p)	Outlook		
		metolachlor	Stalwart, several others		
		s-metolachlor	Dual Magnum, Dual II Magnum		
	oxyacetamides	flufenacet	Define, Axiom (contains metribuzin)	Italian ryegrass	ID, OR
	acetamides	napropamide	Devrinol		
<b>Group 16</b> Unknown	benzofuranes	ethofumesate	Nortron, several others	Annual bluegrass	OR
<b>Group 17</b> Unknown	organo-arsenicals	MSMA	several		
<b>Group 20</b> Inhibitors of cell wall synthesis site A	nitriles	*dichlobenil	Casoron, Barrier		
<b>Group 22</b> Photosystem I electron diverters	bipyridiliums	diquat	Reglone, Reward		
		paraquat	Gramoxone Inteon, several others		
<b>Group 26</b> Unknown	pyrazoliums	difenzoquat	Avenge	Wild oat	ID
	carboxylic acids	pelargonic acid	Scythe		
<b>Group 28</b> Inhibitors of 4-HPPD**	isoxazoles	pyrasulfotole	Huskie (contains bromoxynil)		
	triketones	mesotrione	Callisto		
		topramezone	Impact		
		** 4-hydroxyphenylpyruvatedioxygenase			