PNW 437

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 application is the inherited ability of a plant to survive a herbicide application to which the wild-type was susceptible. Resistant plants occur naturally within a population and differ slightly in genetic makeup but remain reproductively compatible with the wild-type.

Herbicide-resistant plants are present in a population in extremely small numbers. The repeated use of one herbicide 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 the weed.

Resistant plants likely will persist in infested fields for many years, even in the absence of any additional selection with the herbicide. There is no evidence that herbicides cause the genetic mutations that lead to herbicide resistance.

Resistant plants may be resistant to other herbicides (imidazolinones as well as sulfonylureas, for example) that kill plants in the same way (same site of action, or same group). This is called *cross-resistance*.

Weeds can also be resistant to herbicides with different sites of action (aryloxyphenoxy propanoates as well as sulfonylureas, for example). In Australia a biotype of annual ryegrass is resistant to at least five different herbicide groups. This is called *multiple resistance*.

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

The first identified herbicide-resistant weed, spreading dayflower (*Commelina diffusa*), which is resistant to 2,4-D, was identified in 1957 in a sugarcane field in Hawaii. Since then, more than 200 weeds resistant to one or more herbicides have been identified worldwide. Current information on the status of herbicide-resistant weeds can be found at http://WeedScience.org/in.asp

Herbicide-resistant weeds are now common in the Pacific Northwest:

- Kochia, prickly lettuce, and Russian thistle resistant to sulfonylurea herbicides (Glean, Amber, Ally, and other group 2 inhibitors)
- Wild oat and Italian ryegrass resistant to Hoelon and other group 1 (ACCase) inhibitors
- Powell amaranth resistant to triazines and other group 5 inhibitors
- Yellow starthistle resistant to Tordon and other group 4 inhibitors
- Wild oat resistant to Fargo and Avenge

The appearance of herbicide-resistant weeds is strongly linked to repeated use of the same herbicide or herbicides with the same site of action in a monoculture cropping system (for example, wheat after wheat) or in noncrop areas (railway or road rights-of-way, etc.). To manage herbicides to delay and prevent the appearance of herbicide-resistant weeds, you must know in which chemical family a herbicide belongs *and* which herbicides have the same site of action.

The table inside lists herbicides by group number and site of action, chemical family, common name, and trade name and gives examples of resistant weeds. The table is color coded so that different herbicide families that have the same site of action are the same color and group number.

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This publication contains the

Herbicide Rotation

Reference Poster

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tance, do not use herbicides from the same color or group more than once within three years.

Tank-mixing herbicides is not an effective resistance management strategy. If herbicides in the tank mixture control different weed species and have different soil residual characteristics, resistant weed biotypes will continue to be selected.

For example if a long-residual (Glean) and a short-residual (2,4-D) herbicide are tank-mixed, both herbicides may control emerged broadleaf weeds. However, Glean will continue to control weeds throughout the growing season and could continue to select for resistant plants. Tank-mix only when a herbicide combination is required to control the weed spectrum or will result in reduced herbicide use rates. Tank-mixing for other reasons is not economically or ecologically sound.

Management practices can be used to prevent or delay the appearance of herbicide-resistant weeds. The following list of practices can be used along with the information on herbicide families provided in the table to form a herbicide resistance management strategy.

Preventing herbicide-resistant weeds

Herbicide rotation—Avoid year-after-year use of herbicides that have the same site of action. At one time this meant not using herbicides from the same chemical family, but this is no longer the case. For example, two chemically different groups of herbicides, the sulfonylureas and imidazolinones, have the same site of action. For another example, Hoelon and Poast belong to different chemical families but kill susceptible grasses in the same way.

Short-residual herbicides—Using herbicides that do not persist in soil for long time periods and are not applied repeatedly within a growing season reduces the selection of herbicide-resistant weeds. However, repeated applications within a growing season of a herbicide with no soil activity (e.g., Gramoxone) has resulted in weeds resistant to the herbicide.

Crop rotation—Because different crops may require different herbicides, rotating crops can increase herbicide rotation. But with the large number of sulfonylurea and imidazolinone herbicides available for use in many different crops, crop rotation alone may not be enough to avoid weed resistance to herbicides. This also is true for other herbicides with the same site of action.

Cultivation—In row crops, cultivation can be an effective tool for eliminating weed escapes that may represent the resistant population. Fallow tillage will control herbicide-resistant and herbicide-susceptible weeds equally as long as the seedlings of the two biotypes emerge at the same time. Do not use the same site-of-action herbicide in fallow as was used to control weeds in the crop.

Accurate record keeping—To have an effective herbicide rotation or tank-mix system to prevent resistance, you must know which herbicides have been used in the past, at what rate, and how often.

Clean seed—Plant certified seed to prevent the introduction of herbicide-resistant weed seeds.

Integrated weed management—This concept is important for all weed control, not just management of herbicide-resistant weeds. Integrated weed management uses all the tools available to control weeds, including cultural, mechanical, and chemical methods. An integrated approach to weed management, whether it is in crop or noncrop land, is an important environmental and economic consideration.

Dealing with herbicide-resistant weeds

Monitor fields for weed escapes—Weed escapes are not necessarily resistant, but they may be. A resistance problem may not be visible until 30 percent or more of the weeds are no longer controlled. Check to see if the escapes are only one species or a mixture of species. If there is a mixture, the problem is more likely related to environment or 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.

Keep weeds from spreading—Prevent known resistant weeds from flowering and producing seed. After using machinery in fields or areas with known or suspected infestations of herbicide-resistant weeds, thoroughly clean the equipment to reduce the spread of resistant weeds from one field or area to another. Always plant clean seed.

Change crops and tillage systems—Crop rotation and altered tillage practices can affect the weed populations. Alternating spring and winter crops means that the field will be tilled at different times each year. During one of the field preparation operations, resistant as well as susceptible weeds will be killed.

Change herbicide program—If weed resistance occurs, herbicides with other sites of action and other weed management practices must be used.

Recognizing herbicide-resistant weeds

Irregular patches of a single weed species in the field are an indicator of herbicide resistance, especially when:

1. There are no other apparent application problems.
2. Other weed species are controlled adequately.
3. There are no or minimal herbicide symptoms on the single weed species not controlled.
4. There has been a previous failure to control the same species in the same field with the same herbicide or a herbicide with the same site of action.
5. Records show repeated use of one herbicide or herbicides with the same site of action.

What to do if you suspect herbicide resistance

- Do not respray the field with the same herbicide.
- Report your suspicion to university research or extension personnel or to the extension educator in your county.
- Collect plants or seed that can be used to confirm resistance has developed.

Managing herbicide-resistant crops

Herbicide-resistant crops are a recently developed tool for the control of weeds. These crops are resistant to herbicides that are lethal to non-resistant varieties of the same crop species.

Crops resistant to specific herbicides have been developed through genetic engineering and through traditional selective breeding. Examples include Clearfield wheat, which was selected for resistance to imazamox, and Roundup Ready canola, which was genetically engineered to be resistant to glyphosate. Used properly, herbicide-resistant crops can be valuable tools to manage difficult weeds, but they also have two inherent risks that need to be considered prior to planting: the emergence in subsequent growing seasons of herbicide-resistant volunteers and the potential for herbicide-resistant crops to cross with weedy relatives.

Volunteer herbicide-resistant crops as weeds—Consider whether the herbicide-resistant crop typically occurs as a volunteer crop in years following its cultivation, and, if so, whether herbicide options are available in the crop rotation to remove herbicide-resistant volunteers. For example, glyphosate 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 would be required to control the glyphosate-resistant volunteers. Growers should evaluate the impacts on their operation of using these other herbicides or nonchemical control measures. Impacts could be increased cost, increased soil erosion or moisture loss due to increased tillage, or other factors.

Volunteer crops are 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 crop.

Gene flow from herbicide-resistant crops to weedy relatives—Although rarely, the trait that confers herbicide resistance in the crop can move into weedy relatives through cross-pollination, resulting in a herbicide-resistant weed. Consider nearby weedy and native relatives of the herbicide-resistant crop 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. But a crop such as Roundup Ready, Clearfield, or Liberty Link canola could pollinate nearby herbicide-susceptible canola as well as weedy relatives of canola, resulting in volunteer canola plants or weeds that may be resistant to several herbicide families.

Crops that may pose problems—Herbicide-resistant crops at risk for gene flow or volunteer management problems would include some or all of the following traits:

- The crop cross-pollinates with nearby relatives that are problem weeds or with other crops.
- Crop seed shatters or vegetative propagules are left in the ground after harvest, resulting in volunteer crops in subsequent years, for example, with canola or potato.
- Herbicides for managing volunteer crops are limited to ones in the same family to which the crop is resistant.
- Crop seed remains viable in the soil for several cropping seasons.
- Use of the herbicide-resistant crop increases your reliance on herbicide families that would be applied multiple times per season or several times during a cropping system.

The authors—Carol Mallory-Smith, George R. Hyslop Professor, Oregon State University; Donn Thill, Professor of Weed Science, University of Idaho; Jed Colquhoun, Extension Weed Specialist, Oregon State University; Don Morishita, Extension Weed Scientist, University of Idaho.

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Herbicide Rotation

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.

Group number and site of action[1]	Chemical family	Common name[2]	Trade name(s)	Resistant weeds in the PNW	States with resistant weeds
Group 1 Acetyl CoA carboxylase (ACCase) inhibitors	cyclohexanediones	clethodim	Prism, Select		
		tralkoxydim	Achieve		
		sethoxydim	Poast		
	aryloxyphenoxy propanoates	diclofop	Hoelon	Italian ryegrass Wild oat	ID, OR, WA ID, OR, WA
		clodinafop	Discover		
		fenoxaprop	Puma, Tiller, Whip, Acclaim	Wild oat	ID, OR
		fluazifop	Fusilade DX		
		quizalofop	Assure II		
Group 2 Acetolactate synthase (ALS) inhibitors	imidazolinones	*imazamethabenz	Assert		
		*imazapic	Plateau		
		*imazapyr	Arsenal		
		*imazethapyr	Pursuit	Prickly lettuce Kochia	ID ID
		*imazamox	Raptor, Beyond		
	sulfonylureas	*chlorsulfuron	Glean, Telar	Prickly lettuce Kochia Russian thistle Italian ryegrass Mayweed chamomile	ID, OR, WA ID, OR, WA ID, OR, WA OR ID, WA
		*chlorsulfuron/ metsulfuron	Finesse	Smallseed falseflax	OR
		*metsulfuron	Ally, Escort	Prickly lettuce	ID
		*ethametsulfuron	Muster		
		thifensulfuron	Harmony		
		tribenuron	Express		
		thifensulfuron/ tribenuron	Harmony Extra		
		*thifensulfuron/ tribenuron/ metsulfuron	Canvas		
		*halosulfuron	Permit		
		*nicosulfuron	Accent		
		*primisulfuron	Beacon	Downy brome	OR
		*prosulfuron	Peak		
		*triasulfuron	Amber		
		*rimsulfuron	Matrix		
		*triflusulfuron	UpBeet		
		*sulfometuron	Oust		
		*sulfosulfuron	Maverick	Downy brome	OR
	pyrimidinylthiobenzoates	pyrithiobac	Staple		
	sulfonylaminocarbonyl-triazolinone	flucarbazone	Everest		
		propoxycarbazone	Olympus		
	triazolopyrimidines	flumetsulam	Broadstrike		
Group 3 Microtubule assembly inhibitors	dinitroanalines	*trifluralin	Treflan		
		*ethalfluralin	Sonalan		
		*pendimethalin	Prowl		
		benefin	Balan		
		oryzalin	Surflan		
	benzamides	pronamide	Kerb		
Group 4 Synthetic auxins	phenoxy acetic acids	2,4-D	several		
		2,4-DB	several		
		MCP	several		
		mecoprop	several		
	benzoic acid	*dicamba	Banvel, Clarity	Kochia	ID
	pyridines	*picloram	Tordon	Yellow starthistle	WA
		*clopyralid	Stinger		
		*fluroxypyr	Starane		
		*triclopyr	Garlon		
	quinoline carboxylic acid	*quinclorac	Paramount		
Group 5 Photosystem II inhibitors	triazines	*atrazine	Aatrex	Common lambsquarters Pigweed (8 species) Common groundsel Annual bluegrass Kochia	ID, OR, WA ID WA, OR OR ID
		*cyanazine	Bladex		
		*simazine	Princep	Common groundsel	WA
		*hexazinone	Velpar		
		*metribuzin	Lexone, Sencor		
	uracils	*terbacil	Sinbar	Common groundsel Pigweed spp. Common lambsquarters	OR OR, WA OR
		*bromacil	Hyvar		
Group 6 Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	benzothiadiazoles	bentazon	Basagran		
	nitriles	bromoxynil	Buctril	Common groundsel	OR
	phenylpyridazines	pyridate	Tough		
Group 7 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		
		*tebuthiuron	Spike		
Group 8 Lipid synthesis inhibitors, but not ACCase inhibitors	thiocarbamates	EPTC	Eptam		
		EPTC + safener	Eradicane		
		butylate	Sutan		
		cycloate	Ro-Neet		
		triallate	Far-Go	Wild oat	ID
Unknown site of action	no family name	difenzoquat	Avenge	Wild oat	ID
Group 9 EPSP synthase inhibitors	no family name	glyphosate	Roundup, Touchdown IQ, Rodeo, several others		
Group 10 Glutamine synthase inhibitors	phosphinic acid	glufosinate	Rely, Liberty		
Group 15 Unknown site of action	chloroacetamides	acetochlor	Harness, Surpass		
		alachlor	Lasso		
		dimethenamid	Frontier, Outlook		
		metolachlor	Dual		
		propachlor	Ramrod		
	oxyacetamides	flufenacet	Axiom (also contains metribuzin), Define		
	acetamides	napropamide	Devrinol		
Group 16 Lipid synthesis inhibitors	benzofuranes	ethofumesate	Nortron	Annual bluegrass	OR
Group 22 Photosystem I electron diverters	bipyridiliums	paraquat	Gramoxone Extra, Boa		
		diquat	Diquat		

[1]Herbicide classification according to primary site of action. [2]*Indicates herbicides that can persist in soil for most of the growing season or from one growing season to the next.