PNW 571

Plantback restrictions for herbicides used in the dryland wheat production areas of the Pacific Northwest

By Bradley D. Hanson, Traci A. Rauch, and Donald C. Thill

Consider soil persistence characteristics of herbicides when planning crop and herbicide rotations to maximize economic yield and minimize rotational crop injury.

Selective or non-selective herbicides are applied at least once each year to the majority of all wheat, barley, canola, mustard, pea, lentil, and fallow acres in dryland wheat production areas of the Pacific Northwest. Ideally, soil-active herbicides control weeds during the growing season of the treated crop and dissipate to a non-toxic level before the next crop is seeded. However, they potentially can carry over and injure subsequently planted crops.

Dissipation rate, soil persistence, and hence the potential for carryover injury to subsequently seeded crops are carefully researched before a new herbicide is labeled or before an existing herbicide is labeled for a new crop. Herbicides containing an active ingredient that can persist in the soil usually have a section on the product label detailing specific rotational crop (plantback) restrictions. These restrictions often are relatively simple guidelines expressing how much time must pass between herbicide application and the seeding of a sensitive crop, but they also can include specific rainfall or tillage requirements, requirements for different pH soils, and application rate restrictions.

This bulletin condenses rotational crop restrictions from herbicide labels into one table and discusses important factors affecting herbicide dissipation in the soil environment. For specific rotational crop restrictions for currently labeled herbicides used in dryland winter wheat production areas of the Pacific Northwest, please refer to the table that starts on page 2 and the herbicide product label.

Herbicide Classification: Site of Action

The potential for rotational crop injury depends on complex interactions among herbicide characteristics, soil type, soil moisture and temperature, and the sensitivity of the rotational crops. Because herbicides with the same site of action often have similar persistence characteristics, the rotational crop restrictions discussed in this bulletin are arranged by site of action and chemical family. (See PNW 437, *Herbicide-Resistant Weeds and Their Management.*)

Herbicide site of action refers to the specific way that susceptible plants are affected by the herbicide. Herbicides with the same site-of-action group disrupt the same biochemical process in plants. A site-of-action group may, however, consist of several structurally diverse chemical families. For example, the group 2 herbicides, which include sulfonylureas, imidazolinones, and others, all inhibit the enzyme acetolactate synthase (ALS). An understanding of site-of-action classification is very important in developing herbicide rotations to minimize injury to rotational crops and to minimize selection for herbicide-resistant weeds. For more information on herbicide-resistant weeds and their management, see PNW 437.

Herbicide Dissipation and Half-life

Dissipation includes all possible fates of an herbicide once it enters the environment. Two basic processes affect the rate of herbicide dissipation after application, *transfer* and *degradation*. *Transfer* processes change the location or availability of the herbicide without changing its chemical structure or properties. Transfer processes include spray drift at application, volatilization, adsorption to soil, leaching through soil, surface erosion, and plant or animal uptake and removal from the site. *Degradation* processes change the chemical structure and properties of the herbicide, making it less toxic to plants. They include photo-

This publication contains the
Plantback Restrictions
reference table

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Plantback restrictions for herbicides used in the dryland wheat production areas of the Pacific Northwest

Group number, site of action, and chemical family	Trade name	Common name	Rotational crop[1]	Special conditions	Plantback restrictions in OR, WA, ID
Group 1 Acetyl CoA carboxylase (ACCase) inhibitors					
cyclohexanediones	Achieve	tralkoxydim	wheat, barley		30 days
			pea, lentil, chickpea, canola, mustard		106 days
	Hoelon	diclofop	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction
	Poast	sethoxydim	pea, lentil, chickpea, canola		no restriction
			wheat, barley, chickpea, mustard		120 days
	Puma 1EC	fenoxaprop	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction
	Select	clethodim	canola, mustard		no restriction
			wheat, barley, pea, lentil, chickpea		30 days
aryloxyphenoxy propanoates	Assure II	quizalofop	pea, lentil, canola		no restriction
			wheat, barley, mustard		120 days
	Discover	clodinafop	wheat		no restriction
			barley, pea, lentil, chickpea, canola, mustard		30 days
Group 2 Acetolactate synthase (ALS) inhibitors					
imidazolinones	Assert	imazamethabenz	wheat, barley		next season
			pea, lentil, chickpea, canola, mustard		15 months
	Pursuit WDG	imazethapyr	pea, lentil, chickpea		no restriction
			wheat, barley		4 months
			canola, mustard		40 months and field bioassay
	Pursuit Plus EC	imazethapyr + pendimethalin	wheat, pea, lentil, chickpea		4 months
			barley		9.5 months
			canola, mustard		40 months and field bioassay
	Beyond	imazamox	wheat (Clearfield), pea, lentil, chickpea, canola (Clearfield)		no restriction
			wheat (non-Clearfield)		3 months
			barley	pH 6.2 or higher AND more than 18 in. precip.	9 months
			barley	pH 6.2 or lower OR less than 18 in. precip. with plow	9 months
			barley	pH 6.2 or lower OR less than 18 in. precip. with no plow	18 months
			canola (non-Clearfield), mustard		26 months
sulfonylamino-carbonyltriazolinones	Everest	flucarbazone-sodium	wheat		4 months
			barley, canola		9 months
			pea		11 months
			lentil, mustard		24 months
			chickpea		not specified
sulfonylureas	Ally XP	metsulfuron	wheat (except durum)	pH 7.9 or lower	1 month
			durum wheat, barley	pH 7.9 or lower	10 months
			pea, lentil, canola	pH 6.8 or lower AND more than 18 in. precip.	10 months
			pea	pH 6.9 to 7.9 AND more than 18 in. precip.	15 months
			lentil	pH 6.9 to 7.9 AND more than 18 in. precip.	34 months
			canola	pH 6.9 to 7.9 AND more than 18 in. precip.	22 months
			mustard	more than 28 in. precip.	34 months
	Amber Custom Pak	triasulfuron	wheat (except durum)		no restriction
			durum wheat		8 months
			barley	pH 6.9 or less	6 months
			barley	pH 7.0 or higher	18 months
			pea, lentil, chickpea, canola, mustard		4 months and field bioassay

Canvas	thifensulfuron + tribenuron + metsulfuron	wheat (except durum)	pH 7.9 or lower	1 month
		durum wheat, barley	pH 7.9 or lower	10 months
		pea, lentil, canola	pH 6.8 or lower AND more than 18 in. precip.	10 months
		pea	pH 6.9 to 7.9 AND more than 18 in. precip.	15 months
		lentil	pH 6.9 to 7.9 AND more than 18 in. precip.	34 months
		canola	pH 6.9 to 7.9 AND more than 18 in. precip.	22 months
		mustard	more than 28 in. precip.	34 months
		*all crops	* if drought conditions prevail between application and seeding rotational crops, extend all restrictions by 1 crop season	
Express XP	tribenuron	wheat, barley		no restriction
		pea, lentil, chickpea, mustard		45 days
		canola, winter rapeseed		60 days
Finesse	chlorsulfuron + metsulfuron	**rates of 2/10 to 4/10 oz/A**		
		wheat (except durum)		no restriction
		barley, durum wheat	pH 6.5 or lower	10 months
		barley, durum wheat	pH 6.6 to 7.9	16 months
		pea	pH 6.5 or lower AND more than 35 in. precip.	24 months
		lentil	pH 6.5 or lower AND more than 50 in. precip.	36 months
		pea, lentil	pH 6.6 or higher	field bioassay
		canola, mustard, chickpea		field bioassay
		rates above 4/10 oz/A		
		all crops		field bioassay
Glean	chlorsulfuron	wheat	pH 7.6 or lower	no restriction
		wheat	pH 7.6 to 7.9	4 months
		barley	pH 6.5 or lower	10 months
		barley	pH 6.6 to 7.5	16 months
		barley	pH 7.6 to 7.9	24 months
		pea	pH 6.5 or lower AND more than 35 in. precip.	24 months
		lentil	pH 6.5 or lower AND more than 50 in. precip.	36 months
		pea, lentil	pH above 6.5	field bioassay
		chickpea, canola, mustard		field bioassay
Harmony Extra XP	thifensulfuron + tribenuron	wheat, barley		no restriction
		pea, lentil, chickpea, mustard		45 days
		canola, winter rapeseed		60 days
Harmony GT XP	thifensulfuron	wheat, barley		no restriction
		pea, lentil, chickpea, canola, mustard		45 days
Maverick	sulfosulfuron	wheat		no restriction
		barley, canola, lentil	pH less than 7.5 AND more than 24 in. precip.	22 months
		barley, canola, lentil	pH 7.5 or higher OR less than 24 in. precip	field bioassay
		pea, chickpea	pH less than 6.5 AND more than 30 in. precip.	17 months
		pea, chickpea	pH 6.5 or higher AND more than 24 in. precip.	22 months
		mustard		field bioassay
Muster	ethametsulfuron	spring wheat, durum wheat, barley		10 months
		pea, lentil, canola, mustard		22 months
		chickpea		22 months and field bioassy
Peak CustomPak	prosulfuron	wheat, barley	pH 7.2 or lower	no restriction
		pea	pH 7.2 or lower AND applied before July 1 previous yr.	10 months
		lentil, chickpea, canola, mustard	pH 7.2 or lower AND applied before June 15 previous yr.	10 months
		all crops	all other situations	field bioassay
Rave	triasulfuron + dicamba	wheat (except durum)		12 days
		durum wheat		8 months
		barley	pH 6.9 or lower	6 months
		barley	pH above 6.9	18 months
		pea, lentil, chickpea, canola, mustard		4 months and field bioassay

Group number, site of action, and chemical family	Trade name	Common name	Rotational crop [1]	Special conditions	Plantback restrictions in OR, WA, ID
Group 3 **Microtubule assembly inhibitors**					
dinitroanalines	Prowl 3.3 EC	pendimethalin	winter wheat	Prowl rate less than 4.8 pt/A	4 months
			winter wheat	Prowl rate 4.8 pt/A or higher	next season
			barley, pea, lentil, chickpea, canola, mustard		next season
	Sonalan HFP	ethalfluralin	winter wheat, winter barley		no restriction; however, injury may occur if seed is planted 4 months after application under dry conditions
			spring wheat, spring barley, pea, lentil, chickpea, canola, mustard		no restriction
	Treflan HFP	trifluralin	winter wheat, winter barley		no restriction; however, injury may occur if seed is planted into treated zone
			spring wheat, spring barley, pea, lentil, chickpea, canola, mustard		no restriction
Group 4 **Synthetic auxins**					
phenoxyacetic acids	2,4-D LV4	2,4-D	wheat, barley, pea, lentil, chickpea, canola, mustard	1 to 6 pt/A applied in fallow	3 months
	Landmaster BW	2,4-D + glyphosate	wheat, barley		no restriction
			pea, lentil, chickpea, canola, mustard		3 months
	MCPA Amine	MCPA	wheat, barley, pea, lentil, chickpea, canola, mustard	6 pt/A applied in fallow	3 months
	Thistrol	MCPB	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction
benzoic acids	Clarity	dicamba	wheat, barley	rates below 24 fl oz/A	22 days per 8 fl oz/A
			pea, lentil, chickpea, canola, mustard	rates below 24 fl oz/A	120 days
			wheat, barley	rates above 24 fl oz/A	45 days per 16 fl oz/A
			pea, lentil, chickpea, canola, mustard	rates above 24 fl oz/A AND annual precip. above 30 in.	120 days
			pea, lentil, chickpea, canola, mustard	rates above 24 fl oz/A AND annual precip. below 30 in.	180 days
	Weedmaster	2,4-D + dicamba	wheat, barley	rates below 6 pt/A	10 days per 1 pt/A
			pea, lentil, chickpea, canola, mustard	rates below 6 pt/A	120 days
			wheat, barley	rates above 6 pt/A	15 days per 1 pt/A
			pea, lentil, chickpea, canola, mustard	rates above 6 pt/A AND annual precip. above 30 in.	120 days
			pea, lentil, chickpea, canola, mustard	rates above 6 pt/A AND annual precip. below 30 in.	180 days
	Fallow Master	dicamba + glyphosate	wheat, barley		15 days
			pea, lentil, chickpea, canola, mustard		3 months
pyridines	Curtail	clopyralid + 2,4-D	wheat, barley		30 days
			canola, mustard		12 months
			pea, lentil, chickpea		18 months; field bioassay recommended for low organic matter soils and less than 15 in. precip.
	Curtail M	clopyralid + MCPA	wheat, barley		no restriction
			canola, mustard		12 months
			pea, lentil, chickpea		18 months; field bioassay recommended for low organic matter soils and less than 15 in. precip.
	Stinger	clopyralid	wheat, barley, canola		no restriction
			mustard		12 months
			pea, lentil		18 months
			chickpea		18 months; field bioassay recommended if less than 15 in. precip.

	Tordon 22K	picloram	wheat, barley	rates below 0.5 pt/A	45 days with soil temps above 40° F
			wheat, barley	rates between 0.5 and 1 pt/A	90 days with soil temps above 40° F
			pea, lentil, chickpea, canola, mustard		36 months or field bioassay
	Starane	fluroxypyr	wheat, barley		no restriction
			pea, lentil, chickpea, canola, mustard		120 days
quinolinecarboxylic acid	Paramount	quinclorac	wheat		no restriction
			barley, canola, mustard		10 months
			pea, lentil		24 months and field bioassay
Groups 5, 6, 7 Photosystem II inhibitors					
triazines	Sencor DF	metribuzin	wheat, barley	if following pea or lentil	4 months
			wheat, barley, pea, lentil		8 months
			chickpea, canola, mustard		12 months
benzothiadiazoles	Basagran	bentazon	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction
uracils	Bronate Advanced	bromoxynil + MCPA	wheat, barley, pea, lentil, chickpea, canola, mustard		30 days
	Buctril 4EC	bromoxynil	wheat, barley, pea, lentil, chickpea, canola, mustard		30 days
ureas	Karmex	diuron	winter wheat		no restriction
			spring wheat	if applied BEFORE Nov. 1 AND deep tillage	after April 1
			barley, pea, lentil, chickpea, canola, mustard		12 months
Group 9 Inhibitors of EPSP synthase					
	Roundup UltraMax	glyphosate	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction
Group 10 Inhibitors of glutamine synthase					
	Liberty	glufosinate	wheat, barley		70 days
			pea, lentil, chickpea, canola, mustard		120 days
Group 14 Inhibitors of protoporphyrinogen oxidase (PPO)					
aryl triazinones	Spartan	sulfentrazone	wheat, barley		4 months
			canola		24 months
			pea, lentil, chickpea, mustard		not specified
	Aim	carfentrazone	wheat, barley		no restriction
			pea, lentil, chickpea, canola, mustard		12 months
Group 15 Lipid synthesis inhibitors but not ACCase inhibitors					
chloracetamides	Dual II Magnum	metolachlor	pea, lentil, chickpea		no restriction
			wheat, barley		4.5 months
			canola, mustard		not specified
	Outlook	dimethenamid	winter wheat, winter barley		4 months
			spring wheat, spring barley, pea, lentil, chickpea, canola, mustard		no restriction
Group 22 Photosystem I inhibitors					
bipyridiliums	Gramoxone Extra	paraquat	wheat, barley, pea, lentil, chickpea, canola, mustard		no restriction

[1] Only considering wheat, barley, pea, lentil, chickpea, canola, and mustard crops in the Pacific Northwest dryland production area; other crop restrictions may apply.

chemical, microbial, and chemical degradation in soil or water and metabolism in plants or animals.

Herbicide dissipation in soil often is expressed in terms of *half-life*, that is, the amount of time required for one-half of the original amount of herbicide to dissipate (figure 1). For example, a herbicide with a half-life of 12 days would be expected to have dissipated to one-half the original amount 12 days after application, to one-fourth of the original amount 24 days after application, and so on. Half-life differs greatly among herbicides and can vary for the same herbicide in different soil types, temperatures, moisture levels, and pH levels.

Herbicides with a half-life of 120 days or more typically are classified as highly persistent; however, half-life does not address the sensitivity of subsequently planted crops. Some rotational crops may be sensitive to extremely small amounts of even low to moderately persistent herbicides. For example, the herbicide Pursuit typically has a half-life of 60 to 90 days; however, canola is very sensitive to Pursuit and should not be planted for at least 40 months after a Pursuit application (13 to 20 half-lives).

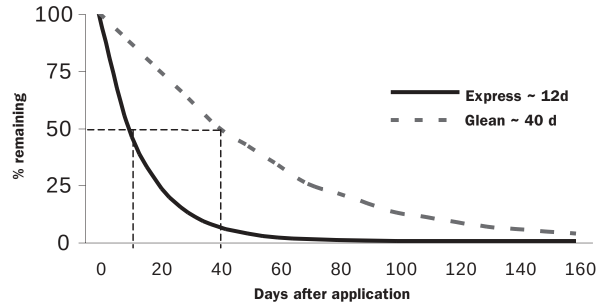

Figure 1. Generalized half-life of two sulfonylurea herbicides. Glean has a typical half-life of 40 days, while Express has a typical half-life of 12 days.

Herbicide Availability

Herbicides in soil usually exist in equilibrium among three phases: adsorbed to the surface of soil particles, in soil water, and, to a lesser extent, in soil air spaces. Different chemical properties of the herbicide and of the soil environment may shift this equilibrium toward one phase over the others. Herbicide adsorption to soil particles greatly affects most transfer and degradation processes. Generally, herbicides in soil water are biologically active; that is, available for plant uptake, transport in the environment, and microbial and chemical degradation. Herbicides bound (adsorbed) to soil particles are less available for transfer and degradation processes and may persist longer. Because adsorption to soil and degradation by chemical or microbial processes have the greatest impact on rotational crop safety, this bulletin focuses on these processes.

Soil factors affecting herbicide adsorption

Soil particle size distribution (relative percentages of sand, silt, and clay) plays an important role in herbicide adsorption. Soils with a higher percentage of clay particles have more surface area per volume of soil and often adsorb more herbicide molecules than more sandy soils. Also, some clay types have relatively more chemically reactive sites and therefore adsorb more herbicide. Sandy soils have relatively few reactive sites and are more prone to herbicide leaching out of the root zone.

The amount of organic matter (OM) in a soil also affects herbicide adsorption. Higher OM soils typically have more reactive sites for herbicide adsorption and can adsorb more herbicide molecules.

Soil pH interacts with the charge characteristics of various herbicides. Some herbicides bind to soil more at low pH, while others do at high pH.

Herbicide factors affecting adsorption

Very water-soluble herbicides such as Clarity are more likely to remain in soil water where they can be degraded, taken up by plants, or leached out of the system. Herbicides with low water solubility such as Prowl tend to be adsorbed to soil particles and often persist longer.

Charge characteristics of the herbicide also affect adsorption, with more positively charged herbicide molecules generally being more strongly adsorbed to negatively charged soil particles and negatively charged herbicide molecules remaining in the soil air or water phases. Gramoxone Extra so tightly binds to soil that it is unavailable for plant uptake or degradation. Charge characteristics of many herbicides such as the triazines, sulfonylureas, imidazolinones, and synthetic auxins are pH dependant.

Factors affecting chemical degradation

Chemical degradation generally involves splitting chemical bonds in the herbicide molecule. These reactions commonly take place in soil water or at the interface between water and soil particles. Soil moisture and temperature affect the rate and amount of chemical degradation. Warm, moist soils generally support much faster rates of degradation than cool, dry soils. Soil pH also can affect the chemical degradation rate of herbicides, depending upon the specific herbicide structure. For example, the sulfonylurea herbicides degrade much more slowly in alkaline soils than in more neutral or slightly acidic soils, while the imidazolinones degrade more slowly in acidic soils than in neutral or slightly alkaline soils.

Factors affecting microbial degradation

Bacteria and fungi in the soil use various enzymes to degrade complex molecules such as herbicides for use as nitrogen and carbon sources. Overall, microbial degradation is the most important mechanism for herbicide dissipation in soil. Microbial activity is the primary mechanism of degradation for each chemical family except for the sulfonylureas (low pH = chemical hydrolysis and microbial, high pH = microbial), the triazines (low pH = chemical hydrolysis, high pH = microbial), and the bipyridiliums (irreversibly bound to soil, very slow degradation).

Generally, environmental factors that encourage growth and reproduction of microbial populations such as warm soil temperature, adequate soil moisture, and high organic matter lead to higher rates of herbicide degradation. Conversely, cold or frozen soils, droughty soils, and low OM in soils often result in longer herbicide persistence. Extremely high or low soil pH also can reduce microbial activity and decrease degradation. As a general rule, soil moisture, temperature, and pH that are ideal for plant growth are also ideal for soil microbes and, hence, microbial degradation of herbicides.

Conclusion

The potential for rotational crop injury depends upon complex interactions among herbicide characteristics, soil type, seasonal differences in soil moisture and temperature, and the sensitivity of the rotational crops. The complexities of these interactions preclude all but a few generalizations. However, some herbicide families tend to have greater persistence due to their specific chemical properties. Also, some rotational crops commonly grown in the Pacific Northwest are more sensitive to herbicides than others.

Because herbicide dissipation rates can vary from year to year and even among areas within a field, injurious persistence of a particular herbicide can be difficult to predict. When considering the application of herbicides, it is very important to understand the effects that a persistent herbicide may have on all crops in the rotation.

Information on herbicide labels can be used to make better decisions about the crop sequence in a rotation, about which herbicides to use or avoid in a system, and about the rate and timing of herbicide applications. The rotational crop restrictions on herbicide labels take into account basic chemical properties of the herbicide, the half-life of the herbicide, typical environmental characteristics of the state or region, and the sensitivities of rotational crops. Thus, the label for each herbicide used in the crop rotation should be studied along with this bulletin to reduce economic losses due to herbicide carryover.

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Trade Names— To simplify information, trade names have been used. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

Pesticide Residues— Any recommendations for use are based on currently available labels for each pesticide listed. If followed carefully, residues should not exceed the established tolerances. To avoid excessive residues, follow label directions carefully with respect to rate, number of applications, and minimum interval between application and reentry or harvest.

Groundwater— To protect groundwater, when there is a choice of pesticides, the applicator should use the product least likely to leach.

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