Understanding Factors Affecting Residual Herbicide Recropping Restrictions

Residual herbicides are important weed management tools. Labels provide guidelines for recropping to sensitive crops. In a dry year, a soil residual herbicide may not break down over the summer, and unexpected residue may carryover injuring sensitive, and sometimes even more tolerant crops.

Growers should be extra cautious when planning crop rotations following dry years, especially in areas with rainfall of less than 150 millimetres (six inches) between June 1-September 1.

Factors That Influence Herbicide Carryover

The degradation of soil residual herbicides occurs over time. Some soil residual herbicides may have rapid initial degradation. This is why some medium tolerant crops can be grown relatively quickly after herbicide application. The degradation curve may slow down with some active ingredients, requiring a longer period of time before residues are low enough to grow sensitive crops. For example, clopyralid (Lontrel™) requires at least two years between application and seeding of a pulse crop. In dry years, degradation is even slower and can cause unexpected crop damage.

Herbicide residues in the soil are deactivated in various ways including:

- **Break down by soil microbes** (most common method of degradation)
- **Break down by chemical hydrolysis** (water breaks herbicide molecules into less active pieces)
- **Escape to the atmosphere as a gas** (volatilization)
- **Break down by light** (photo degradation)
- **Binding to soil particles**

Microbial degradation is responsible for the majority of herbicide breakdown. Soil moisture and temperature are by far the most important factors in microbial activity.

Moisture: Moisture is the most important factor impacting herbicide breakdown, with microbial activity highest under moist but not saturated soils. Under dry or drought conditions, herbicide breakdown by soil microbes is reduced and carryover into the next growing season can occur. Herbicide adsorption to soil particles may also be increased with dry conditions. Additionally, breakdown by chemical hydrolysis is slower when rainfall and soil moisture are limited during the growing season.

Temperature: Optimum soil microbial activity occurs in June, July, and August when soil temperatures are warm between 20-30°C. Outside of this time frame, little herbicide breakdown occurs from soil microbes with minimal breakdown below soil temperatures of 10°C. Herbicides that are broken down by chemical hydrolysis can also slow down as chemical reactions occur more slowly at lower temperatures.

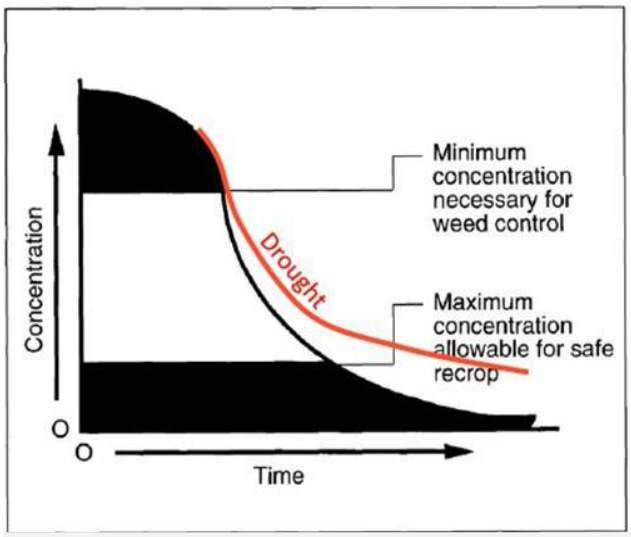

Figure 1. Herbicide Degredation Curve
Source: Adapted from Persistence of Herbicides in Soil. Penn State University.

Soil texture and organic matter: Herbicide degradation decreases as soil organic matter decreases, due to lower water holding capacity and less microbial activity. Soils with low clay content have decreased adsorption of residual herbicides, which increases the potential availability of the herbicide to sensitive plant roots when a significant rainfall occurs. Potential for injury on subsequent sensitive crops increases as organic matter and clay content decrease.

Soil pH. Chemical hydrolysis of residual herbicides within Groups 2, 5, 14, and 15 are influenced by soil pH.

- **Group 2 imidazolinones (IMI)** persist longer under acid (low pH) soil conditions, whereas sulfonylureas (SU) persist longer in high pH soils
- **Group 2 herbicide flucarbazone-sodium (Everest®)** has increased persistence under high pH of 8 or more
- **Group 5 triazines** degrade slower under high pH soils
- **Group 14 sulfentrazone (Authority®)** dissipates faster in high pH soils
- **Group 15 pyroxasulfone (found in Focus® + Zidua®)** dissipates faster in high pH soils

Degradation also varies across the field because soil texture, soil organic matter, pH, soil temperature, and soil moisture also vary across the field.

Recropping Restrictions Under Normal Environmental Conditions

The re-cropping restrictions for residual herbicides is the period of time between herbicide application and when a sensitive crop can be planted under normal environmental conditions. Under drier conditions when June 1 to September 1 rainfall is less than 150 mm, these recropping restrictions may need to be extended by another year and a more tolerant crop grown. Re-cropping restrictions for pulses and crops following pulses can be found in Tables 2 and 3.

Table 1. Soil Factors That Affect the Degradation of Some Residual Herbicides

Group No.	Herbicides	Mechanisms of Degradation	Rate of Degradation is Slowed When
2	Imazethapy, Imazamox, Imazamethabenz, Imazapyr	Microbial	Soil pH < 7.0 Drought
2	Metsulfuron	Microbial/Chemical hydrolysis	Soil pH > 7.0 Drought
2	Flucarbazone	Microbial	Soil pH > 8.0 Drought
3	Trifluralin, Ethafluralin	Microbial	Drought
4	Clopyralid	Microbial	Drought
4	Halauxifen	Microbial	Drought
4	Quinclorac	Microbial	Drought
14	sulfentrazone	Microbial	Drought Low soil pH
14	flumioxazin	Microbial	Drought
15	pyroxasulfone	Microbial	Drought Low soil pH
27	pyrasulfotole	Microbial	Drought

Source: Factors Affecting Herbicide Residue: Impact of a dry year. Eric Johnson, University of Saskatchewan.

Recropping Restrictions in Dry Years

Moisture after herbicide application is a critical factor in the degradation of soil residual herbicides. In years when rainfall is limited between June 1-September 1, herbicide degradation is slowed ,and unexpected herbicide carryover may occur and injure the following crop, even if the labeled recropping guideline is followed.

The Saskatchewan Ministry of Agriculture's *Herbicide Carryover Risk Map* is based on 2018 rainfall from June 5-September 3, 2018. In high risk areas that had little rainfall during this time period, little herbicide breakdown will have occurred. The Ministry's crop rotation recommendations based on rainfall are:

- **Normal risk areas (greater than 150 mm rainfall):** follow label directions to determine what crops may be planted following the application of a residual herbicide
- **Moderate risk areas (150-125 mm):** if soil also has low organic matter or soil pH less than 6.5 or greater than 7.5, contact the manufacturer of the residual herbicide
- **Extreme (less than 75 mm), very high (less than 100 mm), and high (less than 125 mm) risk areas:** contact the manufacturer of that residual herbicide for rotational crops supported by the company

Growers are also advised to use their own rainfall records since precipitation can vary dramatically over short distances.

Risk of Greater than Expected Herbicide Carryover

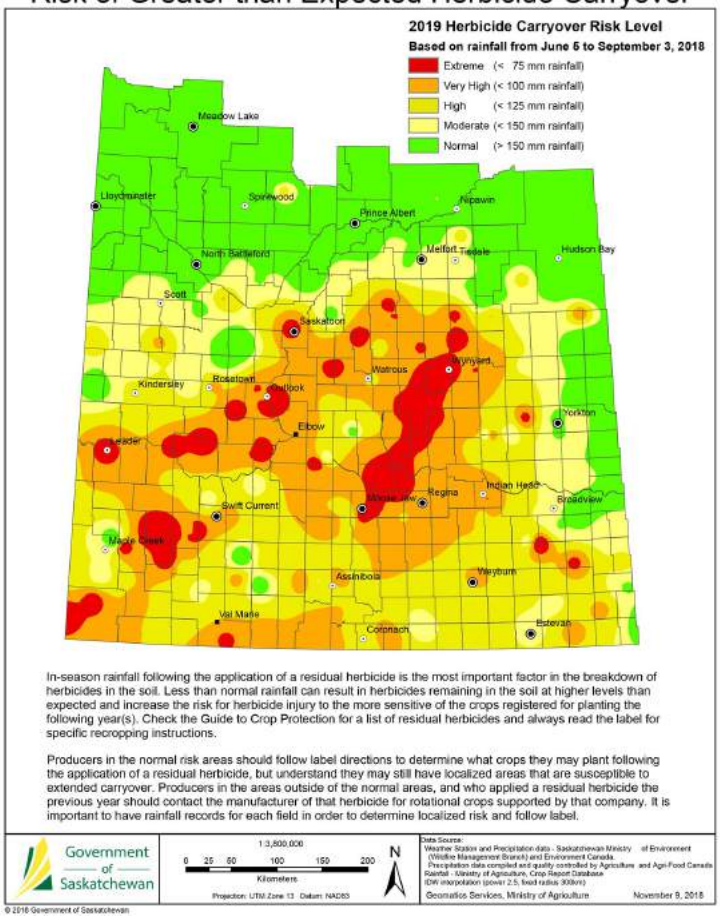

Table 2. Herbicide Recropping Restrictions Following Pulses

Product	Active ingredient(s)	Herbicide Group	Alfalfa	Barley	Canary seed	Clearfield canola	Clearfield canola	Field corn	Flax	Forage grasses	Mustard†	Oats	Potatoe	Rye	Sunflower	Wheat (durum)	Wheat (spring)	Wheat (winter)
Ares*	*imazamox + imazapyr*	2		1	1	1	2	1	2			1			2	2	1	4 mths
Authority/Authority Charge	*carfentrazone + sulfentrazone*	14	1	1	3	1	1	1	0	3	0	3	0	3	0	1	1	4 mths
Authority Supreme	*sulfentrazone + pyroxasulfone*	14 + 15	3	3	3	3	3	1	3	3	3	3	3	3	1	1	1	4 mths
Avadex	*triallate*	8	0	0	0	0	0		0		0	2				0	0	0
Dual II Magnum	*metolachlor*	15						1					1					4.5 mths
Edge	*ethalfluralin*	3	0		2	0	0			2	0	2			0	1	1	
Engenia, Oracle, Xtendimax	*dicamba**	4		0	0	1	1	0		0		0		0		0	0	0
Fierce	*flumioxazin + pyroxasulfone*	14 + 15	1^	1^	1^	1^	1^	7 days	1^	1^	1^	1^	1^	1^		1^	7 days	4 mont
Focus	*carfentrazone + pyroxasulfone*	14 + 15						0									0	0
Heat	*saflufenacil*	14	1	0	0	1	1	0	1		1	0	1	0	1	0	0	0
Heat Complete	*saflufenacil + pyroxasulfone*	14 + 15	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Imazethapyr	*imazethapyr*	2	1	1		0											1	
Metribuzin	*metribuzin*	5	0	0		2	2						1	1	2	1	1	1
Imazamox/imazethapyr, Odyssey Ultra NXT	*sethoxydim+ Imazamox + imazethapyr*	2; 1 + 2	1	1	1	1	2	1	2			1			2	1	1	
Permit	*halosulfuron*	2	9 mths	2 mths		2	2	1 mth		2 mths		2 mths	1	(fall) 2 mths	2	2 mths	2 mths	2 mths
Solo	*imazamox*	2	1	1	1	1	1	1	1		2	1			1	1	1	3 mths
Viper ADV	*imazamox + bentazon*	2 + 6	1	1	1	1	1	1	1		2	1			1	1	1	3 mths
Trifluralin	*trifluralin*	3	0	1	2	0	0	1	1	2	0	2		0	0	1	0	1
Valtera	*flumioxazin*	14	11 mths	11 mths	1^	11 mths	11 mths	7 days	1^	1^	1^	1^	1^	1^	1 mnth	1 mnth	7 days	4 mths
Zidua SC	*pyroxasulfone*	15		11 mths		1	1	1	1			11 mths				11 mths	1	4 mths

* The minimum re-cropping intervals are listed. These intervals may be longer than those listed depending on the use rates, region, province, soil types, environment, time of application, and crop variety.

Recropping Restriction Descriptions of Codes:

0 - Crop listed may be seeded or reseeded the year of application (No re-cropping restrictions)

1 - Crop listed may be seeded next cropping season after application

2 - Crop listed may be seeded two cropping seasons after application

NR - Not recommended

Shaded - no testing done. Contact manufacturer or distributor

† May not be valid for all varieties or crop types. See product page for details

^ Minimum one year plus a successful soil bioassay must be performed. Contact manufacturer or distributor for more information

Note: The re-cropping intervals listed may not be sufficient to prevent crop injury during periods of below average rainfall. If there is a lack of adequate or normal soil moisture due to drought conditions following an application.

Many products suggest increasing the crop interval listed in the table for one additional year and a representative bioassay of the field be conducted with the potential rotational crop.

This table provides guidelines for recropping following pulse herbicide products used. Please refer to manufacturer labels and recommendations for further information or clarity.

Products listed are considered applied as fall of previous year/pre-seed/pre-emerge or in-crop applications.

Source: Adapted from 2019 Saskatchewan Guide to Crop Protection and individual product labels.

Table 3. Herbicide Recropping Restrictions for Seeding Pulses

PRODUCT	Active Ingredient(s)	Herbicide Group	Faba Beans	Dry Beans	Field Peas	Lentils (non Clearfield)	Chickpeas	Soybeans
2,4-D*	*2,4-D*	*4*		1	1	1		
Accent	*nicosulfuron*	*2*		10 mths†	10 mths			10 mths
Ally Toss - N - Go	*metsulfuron*	*2*				3 - 4*		
Altitude FX2	*imazamox + fluroxypyr*	*2 + 4*			1	1		
Ares	*imazamox + imazapyr*	*2*			1	1*	1	
Attrex, Primextra II Magnum	*atrazine; s-metachlor + atrazine*	*5; 5+15*	1*		1*			
Authority/Authority Charge	*sulfentrazone; carfentrazone + sulfentrazone*	*14*	0		0	2	0	0
Authority Supreme	*sulfentrazone + pyroxasulfone*	*14 + 15*	3		0	3	0	0
Avadex	*triallate*	*8*	1	1	0	1	1	1
Barricade II, Predicade, Retain, Signal FSU, TraxosTwo	*Fluroxypyr + tribenuron+ thifensulfuron actives*	*4*		1	1	1		2
Command 360 ME	*clomazone*	*13*	2	1	1	1	2	1
Curtail M, Prestige XL, Eclipse III, Mpower Cobber, Salute, Spectrum; Lontrel, Lontrel XC, Pyralid	*clopyralid active ingredient components*	*4 +*	2	2	1*- 2	2	2	2
Dicamba*	*dicamba*	*4*		1*				1*
Dual II Magnum	*metolachlor*	*15*		0*†	0*†			0
Fierce	*flumioxazin + pyroxasulfone*	*14 + 15*			0	6 mths	0	0
Florasulam + fluroxypyr + MCPA, Outshine, Stellar, Stellar XL	*florasulam + fluroxypyr + MCPA*	*2 + 4*		1	1	1		1
Florasulam + glyphosate (prior to Aug 1), PrePass XC, PrePass Flex, Priority, MPower Kickoff, Blitz, FirstPass	*florasulam + glyphosate*	*2 + 9*		1	1	1	1	1
Florasulam + MCPA, Frontline XL, Topline, MPower Battlefront; florasulam + 2,4-D, Frontline 2,4-D, MPower Battlefront 2,4-D;	*florasulam + MCPA; florasulam + 2,4-D*	*2 + 4*	1	1*	1	1		1
Flucarbazone, Everest 3.0, Sierra 3.0; Everest GBX	*flucarbazone; flucarbazone + tribenuron methyl*	*2*		1-2*††	1*			
Fluroxypyr, fluroxypyr + 2,4-D, fluroxypyr + MCPA, Mpower Foxxy, Ukwin, Attain XC, Flurox-24, Rush 24, Rush M, Trophy, TraxosTwo, OcTTain XL	*fluroxypyr active ingredient component*	*2 +*		1	1	1		1
Focus	*carfentrazone + pyroxasulfone*	*14 + 15*				0*		0
Frontier Max, Outlook	*dimethanamid*	*15*		0*				
Imazamethabenz	*imazamethabenz*	*2*			1 - 2*			
Imazamox, Solo, Mizuna, Davai; Viper ADV	*imazamox; imazamox + bentazon*	*2; 2 + 6*	0		0	1	1	0
Imazethapyr	*imazethapyr*	*2*			0	1		
Imazamox/imazethapyr*, Duet, MPower Ninja; Odyssey Ultra NXT*	*imazamox + imazethapyr; imazamox + imazethapyr + sethoxydim*	*2 + 1*	0		1	1	1	1
Infinity (incl. FX)/Tundra/Velocity m3/Axial iPak/Axial Xtreme iPak	*pyrasulfotole active ingredient component*	*27*			1	2		1
Kerb	*propyzamide*	*15*	1	1	1	1	1	1
Korrex II	*florasulam + dicamba*	*2 + 4*		1	1	1	1	1
Muster Toss-N-Go	*ethametsulfuron*	*2*	2	2	2	2		
Option	*foramsulfuron*	*2*		1	1			1
Paradigm	*florasulam + halauxifen*	*2 + 4*		1	1	2		1
Permit	*halosulfuron*	*2*		0	1			1
Pixxaro, Rezuvant	*halauxifen + fluroxypyr + MCPA; halauxifen + fluroxypyr+ pinoxaden*	*4*		1	1	2		1
Prism	*rimsulfuron*	*2*	1	1	1	1	1	1
Pulsar	*dicamba + fluroxypyr*	*4*	2	2	1	1		2
Quinclorac, Facet, Clever, Ingenious, MasterLine Quinclorac	*quinclorac*	*4; 26*			1	2		
Rexade	*pyroxsulam + halauxifen + 2,4-D*	*2 + 4*			1	2		1
Simplicity	*pyroxsulam*	*2*		1	1	1	1	1
Tandem; Avenza; Tridem	*pyroxsulam + fluroxypyr; pinoxaden + fluroxypry + florasulam; pyroxsulam + floroxypyr + florasulam*	*2 + 4*		1	1	1		1
Travallas	*metsulfuron + thifensulfuron + fluroxypyr*	*2 + 4*	10 mths		10 mths	22 mths		10 mths
Tribenuron/Metsulfuron, Express Pro, MPower X-Pro	*tribenuron + metsulfuron*	*2*	10 mths		10 mths	10 mths		10 mths
Triton C*	*thifensulfuron + tribenuron + quinclorac*	*2 + 4*			1	1 - 2*		
Valtera (Crop uses)	*flumioxazin*	*14*	1	9 mths	0	6 mths	0	0
Varro	*thiencarbazone*	*2*		1	1	1	1	1

Refer to footnotes with Table 3. Use this table as a guideline only. Always refer to product manufacturer or label.
Adapted from the 2019 Guide to Crop Protection, published by Saskatchewan Ministry of Agriculture.

Herbicide Stacking in Successive Drought Years

Research has found that repeated use of Group 2 herbicides over successive years in a crop rotation can result in additional residue building up during dry years, and is known as herbicide stacking. Small amounts of different Group 2 residual herbicides accumulate over several growing seasons to contribute to injury of a sensitive crop. The research found that imazethapyr and sulfosulfuron (no longer available) had the most stacking. It is important to note that not all Group 2 herbicides have residual properties.

In theory, stacking can happen within any herbicide Group that has residual activity. Growers in areas where dry conditions have persisted for several years and who have been using residual herbicides in the same Group in rotation, should be especially cautious, and consider planting less sensitive crops until environmental conditions allow the breakdown of herbicide residues.

Another concern, although not true stacking, is in areas with two successive dry years where different Groups of residual herbicides have been applied. For example, if clopyralid (Group 4) was applied in 2017, and then followed up by Odyssey® (Group 2) in 2018 on field peas, not only is it likely that the field peas would have been injured by the clopyralid, but the recropping options in this case in 2019 could be restricted to Clearfield® canola or Clearfield® wheat.

Assessing Herbicide Residues In Soil

Soil samples can be collected and sent for chemical extraction analysis to help identify herbicide residues prior to seeding a crop. However, there is very low correlation between the concentrations of an active ingredient in a soil test with crop injury, because of the relative plant availability of those herbicides due to organic matter and clay content.

Plant bioassays can be conducted by growing a sensitive rotational crop in soil from a field with suspected residues and comparing to soil that was not treated with the herbicide. Growers can conduct their own plant bioassay using garden pots, but for more dependable results, labs such as A&L Labs in London, Ontario can conduct bioassays. However, because of field variability, the results of plant bioassays may not provide reliable recommendations.

An example of a plant bioassay is a mustard root length bioassay developed by Dr. Jeff Schoenau at the University of Saskatchewan, for detection of Group 2 residues. Oriental mustard is germinated and grown out in treated soils. The root lengths are measured after three days of growing in two-ounce Whirl-Pak bags. In soils free of ALS-inhibitor herbicides, root length is in the range of 7 cm plus/minus 1 cm. A root length of 6 cm or less in the ALS-inhibitor soils is considered to be indicative of herbicide residue.

Field sampling, though, can be a major source of error in each of these tests. If the soil sample is collected too deeply the soil is diluted, which increases the risk of a false negative. Samples should be drawn from the top two inches of soil

A field bioassay, planting a test strip to a sensitive crop, can also help to determine when herbicide residue has broken down enough to allow a more sensitive crop to be grown in subsequent years.

The best advice for growers in low rainfall situations following residual herbicide application is to assess their risk based on rainfall from June 1-September 1. Consult with agronomists and herbicide company representatives to determine the best rotational cropping options, which may be to plant a more tolerant crop the following year to minimize the risk of crop injury.