

Herbicide Soil Residues

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1. Introduction

Soil residual herbicides have been available to Western Canadian farmers for the past thirty years. Residual herbicides offer many advantages to growers. It is well documented that early weed removal is required to maximize crop yields and an early application of a residual herbicide eliminates the concern over late emerging weeds. Products such as trifluralin were very cost effective since they controlled weeds in an oilseed or pulse crop, plus provided control of wild oat and some broadleaf species in the follow-up cereal crop. However, severe drought over the past few years has resulted in a number of herbicide carryover concerns and raised producer awareness of potential problems.

Herbicide degradation is a very complex process which is highly unpredictable under the extreme environmental conditions of Western Canada. The lack of precise predictability is frustrating for farmers, but it is important that farmers understand the factors that affect the persistence of residual herbicides so they can plan rotational crops accordingly.

2. Factors Affecting Herbicide Persistence

It is important that farmers distinguish between the terms persistence and bioavailability. A herbicide may persist in the soil and may be detectable by chemical extraction; however, this does not necessarily mean that it is available to cause injury to sensitive crops. The herbicide paraquat has a relatively long half-life in the soil (estimated at about 1000 days) but is strongly adsorbed to soil colloids making it unavailable. A herbicide must be present in the soil solution in order for it to cause injury to sensitive rotational crops.

Environment has a major effect on the persistence of herbicides in Western Canada. Soil moisture and temperature are very important factors in determining the rate of pesticide breakdown. There are a number of mechanisms which determine the environmental fate of a herbicide such as volatilization, photolysis (breakdown from sunlight), leaching and others. However, the two primary mechanisms of herbicide degradation are microbial and chemical hydrolysis (splitting of a molecule with water). Both these processes are highly dependent on soil water and temperature. Soil microbes thrive in warm, moist soils, which results in faster degradation. It is estimated that there is a two to three-fold increase in chemical half-life with a 10 C decrease in temperature and a one and one-half to two-fold increase in chemical half-life if soil moisture content is reduced by a factor of two (Walker 1987).

The importance of growing season precipitation on herbicide breakdown is illustrated in Table 1. Odyssey residues may carry over and cause damage to canola two years after

application in dry, acidic soils common to the area around Scott. The level of canola injury was dependent on the amount of growing season precipitation received between the Odyssey application and the year the canola was grown. However, the amount of yield loss was also dependent on the amount of precipitation that the canola crop received during the growing season. In 1998, the years between Odyssey application and the rotational canola crop had below normal precipitation. The 1998 growing season precipitation was 47% of normal and the canola experienced a 77% yield loss. In 1999, the years between Odyssey application and canola were extremely dry (56% of normal) and extreme injury was recorded on the canola. However, the 1999 growing season had 127% of normal growing season precipitation and only a 30% yield loss was recorded. The years of 2000 and 2001 were generally wetter and the canola showed minor injury symptoms and did not experience any yield reductions from Odyssey carryover.

Table 1: Effect of growing season precipitation following Odyssey application on canola injury and yield two years after application. Scott Research Farm 1996-2001.

Year Odyssey Applied	Year Canola Seeded	Precipitation		Canola Visual injury (%)	Canola Yield loss (%)
		Time of Precipitation	% of long-term average		
1996	1998	Post-Odyssey application ^z	92%	46%	77%
		Growing season precipitation ^y	47%		
1997	1999	Post-Odyssey application ^z	56%	70%	30%
		Growing season precipitation ^y	127%		
1998	2000	Post-Odyssey application ^z	87%	<10%	0
		Growing season precipitation ^y	112%		
1999	2001	Post-Odyssey application ^z	120%	<10%	0
		Growing season precipitation ^y	88%		

^z Precipitation received in two growing seasons – the year of and the year following Odyssey application.

^y Precipitation received during the canola growing season.

Soil properties such as organic matter content, soil texture, and soil pH also play an important role in the carryover potential of residual herbicides. Generally, there are fewer problems with herbicide carryover when soil organic matter is high. It is the most important variable in controlling adsorption and the distribution of the herbicide between solid and solution phases (Walker 1987). Herbicide adsorption to organic matter may reduce its bioavailability. The moisture holding capacity of high organic matter soils makes them conducive for increased microbial activity. The importance of soil organic matter in reducing carryover potential has been shown in studies conducted on Sundance and Everest (Moyer and Hamman 2001; Eliason et al. 2002). The effect of clay content on herbicide residues is similar to organic matter in that it tends to adsorb the herbicide as well as improve water-holding capacity.

Soil pH is another factor affecting the residual characteristics of some herbicides. A low soil pH (less than 7.0) tends to increase the persistence of imidazolinone herbicides such

as Pursuit and Odyssey. The reason for the increased persistence is not well understood although it is known that the imidazolinone herbicides tend to be more adsorbed under acidic or low soil pH. It is thought that this increased absorption reduces its availability for microbial degradation (Loux and Reese 1992). Recent research suggests that the extended carryover in acidic soils may be related to their sorption-desorption characteristics. A higher level of Pursuit was sorbed at low soil pH than at high pH, but it was also more readily desorbed at a low soil pH (Bresnahan et al. 2000). Less Pursuit was sorbed initially at high soil pH, but it did not readily desorb. It was concluded that Pursuit was more desorbable and bioavailable in low pH soil, which resulted in injury to rotational canola and sugarbeet crops. Understanding the mechanism by which this group of herbicides persists is not critical for producers; however, it is important that growers know the pH of the soils they are farming. Sulfonylurea herbicides such as Ally, Amber, and Sundance react in the opposite manner to the imidazolinones. They are broken down primarily by chemical hydrolysis and this process occurs much quicker under acidic conditions. Therefore, they tend to degrade faster when soil pH is low. Soil factors that affect the persistence of residual herbicides are summarized in Table 2.

Table 2: Soil factors that effect the degradation of some residual herbicides

Group Name	Group Number	Herbicides	Mechanism of Degradation	Rate of Degradation is slowed when:
Imidazolinone	2	Pursuit Odyssey Assert	Microbial	Soil pH < 7.0 Drought
Sulfonylurea	2	Ally Muster Unity	Chemical Hydrolysis	Soil pH > 7.0 Drought
	2	Sundance	Hydrolysis, microbial	Soil organic matter <4% Soil pH > 7.0 Drought
Sulfonylamino carbonyltriazolinone	2	Everest	Microbial	Low soil organic matter Soil pH > 7.0 Drought
Triazolopyrimidine Sulfonamide	2	Frontline Pre-Pass	Microbial	Low soil temperature
Dinitroanilines	3	Treflan, Rival, Edge	Microbial	Drought
Pyridinecarboxylic acid	4	Lontrel Curtail-M Prestige	Microbial	Drought Low organic matter

Research conducted in the greenhouse has indicated that the residues of some Group 2 herbicides are additive (Moyer and Hamman 2001). However, the research has not been validated in the field and a number of questions have arisen over the repetitive application of different Group 2 herbicides. Is a crop predisposed to Group 2 injury if a residual Group 2 herbicide was applied the previous year? In other words, if Odyssey in

applied to field pea in year one, does this increase the sensitivity of spring wheat grown the following year to a herbicide like Everest? Also, does the repeated application of different Group 2 herbicides in two successive years result in increased plant-back sensitivity to susceptible crops grown in years three or four. These questions are being addressed by research conducted at Agriculture and Agri-Food Research Centers as well as universities and private industry. The Saskatchewan Pulse Growers and private industry are generously funding the field research. Results are preliminary, but there is an indication that Group 2 injury to spring wheat was increased if a Group 2 herbicide was applied the previous year. However, this phenomenon was not widespread and limited to some select soil environments.

3. Symptoms of Herbicide Carryover

It is important that growers know the symptoms of herbicide carryover or they should employ the services of a skilled crop diagnostician when assessing crop injury. Many growers assume that if the crop does not emerge, then there must be herbicide carryover. This is not always the case. With many of the Group 2 residual herbicides, crop emergence is normal and injury symptoms show up after root uptake has occurred. Growers should be aware that symptoms from herbicide carryover might occur shortly after a heavy rainfall. Water displaces the adsorbed herbicide off the soil colloids and moves the molecules into the soil solution where it can be taken up by the crop. Table 3 lists the injury symptoms associated with a number of herbicide groups.

Table 3: Common crop injury symptoms from herbicide groups.

Group Name	Group Number	Herbicides	Crop	Symptoms
Imidazolinone	2	Pursuit Odyssey	Cereals	Inter-veinal striping of youngest leaf
	2	Pursuit Odyssey Assert	Canola, Mustard	Stunting, yellowing and purpling of new growth, terminal bud death
Sulfonylurea Sulfonylamino carbonyltriazolinone	2	Ally, Everest, Sundance	Canola, Mustard	Stunting, yellowing and purpling of new growth, terminal bud death
	2	Ally, Everest, Sundance	Pulse crops	Stunting, yellowing of new growth, loss of leaflets on newest growth
Dinitroanilines	3	Treflan, Rival, Edge	Cereals	Stunting, shortened and swollen roots, poor emergence
Pyridinecarboxylic acid	4	Lontrel Curtail-M Prestige	Pulse crops	Malformation; bending and twisting of stem, leaf cupping, and curling

4. Testing for Herbicide Residues

There are three ways to test for herbicide residues, which include:

- 1) chemical analysis;
- 2) plant bioassay;
- 3) and a field bioassay.

Many labs can test for chemical residues, but the information may be of little use to the grower. As mentioned earlier, a chemical extraction only indicates if the herbicide is present and does not indicate the bioavailability of the herbicide. It is a very costly procedure with analysis costing \$300.00 or higher per sample.

The Alberta Research Council offers a plant bioassay service to growers. The grower can send soil samples to the lab where a greenhouse bioassay is conducted. Indicator species are grown in the submitted soil and are compared to plants grown in a herbicide-free soil sample. The cost is about \$75.00 per field so it is relatively inexpensive. The plant bioassay should only be used as a tool and not as a definitive answer for cropping decisions. Consider all other climatic and soil factors when making your decision. Additional information on the plant bioassay service is available at the Alberta Agriculture, Food and Rural Development website: <http://www1.agric.gov.ab.ca/>.

A limitation of both the chemical analysis and the plant bioassay is that residual carryover is not consistent across the field and the amount of injury a crop experiences may be dependent on landscape position. For example, Moyer et al. (2001) reported that Ally carryover on lentil was more prominent on upper slope positions with a high soil pH. The opposite occurred with Pursuit where carryover injury on canola was more prominent in lower slope positions. Therefore, a field can not be considered a homogenous unit so it is difficult to obtain a soil sample that will represent an entire field.

A field bioassay is recommended on a number of herbicide labels. This procedure has limitations as well. The bioassay needs to be large enough to accommodate differences in landscape. It is also beneficial if the bioassay area is compared to an untreated area since visual injury can be subtle and easier to detect when compared to a check. For these reasons, it is very difficult for growers to conduct a satisfactory field bioassay.

More tools are required for growers to determine risk of herbicide carryover. Most recently, a degree-day model has proven to be quite accurate in predicting herbicide degradation in the United States (Jackson 2003) and it may be serve as a basis for a model for Western Canada.

5. What to look for in 2004

Precipitation maps for 2003 shows a relatively large area in Saskatchewan that had below normal growing season precipitation (Figure 1). A detailed color map is available at the following web-site:

http://www.agr.gc.ca/pfra/drought/prgrowing_e.htm

The area south and west of the Battlefords experienced below normal precipitation. Typically these soils are acidic as well. Therefore, the Unity-Kerrobert-Macklin area would be at a moderate to high risk for Odyssey carryover. The soils on the east side of

the province tend to have a higher pH. An area extending from Weyburn through Melville to Wynyard should be considered a moderate to high risk for Sundance and Everest carryover. Carryover risk of clopyralid products (Curtil-M, Prestige) to sensitive pulse crops would be considered moderate in those areas where moderate to severe drought occurred. Growers should consult product labels for specific recropping recommendations.

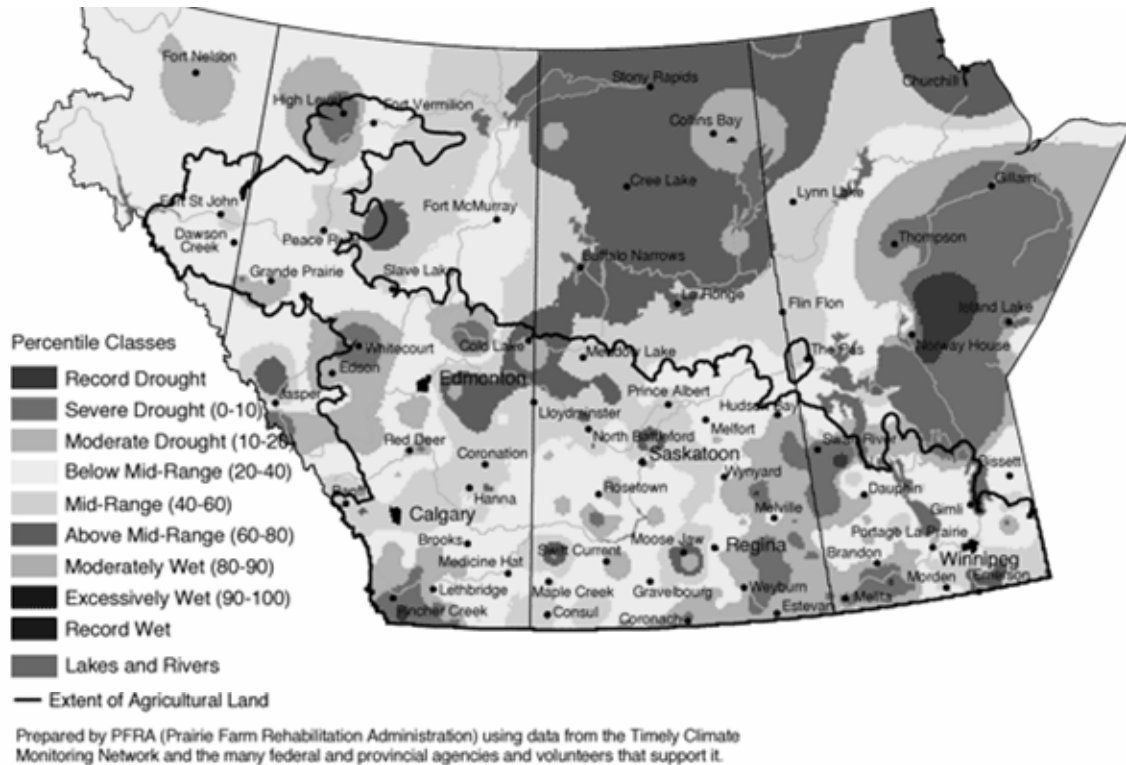


Figure 1: 2003 Growing season precipitation (April 1, 2003 to August 31, 2003) compared to historical distribution. Source: PFRA (http://www.agr.gc.ca/pfra/drought/prgrowing_e.htm).

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