

*Residual Herbicides,
Degradation, and
Recropping Intervals*



Residual Herbicides and Weed Control.

Residual herbicides are often applied to crops to provide season-long weed control. However, herbicidal activity is beneficial only for the time it is needed; longer herbicide activity can cause injury to subsequent crops.

The length of time a herbicide remains active in the soil is called soil residual life or soil persistence. Herbicide carryover is a term used to describe the presence of a herbicide in soil after its weed control mission has been accomplished. Many herbicides used on crops in Kansas decompose quickly enough that they pose no hazard to succeeding crops. However, several herbicides commonly persist in the soil long enough to injure subsequent crops. In addition, misapplication, crop failures, late applications, and adverse weather conditions can result in carryover (residual) of herbicides that normally decompose fairly rapidly.

This publication will examine the soil persistence and recropping intervals for field crop herbicides, factors that influence herbicide persistence, mechanisms of herbicide decomposition, and management practices that may accelerate herbicide breakdown in soils.

Soil Persistence and Recropping Guidelines.

The average persistence, recropping restrictions, and grazing restrictions of several commonly used field crop herbicides are presented in Table 1. Persistence in soils is noted for average conditions, and will be influenced by factors such as weather, soil pH, and crops grown.

Factors Affecting Persistence of Herbicides in Soil.

Herbicide soil persistence or residual life is the length of time a herbicide remains active in a soil. The soil persistence of a herbicide is often stated as "half-life," which is the amount of time it takes to decompose

50 percent of the applied chemical to a herbicidally inactive form. The stated half-life of a herbicide is determined under standard conditions in the laboratory. The half-life of a herbicide in the field will vary depending on environmental and soil conditions. For example, a herbicide with a half-life of 4 weeks would be 50 percent decomposed, with 50 percent remaining in the soil 4 weeks after application (Figure 1). After 8 weeks, 75 percent of the herbicide would be degraded, with 25 percent remaining, and after 12 weeks, only 12.5 percent would remain. The time it takes to degrade half of the applied herbicide—half-life—is independent of the herbicide rate that is applied. Refer to KSU Extension publication C-707, "Factors Affecting Pesticide Behavior and Breakdown," for additional information on herbicide persistence in soil.

The herbicide concentration in the soil and the susceptibility of the following crops determines whether rotational crop injury will occur. Most crops on which a herbicide is labeled will tolerate two to four times the highest labeled herbicide application rate. In the example (Figure 1), the herbicide rate applied is not high enough to injure the tolerant crop, but would kill both the less susceptible and very susceptible weed species present and the susceptible rotational crop. By 4 weeks following application, the herbicide concentration would be low enough that the less susceptible weed species would not be controlled, but high enough to injure the susceptible rotational crop. By 6 to 8 weeks after application (Figure 1), the herbicide concentration should be low enough to avoid injury to the susceptible rotational crop.

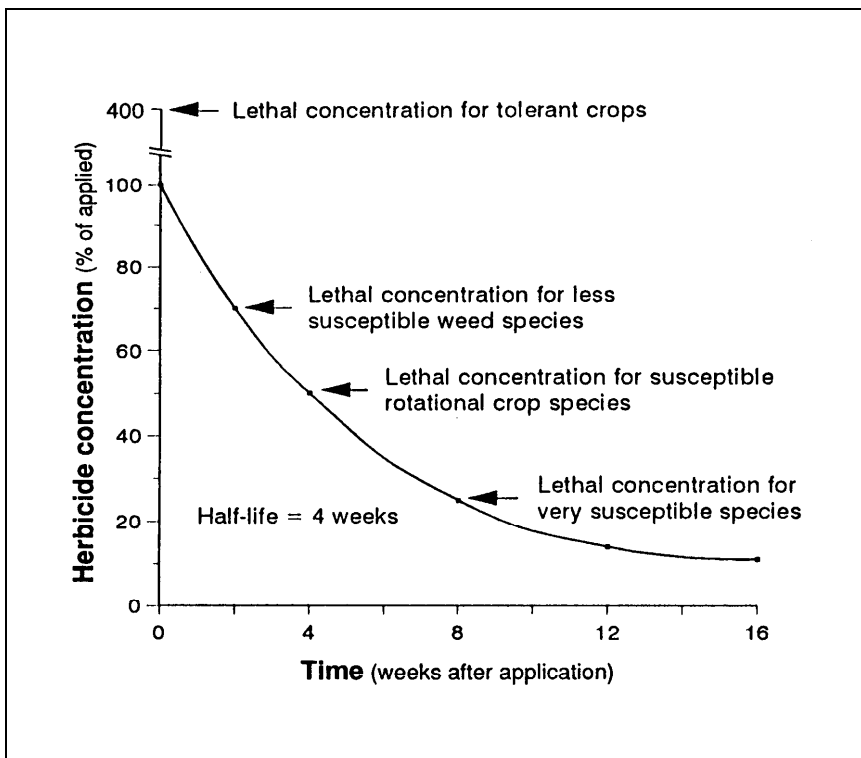


Figure 1. An example of how half-life and herbicide residues affect weed control and rotational crop injury.

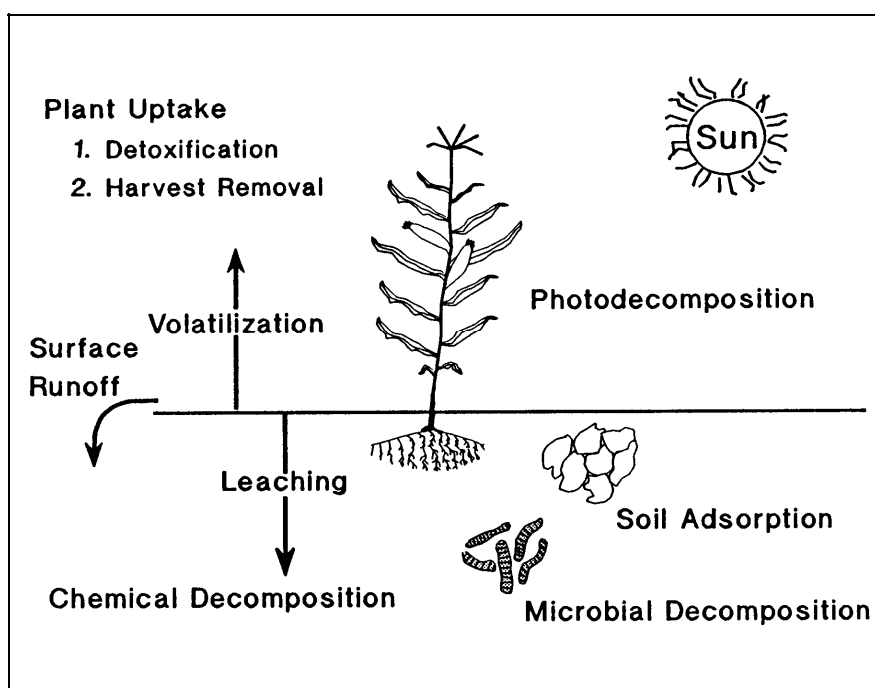


Figure 2. Factors affecting persistence of herbicides applied to crops.

Factors affecting herbicide persistence and concentration in the soil (Figure 2) include:

1. Microbial decomposition
2. Chemical decomposition
3. Soil adsorption
4. Volatilization
5. Photodecomposition
6. Plant uptake and metabolism
7. Leaching
8. Surface runoff

1. Microbial decomposition.

Microbial decomposition is one of the most important methods by which herbicides are decomposed in soil. Microorganisms in the soil metabolize organic herbicides either aerobically (with oxygen) or anaerobically (without oxygen). In most cases, the microorganisms consume the herbicide molecules and utilize them as a source of energy and nutrients for growth and reproduction. Microbes can also degrade herbicides by a process called cometabolism, which occurs when the organic herbicide is not used by the microorganism for growth but is metabolized in conjunction with another substrate used for growth. Some herbicides are decomposed easily by microorganisms while others are not. Figure 3 shows the

degradation pathway of 2, 4-D by soil bacteria.

Microorganisms in the soil include algae, fungi, actinomycetes, and bacteria. The population levels and activity of these microorganisms depend on food supply, temperature, soil moisture, oxygen, soil pH, and organic matter content. When a herbicide is applied to a soil, microorganisms may immediately attack it. The population of the particular microorganism that uses that herbicide for an energy source will increase (Figure 4). After the herbicide is degraded, the microbial population may return to the original level, or it may stabilize at a level greater than before application (Figure 4). The increased population could cause more rapid herbicide degradation upon subsequent herbicide applications.

The optimum temperature for microbial activity generally is 80–90°F. As soil temperatures decrease, soil microbial activity declines, with minimal activity below approximately 40°F. Therefore, maximum microbial herbicide breakdown occurs in the summer when soils are warm. The rate of microbial breakdown decreases in the fall as soils cool, and virtually

ceases as soil temperatures drop below 40°F.

Soil moisture is essential for soil microbial activity. Soil moisture levels between 50-100 percent of field capacity are optimum for microbial activity and, therefore, herbicide breakdown. When soil moisture is limited throughout the growing season, the rate of microbial degradation of a herbicide is reduced, and the herbicide is more likely to carry over and injure later rotational crops.

The majority of microbial degradation of herbicides is by aerobic organisms, which are very sensitive to the oxygen supply. Flooded and compacted soils with poor aeration will reduce microbial activity and herbicide breakdown.

Soil pH also affects microorganisms. Soil bacteria and primitive fungi called actinomycetes usually favor and are most active in soils with a pH above 5.5. Other fungi are less sensitive to soil pH and predominate at pH 5.5 and below.

Soil organic matter content is important to soil microbial populations and activity. Organic matter is the primary source of energy and nutrients for soil microorganisms. The highest microbial populations and the majority of microbial herbicide breakdown will be in the surface foot of soil where organic matter content is highest. Small increases in soil organic matter content can increase microbial activity and the rate of herbicide breakdown.

A warm, moist, well-aerated soil with pH between 5.5 and 7.0 generally is most favorable for rapid microbial breakdown of herbicides. Any adverse condition, such as cold temperatures or dry soils, will reduce the rate of herbicide decomposition by microorganisms and lengthen the soil persistence (half-life) of a herbicide.

2. Chemical decomposition.

Decomposition of herbicides in the soil purely by chemical (non-biological) processes is common for some herbicides. Decomposition may occur as the result of processes such as oxidation-reduction and hydrolysis.

Table 1. Field crop herbicides, soil persistence, recropping intervals, and grazing limitations.

Herbicide			Minimum recropping interval before planting (according to label)										
Trade name	Common name	Chemical class	Registered uses	Persistence in or on soils	Alfalfa	Barley	Corn	Oats	Grain sorghum	Soybeans	Sunflowers	Winter wheat	Grazing limitations
<i>Aatrex</i> , Atrazine	Atrazine	Triazine	Corn, Sorghum	Half-life 60 days	Do not rotate next year	Do not rotate next year	None	Do not rotate next year	None	See label	See label	Following year	21 days
<i>Accent</i>	Nicosulfuron	Sulfonylurea	Corn	Half-life, 1-2 mo.	10-12 mo.	4-8 mo.	None	8 mo.	10-18 mo.	10 mo.	10-18 mo.	4 mo.	30 days
<i>Ally</i> *	Metsulfuron	Sulfonylurea	Wheat, Barley	2-4 wks.	34 mo.	10 mo.	12-22 mo.	10 mo.	10 mo.	14-34 mo.	22 mo.	1 mo.	No restrictions
<i>Amber</i> *	Triasulfuron	Sulfonylurea	Wheat, Barley, Fallow	Half-life, 4-12 wks.	Field bioassay	10-24 mo.	Field bioassay	Field bioassay	14-24 mo.	36 mo. or Field bioassay	Field bioassay	0-2 mo.	No restrictions
<i>Assure II</i>	Quizalofop	Aryloxy-phenoxy-propionate	Soybeans	1 mo.	None	None	None	None	None	None	None	None	Do not graze
<i>Balan</i>	Benefin	Dinitroaniline	Alfalfa	4-5 mo.	None	Following season	Following season	Following season	Following season	Following season	Following season	Following season	None stated
<i>Banvel</i> , <i>Banvel SGF</i>	Dicamba	Benzoic acid	Corn, Wheat, Barley, Oats, Sorghum, Pasture	2-12 wks.	Following season	None	None	None	None	Following season	Following season	None	0-90 days, See label
<i>Basagran</i>	Bentazon	Benzothio-diazole	Soybeans, Corn, Sorghum	Less than 6 wks.	None	None	None	None	None	None	None	None	12 days
<i>Beacon</i>	Primisulfuron	Sulfonylurea	Corn	Half-life, 1 mo.	8 mo.	3-8 mo.	14 days	8 mo.	8 mo.	8 mo.	8 mo.	3 mo.	None stated
<i>Bicep</i>	Atrazine + Metolachlor	Triazine + Acid amide	Corn, Sorghum	1 year or more	18 mo.	15 mo.	None	15 mo.	None	Following season	18 mo.	15 mo.	21 days
<i>Bladex</i>	Cyanazine	Triazine	Corn, Sorghum	Half-life, about 2 wks.	None	None	None	None	None	None	None	None	None stated
<i>Blazer</i>	Acifluorfen	Diphenyl-ether	Soybeans	Half-life, 2-4 wks.	Following season	Following season	Following season	Following season	Following season	None	Following season	Following season	Do not graze or feed
<i>Buctril</i>	Bromoxynil	Nitrile	Alfalfa, Wheat, Barley, Oats, Corn, Sorghum	< 1 mo.	None	None	None	None	None	Following season	Following season	None	30 days

Table 1 cont'd. Field crop herbicides, soil persistence, recropping intervals, and grazing limitations.

Trade name	Herbicide			Persistence in or on soils	Minimum recropping interval before planting (according to label)								Grazing limitations
	Common name	Chemical class	Registered uses		Alfalfa	Barley	Corn	Oats	Grain sorghum	Soybeans	Sunflowers	Winter wheat	
<i>Buctril + Atrazine</i>	Bromoxynil + Atrazine	Nitrile + Triazine	Corn, Sorghum	3-12 mo.	See label	See label	None	See label	None	See label	See label	See label	30 days
<i>Bullet</i>	Alachlor + Atrazine	Acid amide + Triazine	Corn	1 year or more	Do not rotate	Do not rotate	None	Do not rotate	Following season	Following season	Do not rotate	Do not rotate	21 days
<i>Canopy*</i>	Chlorimuron + Metribuzin	Sulfonylurea + Triazine	Soybeans	3-12 mo.	10-18 mo.	4 mo.	9-18 mo.	18 mo.	10-18 mo.	None	18 mo.	4 mo.	Do not graze
<i>Classic *</i>	Chlorimuron	Sulfonylurea	Soybeans	Half-life, 2-4 wks.	9 mo.	3 mo.	9 mo.	3 mo.	9 mo.	None	Field bioassay	3 mo.	Do not graze
<i>Cobra</i>	Lactofen	Diphenylether	Soybeans	4-6 wks.	None	None	None	None	None	None	None	None	Do not graze
<i>Command</i>	Clomazone	Isoxazolidinone	Soybeans, Fallow	Half-life, 15-45 days	16 mo.	16 mo.	9 mo.	16 mo.	9 mo.	None	16 mo.	12 mo.	Do not graze
<i>Commence</i>	Clomazone + Trifluralin	Isoxazolidinone + Dinitroaniline	Soybeans	Half-life, 15-45 days	15 mo.	15 mo.	9 mo.	15 mo.	12-18 mo.	None	Do not rotate	15 mo.	Do not graze
<i>Cyclone, Gramoxone Extra</i>	Paraquat	Bipyridillium	Alfalfa, Fallow, Burndown	Inactive in soil	None	None	None	None	None	None	None	None	Do not graze See label
<i>Dual</i>	Metolachlor	Acid amide	Corn, Sorghum, Soybeans	2-4 mo.	4 mo.	4.5 mo.	None	4.5 mo.	None	None	18 mo.	4.5 mo.	None stated
<i>Eptam</i>	EPTC	Carbamothioate	Alfalfa	1-2 mo.	None	None	None	None	None	None	None	None	None stated
<i>Eradicane</i>	EPTC + safener	Carbamothioate	Corn	1-2 mo.	None	None	None	None	None	None	None	None	None stated
<i>Express</i>	Tribenuron	Sulfonylurea	Wheat	< 1 mo.	2 mo.	None	2 mo.	2 mo.	2 mo.	2 mo.	2 mo.	None	Do not graze
<i>Extrazine II</i>	Atrazine + Cyanazine	Triazine + Triazine	Corn	3-18 mo.	18 mo.	15 mo.	None	15 mo.	Following season	Following season	18 mo.	15 mo.	None stated
<i>Fallow Master</i>	Glyphosate + Dicamba	Amino acid derivative + Benzoic acid	Fallow, Burndown	2-3 mo.	3 mo.	15 days	None	15 days	15 days	3 mo.	3 mo.	15 days	8 wks.
<i>Far-Go</i>	Triallate	Carbamothioate	Wheat	6-8 wks.	None	None	None	Following season	None	None	None	None	Do not graze
<i>Finesse*</i>	Chlorsulfuron + Met-sulfuron	Sulfonylurea + Sulfonylurea	Wheat	1 year or more	Field bioassay	16 mo.	Field bioassay	10 mo.	14-26 mo.	26-36 mo.	Field bioassay	4 mo.	No grazing restrictions
<i>Freedom</i>	Alachlor + Trifluralin	Acid amide + Dinitroaniline	Soybeans	3-6 mo.	Following season	Following season	Following season	Following season	Following season	None	Following season	Following season	Do not graze or feed

Table 1 cont'd. Field crop herbicides, soil persistence, recropping intervals, and grazing limitations.

Trade name	Herbicide		Registered uses	Persistence in or on soils	Minimum recropping interval before planting (according to label)								Grazing limitations	
	Common name	Chemical class			Alfalfa	Barley	Corn	Oats	Grain sorghum	Soybeans	Sunflowers	Winter wheat		
<i>Fusilade 2000</i>	Fluazifop-P	Aryloxy-phenoxy-propionate	Soybeans	2 mo.	2 mo.	2 mo.	2 mo.	2 mo.	2 mo.	2 mo.	None	2 mo.	2 mo.	Do not graze
<i>Fusion</i>	Fluazifop-P + Fenoxaprop	Aryloxy-phenoxy-propionate	Soybeans	2 mo.	None	60 days	60 days	60 days	60 days	60 days	None	None	60 days	Do not graze or harvest for feed
<i>Glean *</i>	Chlorsulfuron	Sulfonylurea	Wheat, Barley, Oats	Half-life, 4-6 wks.	Field bioassay	10 mo.	Field bioassay	10 mo.	14-48 mo.	14-36 mo.	Field bioassay	None	None	No grazing restrictions
<i>Harmony Extra</i>	Tribenuron + Thifensulfuron	Sulfonylurea + Sulfonylures	Wheat, Barley	< 1 mo.	60 days	None	60 days	60 days	60 days	60 days	60 days	60 days	None	Do not graze
<i>Hoelon</i>	Diclofop	Diphenylether	Wheat	3-4 wks.	None	None	None	None	None	None	None	None	None	Do not graze
<i>Karmex</i>	Diuron	Urea	Alfalfa	At least 1 year	2 years	2 years	2 years	2 years	2 years	2 years	2 years	2 years	2 years	None stated
<i>Laddok</i>	Bentazon + Atrazine	Benzothiadiazole + Triazine	Corn, Sorghum	6-12 mo.	Following season	Following season	None	See label	None	None	Following season	18 mo.	Following season	21 days
<i>Landmaster BW</i>	Glyphosate + 2, 4-D	Amino acid deriviate + Phenoxy	Fallow, Burndown	2-4 wks.	3 mo.	None	None	None	None	None	3 mo.	3 mo.	None	8 weeks
<i>Lasso, Micro-Tech, Partner</i>	Alachlor	Acid amide	Corn, Sorghum, Soybeans	6-10 wks.	Following season	Following season	None	Following season	None	None	None	None	Following season	None stated
<i>Lexone* Sencor*</i>	Metribuzin	Triazine	Alfalfa, Corn, Soybeans, Wheat	Half-life, 7-28 days	4 mo. after 1 lb.	8 mo. after 0.5 lb.	4 mo. after 1 lb.	12 mo.	12 mo.	None	12 mo.	4-8 mo. after 0.5 lb.	40 days for soybeans, 28 days for alfalfa	
<i>Lorox</i>	Linuron	Urea	Soybeans, Sorghum	Half-life, 2-5 mo.	4 mo.	4 mo.	None	4 mo.	4 mo.	None	4 mo.	4 mo.	4 mo.	3 mo.
<i>Lorox Plus*</i>	Linuron + Chlorimuron	Urea + Sulfonylurea	Soybeans	Half-life, 2-5 mo.	Field bioassay	4 mo.	10-11 mo.	4 mo.	10-11 mo.	None	Field bioassay	4 mo.	Do not graze	
<i>Marksman</i>	Dicamba + Atrazine	Benzoic acid + Triazine	Corn, Sorghum	3-12 mo.	18 mo.	10 mo.	None	10 mo.	None	Following season	18 mo.	10 mo.	Do not graze	
<i>Option II</i>	Fenoxaprop	Aryloxy-phenoxy-propionate	Soybeans	< 1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	1 mo.	Do not graze

Table 1 cont'd. Field crop herbicides, soil persistence, recropping intervals, and grazing limitations.

Herbicide				Minimum recropping interval before planting (according to label)									
Trade name	Common name	Chemical class	Registered uses	Persistence in or on soils	Alfalfa	Barley	Corn	Oats	Grain sorghum	Soybeans	Sunflowers	Winter wheat	Grazing limitations
<i>Tri-Scept</i>	Imazaquin + Trifluralin	Imidazolinone + Dinitro-analine	Soybeans	3-12 mo.	18 mo.	11 mo.	See label	11 mo.	11 mo.	None	18 mo.	4 mo.	Do not graze
<i>Tordon</i>	Picloram	Pyridine	Noncropland Fallow, Wheat, Oats, Pastures	1 year or more	See label	45-60 days, See label	See label	45-60 days, See label	See label	See label	See label	45-60 days, See label	See label
<i>Treflan, Tri-4, Trifluralin</i>	Trifluralin	Dinitroanaline	Soybeans, Sunflowers, Wheat	4-6 mo.	Following season	Following season	Following season	12-18 mo.	12-18 mo.	None	None	Following season	None stated
2, 4-D	2, 4-D	Phenoxy	Corn, Sorghum, Wheat, Oats, Barley, Fallow, Pasture	< 1 mo.	See label	See label	None	See label	See label	See label	See label	See label	0-2 weeks, See label
<i>Velpar</i>	Hexazinone	Unclassified	Alfalfa	Half-life, 1-6 mo.	2 years	2 years	12 mo.	2 years	2 years	2 years	2 years	2 years	30 days

**Ally, Canopy, Classic, Glean, Finesse, Lexone, Lorox Plus, Preview, and Sencor* have soil pH restrictions on the product label. Do not use these herbicides on fields with soil pH greater than: *Ally* 8.0; *Classic* and *Canopy* 7.0; *Glean* and *Finesse* 7.9; *Lorox Plus* and *Preview* 6.8; *Lexone/Sencor* 7.7 (wheat), 7.5 (soybeans). Using these on high pH soils can result in crop injury or longer carryover intervals.

7

Oxidation-reduction reactions involve the transfer of electrons (negatively charged particles) from one substrate to another. A variety of compounds exist within the organic matter matrix that have the potential to receive electrons from or donate electrons to herbicide molecules. These reactions are not well understood but apparently occur in soil, resulting in reduced herbicidal activity.

Hydrolysis is a process in which the herbicide molecules react with water. Usually, chemical bonds in the herbicide molecule are broken and one or more atoms or groups of atoms in the herbicide molecule are replaced by hydroxyl ions (OH⁻) from water. This change in molecular structure may inactivate the herbicide (Figure 5). Even very dry field soil has enough moisture for some hydrolysis to occur. Hydrolysis is the major method by which sulfonylurea herbicides such as *Ally Classic*, and *Glean* are degraded in soils. The major hydrolytic pathway in soil for the sulfonylurea herbicides is the cleavage of the sulfonylurea bridge, resulting in sulfonamide and heterocyclic amine molecules (Figure 6). Cleavage by hydrolysis is pH sensitive. As the soil pH increases, the rate of chemical hydrolysis in the soil decreases. Therefore, sulfonylurea herbicides degrade more rapidly at a lower soil pH than at a higher soil pH. For this reason, there is more potential for *Classic* or *Glean* herbicide carryover in higher pH soils than in lower pH soils. In addition, chemical hydrolysis of sulfonylurea herbicides is faster during the summer when soil temperatures are warm than in the fall and winter when soils are cool.

3. Soil adsorption. Adsorption is an important factor that makes herbicides unavailable for uptake by plants. Adsorption is the attraction or adhesion of molecules or ions to the surface of soil particles (colloids). Almost all soil-applied herbicides are adsorbed to some extent. Weed control is inversely proportional to how much herbicide is adsorbed to the soil. Normally, the adsorption of herbicides occurs on both the clay and humus fractions. In general,

small increases in the organic matter content of a soil greatly increase its ability to adsorb herbicides. A soil high in organic matter content will generally require a higher herbicide rate than a soil with less organic matter. Adsorbed herbicide molecules are unavailable for biological, physical, and chemical processes until released from the soil into the soil solution or vapor phase.

Herbicides generally are more tightly adsorbed in dry soils than in wet soils. Water molecules compete and displace herbicide molecules from adsorption sites, making the herbicides available for plant uptake.

4. Volatilization. Volatilization of herbicides is the vaporization of a herbicide to a gaseous form. Herbicides vary widely in volatility and loss to the atmosphere as a gas. Herbicide volatilization increases as the temperature rises. Usually, very little volatilization occurs once the herbicide is mixed into the soil either by mechanical incorporation

or rainfall. Volatility loss is greater when herbicides are applied to a moist soil surface than a dry soil surface.

5. Photodecomposition. Photodecomposition is the degradation of herbicides by sunlight. In the photodecomposition process, the herbicide molecule absorbs energy from sunlight, causing chemical reactions that result in herbicide inactivation. Certain dinitroaniline herbicides, for example, are readily degraded by sunlight if left on the soil surface. Soil incorporation will reduce or eliminate photodecomposition.

6. Plant uptake and metabolism. Plant roots may absorb (take up) herbicides from soils and plant foliage may intercept foliar-applied chemicals. Crops and plants tolerant to a herbicide often metabolize the chemical into non-toxic substances. Differential metabolism is often the basis for herbicide selectivity. For example, corn and sorghum absorb and metabolize (detoxify) atrazine,

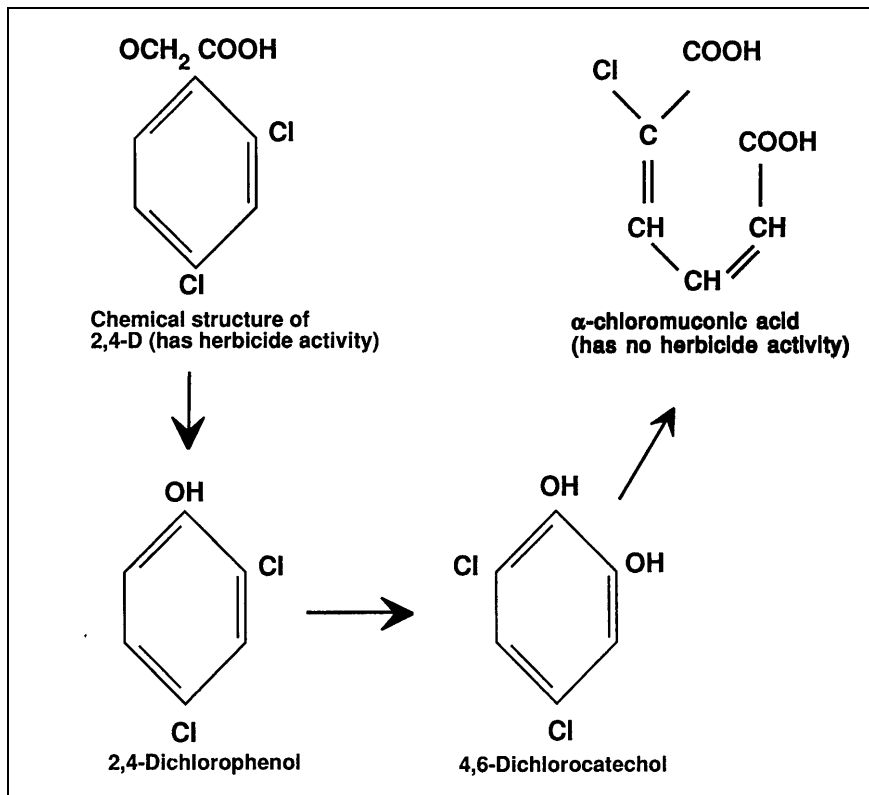


Figure 3. Degradation pathway of 2, 4-D by soil bacteria.

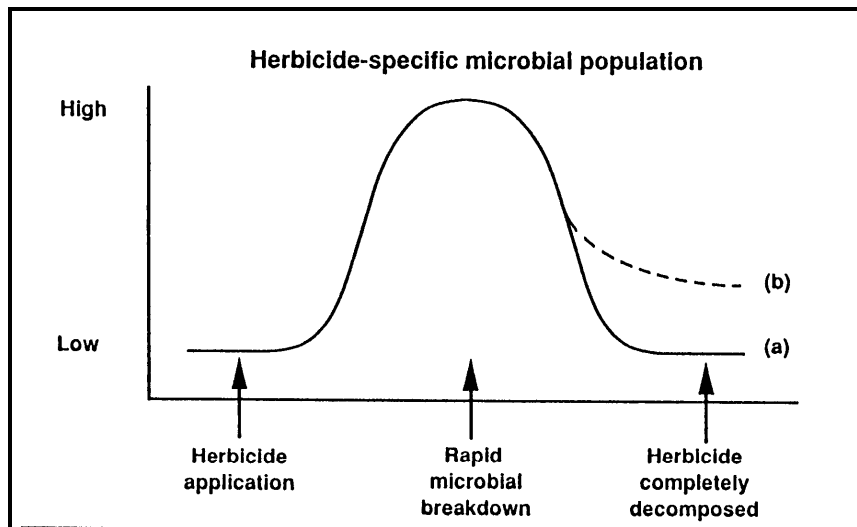


Figure 4. Effect of herbicide on microbial populations over a period of time. (a) shows microbial populations returning to original level after herbicide is decomposed; (b) shows microbial population stabilizing at a level greater than before herbicide application.

and wheat absorbs and metabolizes *Glean*. Plants susceptible to these herbicides are incapable of metabolizing and detoxifying the chemical rapidly enough to escape the herbicidal activity.

These factors result in herbicide breakdown or deactivation; however, herbicide concentrations in soils are also affected by the movement of intact herbicide molecules via leaching and surface runoff.

7. Leaching. Leaching is the movement of herbicides through soil by water. Leaching may occur in any direction (down, up, sideways), depending on water movement, but usually refers to the downward movement of a herbicide as water percolates down through the soil following precipitation or irrigation.

The movement of a herbicide by leaching is important to weed control effectiveness, herbicide carryover, and the potential for environmental problems. When a herbicide is leached downward, the concentration of herbicide near the soil surface is reduced, lessening the chances for herbicide carryover problems.

Leaching is greater in coarse-textured soils (sandy loams, etc.)

than in finer-textured soils (clay loams, etc.), and is limited by lack of rainfall and by compaction layers.

The tendency of a herbicide to leach is determined by its solubility in water and its soil adsorption tendencies. The dinitroanilines, for example, have very low water solubility and moderate soil adsorption, and thus have a low leaching potential.

Herbicides that are strongly adsorbed to soil particles, like glyphosate and paraquat, cannot be leached unless the soil particles are moved by the water. Soil pH can play a major role in how tightly a herbicide is adsorbed to soil particles.

8. Surface runoff. Intact herbicide molecules may be carried by surface water flow. They may be adsorbed to soil particles that move, dissolved in surface runoff water, or carried intact by surface runoff water.

The primary mechanisms of herbicide dissipation in and on soils are presented in Table 2.

Management Practices to Reduce Herbicide Carryover Problems. Proper management is the key to reducing herbicide carryover problems. The product label should

be read and understood before using any herbicide. The label usually will contain information on soil persistence and crop rotation restrictions. Future cropping plans should be decided before using any residual herbicide. If plans are to use a soil-persistent herbicide and the following crop is susceptible to that herbicide, it may be necessary to apply a different herbicide or plant a less susceptible rotational crop.

Proper herbicide application is essential. Excessive rates, overlapping, or sloppy application techniques contribute to herbicide carryover. Sprayer calibration and proper operating techniques are necessary to avoid crop injury and herbicide carryover.

Adverse conditions. Adverse environmental conditions such as low rainfall, soil compaction, or waterlogged soils may increase herbicide carryover. In years of below-normal rainfall, more herbicide carryover can be expected. Deep tillage may help reduce carryover problems by diluting the herbicide concentration into a larger volume of soil, and by fracturing compaction layers. Thorough mixing of the soil can help dilute banded herbicides or herbicides concentrated near the soil surface, such as atrazine, *Treflan*, or *Prowl*. However, tillage may not help alleviate carryover of systemic herbicides that cause chronic injury to susceptible plants at extremely low concentrations, such as *Tordon*, *Scepter* or *Pursuit*.

Compaction layers, which may be present even in normal rainfall years, can restrict plant growth by not allowing root penetration through the herbicide zone. Tillage operations in the fall are usually the most effective method of breaking up a compaction layer. However, fall tillage following harvest is normally not recommended because of the increased potential for soil erosion, especially following a dry summer.

Agronomic practices. Agronomic practices should encourage rotational crop emergence as quickly as possible and promote good seedling growth. Rapidly growing seedling

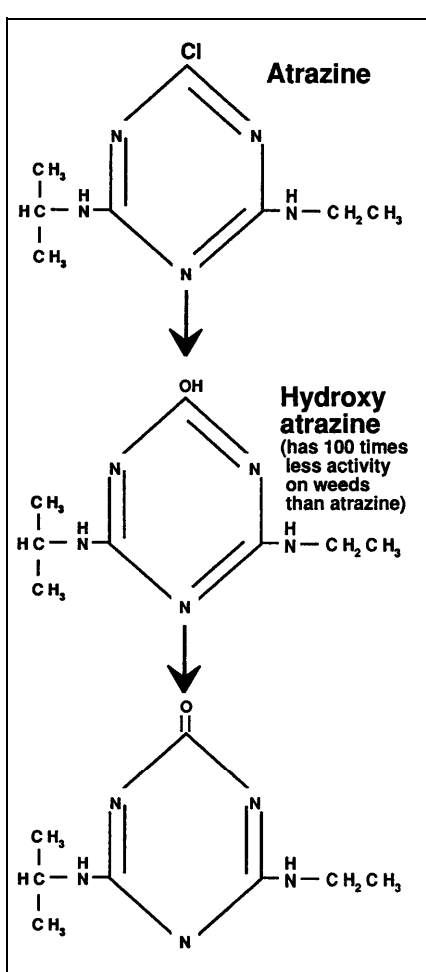


Figure 5. Chemical hydrolysis of atrazine.

plants are normally less affected by herbicide residues in the soil than are stressed plants. Management practices that can increase seedling vigor and growth are:

1. Soil test and fertilize accordingly. A starter fertilizer may increase the seedling growth rate and reduce herbicide damage.
2. Establish a favorable seedbed to ensure good seed/soil contact and plant at the optimum depth. Deep seeding places additional stress on the crop and exposes the emerging shoot to herbicide residues for a longer period of time.
3. Plant at the optimum planting date. For example, planting corn after soil temperatures reach 55°F will result in faster germination and seedling growth than planting in cooler soils. Late planting dates also

allow more time for dissipation of previously applied herbicides.

4. If possible, plant hybrids or varieties that are tolerant to the residual herbicide, adapted for your area, and known to have good early seedling vigor.

Herbicide carryover tests. The possibility of herbicide carryover can be predicted somewhat by considering the herbicide rate used, the method and time of application, the soil type and pH, and the weather after application. In addition, chemical assays and plant bioassays are available to help determine if herbicide carryover will be a problem. Chemical analysis and bioassays should be conducted on soil samples taken as close as possible to planting time for the rotational crop. Any assay is only as good as the soil sampling procedure. Ten or more soil samples should be collected at random locations across the field to a depth of 3–6 inches. Avoid taking samples near the edge of the field, or where application skips or overlaps are suspected. A second set of samples from the turnrows and other high-risk areas of the field may provide additional information on the potential for herbicide carryover. The samples should be mixed thoroughly and promptly assayed, or placed in cold storage until the assay can be conducted.

Several commercial laboratories will analyze soil samples for herbicide residues. Chemical analysis usually costs between \$50 and \$150 per sample and involves extracting herbicide residues from soils and quantifying them. Results are usually reported in parts per

million (ppm) and are often difficult to interpret. For example, on the average, 1 acre of soil 6 inches deep weighs approximately 2 million pounds. If 0.2 ppm atrazine was found in soil samples taken from the top 6 inches of soil, the atrazine level would be approximately equal to 0.4 lbs atrazine per acre. If a soil sample is taken from a depth of 3–4 inches, ppm is about equal to pounds per acre, assuming the herbicide is not present below that depth. The problem with the chemical analysis is that the same concentration of herbicide may be harmful in one soil, yet safe in others. Factors such as high pH, coarse-textured soils, low organic matter, or stress conditions may allow a herbicide at a certain residual level to injure a rotational crop in one field but not another. A chemical analysis provides information on the herbicide level in a soil, but not whether that level will injure a crop.

A bioassay involves collecting a soil sample from a probable herbicide carryover site, planting a susceptible plant species in it, and observing the plants for injury. If a representative soil sample is collected, this test should measure the herbicide that is available to the plants and should correlate to what will happen in the field. However, the validity in some cases maybe questionable because the growing conditions of the bioassay are usually different from those expected in the field. The bioassay is simpler and less expensive to conduct than a chemical analysis, and can be conducted in one's own home or office.

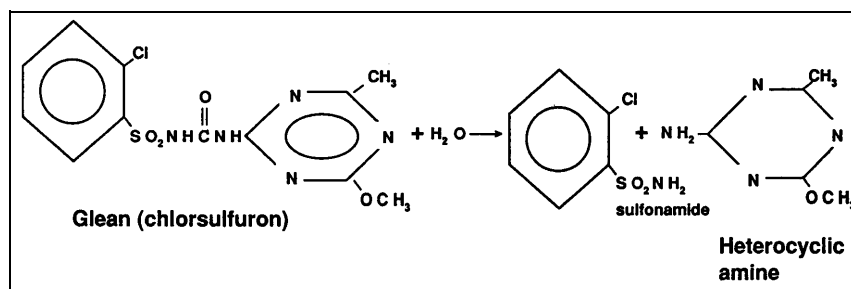


Figure 6. Breakdown of Glean (chlorsulfuron) in soil by chemical hydrolysis.


Table 2. Mechanisms of herbicide loss in or on soils.

Chemical family	Herbicide	Average persistence in or on soils	Soil degradation ^a		Potential for surface loss ^b		
			Microbial	Chemical	Photo-decomposition	Volatility	Leachability ^c
Acid Amide	<i>Dual</i>	2-4 mo.	•••	•	L	M	M
	<i>Lasso</i>	1.5-2.5 mo.	•••	•	L	L	M
	<i>Ramrod</i>	1-1.5 mo.	•••	•	L	L	L
Amino Acid derivative	<i>Roundup</i>	None ^d	•••	•	L	L	L
Aryloxy-phenoxy-propionate	<i>Fusilade 2000</i>	2 mo.	••	••	L	L	L
	<i>Assure II</i>	1 mo.	•••	•	L	L	L
	<i>Option II</i>	<1 mo.	••	••	L	L	L
	<i>Hoelon</i>	1 mo.	•••	••	L	L	L
	<i>Fusion</i>	1 mo.	••	•	L	L	L
Benzoic acid	<i>Banvel</i>	0.5-3 mo.	•••	•	L	L	H
Benzothiadiazole	<i>Basagran</i>	<1.5 mo.	•••	•	L	L	M
Bipyridillium	<i>Gramoxone Extra, Cyclone</i>	None ^d	•	•	M	L	L
Carbamothioate	<i>Eptam</i>	1-2 mo.	•••	•	L	H	M
	<i>Eradicane</i>	1-2 mo.	•••	•	L	H	M
	<i>Far Go</i>	1.5-2 mo.	•••	•	L	H	L
	<i>Sutan +</i>	0.5-1 mo.	•••	•	L	H	L
Cyclohexanedione	<i>Select</i>	<1 mo.	•••	•	L	L	L
	<i>Poast, Poast Plus</i>	<0.5 mo.	•••	•	H	L	L
Dinitroaniline	<i>Balan</i>	4-5 mo.	•	•••	H	L	L
	<i>Prowl</i>	3-4 mo.	•	•••	M	L	L
	<i>Sonalan</i>	4-5 mo.	••	••	M	L	L
	<i>Treflan</i>	4-6 mo.	••	••	H	M	L
Diphenyl-ether	<i>Blazer</i>	0.5-1 mo. half life	•••	•	H	L	M
	<i>Cobra</i>	1-1.5 mo. half life	•••	•	M	L	L
Imidazolinone	<i>Pursuit</i>	2-3 mo.	•••	•	L	L	M
	<i>Scepter</i>	2-3 mo.	•••	•	L	L	H
Isoxazolidinone	<i>Command</i>	0.5-1.5 mo.	••	••	L	H	H
Nitrile	<i>Buctril</i>	14 days	—	—	—	L	L
Phenoxy	2, 4-D amine	0.25-1 mo.	•••	•	L	M	M
	2, 4-D ester	0.25-1 mo.	•••	•	L	M-H	L
	MCPA amine	1-6 mo.	•••	•	L	L	H
	2, 4-DB amine	None	•••	•	L	M	M
Pryridine	<i>Stinger</i>	0.5-2.5 mo. half-life	•••	•	L	L	H
	<i>Tordon</i>	1 year or more	•	•••	M	L	H
Sulfonylurea	<i>Accent</i>	1-2 mo. half life	•	•••	L	L	M
	<i>Ally</i>	0.5-1 mo. half life	•	•••	L	L	H
	<i>Amber</i>	1 mo. half life	••	••	L	L	H
	<i>Beacon</i>	1 mo. half life	•	•••	L	L	M
	<i>Classic</i>	0.5-1 mo. half life	•	•••	L	L	H
	<i>Express</i>	<1 mo.	••	••	L	L	M
	<i>Glean</i>	1-1.5 mo. half life	•	•••	L	L	H
	<i>Pinnacle</i>	<0.5 mo.	•	•••	L	L	L
Triazine	<i>Atrazine</i>	12 mo.	••	•••	L	L	H
	<i>Bladex</i>	0.5 mo. half life	•••	•	L	L	M
	<i>Lexone/Sencor</i>	1 mo. half life	•••	•	L	L	H
Urea	<i>Lorox</i>	2-5 mo. half life	•••	•	L	L	M
	<i>Karmex</i>	3-12 mo.	•••	•	L	L	M
Unclassified	<i>Velpar</i>	1-6 mo. half life	•••	•	L	L	H

^a•••= major factor; ••= secondary factor; •= minor factor. ^bH = high potential; M = medium potential; L = low potential.

^cWauchope, R.D. 1988. USDA-ARS Interim Pesticide Properties Data Base, Version 1.0.

^dMajor soil loss mechanism is adsorption to soil colloids.



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