



Persistence of Herbicides in Soil

Herbicides are applied to soil to manage weeds. While it is desirable for the chemicals to control weeds during the season of application, it is not desirable for them to persist and affect subsequent crop growth.

The length of time a herbicide remains active in soil is called “soil persistence,” or “soil residual life” (Figure 1). For some herbicides, there may be a fine line between controlling weeds for the entire growing season and then planting a sensitive rotation crop. Anything that affects the disappearance or breakdown of herbicides affects persistence. Herbicides vary in their potential to persist in soil. Herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, isoxazolidinones, imidazolinones, and certain plant growth regulators belonging to the pyridine family. Table 1 lists common herbicides in these groups.

Several factors determine the length of time herbicides persist. These factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. Factors from each category strongly interact with one another.

SOIL FACTORS

Soil factors affecting herbicide persistence include soil composition, soil chemistry, and microbial activity. Soil composition is a physical factor determined by the relative amounts of sand, silt, and clay in the soil (the soil texture), as well as by the organic matter content. An important

chemical property of soil that can influence herbicide persistence is pH. The microbial aspects of the soil environment include the types and abundance of soil microorganisms present in the soil.

Soil composition affects herbicidal activity and persistence through soil-herbicide binding (adsorption), leaching, and vapor loss (volatilization). Generally, soils high in clay, organic matter, or both have a greater potential for carryover because of increased binding of the herbicide to soil particles, with a corresponding decrease in leaching and loss through volatilization. This “tie-up” results in decreased initial plant uptake and herbicidal activity. More herbicide is held in reserve, potentially injuring susceptible crops in the future.

Figure 1. Herbicide dissipation over time.

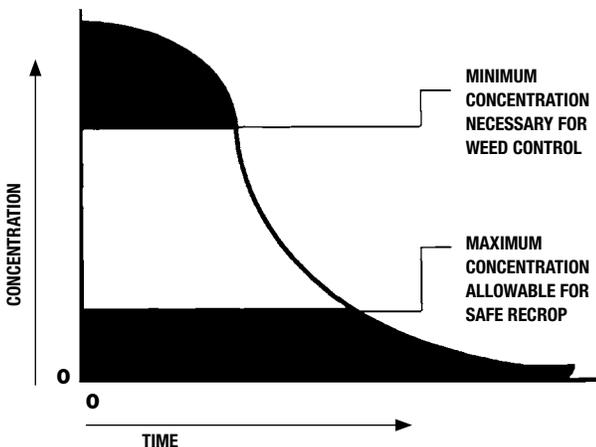


Table 1. Herbicide families with potentially persistent members.

TRIAZINES	PHENYLUREAS	SULFONYLUREAS
atrazine	diuron (Karmex)	chlorimuron (Canopy, Classic)
hexazinone (Velpar)	tebuthiuron (Spike)	chlorsulfuron (Glean, Finesse)
simazine (Princep)		metsulfuron (Ally)
		nicosulfuron (Accent)
		primisulfuron (Beacon)
		proflufuron (Peak, Exceed, Spirit)
		sulfometuron (Oust)
DINITROANILINES	URACILS	
benefin (Balan)	terbacil (Sinbar)	
pendimethalin (Prowl)		
trifluralin (Treflan)		
OTHERS	IMIDAZOLINONES	PLANT GROWTH REGULATORS
clomazone (Command)	imazapyr (Arsenal, Lightning)	clopyralid (Stinger)
sodium borates	imazaquin (Scepter)	picloram (Tordon)
	imazethapyr (Pursuit)	

In general, medium- and fine-textured soils with an organic matter content of more than 3 percent have the greatest potential to bind or hold herbicides and injure sensitive rotation crops. Coarse- to medium-textured soils with a lower organic matter content (less than 3 percent), more typical of the soils common to Pennsylvania, are less likely to retain herbicides and have carryover problems. Under the right circumstances, however, herbicide carryover can occur in any type of soil.

Soil pH can influence the persistence of some herbicides, especially the triazines and sulfonylureas (see Table 1). Chemical and microbial breakdown, two ways herbicides degrade in soil, often are slower in higher-pH soils. In particular, the chemical degradation rate of the triazine and sulfonylurea herbicide families slows as the soil pH increases, particularly above 7.0. In addition, in higher-pH soils, lesser amounts of these herbicides are bound to soil particles, making more available for plant uptake. So in higher-pH soils, the triazine and sulfonylurea herbicides persist longer, and more is available for plant uptake. (Some triazine and sulfonylurea herbicides do not persist and carry over regardless of how high the soil pH is.)

Low pH also can affect the persistence of both the triazine and the sulfonylurea herbicides. Soil pH levels below 6.0 allow a more rapid dissipation of both these herbicide families. In acid soils, herbicides like atrazine become bound to soil particles, making them unavailable for weed control; but at the same time, they are chemically degraded more quickly. This makes liming an acid soil important for achieving an adequate performance from these two herbicide families.

In contrast, a low soil pH increases the persistence of the imidazolinone herbicides imazaquin (Scepter) and imazethapyr (Pursuit). As the soil pH drops below 6.0, imazaquin and imazethapyr become increasingly bound, or adsorbed, to soil particles. Adsorption of these herbicides appears to reduce their availability to soil microorganisms, the primary mechanisms of degradation. Even though adsorption is greater in lower-pH soils, the herbicide can still be released several months later, becoming available for plant uptake and potentially injuring a sensitive follow crop.

Degradation processes by *soil microorganisms* probably are the most important pathways responsible for the breakdown of herbicides. The types of microorganisms (fungi, bacteria, protozoans, etc.) and their relative numbers determine how quickly decomposition occurs. Microorganisms

require certain environmental conditions for optimal growth and utilization of any pesticide. Factors that affect microbial activity are moisture, temperature, pH, oxygen, and mineral nutrient supply. Usually, a warm, well-aerated, fertile soil with a near-neutral pH is most favorable for microbial growth and, hence, herbicide breakdown.

CLIMATIC FACTORS

The climatic variables involved in herbicide breakdown are moisture, temperature, and sunlight. Herbicide degradation rates generally increase as temperature and soil moisture increase because both chemical and microbial decomposition rates increase with higher temperatures and moisture levels. Cool, dry conditions slow down herbicide degradation. Carryover problems are always greater the year following a drought. If winter and spring conditions are wet and mild following a previously dry summer, the likelihood of herbicide carryover is lower. The relative importance of rainfall, clay and organic matter content, and soil pH for increasing the persistence of selected herbicides is shown in Table 2.

Sunlight is sometimes an important factor in herbicide degradation. Photodecomposition or degradation catalyzed by sunlight (photolysis) has been reported for many herbicides, especially in liquid solution (i.e., water) or on plant leaf surfaces. But for most of the more persistent soil-applied herbicides, once soil contact is made, losses due to photolysis are small. The exception may be the dinitroanilines, including trifluralin (Treflan) and pendimethalin (Prowl). These can be lost if they remain on the soil surface for an extended period without rainfall. A sensitivity to sunlight and losses through volatilization are primary reasons for incorporating the dinitroanilines at application time.

HERBICIDE PROPERTIES

A herbicide's chemical properties affect its persistence. These properties include water solubility, vapor pressure, and the molecules' susceptibility to chemical or microbial alteration or degradation.

Leaching is one mechanism responsible for herbicide dissipation. The solubility of a herbicide in water helps determine its leaching potential. Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away from crop and weed germination zones.

Herbicide leaching is determined by other factors as well. These include herbicide-soil binding properties, soil

Table 2. Soil and climatic conditions that increase the persistence of selected herbicides or families (ranked in order of importance).

IMPORTANCE	GLOMAZONE	DINITROANILINES	IMIDAZOLINONES	PYRIDINES	SULFONYLUREAS
very important	low rainfall	low rainfall	low rainfall	low rainfall	high pH
important	high clay/organic matter	high clay/organic matter	high clay/ organic matter	high clay/ organic matter	high clay/organic matter
somewhat important	high or low soil pH	high or low soil pH	low soil pH	high or low soil pH	low rainfall

physical characteristics, rainfall frequency and intensity, herbicide concentration, and time of herbicide application. In general, herbicides that are less soluble in water and strongly attracted to soil particles are less likely to leach, particularly in dry years.

The *vapor pressure* of a herbicide determines its volatility. Volatilization is the process whereby a herbicide changes from a liquid or solid to a gas. Volatile herbicides (those with higher vapor pressures) generally dissipate more rapidly than herbicides with lower vapor pressures. Volatilization increases with temperature and moisture. Most herbicides are relatively nonvolatile under normal field-use conditions. The more volatile herbicides are generally incorporated to avoid gaseous losses. Volatile herbicides include members of the thiocarbamate family EPTC (Eradicane, Eptam) and butylate (Sutan+); the dinitroanilines trifluralin (Treflan) and ethalfluralin (Sonalan); and clomazone (Command).

A herbicide's chemical structure dictates how the herbicide will degrade in soil. Some herbicides are rapidly decomposed by microorganisms if the right kind and number are present and if soil conditions are favorable for their growth. But herbicides vary greatly in their susceptibility to microbial decomposition. The chemical structure of 2,4-D, for example, allows microbes to quickly detoxify the molecule into inactive metabolites, whereas atrazine is not as prone to microbial attack; hence, degradation is slower.

Some herbicides are prone to chemical reactions. Members of the sulfonylurea herbicide family, for example, are degraded through chemical hydrolysis as well as through microbial processes. Remember that for the sulfonylureas as well as the triazines, the rate of chemical hydrolysis is dependent on soil pH. Although it is less sensitive than microbes to fluctuations in soil physical characteristics and often soil moisture, the rate of chemical reaction also will vary depending on the surrounding soil environment. Several families of herbicides are degraded through both chemical and microbial pathways. Others less prone to chemical breakdown are lost primarily through microbial alteration.

AVOIDING HERBICIDE PERSISTENCE IN SUBSEQUENT CROPS

There are several ways to avoid herbicide carryover problems. First, check the recrop statement on the herbicide label and do not plant a sensitive crop prior to the specified time. Check the most recent edition of the *Penn State Agronomy Guide* or the current herbicide label for recrop restrictions. Second, always apply the correct rate of any pesticide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. Higher rates of more persistent products certainly carry a greater risk of injury to subsequent crops. Accurate acreage determination, chemical measurement, proper sprayer calibration, and uniform application are essential for avoiding misapplication problems. *Always read the label before applying any herbicide.*

Several management considerations can influence herbicide persistence. One is application timing. In general, her-

bicide treatments applied later in the growing season have a greater potential for influencing subsequent crop growth than earlier applications. Early preplant timings may reduce the risk of carryover, and foliar applications may not carry the same risk as applications to bare soil if significant live vegetation is present at the time of application.

The *method of application* can influence herbicide residual activity. Some herbicides must be incorporated, while incorporation is optional for others. Mechanically incorporating the herbicide can make it less susceptible to loss by volatilization and photodecomposition. Also, an incorporated herbicide is immediately exposed to charged soil particles and may become tied up through adsorption. Decreased environmental losses (through volatilization and photodecomposition) and increased adsorption favor herbicide persistence.

Banded herbicide applications can reduce carryover potential compared to broadcast applications since banding uses less total herbicide per unit of land. Herbicide residues should be lower between the banded herbicide zones regardless of tillage system or lower throughout the field following a primary tillage operation.

The *amount of tillage* following herbicide application can affect persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect shallow-planted susceptible crops. If a potential herbicide carryover problem exists and soil erosion is not a concern, moldboard plowing, in particular, can help dilute the pesticide.

Herbicide combinations may reduce the risk of carryover problems. Application rates can sometimes be reduced by tank-mixing two or more herbicides rather than making single-ingredient applications. At the same time, combining herbicides can broaden the weed control spectrum. However, avoid applying two or more herbicides with a longer residual life during the same season. More persistent herbicides can interact with one another when applied in the same year or in consecutive years, enhancing crop injury. A soybean crop, for example, may tolerate a certain level of atrazine residue. But if another photosynthetic inhibitor such as metribuzin (Sencor or Lexone) is applied to soybeans the year following atrazine-treated corn, soybean injury is more likely. The same type of interaction can occur when EPTC (Eptam) is used for alfalfa establishment if small amounts of atrazine residue remain from previous use in corn.

Finally, the use of *tolerant rotational crops* or varieties helps to minimize carryover problems. Crop rotation is often dictated by economics, but important differences exist between crops and even among varieties. In general, smaller-seeded crops or varieties are more susceptible to injury from persistent herbicides than larger-seeded species. Ask local seed suppliers about varietal differences that might affect the likelihood of serious crop injury.

Some soybean varieties are more sensitive than others to the triazine herbicides and should not be used with these herbicides or when triazine carryover is a concern. Corn varieties are available that possess greater tolerance to the imidazolinone herbicides. If imazaquin or imazethapyr carryover is a concern, certain varieties can be planted with minimal risk of herbicide injury.

If herbicide residues are suspected in a particular field, a chemical analysis or bioassay can help determine if harmful levels are present. Chemical analysis can be expensive and not all herbicides can be analyzed, so a bioassay may be more feasible. Either can help you determine if herbicide residues exist and if a tolerant crop or variety should be planted in a particular area. Consult your county extension office about available analyses.

In summary, the first step for avoiding herbicide persistence problems is to choose less persistent products. Check the herbicide label for recrop statements before selecting any material. For all pesticides, use the appropriate rates and application timings. Selective tillage, herbicide combinations, and tolerant crops and varieties also help reduce the risk of carryover crop injury. Wise herbicide use ensures the continued availability of these important weed management tools for the future.

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