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Factors Affecting Herbicide Persistence

Herbicides are applied to the soil in hopes of obtaining season-long weed control. It is desirable for the chemicals to control weeds during the season of application, but they should not remain to affect subsequent crop growth. The length of time that a herbicide remains active in the soil is called "soil persistence" or "soil residual life." Anything that affects the disappearance or breakdown of a herbicide affects persistence. Many factors determine the length of time herbicides persist. Most factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. These categories strongly interact with one another.

Herbicides vary in their potential to persist in the soil. Some herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, pigment inhibitors, imidazolinones, and certain plant-growth regulators. Table 1 lists several common herbicides in these groups. Table 2 lists the soil persistence of some common herbicides.

Soil Factors

The soil factors affecting herbicide persistence fit into three categories: physical, chemical, and microbial. Soil composition is a physical factor that measures the relative amounts of sand, silt, and clay (the soil texture) and the organic-matter content of the soil. Chemical properties of the soil include pH, cation-exchange capacity (CEC), and nutrient status. The microbial aspects of the soil environment include the type and abundance of soil microorganisms present.

Soil composition affects herbicide phytotoxicity and persistence through adsorption, leaching, and volatilization. Generally, soils high in clay, organic matter, or both have a greater potential for herbicide carryover because there is increased adsorption to soil colloids, with a corresponding decrease in leaching and loss through volatilization. This "tie-up" results in decreased initial plant uptake and herbicidal activity. Therefore, more herbicide is held in reserve to be released later, thus potentially injuring susceptible future crops.

Some herbicides, principally the triazines (atrazine and simazine), are particularly affected by soil pH, an important part of the soil chemical makeup. Lesser amounts of these herbicides are adsorbed or held to soil colloids at higher soil pH, so they remain in the soil solution. Herbicides in the soil solution are available for plant uptake. Chemical breakdown and microbial breakdown, two major herbicide degradation processes, are often slower in soils of higher pH. So although decreased adsorption of triazine herbicides occurs in soils of higher pH, there is also less breakdown activity. Therefore, these herbicides are more available for plant uptake for a longer period of time on soils of higher pH. Certain members of the sulfonylurea group (chlorsulfuron and chlorimuron) can also persist in higher-pH soils because rates of chemical breakdown are decreased. Low pH affects the persistence of clomazone and the imidazolinones (imazaquin and imazethapyr). Soil pH has little effect on the persistence of other herbicides.

Research shows that various nutrients and cations in the soil affect both herbicide activity and degradation. The CEC, principally a function of clay type and organic-matter content, is directly involved in herbicide adsorption. Some herbicides are more available in the presence of certain cations, whereas others may

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Herbicide families with their persistent members

S-triazines
atrazine (AAtrex, Atrazine)
hexazinone (Velpar)
prometon (Pramitol)
simazine (Princep)

Dinitroanilines
benefin (Balan)
oryzalin (Surflan)
pendimethalin (Pendimax, Pentagon, Prowl)
prodiamine (Barricade)
trifluralin (Treflan, Tri-4)

Others
bensulide (Betasan, Prefar)
clomazone (Command)
tebuthiuron (Spike)

Phenylureas
diuron (Karmex)

Uracils
bromacil (Hyvar-X)
terbacil (Sinbar)

Imidazolinones
imazapyr (Arsenal)
imazaquin (Scepter)
imazethapyr (Pursuit)

Sulfonylureas
chlorimuron (Classic)
chlorsulfuron (Telar)
nicosulfuron (Accent)
primisulfuron (Beacon)
prosulfuron (Peak)
sulfometuron (Oust)

Plant-growth regulators
clopyralid (Stinger)
picloram (Tordon)
triclopyr (Garlon)

be tied up and therefore unavailable. The literature indicates that there is much variation in the effect that cations and nutrients can have on herbicide activity and breakdown, depending on soil composition, nutrient type and concentration, and chemistry of the herbicide.

Soil microorganisms are partially responsible for the breakdown of many herbicides. The types of microorganisms and their relative amounts determine how quickly decomposition occurs. Soil microbes require certain environmental conditions for optimal growth and utilization of any pesticide. Factors that affect microbial activity are temperature, pH, oxygen, and mineral nutrient supply. Usually, a warm, well-aerated, fertile soil with a medium soil pH is most favorable for microorganisms and hence herbicide breakdown.

Climatic Conditions

The climatic variables involved in herbicide degradation are moisture, temperature, and sunlight. Herbicide degradation rates generally increase with increased temperature and soil moisture because both chemical and microbial decomposition rates increase under conditions of higher temperature and moisture. Cool, dry conditions slow degradation, causing greater carryover potential. If winter and spring conditions are wet and mild, herbicide persistence is less likely.

Sunlight is another important factor in herbicide degradation. Photodecomposition, or decomposition by light, has been reported for many herbicides. The dinitroanilines (trifluralin and pendimethalin) are sensitive to light degradation. They may be lost when surface-applied if they remain for an extended time without rainfall. Therefore, degradation is accelerated on very sunny days. This sensitivity to light and loss by volatility are primary reasons for soil incorporation.

Herbicidal Properties

Finally, the chemical properties of a herbicide affect its persistence. Important factors include water solubility, vapor pressure, and susceptibility to chemical and microbial alteration or degradation. The water solubility of a herbicide helps to 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 or carried to rooting zones of susceptible plants. Herbicide leaching is determined not only by a herbicide's water solubility but also by its ability to adsorb to soil particles. Additionally, soil texture and available soil water affect herbicide leaching. Herbi-

Table 2. Soil persistence of some common herbicides applied at labeled Illinois use rates

1 month	1 to 3 months	3 to 12 months	More than 12 months
2,4-D glyphosate (Roundup Ultra) MCPA	acetochlor (Harness, Surpass) acifluorfen (Blazer, Status) alachlor (Lasso, Micro-Tech) ametryn (Evik) bentazon (Basagran) butylate (Sutan+) cyanazine (Bladex, CyPro) DCPA (Dacthal) dimethenamid (Frontier) EPTC (Eptam, Eradicane) flumetsulam (Python) halosulfuron (Permit) lactofen (Cobra) linuron (Lorox) metolachlor (Dual II Magnum) metribuzin (Sencor) naptalam (Alanap) propachlor (Ramrod) siduron (Tupersan)	atrazine (AAtrex) benefin (Balan) bensulide (Betasan, Prefar) bromoxynil (Buctril) chlorimuron (Classic, Skirmish) diuro (Karmex) ethalfluralin (Cucurbit, Sonalan) fomesafen (Flexstar, Reflex) clomazone (Command) hexazinone (Velpar) imazaquin (Scepter) imazethapyr (Pursuit) oryzalin (Surflan) pendimethalin (Pendimax, Prowl) primisulfuron (Beacon) prodiamine (Barricade) pronamid (Kerb) prosulfuron (Peak, in Exceed and Spirit) simazine (Princep) sulfentrazone (Authority) terbacil (Sinbar) trifluralin (Treflan, Tri-4)	bromacil (Hyvar) chlorsulfuron (Telar) imazapyr (Arsenal) picloram (Tordon) prometon (Pramitol) sulfometuron (Oust) tebuthiuron (Spike)

cides that are low in water solubility, are strongly adsorbed to soil colloids, and exist in dry soils are less likely to leach and have a greater potential to persist.

The vapor pressure of a herbicide determines its volatility, the process of changing from a liquid or a solid to a gas. Volatility increases with temperature. Volatile herbicides such as the thiocarbamates (EPTC, butylate) must be incorporated immediately to avoid gaseous losses. These herbicides are less likely to persist than herbicides with low vapor pressures.

Herbicides may be rapidly decomposed by microorganisms in the soil if the right kinds and numbers of microorganisms are present and if soil conditions are favorable for their growth. However, herbicides vary greatly in their susceptibility to microbial decomposition. For example, microbial degradation of 2,4-D occurs very quickly in the soil, whereas microbial degradation of atrazine is slow.

Chemical decomposition is dependent not only on the chemistry of the herbicide (how susceptible it is to chemical breakdown) but also on soil and climatic factors. Chemical breakdown of a herbicide involves reactions such as hydrolysis, oxidation, and reduction. The occurrence of these reactions and the rates at which they take place vary with soil type and climatic conditions. These reactions, along with microbial degradation, are important processes in the decomposition of herbicides.

Avoiding Herbicide Persistence to Subsequent Crops

There are several ways to avoid herbicide carryover problems. First, always apply the correct rate of any herbicide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. To accomplish this goal, accurate acreage determination, accurate chemical measurement, proper sprayer calibration, and uniform application are essential. Always read the label before applying any herbicide.

The method and time of application can be important in avoiding herbicide carryover. Incorporation dilutes herbicide; however, herbicides that have the potential to persist longer than desired will more likely remain longer if incorporated than if surface-applied without incorporation. Incorporating the herbicide makes it less susceptible to loss by volatilization and photodecomposition. In addition, an incorporated herbicide is immediately exposed to soil particles and may be tied up temporarily through adsorption and later released. Decreased environmental losses (volatilization and photodecomposition) and increased adsorption favor herbicide carryover. Banded herbicide applications can reduce carryover potential because less total herbicide is applied than in a broadcast application. Postemergence and late soil applications have greater potential than earlier applications for being present the following season.

The amount of tillage affects herbicide persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till, which leave crop residue on the soil surface, also tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect susceptible crops. In addition, higher rates of herbicides are often used in reduced-tillage systems to maximize weed control and adjust for greater amounts of crop residues. If a herbicide-carryover problem already exists, some tillage to dilute the chemical may help.

Herbicide combinations may reduce the risk of carryover problems. By tank-mixing two or more herbicides, you may reduce the application rates of those products that can potentially cause problems and at the same time broaden the weed-control spectrum.

Herbicides may interact with one another or with other pesticides and may enhance crop injury when applied in the same year or in consecutive years. For example, a soybean crop may tolerate a certain level of atrazine carryover. However, if another photosynthetic inhibitor, such as metribuzin, is applied to soybeans after atrazine-treated corn, injury is more likely.

Plants absorb herbicides from the soil in which they are growing. Persistence may be reduced if the herbicide is metabolized (broken down) by the plant or if the plant containing the absorbed herbicide is harvested and removed from the field. Plant extraction of the herbicide from the soil may not be an important factor under most situations, but it has been used in some cases to help remove persistent herbicides from treated soils.

Finally, the selection of a tolerant rotational crop or variety helps minimize carryover problems. Quite often, economics dictates crop rotation; however, there are varietal differences that might affect the likelihood of serious crop injury. For example, some soybean varieties are more sensitive to the triazine herbicides than others and should not be used if the potential for triazine injury exists. Also, as a general rule, smaller-seeded crops and varieties have a greater potential for injury from persistent herbicides than do larger-seeded species.

If herbicide carryover is suspected, a soil chemical test or biological assay can help determine if harmful levels of herbicide residue are present. Chemical analysis can be expensive, 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 into a problem area. (See Chapter 21, "Testing for Herbicide Residues in Soils.")

Many variables interact in predicting herbicide persistence. Factors involved in the degradation of herbicides include many soil, climatic, and herbicidal properties. The potential for herbicide carryover problems can be reduced by using the appropriate rates and accurate timing of proper application methods. The use of selective tillage, herbicide combinations, and tolerant crops and varieties can also help reduce the risk of crop injury.

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