# 13

# HERBICIDE PERSISTENCE AND HOW TO TEST FOR RESIDUES IN SOILS

## TOPICS OF INTEREST

- Factors affecting herbicide persistence
- Herbicide families that persist in soils
- Precautions to avoid herbicide carryover
- Testing soils for herbicide residues
- Practices to overcome herbicide residues in soils

## 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 long enough 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, 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 on soils of higher pH. Certain members of the sulfonylurea group (chlorsulfuron

---

*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, Prowl)
prodiamine (Barricade)
trifluralin (Treflan, Tri-4, Trilin)

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

**Phenylureas**
diuron (Karmex, Direx)

**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)

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 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. Photodegradation, 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, soil adsorption, 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

**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<br>glufosinate (Liberty)<br>glyphosate (Roundup, Touchdown, many)<br>MCPA | acetochlor (Degree, Harness, Surpass, TopNotch)<br>alachlor (IntRRo, Micro-Tech)<br>ametryn (Evik)<br>bentazon (Basagran)<br>butylate (Sutan+)<br>DCPA (Dacthal)<br>dimethenamid (Outlook)<br>EPTC (Eptam, Eradicane)<br>flumetsulam (Python)<br>foramsulfuron (Option)<br>halosulfuron (Permit)<br>lactofen (Cobra, Phoenix)<br>linuron (Lorox)<br>mesotrione (Callisto)<br>metolachlor (Dual II Magnum)<br>metribuzin (Sencor)<br>naptalam (Alanap)<br>siduron (Tupersan) | atrazine (AAtrex)<br>benefin (Balan)<br>bensulide (Betasan, Prefar)<br>bromoxynil (Buctril, many)<br>chlorimuron (Classic)<br>clomazone (Command)<br>diuron (Direx, Karmex)<br>ethalfluralin (Curbit, Sonalan)<br>fomesafen (Flexstar, Reflex)<br>hexazinone (Velpar)<br>imazaquin (Scepter)<br>imazethapyr (Pursuit)<br>isoxaflutole (Balance Pro)<br>oryzalin (Surflan)<br>pendimethalin (Pendimax, Prowl)<br>primisulfuron (Beacon)<br>prodiamine (Barricade)<br>pronamide (Kerb)<br>prosulfuron (Peak, in Spirit)<br>simazine (Princep)<br>sulfentrazone (Authority First, Sonic)<br>terbacil (Sinbar)<br>topramezone (Impact)<br>trifluralin (Treflan, many) | bromacil (Hyvar)<br>chlorsulfuron (Telar)<br>imazapyr (Arsenal)<br>picloram (Tordon)<br>prometon (Pramitol)<br>sulfometuron (Oust)<br>tebuthiuron (Spike) |

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. Herbicides 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 CARRYOVER

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 labeled 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 herbicides; 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 photodegradation. 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 photodegradation) 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.

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.

## Testing for Herbicide Residues

If herbicide carryover is suspected, a soil chemical test or a bioassay can be used to determine if harmful levels of herbicide are present. Chemical analysis can be expensive, so a bioassay conducted either in the suspect field or in a warm, sunny indoor location (such as a greenhouse) may be more feasible. These tests help predict potential herbicide-residue problems so the grower can make better decisions about crop rotation, herbicide selection, planting date, and other cultural practices.

## Soil Collection and Preparation

With the lab analysis or indoor bioassay, proper sampling of soil is the first step. The procedures for submitting a soil for laboratory analysis and for conducting an indoor bioassay are similar. These guidelines should be followed:

1. In early spring to midspring or before planting time, collect representative soil samples from the suspect field. Take samples from several locations in the field. For the bioassay or laboratory analysis, take 15 to 20 soil cores and combine them to make a composite sample. This sample should represent no more than 15 to 20 acres. Enough areas must be sampled to avoid missing locations with high herbicide-residue content. Take separate samples from areas where excessive residues are suspected,

such as sprayer turnaround points and end rows. Do not mix these samples with the others. Sample the soil to a 6-inch depth, and divide the samples into two sections for greater accuracy—those from 0 to 3 inches and those from 3 to 6 inches. Be sure to mark on the bags the depths from which the samples came. About 8 pounds of soil (about 4 quarts) are needed for each bioassay and 2 pounds of soil (about 1 quart) for each laboratory analysis.

2. Sample an area that is not suspect for use as a “check” soil. This soil may be taken from a nearby fencerow or another untreated area. Keep this sample separate from the others. Many laboratories require a check soil.
3. Submit the samples to the laboratory as soon as possible after sampling. If bioassays are to be performed, they should be run on the soil samples as soon as possible after they have been obtained from the field. If samples cannot be assayed immediately, store the soil in a refrigerator or freezer that is not used for food. If samples are stored in a warm environment, herbicide residue may decrease with time.

## BIOASSAY

The bioassay can help predict potential crop injury. The test is inexpensive and can be done with a few simple supplies. A bioassay does not measure the amount of herbicide residue present in the soil, but it may indicate whether or not enough residue is present to injure a sensitive crop.

### FIELD BIOASSAY

A field bioassay is conducted by planting one or more strips of a species sensitive to the suspect herbicide in the field. This procedure can be done in the fall or spring, but it is more accurate when performed closer to the planting of the intended crop. Before planting the desired crop, allow the test plants to grow and develop symptoms of injury from any herbicide residues. Plant the strips in several locations, if possible, and include an area that is most suspect and an area that can serve as a check. Choose an appropriate species for the bioassay, such as one of the more sensitive ones listed in this chapter. Include several species of differing sensitivity for greater accuracy.

### INDOOR BIOASSAY

The procedures for conducting an indoor bioassay vary, depending on what herbicide residue is of concern. However, for the indoor bioassay, the procedures for soil collection and preparation are the same.

1. For an indoor bioassay, collect the samples and allow them to air dry if needed until they can be worked readily. Do not overdry. If the soil is cloddy, crush the clods into pieces (the size of a pea or smaller). If the soil contains a high amount of clay, the addition of coarse sand (50 percent by volume) improves its physical condition. If sand is added, mix it thoroughly with the soil.
2. Tin cans, milk cartons, and cottage cheese containers are appropriate containers in which a bioassay can be conducted. Punch holes in the bottoms of the containers to allow water drainage. Fill two or more containers (a set) with soil from each sample. Additional containers increase the accuracy of the test. Place the soil samples obtained from depths of 0 to 3 inches in one set of containers; in another set, place the soil obtained from depths of 3 to 6 inches. Follow this procedure for the composite sample and the sample taken from areas where excessive residues are expected. In addition, fill a final set of containers with the check soil.

## TESTING FOR SPECIFIC HERBICIDE GROUPS

### TRIAZINE RESIDUES

For suspected carryover from triazine herbicides, such as atrazine and Princep (simazine), an oat plant bioassay works best. Place about 15 oat seeds in each container of soil and cover the seeds with about 1 inch of soil. Wet the soil with water, but do not saturate it.

Place the containers in a warm location ($70^{o}$ to $75^{o}$F) where they can receive ample light. Sunlight is essential for the development of the plant, as well as for inducing symptoms of triazine injury. The container should be watered as needed.

Injury symptoms should become apparent within 10 to 14 days after emergence. Triazine injury is characterized by chlorosis (yellowing), then necrosis (browning) of leaf tissue. As injury symptoms start at the leaf tip and develop toward the base, a comparison with the plants in the check soil is essential.

If injury appears on the oats, enough herbicide residue may be present to injure a susceptible crop. Planting a more tolerant crop is suggested. In general, the order of susceptibility from most to least susceptible to triazine herbicides is as follows:

Ryegrass > Alfalfa > Oats > Wheat >
Soybean > Sorghum > Corn

### DNA RESIDUES

If residues from dinitroaniline (DNA) herbicides, such as Treflan (trifluralin) or Prowl, Pendimax (pendimethalin), are suspected, a different assay technique is used. A sorghum or corn root bioassay is relatively quick and easy to perform.

Wrap a number of sorghum or corn seeds in a moist paper towel and store them at room temperature for 2 to 3 days. This procedure allows the seed to imbibe water and germinate. Once the seed has germinated, carefully place three to five seeds into containers with the suspect soil and the check soil. Cover the seeds with soil to a depth of about 1 inch and leave them for 10 to 14 days, depending on the air temperature. Water the plants as needed but do not saturate the soil.

At the end of the period of 10 to 14 days, carefully remove the plants and observe the root formation. DNA herbicides inhibit root development. Symptoms include stunted plants, stubbed roots, inhibited root-hair development, thickened hypocotyls on broadleaf species, and leaves that fail to unroll. If the plants in the suspect soil display any of these symptoms in comparison to the check plants, DNA residues may be present at concentrations high enough to injure susceptible crops. In general, the order of susceptibility from most to least susceptible to DNA herbicides is as follows:

Annual rye > Oats > Sorghum > Corn >
Wheat > Alfalfa > Soybean

### IMAZAQUIN, IMAZETHAPYR, AND CHLORIMURON RESIDUES

Imazaquin, the active ingredient in Scepter; imazethapyr, the active ingredient in Pursuit and a component of Pursuit Plus, Extreme, and Lightning; and chlorimuron, the active ingredient in Classic and a component of Canopy, Canopy EX, and Synchrony XP, have the same mode of action. These herbicides affect root and shoot growth and development. Symptoms of plant injury include inhibited root development, stunted plants, and interveinal chlorosis or leaf striping. Therefore, a sorghum or corn-root bioassay performed according to the procedure outlined for suspected DNA residue is appropriate. Corn is more sensitive to imazaquin, and sorghum is more sensitive to imazethapyr and chlorimuron. In addition to making root observations, look for stunted shoot growth and interveinal chlorosis or yellowing. Bioassay plants should be grown for 14 to 21 days. The order of crop susceptibility from most to least susceptible to imazaquin, imazethapyr, and chlorimuron is as follows:

*Imazaquin*: Canola > Alfalfa = Corn = Sunflower >
Sorghum > Oats > Wheat > Soybean

*Imazethapyr*: Canola > Sorghum > Sunflower >
Oats > Wheat > Corn > Alfalfa > Soybean

*Chlorimuron*: Canola > Alfalfa > Sunflower >
Sorghum > Corn > Oats > Wheat > Soybean

Introduction and commercialization of Clearfield (CL) corn hybrids resistant to the imidazolinone herbicides provide producers with a viable option for corn production in fields suspected of having soil-residue levels (carryover) of imidazolinone herbicides high enough to cause injury to conventional hybrids. If bioassay results show residue levels of imidazolinone herbicides are high enough to cause potential injury to conventional hybrids, you may consider planting a Clearfield hybrid if corn is the rotational crop of choice.

### COMMAND (CLOMAZONE) RESIDUES

Clomazone, the active ingredient in Command, inhibits the production of photosynthetic pigments in susceptible plants, causing them to emerge lacking green color (that is, they are white). Lower levels of Command injury may appear as a chlorosis or mild bleaching of the plants. Oats or wheat can be used to detect Command residues using the same procedure as was outlined for detecting triazine residues. Bioassay plants should be grown for 10 days to 2 weeks. Susceptible plants that are exposed to significant levels of Command residues will be white, while untreated or tolerant plants will be green. Keep in mind that oats and wheat are usually more susceptible than corn to injury from Command. The order of susceptibility from most to least susceptible to Command residues is as follows:

Oats = Wheat = Alfalfa > Sunflower =
Sorghum = Corn > Soybean

### OTHER RESIDUES

Bioassays may be made for other herbicides using similar techniques. If the site of action of a specific herbicide is known, then a procedure for detecting the herbicide can be developed. For example, if the herbicide is a root meristematic inhibitor (that is, if it stops cell division in the roots), then a root bioassay is the appropriate test. If the herbicide inhibits photosynthesis, then injury symptoms first appear in the leaves. Choose a species that is moderately susceptible to the suspected herbicide, and always include a check soil. Wheat and oats are very good indicator plants for many herbicides but may be more sensitive than the desired crop. Include several species in the bioassay to give a better range of susceptibility. The desired rotational crop is a good bioassay plant to include.

## LABORATORY ANALYSIS

Laboratory analysis involves extracting herbicide from the soil with the use of specialized equipment to detect very small amounts. The amount is usually expressed in parts of herbicide per million parts of soil (ppm). This measurement can be transposed into pounds of herbicide active ingredient per acre (lb a.i./A) if we assume that an acre of soil weighs 1 million pounds in the top 3 inches and 2 million pounds in the top 6 inches. For a soil sample taken to a 3-inch depth, 1 ppm = 1 lb/A of residue. For a soil sample taken to a 6-inch depth, 1 ppm = 2 lb/A of residue.

A lab report of 0.2 ppm atrazine, then, means that there is 0.2 pound of atrazine per acre if the samples were taken to a 3-inch depth, and 0.4 pound per acre if taken to a 6-inch depth.

The location and concentration of the chemical depend on the herbicide used, the soil type, whether the ground was tilled, and the amount of rainfall since application. In most medium-textured soils (silt loams, silty clay loams, sandy clay loams), the herbicide remains primarily in the top 3 inches unless there was excessive rainfall, the ground was plowed, or the herbicide was deeply incorporated. If the soil has a high sand content (coarse texture), then herbicide leaching may be greater. Movement of the herbicide from the surface soil zone by tillage or by rainfall decreases the likelihood of crop injury. The risk of injury is greater when the herbicide residue is concentrated in the top 3 inches rather than distributed throughout a 6-inch soil depth. Therefore, it is best to sample in two separate sections, from 0 to 3 inches and from 3 to 6 inches.

Whether parts per million or pounds of active ingredient of herbicide per acre is used, it is difficult to translate these units of measure into potential crop injury. Many variables affect crop susceptibility or tolerance, including soil type, crop sensitivity, and environmental conditions after planting. Crop injury is more likely on more coarsely textured soils or under cool, wet weather conditions. Additionally, high soil pH increases the potential of triazine or chlorimuron injury. General guidelines are provided in Table 3, although you are cautioned that crop injury may still occur below these levels.

Laboratories may differ in available tests and in the prices for analysis. The cost can range from $20 to $200 per sample for herbicide analysis. Most laboratories can analyze a sample and have the results in 5 to 7 days. Contact your local Extension office for more information on laboratory selection.

## CORRECTING FOR HERBICIDE RESIDUES

If the lab test or bioassay indicates a potential herbicide-residue problem, several steps can be taken.

1. First select a tolerant crop or variety. This selection depends on what herbicide is of concern. Check current herbicide labels for more information on crop tolerance.
2. Tillage can help dilute herbicide in a problem field.
3. Plant the field that concerns you last. Delaying planting allows more time for the herbicide to dissipate.
4. If the triazine herbicides or chlorimuron is suspect, be sure to check the soil pH and adjust your management practices accordingly.
5. If imazaquin or imazethapyr is suspect, check for low soil pH (< 5.5). Liming would both benefit crop growth and minimize carryover of these herbicides.

Soil bioassays or laboratory tests are not 100 percent accurate in predicting herbicide-residue problems. Crop response to herbicide residue depends on various factors, including species and variety, soil type, and environmental conditions after planting. So, predicting crop injury is often difficult. However, using a soil chemical test or bioassay can help in deciding whether a potential problem exists and in choosing the appropriate crop or variety.

**Table 3. General guidelines for interpreting laboratory soil analysis**

| | Safe level* | | |
|---|---|---|---|
| Herbicide | Parts per billion | Parts per million | Crop |
| Triazine | 150–250 | 0.150–0.250 | Soybean |
| | 40–100 | 0.04–0.100 | Alfalfa |
| | 60–150 | 0.06–0.150 | Oats |
| | 75–180 | 0.075–0.180 | Wheat |
| Dinitroaniline | 100–200 | 0.100–0.200 | Corn |
| | 200–300 | 0.200–0.300 | Wheat |
| Clomazone | 50–200 | 0.050–0.200 | Corn |
| | 15–100 | 0.015–0.100 | Wheat, alfalfa |
| Imazaquin | 2–10 | 0.002–0.010 | Corn |
| | 10–30 | 0.010–0.030 | Wheat |
| Imazethapyr | 10–30 | 0.010–0.030 | Corn |
| | 4–15 | 0.004–0.015 | Sorghum |
| Chlorimuron | 1–2 | 0.001–0.002 | Corn |
| | 2–5 | 0.002–0.005 | Wheat |

*Due to differences in herbicide availability from the soil, “safe” values for herbicide residues differ according to soil type. Low-range values are for coarsely textured soils with low levels of organic matter; higher-range values are for finely textured soils with higher levels of organic matter. 1 ppm = 1,000 ppb.

## AUTHORS

**Aaron G. Hager and Dawn Refsell**
*Department of Crop Sciences*