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Determining Herbicide Carryover Risk- How Close Can We Come?

Mark M. Loux  
Ohio State University

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Factors Determining Injury from Herbicide Carryover

Crop injury resulting from herbicide carryover is a function of four variables: 1) the herbicide residue persisting from one year or crop to the next (or the herbicide concentration in soil at the time of planting); 2) the availability of the herbicide for uptake by the germinating seed, emerging seedling, or young plant; 3) the sensitivity of the follow crop to the herbicide; and 4) the environmental conditions in the early part of the growing season. These four factors interact to determine the potential for or the severity of injury due to carryover.

Herbicide Concentration. The herbicide residue present at the time of follow crop planting is usually determined by soil and environmental conditions during the previous crop season. Soil factors affecting herbicide persistence are discussed in another part of this proceedings. Environmental conditions causing herbicide persistence that may be considered atypically long for a given soil type are: drought, especially during the first few months following herbicide application; or a winter that is longer, colder, and dryer than average.

Herbicide Availability. The availability of the herbicide for plant uptake can vary with soil moisture, organic matter content, soil texture, and pH. All of these factors affect the degree of adsorption, or reversible binding, of herbicide to soil. As herbicide adsorption increases, the amount of herbicide in the soil solution available for plant uptake decreases. While herbicides degrade more slowly in high organic matter, fine-textured soils than in low organic matter, coarse-textured soils, they are also less available for plant uptake in the former. Thus, while carryover injury does tend to occur more frequently in soils of medium to high organic matter content and medium to fine texture than in low organic matter, coarse-textured soils, increased persistence does not always result in increased crop injury due to carryover.

Soil moisture has a major role in determining herbicide availability. The actual concentration of herbicide in the soil may be similar in samples taken in the fall and spring following application, but availability for plant uptake is likely to be higher in the spring. This is because herbicide may become more tightly adsorbed and adsorption less reversible over the five
months following application, in response to reduced soil moisture from crop evapotranspiration. The herbicide may then become more available for plant uptake the next spring over the period between soil thaw and planting of the follow crop, since soil moisture is often high during this period (some herbicide degradation may also occur over this period, though). In other words, extended periods of low soil moisture promote increasingly tighter herbicide adsorption to soil, while extended periods of high soil moisture promote release of herbicide into the soil solution. This can affect the results of laboratory analysis of soil for herbicide concentration as well as plant injury. Some herbicides are more difficult to extract from dry soil than moist soil.

Crop Sensitivity. A given crop is not equally sensitive to all herbicides. For every herbicide, there is a different order of crop sensitivity (corn > sorghum > canola, etc.), although this order may be similar among herbicides in the same class of chemistry (e.g. dinitroanilines). For example, the order of crop sensitivity to atrazine is: ryegrass > alfalfa > oats > wheat > soybean > sorghum > corn. The order of crop sensitivity to clomazone (Command) is: oats = wheat = alfalfa > sunflower = sorghum = corn > soybean.

Environmental Conditions. In many cases, the crop is able to outgrow early injury from herbicide carryover due to favorable environmental conditions. Conversely, when crop emergence and early growth is slow due to cool, wet conditions, the severity and duration of injury is likely to be more extensive. This holds true for injury from the herbicides applied to that crop as well as from carryover of a herbicide. While it may be possible to determine the herbicide concentration in the soil with some degree of accuracy, predicting crop response to that concentration may be impossible due to variable weather.

Methods for Assessing Carryover Risk

There are three methods for determining the potential for crop injury due to carryover: laboratory determination of herbicide concentration, indoor bioassay, and field bioassay. Each method has advantages and drawbacks, as described below.

Laboratory Analysis. For this procedure, herbicide is extracted from the soil with an organic solvent (e.g. methanol), and the amount extracted is measured by specialized equipment. Cost of the analysis ranges from about $50 to $200 per sample. Concentration is usually stated in ppm or ppb, which is parts of herbicide per million or billion parts soil, respectively. The ppm or ppb can be transposed into pounds of herbicide per acre when the depth of sampling is known. Possible problems with the laboratory analysis:
1. The extractability of herbicide from soil varies over time and with varying soil moisture content. For this reason, it is difficult to know whether all herbicide present in a soil sample is being measured. Herbicide concentration may be underestimated when the soil conditions reduce herbicide extractability.

2. The laboratory analysis is an effective tool for predicting carryover risk only when we know the range of concentrations or rates over which the follow crop will be injured by that herbicide. For most herbicides and major crops, rough guidelines are available. However, this range is dependent upon soil texture, organic matter content, and soil moisture content. In addition, environmental conditions at the time of follow crop planting greatly affect plant response to herbicide residues.

Indoor Bioassay. For this method, soil is collected as for a laboratory analysis, placed in containers and the seed of a sensitive crop is planted and allowed to grow for 10 to 21 days. Injury or inhibition of shoot or root growth observed at the end of this growth period provides an indication of the risk of follow crop injury due to carryover. It is important to sample some soil from an adjoining untreated area to use as a control, in order to determine if plant growth in the suspect soil is inhibited by herbicide. This is an easy and inexpensive method that gives a rough idea of carryover risk. Potential problems with this method:

1. As stated above, herbicide availability for plant uptake from soil varies over the year with varying soil moisture content. Past studies with atrazine have shown that a bioassay may detect less atrazine in the samples taken in the fall following application, compared to those taken the next spring for the reasons stated above. In addition, when soil in the container is watered to promote seed germination and plant growth, availability of herbicide for plant uptake may increase, causing more injury than might be observed under field conditions.

2. As stated for the laboratory analysis, plant response to herbicide residues in the field is highly dependent upon environmental conditions. Response under field conditions may be different than in the indoor bioassay.

3. In the indoor bioassay, plant roots are confined to soil in the container. This allows no opportunity for roots to move into soil with a reduced concentration of herbicide, as might occur when roots move downward in the soil profile in the field. The indoor bioassay may thus indicate more severe injury than that occurring in the field.

4. There may be some question as to how sensitive the bioassay crop should be. Using the intended follow crop as the bioassay species would appear to be appropriate, since one is trying to
assess the risk of injury when that crop is planted the following spring. However, when that crop is not extremely sensitive to the herbicide and soil conditions at the time of sampling result in reduced availability of herbicide, the bioassay may underestimate the risk of injury. For this reason, the bioassay crop should be at least moderately sensitive to the herbicide. An effective alternative when the intended follow crop is not extremely sensitive to the herbicide is to bioassay with both that crop and a second crop that has greater sensitivity.

Field Bioassay. For this method, one or more strips of a sensitive crop are planted into the suspect field. This can be done in the fall or spring, but will be most effective if performed close to the planting of the intended follow crop. However, growing conditions at the time of field bioassay planting must be favorable for plant growth, and the plants must have enough time to grow to the point that injury symptoms develop. Early spring and late fall conditions may be unsuitable to support adequate plant growth. As started above, a field bioassay conducted in the fall may not accurately predict the risk of injury to a follow crop due to herbicide availability differences. However, the field bioassay may more accurately show the potential for injury than an indoor bioassay, as soil moisture in the field is often adequate for plant growth without additional irrigation, which can alter availability. In addition, the field bioassay exposes plants to a realistic distribution of herbicide throughout the soil profile, and plant roots have some opportunity to move into soil with less herbicide.

Sampling. Effectiveness of the laboratory analysis and indoor bioassay is dependent upon the time and method of sampling. Ideally, the sample should be taken as late in the spring before planting as possible, since this is when availability and concentration of herbicide in the soil will most closely approximate that at planting. However, spring sampling may not allow enough time for the grower to receive results and change plans. Late-fall sampling is another option, under the assumption that herbicide concentrations do not change much between late fall and early spring. This may be a correct assumption, but differences in herbicide availability in the soil between fall and spring are highly likely, possibly resulting in an inaccurate prediction of carryover risk.

Most fields have areas where herbicide rates are likely to be higher than intended, due to sprayer overlaps. Sampling should account for rate differences, with samples of soil from suspected sprayer overlap areas kept separate from other samples for the purpose of bioassay or laboratory analysis. Depth of sampling is another factor to consider. Most herbicide remains in the upper few inches of the undisturbed soil profile, but herbicide may move deeper in coarse-textured, low organic matter
soils. Moldboard plowing moves herbicide deeper into the profile, compared to no-till or conservation tillage implements. The most effective sampling technique for an accurate determination of carryover risk may be to sample the soil to a 6-inch depth, and divide the samples into 0- to 3-inch and 3- to 6-inch sections before bioassay or analysis.

Summary

None of the common methods used to estimate herbicide residues in soil will necessarily provide an accurate prediction of the risk of crop injury due to carryover. Inaccuracy in carryover prediction stems mainly from the effect of soil and environmental conditions on herbicide availability for plant uptake and germination and early growth of the follow crop. Laboratory analysis and bioassays provide a rough estimate of the amount of herbicide present in the soil, and are thus helpful in managing persistent herbicides. Each method has advantages and disadvantages. Laboratory analysis to determine herbicide concentration in soil is expensive, and is only useful where one knows the range of concentrations required to cause crop injury. Bioassays are inexpensive and relatively easy to conduct, but may show only whether herbicide is present, rather than providing an estimate of concentration. Dependence upon these methods for assessing carryover risk should not substitute for proper herbicide selection, based on a working knowledge of soil type in the target area and how a given herbicide will interact with that soil type.