SOIL PROPERTIES AND HERBICIDE BEHAVIOR

Bill Simmons
University of Illinois

Herbicides with soil activity are still an important component of weed control in corn and soybean. These may include both PRE applied herbicides and POST applied herbicides with soil activity. The interaction of soil properties, water, and application timing affects efficacy, crop response, and potential for carryover. In this presentation I will discuss the following topics:

- The basics of soil interactions with herbicides
- Efficacy of fall-applied herbicides
- Carryover potential as affected by herbicide, soil, and climatic conditions
- Value of residual control in total post systems

The Basics of Soil Interactions with Herbicides

Soils contain the organic matter and clay particles that control herbicide sorption, water relations, and provide the environment that influences microbial activity. The primary herbicide loss pathways in soil are microbial breakdown and chemical breakdown primarily driven by reactions with water. The effects of soil temperature and moisture on herbicide degradation are straightforward in that degradation mechanisms that involve microorganisms operate best at optimum biological growth conditions. In addition, nonbiological chemical reactions are typically enhanced with increased temperature. Water is essential for microbial activity and increases aerobic processes up to the point that saturation occurs and gas transfer with the atmosphere is hampered. Soil texture and organic matter content have a surprisingly small effect on carryover because the differences in water and nutrient availability are often counterbalanced by the differences in herbicide adsorption. Thus, a fertile soil rich in organic matter may promote faster degradation of an herbicide but also have less available to degrade based on its greater adsorption sites.

Soil pH is important in affecting the stability of some herbicides and herbicide families. High soil pH associated with calcitic soils, over-liming, or proximity to limestone gravel lanes may reduce herbicide degradation and increase carryover. This may be important for trains and some sulfonylureas. Hydrolysis, an important breakdown mechanism, slows significantly at soil pH values near 7.0.

Bio-persistence, or the ability of the parent compound to exist in the soil, is an important feature of soil-applied and some post emergence herbicides and determines the suitability of early preplant applications, residual weed control, and threat of off-site loss to surface or groundwater. To optimize the application timing of soil-applied herbicides a balance between persistence and requirement for rainfall needs to be considered.

The soil-applied acetamide market in corn is still a significant and competitive marketplace where performance profiles across application timings determine use and market share. Subtle differences in performance based on rainfall patterns and amounts do exist among different herbicides and different herbicide formulations. Future changes in the use patterns of these herbicides may occur in transgenic corn, in mixes with other herbicides, and in formulations that allow post application of these herbicides.

Herbicide persistence is an important property of soil-applied herbicides and some postemergence herbicides that allows for extended weed control. When the herbicide remains unaltered in the soil during the crop season of application it is an advantage. If an herbicide remains in the soil and is present when a rotational (and susceptible) crop is planted the persistence causes herbicide carryover. Most herbicides do not carryover. Degradation rates in the soil under normal environmental conditions typically reduce herbicide concentrations to sub-lethal levels for rotational crops. Some herbicides have additional safety in that they are not injurious to rotational crops.

Shifts in herbicide application timing to earlier applications have put a premium on herbicide persistence to coincide with weed emergence. In a broad sense, the resistance to degradation and downward movement within the soil profile are both important to obtaining satisfactory weed control.

Persistence is an important characteristic of an herbicide since it affects efficacy, exposure to environmentally important transport, and carryover to subsequent crops. Persistence is the integrated result of all herbicide loss pathways that act upon the parent compound when it is in the soil environment.

Degradation of many herbicides follows first order kinetics, meaning that the rate of degradation is roughly proportional to the herbicide concentration. The "half-life," or time when 50% of the parent compound is gone, is an herbicide property that is frequently cited in technical information and promotional literature. Under field conditions, the half-life is quite variable and dependent upon environmental conditions.

Tillage Systems and Weed Control

Selection of a tillage system may impact herbicide preference, application timing, and efficacy as well as the type of weed species that will dominate. The primary influence of tillage on herbicide performance and weed control is twofold: (1) the degree of tillage influences the amount of crop residue on the soil surface, and (2) tillage systems without cultivation rely on post-emergence herbicides to deal with weeds.

Tillage is used in agriculture to disrupt soil, incorporate crop residues, help control weeds, and prepare seedbeds. The moldboard plow was the standard tillage system used by European settlers to “break ground” as they found it in their westward expansion through North America. In the 1930s, newer systems utilizing chisel plows were designed to leave partial residue and help control wind and water erosion. In the 1960s, no-till systems were developed to allow farmers to plant directly into undisturbed crop residue. Reducing tillage permitted them to farm more acres, reduce equipment and fuel costs, and further control erosion. A further boost to interest in reduced tillage occurred with passage of the 1985 Food Security Act (Farm Bill) that directly tied the use of reduced tillage to participation in government programs. Today, the full continuum of tillage options exists from moldboard plow, to strict no-till, and everything in between.

The maintenance of coarse residues at the soil surface through reduced tillage can change the general flow of water, heat, and gases from the soil to the atmosphere. The primary physical effects are:

1. Protection of the soil surface from raindrop energy.
2. Insulation of the soil surface.
3. Reduction of evaporation.
4. A surface with higher reflectance than dark soil.

The net result of these physical alterations is typically a wetter and cooler soil. Cooler soils are a relative advantage in warmer climates while they can be a severe limitation in the north. The geographic pattern of adoption of reduced tillage reflects this principle.

Raindrops that fall on crop residue are less likely to physically disperse soil, thereby leaving intact soil structure that can more successfully absorb rainfall. In moldboard-plowed fields, a hard rainfall can lead to soil crusting and reduce infiltration of subsequent rains. Crusting can lead to erosion when it occurs even on gentle slopes. Erosion can reduce weed control by scouring away upper surface soils where herbicide is present. There are also negative water quality consequences associated with erosion of herbicide-treated soils.

Insulation of the soil surface decreases temperature fluctuations, reduces evaporation, and creates a zone of high humidity under the residue. In some cases the extra moisture can facilitate germination of small seeds with limited soil contact. Later in this article the effect of residue cover on weed species in limited tillage will be discussed.

Crop injury caused by soil-applied herbicides may be accentuated by cooler and wetter soils. No-till soils favor such conditions. Crop safety is an important issue for newer herbicides especially as many of them are shifted to early preplant applications and earlier planting times.

Another potential effect of reduced tillage on herbicide performance is the development of thin pH and organic matter stratification zones, especially in long-term systems. Without tillage surface pH levels may drop over time, especially with surface applied ammonium sources of nitrogen. Corrections made with lime are not incorporated and can result in high pH zones. The effects of pH and organic matter on herbicide availability and persistence are well known.

Weed Species Shifts in Reduced Tillage

Crop production systems that forgo primary tillage rely on a burndown herbicide treatment to control existing vegetation. Following or concurrent with the burndown treatment, a soil-applied early preplant (EPP) or preplant (PRE) herbicide is used to control emerging weeds. Post emergence (POST) treatments are used to treat weeds not controlled by the PRE treatment.

Reducing tillage favors two categories of weed species: (1) annual grasses and some small seeded broadleaves, and (2) perennial weeds. Larger seeded broadleaf weeds tend to proliferate more in systems with tillage since their seeds are incorporated into a favorable zone for germination. Behaviors of small seeded broadleaf seeds are species dependent. The difference in response is related to ability to surface germinate and the possible effects of shading and allelopathic effects provided by the residue.

Another important aspect of the interaction with tillage, residue, and herbicide performance is the timing of germination with herbicide application. Limited tillage soils are typically colder and may delay germination of some species. Differential burial depth of seed may also delay emergence. Species such as tall and common waterhemp that have a staggered germination pattern to begin with may continue to emerge before soybean canopy closure and require several POST treatments to obtain control.

Soil-applied Herbicide Performance in the Reduced Tillage Environment

Crop residues interact with herbicides and weed control by intercepting herbicide applications, promoting shading, and leaking allelopathic compounds that suppress weeds. The role of crop residue on weed control is complex. Herbicides with high affinity for organics (high Koc values) may bind with residue and never reach the soil surface.

Because reduced tillage may stagger germination times, short half-life herbicides may be even less effective than they would be in a clean-tilled environment. Weed control may result when a strongly adsorbing herbicide is sprayed onto crop residue and subsequent planting operations disturb residue and expose bare untreated soil.

The following generalizations may be made:

1. Crop residues promote germination of surface germinating weed species.
2. Without herbicide use, residue generally suppresses weed growth when compared to a bare soil.
3. Low solubility, hydrophobic herbicides are more likely to be sorbed to crop residue.
4. Corn and rye residue may suppress germination of other grass species.

Value of Residual Control in Total Post Systems

Glyphosate-resistant crops treated with glyphosate alone do not allow for any residual control of weeds that might germinate after the last POST application is made. What is the value of a residual herbicide either mixed in with glyphosate or applied to the soil at planting? Data will be presented that addresses this issue.