Group 2 Herbicide Interactions and Approaches to Detection in Soils

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Background

The Group 2 herbicides are those that inhibit plant growth by inhibiting acetolactate sythase (ALS), an enzyme required for synthesis of some amino acids in plants. The ALS inhibitors include compounds in the imidazolinone, sulfonylurea, triazolopyrimidine sulfonanalide, pytimidinylthiobenzoate, and sulfonylaminocarbonyl-triazolinone categories. The herbicides are rather unique in their ability to control weeds through both foliar uptake and through root uptake as they are also biologically active in soil. This provides control of both emerged weeds and those that emerge after time of application. Other benefits include low application rates and low mammalian toxicity. Carryover of a herbicide beyond the year of application can be of benefit in controlling weed growth in subsequent years, but can also be of concern in causing injury to sensitive crop species that may be grown in the years following application.

Carryover

Some rotational crops grown in years following application of ALS inhibitors are sensitive to very low concentrations of these compounds that persist in the soil beyond the year of application. Damage often appears as root stunting and pruning due to the growing point being affected (Figure 1) and can ultimately result in reduced biomass or economic yield. The extent to which re-cropping injury may occur from Group 2 herbicide carryover depends on a host of factors including the herbicide, its rate of application, sensitivity of crop grown in rotation, soil and environmental conditions.

Figure 1. Root pruning from ALS inhibiting herbicide residue in soil. Seedling from untreated soil on the left and progressing to higher concentrations moving right.

The phytotoxicity of a soil residual herbicide refers to the toxic effect that the residue has on plant growth. Phytotoxicity is dependent on the amount of herbicide that sorbs to the soil particles and the rate at which it can desorb back into the soil water. Organic matter and clay content are the two components of soil largely responsible for herbicide sorption. Many studies have shown that soils with high organic matter and clay content result in increased sorption and reduced phytotoxicity of Group 2 herbicide compounds like imazethapyr, flucarbazone and many sulfonylurea herbicides (Eliason et al., 2004). While the sorption of a herbicide will reduce its phytotoxicity by removing it from the soil solution, it can also increase its persistence or half-life (time for 50% of the herbicide to disappear), as the adsorption can render the compound unavailable for degradation. Different herbicide compounds have different rates of degradation in the soil, with reported half - lives ranging from two days to over 100 days, depending on the compound.

Other important soil factors affecting phytotoxicity and persistence of a Group 2 herbicide beyond the growing season include soil pH, moisture content and temperature. For example, higher pH can result in reduced sorption of some Group 2 herbicides like sulfonylureas and produce greater phytotoxicity and injury. On the other hand, high pH and reduced sorption can sometimes result in greater degradation rates and reduced persistence such as for the imidazolinone herbicides.

Many herbicides that have residual activity are degraded in soil by microbial activity and/or hydrolysis. At higher pH values, microbial degradation is the dominant pathway for dissipation. Soil temperature and moisture have a profound effect on the rate of microbial decomposition. In cooler and drier soils, microbial degradation rates are reduced. As a consequence the risk of carryover and injury in recropping is increased with lower than average growing season precipitation and temperature. As such, some Group 2 herbicides have recropping restrictions outlined on their label that are sensitive to growing season precipitation and temperature in the year of application, along with soil properties like organic matter and pH.

Given the sensitivity of herbicide carryover and injury potential to environmental and soil conditions, it is not surprising that any observed recropping injury tends to be variable across farm fields, owing to variations in soil organic matter content, texture, pH, moisture and temperature. Field and laboratory studies in Western Canada have shown that phytotoxicity and persistence of several Group 2 herbicides, including imidazolinones and sulfonylureas are dependent on position in the landscape (Szmigielski and Schoenau, 1999).   As shown in Figure 2, injury tends to be greatest in the upslope areas of fields, especially on eroded knolls where a combination of low organic matter content, high pH, and lower soil moisture content combine to result in greater phytotoxicity and persistence of residues (Schoenau et al., 2006).

Figure 2. Landscape dependency of Group 2 herbicide carryover on left side, showing greater phytotoxicity to canola in upslope regions of the landscape than in the depressions, compared to untreated landscape on right side.

Interactions

The simultaneous presence of two or more herbicide residues in soil can occur as a result of use of multiple herbicides in a single growing season that persist beyond the season of use into the following season. More commonly, it is the result of use of one herbicide in one season, followed by use of another herbicide the following season, with both compounds carrying over in the soil into the third season. This scenario, sometimes called "stacking", raises questions about possible interactions among the residues in the soil. Interactions may be additive, synergistic, or antagonistic. Additive interactions mean that the herbicides work independently of each other, and the net effect when the herbicides are present together is the sum of the effects of each herbicide applied individually. Synergistic and antagonistic interactions result in more or less toxicity, respectively, than the sum of the independent effects.

Laboratory and field work conducted at three sites in Saskatchewan on soils collected from treatments with application of the herbicide imazamox/imazethapyr to peas, followed by either imazamethabenz, flucarbazone, sulfosulfuron, or florasulam to wheat the next year revealed no antagonistic or synergistic interactions of the herbicide residues. The injury from sequential field applications of ALS inhibiting herbicides over two years was additive in nature, as assessed by root length inhibition in a mustard root length bioassay (Figure 3).

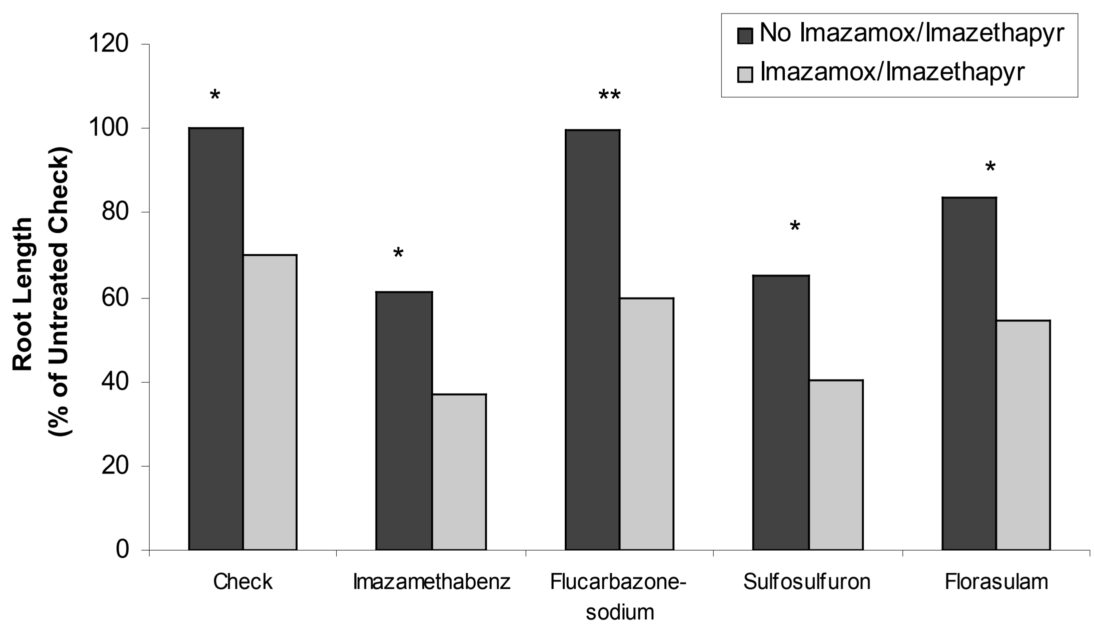

Figure 3. Oriental mustard root length responses as a percent of the untreated check averaged over six site years in three Saskatchewan soils from samples taken one year after the application of four herbicides (if applied) and two years after the application of imazamox/imazethapyr (if applied). Paired bars with a single asterisk are significantly

different with a p value < 0.05; double asterisks indicate a p value < 0.01 (B. Geisel, MSc thesis, University of Saskatchewan).

However, this implies that the potential is still there for greater phytotoxic effects when two separate residual herbicides are applied as compared to one. Therefore there is possibility for rotational crops to be injured from two residues present and acting together in an additive manner compared to only one residue present if the rotational crop is sensitive to both compounds. It may be desirable to avoid sequential application of residual ALS inhibiting herbicides over two years if sensitive crop species are grown in rotation.

Detection

There are two main approaches for detection of herbicides in a sample of soil: 1) direct assessment by extraction and instrumental analysis and 2) bioassay using a sensitive plant species. Direct assessment involves extraction of the compound from the soil and measurement using an instrument like a chromatograph or mass spectrometer. The advantage of this approach is that provides a quantitative measure of the total concentration of the compound in the soil. However, such techniques are typically time consuming and expensive, often costing hundreds of dollars per sample. Furthermore, they do not provide a measure of the biological activity of the herbicide in the soil and an extensive database to relate the total concentration to damage potential in the field often does not exist, or is not readily accessible. As such, direct extractions are not typically used on a routine basis in predicting injury potential.

The second approach to detection of herbicide in a sample of soil is the use of a bioassay. A plant bioassay involves assessment of the inhibition of some component of plant growth such as root length, shoot length or yield that is measured and related to the concentration of the herbicide in the soil. Bioassays are sensitive to the biologically active portion of the herbicide in the soil and can be used to assess potential phytotoxicity. Using a dose response curve, they can also be used to determine the total amount of herbicide in the soil. Compared to chemical extraction, bioassay analysis is less expensive and does not require sophisticated analytical instrumentation.

For detection of Group 2 herbicides with bioassays, inhibition of shoot growth and root length are often used. To this end, a simple mustard root length bioassay was developed at the University of Saskatchewan for detection of ALS inhibitor residues in soil. This bioassay is completed in three days using 200 g of soil for four replicate measurements (Figure 4).

Figure 4. Oriental mustard root length inhibition bioassay showing mustard roots growing in soil after three days (Szmigielski et al., 2008).

Good agreement between yield reductions observed in treated field soils and the root length inhibition measured in samples collected beforehand led to the conclusion that the mustard root length bioassay has potential as a simple tool for "red flagging" soils where injury from Group 2 carryover could be an issue. However, it must be noted that many environmental and soil factors can affect the extent to which injury occurs in the field that cannot be measured or reliably predicted in a bioassay conducted on a sample of soil. Furthermore, any assessment based on sampling soil has limitations as to how well the sample collected represents the field. For this reason, label directions on recropping intervals for sensitive species should be followed as the guideline.

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