Factors Affecting the Phytotoxicity and Persistence of Group 2 Herbicides in Prairie Soils

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Abstract:

Advantages of Group 2 herbicides include low use rates, broad spectrum weed control and low mammalian toxicity. However,Group 2 herbicides often persist in soil and cause damage to subsequent crops in rotation. Phytotoxicity and persistence are the two parameters that determine the potential damage that could occur from these herbicides. These parameters are affected by soil properties, both chemical and physical, and by environmental factors. Phytotoxicity is often increased and persistence extended by low soil organic matter contents. If the compound is susceptible to hydrolysis, low pH can cause increased rates of dissipation due to this chemical process. Microbial activity and the environmental factors that influence decomposition also play a large role. Increased moisture and temperature typically result in increased microbial activity and decreased persistence. Identifying the factors which are most influential in the phytotoxicity and persistence of Group 2 herbicides is important in managing crop rotations and reducing potential for crop damage.

Introduction:

Group 2 herbicides are characterized by low use rates, broad spectrum weed control and low mammalian toxicity. These characteristics have made such herbicides an important part of production agriculture since their discovery in the mid 1970's (Brown 1990). Group 2 herbicides include imidazolinone, sulfonylurea and sulfonylaminotriazolinone herbicides, which kill weeds by inhibiting production of the acetohydroxyacid synthase (AHAS)/acetolactate synthase (ALS) enzyme. This enzyme is crucial in the production of branched chain amino acids, particularly valine, leucine and isoleucine. However, because this enzyme does not occur in animals, these herbicides show low mammalian toxicity (Tuxhorn 1994).

Another characteristic of Group 2 herbicides is their potential for carryover in the soil and ability to cause damage to successive crops that are sensitive to the herbicide residue. Many sulfonylureas and imidazolinones have been shown to persist in the soil past the initial growing season and cause damage to a variety of rotational crops(Moyer 1995; Moyer and Esau 1996). Because of the high toxicity of Group 2 herbicides at low concentrations, damage can easily occur to crops following in rotation and cause yield loss.

Factors Affecting Phytotoxicity and Persistence:

There are two parameters that govern the potential for crop damage; phytotoxicity and persistence of the compound. Phytotoxicity refers to the amount of herbicide in the soil that is available for plant uptake and will cause injury. This is difficult to measure and is strongly affected by soil properties. Persistence is the length of time the compound remains in the soil, is typically expressed as a half life and is also affected by soil properties as well as environmental factors.

Soil pH can have a direct effect on herbicide degradation if the stability of the compound is pH dependent (Walker 1991). Acidic soils will often enhance the dissipation of herbicides, as acid-catalyzed hydrolysis yields compounds that are inactive against plant species (Joshi 1985). If the compound is susceptible to hydrolysis with a pH range typical of prairie soils, pH could potentially be used as an indicator of potential damage. There are Group 2 herbicides that are stable to hydrolysis in Prairie soils (flucarbazone sodium). However, soil pH can also affect the microbial populations of the soil and the adsorption of the compound to the soil organic and mineral components (Walker 1991), which is important if the primary mode of degradation is microbial.

Environmental factors such as moisture and temperature also play a role in herbicide persistence. Both of these parameters directly affect microbial activity, which in turn can increase or decrease persistence. Generally, the degradation of sulfonylurea herbicides, proceeds more quickly with increasing soil moisture levels (Beckie 1989; Smith 1990; Hill 1998). Moisture typically affects microbial activity and decreased moisture most often results in decreased activity and greater persistence(Figure 1). Increased temperature typically serves to increase microbial activity, and thereby the degradation rate of the herbicide. It follows that during winter months, microbial activity would decline, and the process of degradation would cease.

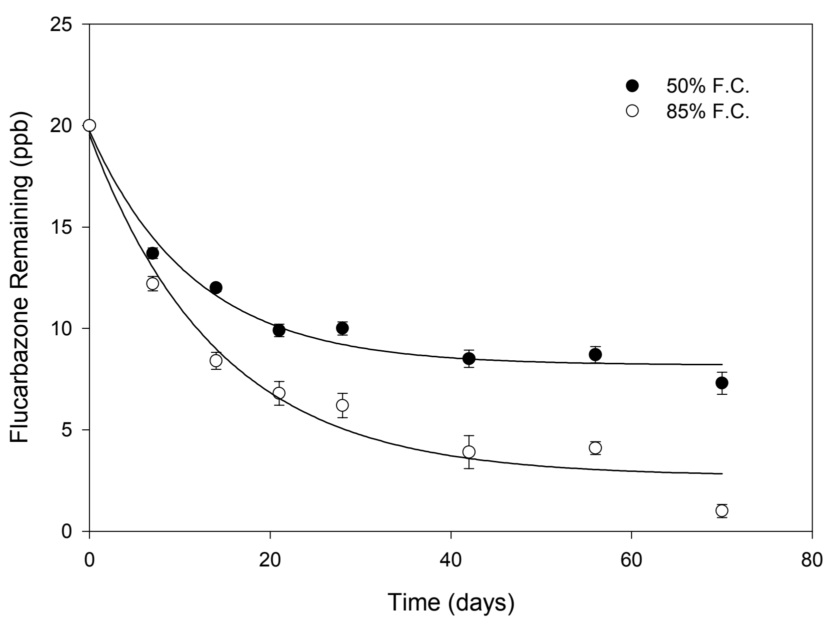

Figure 1. Persistence of flucarbazone sodium in a Brown Chernozem at 50% and 85% field capacity.

Organic matter also plays a key role, both in the persistence and phytotoxicity of herbicide residues in the soil. Organic matter is one of the primary factors controlling herbicide adsorption and therefore, availability in the soil. In many instances, organic matter serves to bind the herbicide and render it unavailable for plant uptake (El Azzouzi 1998). Sulfonylureas and imidazolinones have been shown to have increased sorption in soils with high organic matter(Szmigielska 1999). Because of this, organic matter can reduce the phytotoxicity of compounds in the soil (Figure 2) and decrease the potential for crop damage.

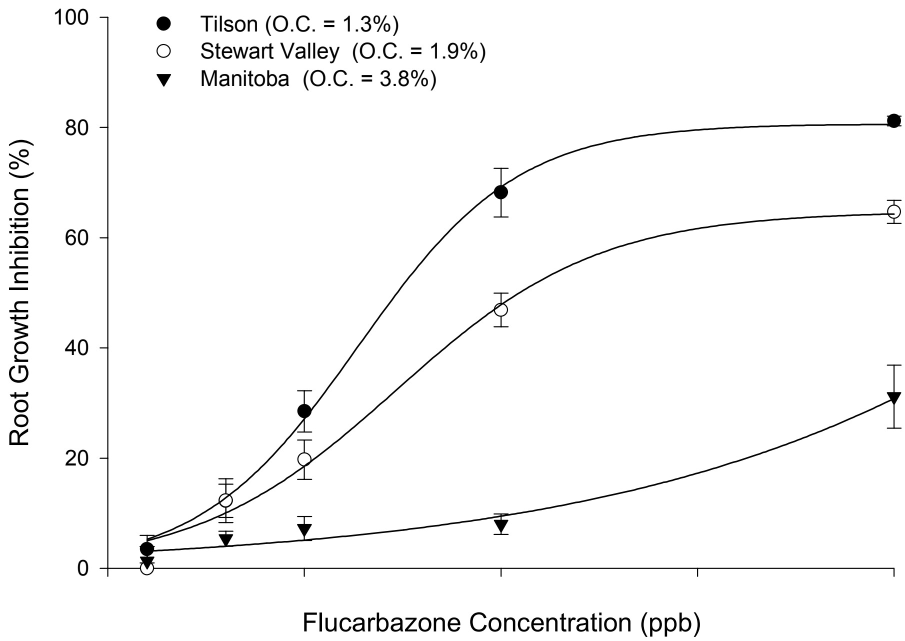

Figure 2. Phytotoxicity of flucarbazone sodium in three soils with different organic matter contents.

Increased organic matter is also associated with increased microbial activity (Walker 1991) and potentially greater dissipation rate but increased sorption to organic matter can also reduce herbicide availability to microbial processes (Derksen 1996). The inability of the microbial population to access the compound can result in increased persistence of the herbicide in the soil as shown in Figure 3. Depending on the phytotoxicity of the herbicide, extended persistence could result in increased potential for crop damage.

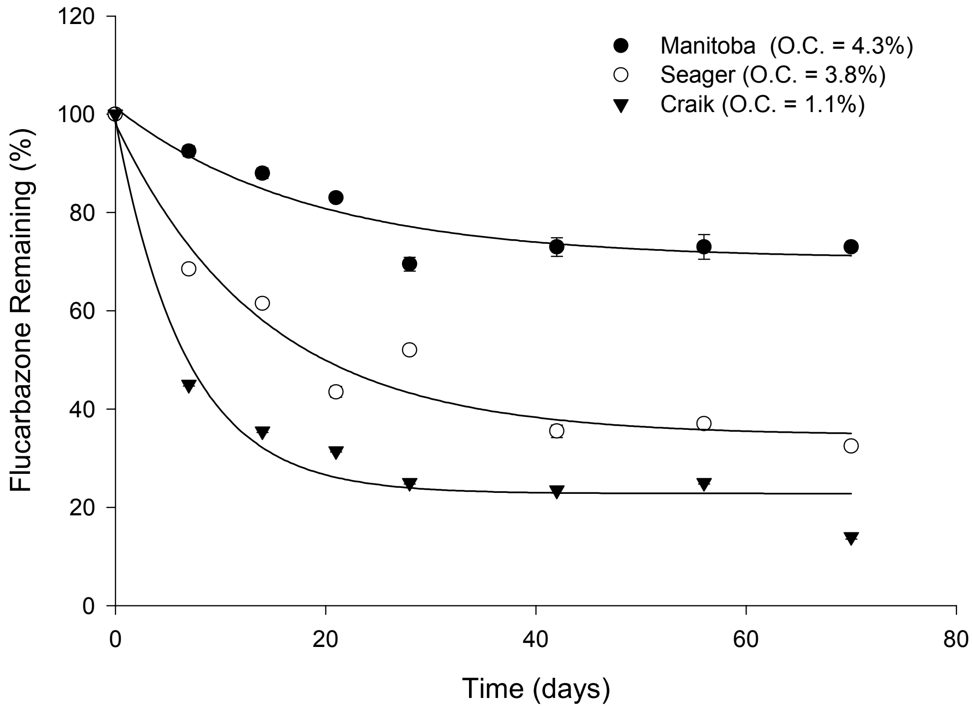

Figure 3. Persistence of flucarbazone as influenced by soil organic carbon (o.c.).

Summary:

The phytotoxicity and persistence of Group 2 herbicides is an important issue in production agriculture. Each herbicide responds differently to changes in contributing factors and so research to identify specific herbicide responses and plant sensitivity is necessary. Identifying conditions that may be more conducive to persistence and high levels of phytotoxicity is important. Landscape areas such as knolls, which typically have low organic matter, low soil moisture and higher pH are more likely to be areas in which carryover damage would be seen.

Understanding the soil and environmental conditions which affect the persistence and phytotoxicity of Group 2 herbicides is the first step in being able to manage and reduce the recropping risks associated with them.

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