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Effects of Soybean Tillage Systems on Imazaquin Persistence

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Abstract

Dissipation studies were conducted during 1988, 1989, and 1990 in Mississippi on a Marietta loam, and during 1988 and 1989 in Tennessee on a Statler loam, to determine the effects of soybean tillage systems on persistence of bioavailable imazaquin. Imazaquin concentration as determined by a corn shoot bioassay was generally not correlated with time after application. This was because of wide fluctuations in rainfall that occurred throughout the duration of the experiments in each of the years. Imazaquin half-life ranged from 30 to 75 days in Mississippi and from 24 to 50 days in Tennessee. Imazaquin dissipation was not affected by tillage systems. The only difference between years occurred in Tennessee, and could be attributed to difference in initial concentration between years and differences in rainfall the first 30 DAT. Differences in locations occurred in 1989, and were attributed to differences in initial concentration and the lack of rainfall 60 to 120 DAT in Mississippi.

Introduction

Imazaquin (2-4[4,5-dihydro-4-methyl-4(1-methyl-ethyl)-5 oxo-1H-imidazol-2-61]-3quinolinecarboxylic acid) is used for control of broadleaf weeds and grasses in soybeans. It is effective for control of various troublesome weeds, including common cocklebur (*Xanthium strumarium* L.), ivy leaf morningglory (*Ipomoea hederacea* L.), sicklepod (*Cassia obtusifolia* L.), and velvetleaf (*Abutilon thheophrasti* Medicus.) (7, 10, 15, 29). Microbial degradation under aerobic conditions is the primary degradation mechanism of the imidazolinon herbicides (4,14). However photodecomposition can be an important degradation mechanism of imidazolinone herbicides when they are applied to the soil surface (1, 6, 20).

Imidazolinone herbicides are generally weakly adsorbed to soil (2, 3, 9, 12, 24, 28, 30). Some studies have shown that imidazolinone adsorption was not affected by clay or organic matter content (9, 28). However, other studies have indicated that adsorption increases with increasing clay and organic matter content (2, 12, 13, 24, 30). One study found that soil type appeared to have little effect on imazaquin adsorption above pH of 6 (13). Adsorption of imazaquin is negatively correlated with soil pH (9, 12, 13, 21, 24, 30). However, pH has little effect on imazaquin adsorption from pH 5.5 to 8.0 (21). The predominant factor for imazaquin adsorption may be aluminum and iron (oxy) hydroxides and kaolinite, all of which have pH-dependent charge characteristics (9).

Soil water may also compete with imazaquin for binding sites (3, 21). Temporary drying and returning to field capacity increased adsorption of imazaquin (9). Imazaquin has shown limited mobility (2, 5, 13, 20). Imazaquin mobility is influenced by clay contnet, organic matter content, humic matter content, and soil pH (11, 13, 24, 25).

Imazaquin degradation is characterized by rapid initial dissipation, followed by a slower second phase breakdown (11, 20, 26). There appears to be a relationship between availability and dissipation rate; dissipation increases with increasing availability (11). Half-life of imazaquin has ranged from 7 to 133 days (5, 16, 17, 22, 23, 26). Dissipation of imidazolinones is slower in clay, silty clay, and silty clay loam than in silt loam soil (1, 2, 11, 13). Other studies have indicated that imazaquin degradation cannot be explained by differences in soil characteristics (22, 26). Soil moisture can also affect degradation of imidazolinones (5,6). In most cases, imidazolinone persistence increased with drier soil conditions (1, 5, 6, 13, 18).

Tillage can affect herbicide persistence in some instances. Imazaquin persisted longer when applied PPI than PRE in some, but not all, instances (5,20). Tillage did not affect dissipation of imazaquin or imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} (5). Tillage did not affect dissipation of imazaquin or imazethapyr in a sandy loam or silt loam soil in Georgia (18). Fall chisel plowing did not reduce carryover potential of imazaquin to sensitive species when compared to no-till systems (27).

In one study, 65% of the applied imazaquin remained on the wheat straw immediately after application (31). When 0.25 cm (0.1 in) of irrigation was added only 30% of the amount applied remained on the wheat straw (31). The amount of imazaquin remaining on the wheat straw 7 DAT with no irrigation was only 30% of that applied (31). Initial concentrations of imazaquin and imazethapyr were greater in convential tillage than no-till due to interception by wheat straw mulch (17). Dissipation of imazaquin differed between conventional tillage and no-tillage, while imazethapyr dissipation was similar between the two tillage systems in one of the two years (17). Similar dissipation of imazaquin and imazethapyr occurred between years in the no-till systems suggesting a moderating influence of the wheat straw mulch (17). Moderation of soil temperature and water content would tend to stabilize the effects of these factors on microbial and/or chemical degradative processes (17).

These experiments were part of a regional project to determine how tillage affects imazaquin persistence in the southern United States on soil types typical for the southern soybean growing area.

Materials and Methods

Similar field studies were conducted in Mississippi on a Marietta loam (fine-loamy, siliceous, thermic Fluvaquentic Eutrochrept), and in Tennessee on a Statler loam (fine-loamy, mixed, thermic Humic Hapludult).

The experimental design of these studies was a split-plot factorial arrangement of treatments in a randomized complete block, with four replications. The main treatments consisted of tillage systems, and included conventional tillage monocrop soybeans and no-till soybeans planted directly into wheat (*Triticum aestivum* L.) residue after chemical burndown. The subplots consisted of 140g ai/ha (0.125 lb ai/A) imazaquin, and an untreated control. These studies were conducted in 1988, 1989, and 1990 in Mississippi; and in 1988 and 1989 in Tennessee. Plot size for the experiment was four 76-cm (30-in) rows, each 6.5 m (21 ft) in length.

Both locations were prepared for wheat planting each year with one pass of a disk in Mississippi or two passes of a disk in Tennessee, followed by one pass of a bed conditioner equipped with rolling baskets and S-tine harrows. 'Florida 302' wheat was planted at 100 kg/ha (90 lb/A) in Mississippi. In Tennessee, 'Arthur' wheat was planted at a120 kg/ha (108 lb/A). At both locations, plantings were in 18-cm (7-in) rows perpendicular to the plots. Glyphosate [*N*-(phosphonomethyl)glycine] at 1.1 kg ai/ha (1 lb/A) was applied 2 to 3 weeks prior to planting to control weeds and wheat present. In Mississippi, 'Epps' soybeans were planted May 27, 1988 and May 26, 1989, and 'Terra Vig 515' soybeans were planted May 25, 1990. In Tennessee, 'Asgrow 5403' soybeans were planted May 30, 1988 and July 10, 1989. Conventional tillage plots for soybeans were prepared as previously described for wheat planting.

Imazaquin was applied prior to soybean planting with a tractor-mounted compressed air sprayer in Mississippi and a CO_2 backpack sprayer in Tennese, with 190 L/ha (20 gal/A) total volume. Imazaquin was incorporated to a depth of 5 cm (2 in) with two passes of a bed conditioner equipped with rolling baskets and S-tine harrows in the same direction as the soybean rows in Mississippi and with one pass of a rotary tiller in the same direction as the rows in Tennessee. Selected soil characteristics and rainfall amounts are listed in Tables 1 and 2.

Plots were maintained weed-free by hand weeding. Fifteen 2.5-cm (1-in) diameter soil samples per plot were collected to a depth of 15 cm (6 in) at both locations from 0 to 134 days after treatment (DAT). Samples were frozen after sampling and remained frozen until bioassays were performed.

Seven-day shoot height of 'HyPerformer HS 9773' corn (*Zea mays*) was used as the indicator for the imazaquin bioassay. Samples were thawed, air dried, and ground to pass through a 4.75-mm (0.19-in) sieve, and 150 g (0.33 lb) soil from each sample was placed in a 21 cm (8.3 in) long cone tube (Super Cell Cone-tainer, Ray Leach Cone-tainer Nursery, 1500 N. Maple St., Canby, OR). Simultaneously, untreated soil from both locations was treated with imazaquin to obtain known soil concentrations of 0, 4, 8, 12, 16, 23, 31, 47, and 63 ppb imazaquin (w/w) to establish a standard bioassay curve. These equations were then used to predict imazaquin concentration. One 24-hour pre-germinated corn seed with a radical length of 3 ± mm (0.12 ± 0.04 in) was planted 2 cm (0.9 in) deep in each cone tube. Soil was saturated with water by subirrigation after planting, and supplemental water was added by subirrigation to field capacity 3 to 4 days after planting.

Greenhouse temperature was kept at 20 ± 5 °C at night and 30 ± 5 °C in the daytime, and day length was extended to 14 hours with metal halide lamps at a miniumum intensity of 300 $\mu E/m^2/s$ photosynthetic photon flux density. Corn shoot heights were measured from the soil line to the tip of the longest leaf, 7 days after planting.

The standard curve equation for Mississippi was $Y = 148.00 - 1.346X1 (R^2 = 0.85)$ and for Tennessee was $Y = 153.27 - 59.79X_2 (R^2 = 0.77)$, where Y is corn shoot heights measured 7 days after planting, X1 is the herbicide concentration in ppb, and X_2 is log of the herbicide concentration + 1 in ppb. Corn shoot heights from field persistence samples were entered into their respective standard curve equations to determine bioavailable herbicide concentration.

Herbicide concentrations over time were subjected to regression analysis in order to develop persistence equations for each tillage system, year, and location (Table 3). Data were subjected to linear and quadratic regression to estimate best fit. The regression equations were of the form $Y = b_0 = b_1 X$ where Y was log of the herbicide concentration $\underline{+}1$ and b_0 and b_1 were partial regression coefficients, and X was days after application. Initial herbicide half-lives between tillage systems, years, and locations were determined by slope comparisons as described by Neter et al.(19).

Results and Discussion

Persistence patterns of bioavailable imazaquin differed between locations for years and locations; therefore, data are presented in separate graphs (Figures 1 and 2). Generally, R^2 values were quite low in this study (Table 3). This could be because of the large variation in rainfall pattern that occurred at both locations. At many times, periods of extremely dry conditions were preceded or followed by periods of extremely wet conditions. Since imazaquin degradation is affected by soil moisture this could have led to low R^2 values (5,6). Adsorption/desorption equilibria reactions of imazaquin may also have affected these data. Temporary drying of soil to 25 or 50% of field capacity and then returning to field capacity increased adsorption of imazaquin (9).

One laboratory study found that significant hysteresis occurred in imazethapyr desorption (8). These factors could have also led to variation in bioavailable imazaquin concentrations detected. Even though all soil samples were air dried for 24 hours, then watered uniformly for the duration of the bioassay, the desorption process can be slow enough to result in substantial differences in detectable imazaquin.

There were no differences in bioavailabe persistence patterns between tillage systems or years in Mississippi (Figure 1). Half-life of imazaquin in Mississippi ranged from 30 to 75 days (Table 4). This agrees with other research in which the half-life of imazaquin has ranged from 7 to 133 days (5, 16, 17, 22, 23, 26).

There were no differences in bioavailable imazaquin persistence patterns between tillage systems in Tennessee in 1988 or 1989 (Figure 2A and 2B). There were differences between years within both tillage systems, however. In 1989, concentrations of bioavailable imazaquin had reached the lower limit of detection by 60 DAT; therefore, data are presented only for that period. Initial concentrations of imazaquin were lower than expected in 1989 in both the conventional tillage and no-till systems compared to 1988. Because of low concentrations and limits of detection for the bioassay, differences could not be detected in later samples, which may have resulted in the short half-life. This lower concentration combined with the fact that almost twice as much rainfall occurred in 1989 in the first 30 DAT could have led to the differences in bioavailable persistence patterns between years in Tennessee. Half-life of imazquin ranged from 24 to 50 DAT in Tennessee.

The persistence patterns of bioavailable imazaquin were compared between the two locations within tillage systems and years. No comparison was made between locations in 1990, since the experiment was not conducted in Tennessee in 1990. Differences occurred between the two locations in 1989, but not in 1988, in both the conventional tillage and no-till systems. Half-life of imazaquin was 22 days longer in the conventional tillage system and 37 days longer in the no-till system in Mississippi in 1989. Differences between locations in 1989 could be because of the low initial concentration in soil at Tennessee. This led to imazaquin being beyond detectable differences by 60 DAT in Tennessee. Bioavailable amount so imazaquin were still detectable in Mississippi through 120 DAT. Because of low rainfall amount from 60 to 120 DAT in Mississippi little or no degradation of imazaquin occurred during this period in 1989. The combination of these factors ultimately could have led to differences between the two locations in 1989.

Bioavailable imazaquin degradation was not affected by tillage in any of the years or locations in these experiments. Therefore, under the conditions of these experiments, imazaquin carryover problems to rotational crops will not be affected by tillage systems.

Large fluctuations in rainfall patterns had a major impact on the degradation characteristics of biologically abailable imazaquin. This led to poor fit between imazaquin degradation over time. Imazaquin half-life ranged from 30 to 75 DAT in Mississippi and 24 to 50 DAT in Tennessee. While this variation in half-life agrees with other research in which half-life or imazaquin has ranged from 7 to 133 days (5, 16, 17, 22, 23, 26), fluctuations in imazaquin concentration over time may indicate that bioavailable dissipation of imazaquin does not reflect degradation of actual imazaquin in the soil.

Further studies need to be conducted to determine factors that affect the adsorption/desorption process of the imidazolinones, as well as how fluctuations in soil moisture affect imidazolinone degradation.

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