Corn Growth Retardation Resulting from Soybean Herbicide Residues[1]

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ABSTRACT. **Imazaquin (trademark Scepter) is a weed control herbicide that was used on 15 and 37% of Ohio's 1987 and 1988 soybean acreage, respectively. Drought conditions in 1987 retarded the microbiological decomposition of imazaquin, resulting in carryover that damaged corn (*Zea mays* L.) grown in those fields so treated. Ohio's farmers were concerned that the more severe 1988 drought would cause even more herbicide carryover, jeopardizing their 1989 corn corp. In early 1989, imazethapyr (trade name Pursuit), another soybean herbicide chemically similar to imazaquin, received federal registration for use in the 1989 soybean crop.**

For two of Ohio's major corn producing soils, Hoytville clay and Crosby silt loam, no data exist regarding the concentrations of imazaquin or imazethapyr which may retard corn growth should there be carryover. A greenhouse study was conducted to measure the effect of six concentrations (0, 7.5, 15, 30, 60, and 120 ppb) of both imazaquin and imazethapyr on corn germination and seedling growth. The 24 treatments (two soils, two herbicides, six doses) were arranged in a completely randomized design with four replications. Corn plants were grown in each of 96 plots filled with either treated or untreated soil. Data on percent emergence, plant height, and total fresh weight were subjected to analysis of variance.

Neither herbicide affected germination, but doses of 7.5 ppb and greater of both herbicides reduced plant growth. All main effects (herbicide, dose, soil) and their interactions were significant for both plant height and total fresh weight except for the herbicide by soil interaction on total fresh weight. Proper use and management of these herbicides is mandatory if carryover and its associated problems are to be circumvented.

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INTRODUCTION

Imazaquin, marketed for broadleaf weed control in soybeans (*Glycine max* L.), was used on 15 and 37% of Ohio's 1987 and 1988 soybean crop, respectively. Imazethapyr, an imidazolinone herbicide similar to imazaquin in chemical structure and weed control properties, received federal registration for use in the spring of 1989. Drought conditions in Ohio in 1987 retarded the microbiological degradation of imazaquin, resulting in carryover and subsequent damage to corn (*Zea mays* L.) grown in fields so treated. This observation created concern that the more severe 1988 drought caused an even greater carryover of imazaquin which could cause severe widespread damage to the 1989 corn crop. Use of imazaquin and imazethapyr in 1989 may have resulted in carryover and potential damage to the 1990 corn crop if drought conditions reduced its microbiological degradation.

Both herbicides exhibit broad spectrum weed control properties when soil- and foliar-applied. Basham et al. (1987) observed reduced imazaquin activity on corn with increases in clay and organic matter content. Stougard et al. (1985) reported greater imazaquin and imazethapyr mobility and injury to wheat with increasing pH and decreasing soil clay and organic matter contents. Loux et al. (1989) found imazaquin to be more detrimental to corn root growth than imazethapyr.

Little is known about the interaction of imazaquin and imazethapyr with the soil. Both are weakly adsorbed on soil in laboratory sorption studies. In studies of imazaquin adsorption in three soils, Basham et al. (1987) observed increased adsorption in the soil with the greatest content of clay and organic matter. Loux et al. (1987) indicated the dissipation rate of imazaquin and imazethapyr was lower in high organic matter, fine-textured soils than on low organic matter, course-textured soils resulting in greater potential to carryover. Except for Renner (1986), no one else has been able to correlate imazaquin adsorption with soil pH, texture or organic matter content. However, imazaquin adsorption was associated with iron and aluminum hydroxides and kaolinite present in some soils by Goetz (1986).

For many agricultural soils a nearly neutral pH level is very typical. Organic matter and soil pH are the soil properties most often correlated with the sorption of acidic herbicides. This has been demonstrated by many workers (Donaldson 1965, Grover 1971, Mersie 1985, Shea 1986, and Stougard 1985, for 2,4-D, chlorsulfuron, and the benzoic acid herbicides, among others).

Studies by Basham (1986) in the area of abiotic degradation have shown photodecomposition of imazaquin to occur from soil-coated glass slides under sunlight and artificial ultraviolet light sources. The rate of dissipation appears to be influenced by soil type. Basham et al. (1987) observed greater persistence in a silty clay loam soil with 2.3% organic matter than in a silt loam soil with 1.4% organic matter, which agrees with observations by Loux et al. (1989). There is insufficient information to provide a clear explanation of the factors affecting the persistence of imazaquin and imazethapyr to date.

The purpose of this study was to determine the soil concentrations of imazaquin and imazethapyr that may retard the growth of corn on two of Ohio's major corn

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producing soils, Hoytville clay and Crosby silt loam. The rate of dissipation appears to be influenced by artificial ultraviolet light sources.

MATERIALS AND METHODS

A greenhouse study was conducted in the fall of 1988 to measure the effect of varying soil concentrations of imazaquin (Scepter) and imazethapyr (Pursuit) on the germination and subsequent growth of corn (*Zea mays* L.). The treatment design was a two by two by six factorial combination of herbicides, soils, and herbicide doses, respectively. The study used a completely randomized experimental design with four replications. Normal soil use concentrations of the herbicides are 15 to 60 ppb, depending on depth of incorporation. Previous research has indicated the potential for carryover is equivalent to 50% of application (Loux 1989). Additionally, misapplication (sprayer overlaps) usually result in application doses 200% of the intended dose. Therefore, soil concentrations of each herbicide were established at 0, 7.5, 15, 30, 60, and 120 ppb.

Soil samples from each experimental area were analyzed at the Research-Extension Analytical Laboratory at the Ohio Agricultural Research and Development Center at Wooster, Ohio. The Hoytville clay soil had a pH of 6.9, contained 5.0% organic matter and accounts for up to 41% of the Ohio annual corn and soybean acreage. The Crosby silt loam soil had a pH of 6.2, contained 1.5% organic matter and accounts for about 27% of the annual Ohio soybean and corn acreage. Each soil was collected from fields where no herbicide had been used in 1988. After air drying, the soil was pulverized prior to being weighed and having the appropriate amount of herbicide uniformly incorporated. After herbicide incorporation, the soil was placed in plastic pots five inches in diameter and five inches tall. Ten seeds of the Pioneer 3377 brand hybrid corn were planted one inch deep in each pot. Ten days after planting, the number of emerged plants in each pot was recorded and all but three plants were removed. Thirty-five days after planting, the distance from the soil surface to the leaf tip of the three plants was measured and recorded (plant height). The plants were removed from the pots intact, soil was removed from the root system by gentle washing, and total fresh weight determined. Per-

TABLE 1

Analysis of variance for plant height (cm) and total fresh weight (g) of corn.

Source of Variation	df	Plant Height mean sq.	Plant Height F-ratio	Total Fresh Weight mean sq.	Total Fresh Weight F-ratio
Herbicide (H)	1	1276	504 *	90	78 *
Soil (S)	1	442	175 *	435	80 *
H * S	1	30.1	12 *	1.5	1.3 NS
Rate (R)	5	2044	809 *	221	93 *
R * H	5	123	49 *	9.5	8.3 *
R * S	5	21	8 *	4.0	3.5 *
R * H * S	5	41	16 *	16.0	14 *
Error	72	2.5		1.15	

* = Significant at P = 0.05

TABLE 2

Effect of herbicide dose, soil type and herbicide type on plant height (cm) of corn.

Herbicide Dose (ppb)	Crosby Soil Imazethapyr	Crosby Soil Imazaquin	Hoytville Soil Imazethapyr	Hoytville Soil Imazaquin	Avg.
0.0	50.0	51.5	52.3	52.3	51.5
7.5	48.0	42.8	50.8	49.5	47.8
15	45.7	37.8	48.8	46.3	44.6
30	39.5	28.3	46.5	35.3	37.4
60	31.7	23.3	41.7	23.8	30.1
120	24.5	17.8	30.8	14.5	21.9
Avg.	39.9	33.5	45.1	36.9	38.9

LSD 0.05: Soil * Herbicide = 0.91; Dose = 1.12; Interaction = 2.2

TABLE 3

Effect of herbicide dose, soil type and herbicide type on total fresh weight (g) of corn.

Herbicide Dose (ppb)	Crosby Soil Imazethapyr	Crosby Soil Imazaquin	Hoytville Soil Imazethapyr	Hoytville Soil Imazaquin	Avg.
0.0	14.4	15.2	18.9	19.1	16.8
7.5	14.0	10.2	16.0	16.7	14.2
15	13.5	9.6	15.6	17.0	13.9
30	10.4	7.2	15.3	12.5	11.3
60	8.5	6.2	14.3	9.6	9.6
120	5.7	5.0	10.4	5.0	6.5
Avg.	11.0	8.9	15.1	13.3	12.1

LSD 0.05: Soil * Herbicide = N.S.; Dose = 0.78; Interaction = 1.57

cent emergence, plant height, and total fresh weight data were subjected to an appropriate analysis of variance with treatment means compared using least significant difference (LSD) values. LSD 0.05 is defined at t 0.05 $(2s^2/r)$ where s^2 is the error variance and r the number of observations per mean. A regression analysis was conducted for each herbicide - soil type combination in order to develop equations describing the response of plant height and total fresh weight to herbicide dose for each combination. Both the intercepts and slopes of the equations for plant height and total fresh weight were analyzed using an analysis of variance and tested for homogeneity using an F-test with means separated by calculating values of LSD.

RESULTS AND DISCUSSION

An analysis of variance indicated no difference in percent emergence of corn as a result of either soil type, herbicide or herbicide dosage. Significant differences in the height of corn occurred with soil type, herbicide and their interaction as well as herbicide dose and its interaction with both soil type and herbicide (Table 1). The three-way interaction of soil type by herbicide by herbicide dose was also significant. In the analysis of total fresh weight, all sources of variation were significant except for the interaction of herbicide by soil type.

Plant height (Table 2) decreased as the concentration of herbicide increased from zero to 120 ppb. The reduction in plant height caused by herbicide dose was moderated by both soil type and herbicide, as well as their interaction. The response of total fresh weight (Table 3) was similar to that of plant height with one exception. The herbicide by soil type interaction had no effect on total fresh weight. These results agree with those reported by Loux (1989) and Basham et al. (1987).

Although analysis of variance (Table 1) indicated that the effect of increasing concentration of herbicide was different for each herbicide - soil combination, it does not indicate how they were different. Regression equations for each herbicide - soil type combination describe the response of plant height (Table 4) and total fresh weight (Table 5) to herbicide dose for each combination.

There were no differences in slopes of the plant height regression lines (Table 4). On average, the plant height decreased 2.4 cm for each 10 ppb increase in herbicide concentration. Some plant height intercepts were different from others. For the Crosby soil, the imazethapyr intercept was greater than the imazaquin intercept, indicating that imazaquin had more effect on plant height than did imazethapyr. Intercepts for the Hoytville soil were not different, nor was there a difference in the Crosby-imazethapyr and Hoytville-imazaquin intercepts for plant height.

Total fresh weight intercepts (Table 5) were not different within the Hoytville soil, and intercepts for the Crosby soil were significantly lower than for the Hoytville soil. Within the Crosby soil, the intercept for imazaquin was significantly lower than for imazethapyr indicating imazaquin's greater effect on total fresh weight. There were no significant differences in slopes of the four regression lines, but on average the total fresh weight decreased 0.775 g for each 10 ppb increase in herbicide concentration.

Both plant height and total fresh weight were greater for the Hoytville soil than the Crosby soil. For the Hoytville soil there were no differences in either slopes or intercepts

TABLE 4

Regression equations describing corn plant height (cm) as affected by herbicide dose for each combination of soil type and herbicide.

Soil	Herbicide	Equation	
Crosby	Imazethapyr	Ht. (cm) = 48.3 - 0.22 ppb	B*
Crosby	Imazaquin	Ht. (cm) = 43.2 - 0.25 ppb	C
Hoytville	Imazethapyr	Ht. (cm) = 51.9 - 0.18 ppb	A
Hoytville	Imazaquin	Ht. (cm) = 49.5 - 0.32 ppb	A B

LSD 0.05: Intercept = 2.8; Slope = N.S.

*Intercepts followed by the same letter are not different.

TABLE 5

Regression equations describing total fresh weight (TFW) of corn as affected by herbicide dose for each combination of soil type and herbicide.

Soil	Herbicide	Equation	
Crosby	Imazethapyr	TFW (g) = 14.0 - 0.07 ppb	B*
Crosby	Imazaquin	TFW (g) = 11.3 - 0.06 ppb	C
Hoytville	Imazethapyr	TFW (g) = 17.3 - 0.06 ppb	A
Hoytville	Imazaquin	TFW (g) = 17.9 - 0.12 ppb	A

LSD 0.05: Intercept = 1.1; Slope = N.S.

*Intercepts followed by the same letter are not different.

for either plant height or total fresh weight, indicating that the two herbicides, imazethapyr and imazaquin, produced similar effects on corn growth. For the Crosby soil, both plant height and total fresh weight were greater for imazethapyr than for imazaquin, indicating that imazaquin is the more likely to damage corn grown on that soil, which agrees with observations by Stougard et al. (1985).

CONCLUSIONS

Both imazethapyr and imazaquin caused severe reductions in the growth of corn as soil concentrations of the herbicide were increased from 0.0 to 120 ppb. Depression of growth was greater for the Crosby soil, possibly resulting from less herbicide being absorbed by the lower levels of clay and organic matter in that soil. For the Crosby soil, imazaquin restricted plant height and total fresh weight more than imazethapyr.

Results indicate that farmers should exercise caution when using these herbicides in fields destined for corn the succeeding year. Although these herbicides are less likely to carryover in Crosby and similar soils, once it occurs, damage to succeeding corn crops will likely be more severe from for soils with higher levels of clay and organic matter such as Hoytville. Additional work with varying dosages of these herbicides should be conducted in field settings were season-long observation can be made.

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