PERSISTENCE OF ACETOLACTATE SYNTHASE INHIBITING HERBICIDES IN A CANTERBURY SOIL

RICHARD W. McDOWELL[1], FARHAD DASTGHEIB[2] and LEO M. CONDRON[1]

Department of Soil Science[1] and Department of Plant Science[2]
P.O. Box 84, Lincoln University, Canterbury

ABSTRACT

The degradation of imazapyr, flumetsulam and thifensulfuron applied at 500, 40 and 30 g/ha respectively to a silt loam soil was studied under laboratory conditions. Herbicide residues were analysed by a lentil (*Lens culinaris*) bioassay. Results showed that temperature had a significant effect on herbicide degradation, while the impact of soil organic matter and pH were less well defined. Half-lives for imazapyr, flumetsulam and thifensulfuron in the soil with low organic carbon (3.5%) at 15°C were 155, 70 and 6.4 days respectively and 77, 24 and 4.8 days at 30°C. In the soil with high organic carbon (6.4%) half-lives were 125, 88 and 5.4 days respectively at 15°C and 69, 30 and 3.8 days at 30°C.

Keywords: Imazapyr, flumetsulam, thifensulfuron, bioassay, herbicide degradation

INTRODUCTION

Agrochemical management requires careful consideration of many factors in order to provide the desired efficacy without exhibiting adverse agronomic effects. Preventing the build-up of herbicides to phytotoxic levels requires detailed knowledge of the persistence of residues under a variety of soil conditions. Herbicides based on the inhibition of acetolactate synthase (ALS) have been shown to vary widely in their degradation rates in response to soil pH, organic matter content and temperature (James *et al*. 1989; Lehmann *et al*. 1993). Thifensulfuron, flumetsulam, and imazapyr are representatives of the sulfonylurea, triazolopyrimidine sulfonanilide and imidazolinone classes of ALS herbicides respectively. Imazapyr has been used in New Zealand for some years, while thifensulfuron and flumetsulam have only recently been registered. The objective of the present study was to determine the persistence of thifensulfuron, flumetsulam and imazapyr at two different temperatures in a Templeton silt loam soil taken from different depths using a bioassay proceedure.

MATERIALS AND METHODS

Herbicides

The herbicides used were commercial formulations of thifensulfuron (Harmony 750 g/kg D.F.), flumetsulam (Preside 800 g/kg D.F.), and imazapyr (Arsenal 250 g/l W.S.C.) applied at 30, 40 and 500 g/ha respectively in the laboratory incubation experiment.

Soil

Soil used for the laboratory incubation experiment comprised two depth increments (0-5 and 15-20 cm) of a Templeton silt loam (Udic Ustochrept) taken from a site at the Henley Block, Lincoln University. The 0-5 cm soil was designated as 'high' organic matter (6.4% organic carbon [C]) and the 15-20 cm soil was designated as 'low' organic matter (3.5% organic C). Initial soil analysis included pH (water) and Tamm oxalate extractable amorphous iron and aluminium (Blakemore *et al*. 1987).

Bioassay development

Preliminary experiments were conducted on the Templeton soil (mixture of 0-5 and 15-20 cm) using lentil (*Lens culinaris*), maize (*Zea mays*), rapeseed (*Brasica napus*), and turnip (*Brasica rapa*). Lentil (var. 'Taitori') was found to be the most susceptible species. The final bioassay procedure for the lentil root length response curve used four replicates of each herbicide at seven different rates (Fig. 1). The mass of herbicide required (2 cm depth, bulk density of 1.1 g/cm^3) was dissolved in 100 ml of water and applied to 2 kg of moist (60% field capacity) soil. The herbicide-soil mixture was then placed in a plastic bag and shaken for 2 minutes and allowed to equilibrate overnight. Sub-samples of soil were then packed gently into square petri dishes (100 x 100 x 20 mm), and 3 pre-germinated lentils were imbedded at the top of the dish. Root tips were then marked on the petri dish, the dish sealed with plastic cling-film, and incubated at 23ºC in the dark. Measurements of root growth were then taken at 4 hourly intervals between 24 and 96 hours after planting.

Laboratory incubation

Herbicide (imazapyr 500 g/ha; flumetsulam 40 g/ha; thifensulfuron 30 g/ha) was applied to the soil (60% field capacity, < 2 mm) and four replicate samples were aerobically incubated at 15 and 30ºC. Sub-samples of each replicate were taken 1, 2, 3, 4, 6, 8, 10, 12, and 14 weeks after herbicide application and analysed for herbicide residues using the lentil bioassay described above. At the cessation of the laboratory incubation, soil from each treatment was analysed for microbial biomass C according to the method of Voroney *et al.* (1993).

RESULTS AND DISCUSSION

Bioassay

Results for the bioassay lentil root length response curve 72 hours after herbicide application are shown in Fig. 1. Data for all other 4 hourly intervals exhibited either greater variability or less sensitivity and hence are not presented. All subsequent

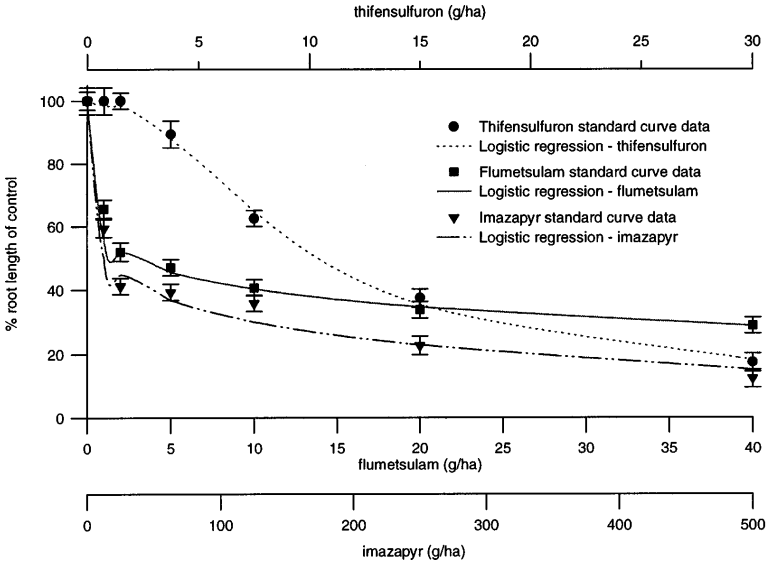

FIGURE 1: Bioassay standard curve of the effect of thifensulfuron, flumetsulam, and imazapyr on lentil root growth [± S.E.M. (I)] after 72 hours.

bioassays were therefore determined after 72 hours. The shape of the lentil root length response curves were similar for imazapyr and flumetsulam, with a sharp decline in root lengths over a limited range of low concentrations. The greatest sensitivity shown by the imazapyr, flumetsulam and thifensulfuron curves was between 10-50, 1-10 and 3-17 g/ha, respectively. A detection limit of 3 g/ha were established for thifensulfuron, while limits of 1 g/ha and 12.5 g/ha were established for flumetsulam and imazapyr respectively. Levels of thifensulfuron below the detection limit appeared to stimulate lentil growth. A four parameter logistic model gave good agreement with the experimental data, estimating model parameters to within a 95% level of tolerance.

Laboratory incubation

The first order kinetic model used to calculate half-life ($t_{1/2}$) estimated parameters to within 95% of the observed data. Thifensulfuron degraded rapidly at both temperatures (3.9-6.4 days), while the half lives for flumetsulam (24.1-87.9 days) and imazapyr (68.6-155.4 days) were much longer (Table 1). As expected, degradation rates were faster at 30°C compared with 15°C in both soils. The effect of organic matter on herbicide degradation was less pronounced. In both the imazapyr and thifensulfuron treated soils the rate of degradation was faster in the low organic matter soil compared with the higher organic matter soil, however the opposite trend occurred in the flumetsulam treated soils (Table 1). Microbial biomass carbon was greatest in the higher organic matter soils of all treatments except imazapyr at 30°C and flumetsulam at both temperatures (Table 1). It was also higher in imazapyr treated soils at 30°C than at 15°C, which may partially account for the reduced half-life of imazapyr at 30°C, although the inherent variability make conclusions concerning microbial biomass C difficult.

TABLE 1: Half lives and mean microbial biomass C (± standard error of the mean [SEM]) for three herbicides, at two temperatures in soil with low and high organic matter contents.

Herbicide	Incubation temperature (°C)	Soil organic matter	$t_{1/2}$ (days)	Microbial biomass carbon (µg C/g soil)
imazapyr	15	low	155.4 ± 9.9	376 ± 127
	15	high	124.7 ± 8.5	622 ± 60
	30	low	76.8 ± 8.7	1233 ± 276
	30	high	68.6 ± 9.3	1161 ± 170
flumetsulam	15	low	69.8 ± 2.1	1298 ± 351
	15	high	87.9 ± 1.5	1286 ± 349
	30	low	24.1 ± 1.6	154 ± 64
	30	high	29.5 ± 1.4	74 ± 155
thifensulfuron	15	low	6.4 ± 2.1	88 ± 82
	15	high	5.4 ± 1.1	1090 ± 45
	30	low	4.8 ± 1.9	134 ± 79
	30	high	3.9 ± 1.3	864 ± 101
Untreated soil	-	low	-	460 ± 135
	-	high	-	840 ± 127

Differences in pH between the low and high organic matter soils (5.9 and 6.4 respectively) may have influenced herbicide degradation (Cambon and Bastide 1992). In retrospect it may have been wise to isolate the effect of organic matter by increasing the pH of the high organic matter soil (to 6.4). The fact that both soils contained similar low levels of amorphous Fe and Al oxides (0.54-0.56% Fe, 0.23% Al) (Blakemore *et al.* 1987) suggests that mineral sorption was not a significant factor in determining differences in herbicide degradation between soils. It should be noted that 'half-life' obtained using a bioassay may be defined as "the time taken for the amount of

herbicide in the 'plant-available' pool to equal half of the total herbicide applied". The present study showed that at both temperatures, half-lives of imazapyr (and thifensulfuron) were inversely related to soil organic matter content (Table 1). While these results may reflect differences in pH and microbial biomass C, the reduced biological activity detected (and hence the half-life) in the higher organic matter soil may be due to enhanced sorption onto soil organic constituents (Sims *et al*. 1992).

ACKNOWLEDGEMENTS

Funding for this project was provided by the New Zealand Plant Protection Society. We would also like to thank Mr Roger Cresswell and Mr Bruce Main for assistance in laboratory work.

REFERENCES

Blakemore, L.C., Searle, P.L. and Daly, B.K., 1987. Methods for Chemical Analysis of Soils. New Zealand Soil Bureau Scientific Report 80, Department of Scientific and Industrial Research, Lower Hutt. 103 pp.

Cambon, J.P. and Bastide, J., 1992. Chemical or microbial degradation of sulfonylureas in soil. III. Thifensulfuron-methyl. *Weed Res.* 32: 357-362.

James, T.K. Rahman, A. and Mortimer, J., 1989. Biological activity of DPX-L5300 in some New Zealand soils. *Proc. 42nd N.Z. Weed and Pest Control Conf.:* 91-94.

Lehmann, R.G., Fontaine, D.D. and Olberding, E.L., 1993. Soil degradation of flumetsulam at different temperatures in the laboratory and field. *Weed Res.* 33: 187-195.

Sims, G.K., Wolt, J.D., Lehmann, R.G., Anderson, J.P.E. and Torstensson, L., 1992. Bioavailability of sorbed pesticides and other xenobiotic molecules. *Proc. Int. Symp. Environ. Aspects Pest. Micro*.: 159-164.

Voroney, R. P., Winter, J.P. and Beyaert, R.P. (1993). Soil microbial biomass C and N. Pp 277-287. *In*: Soil Sampling and Methods of Analysis, M.R. Carter (Ed); Lewis Publishers, Boca Raton.