PERSISTENCE OF SULFONYLUREAS ON ALKALINE SOILS IN SOUTH-EASTERN AUSTRALIA AND THE POTENTIAL DAMAGE TO SUBSEQUENT CROPS AND PASTURES

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Summary Leaching and accumulation of the sulfonylurea herbicides chlorsulfuron, triasulfuron and metsulfuron methyl in an alkaline cropping soil were investigated using laboratory bioassays and field experiments. The bioassays detected all the three herbicides in soil from a depth of 40–50 cm six weeks after application and 56 mm of cumulative rainfall. All the herbicides were detected in the top 0–50 cm of soil 32 weeks after application (134 mm rainfall), but only triasulfuron was found in the top 50 cm 48 weeks after application (235 mm rainfall). The dry matter yield of lentil (*Lens culinaris* L. cv. Digger) was reduced by 46% and medic (*Medicago truncatula* J. Gaertn. cv. Mogul) by 75% when sown two years after chlorsulfuron application. After the same period triasulfuron reduced the dry matter yield of lentil by 57%.

INTRODUCTION

Sulfonylureas are used extensively in south-eastern Australia to control a wide range of grasses including annual ryegrass (*Lolium rigidum* Gaudin), brome grass (*Bromus* spp.) and broad leaf weeds such as capeweed (*Arctotheca calendula* L.), charlock (*Sinapsis arvensis* L.) and wild turnip (*Brassica tournefortii* Gouan). Much of the cropping area in south-eastern Australia has alkaline soils. The breakdown and solubility of sulfonylureas are influenced by soil pH. One of the main breakdown pathways is through hydrolysis which decreases exponentially with increasing soil pH while solubility in water increases with increasing pH (Beyer *et al.* 1988). This greater solubility and decreased rate of breakdown could be expected to increase the rate of leaching and persistence of sulfonylureas in alkaline soils. This has been demonstrated in the field: an experiment on an alkaline sandy loam found that 46% of chlorsulfuron and 21% of triasulfuron were leached beyond 50 cm at nine weeks after application with 103 mm of rain. Residues in the range of 0.1–0.4 ηg g^{-1} soil were detected in the top 50 cm of soil 77 weeks after application (Stork 1995).

The persistence of herbicide residues after cropping may cause poor medic pasture re-establishment, however there is little evidence to support this hypothesis (McCarthy 1995). Evans *et al.* (1993) found medic dry matter and seed yield was reduced in the first year after chlorsulfuron and triasulfuron application, and plant numbers were reduced one and two years after chlorsulfuron application

The accumulation and persistence of the sulfonylurea herbicides chlorsulfuron, metsulfuron methyl and triasulfuron on alkaline soils in Victoria and South Australia has been the focus of an ongoing research project using laboratory bioassays as a detection method. The Victorian site at Dooen was selected for field crop experiments as it had high levels of sulfonylurea residues persisting over time. The aim of these experiments was to investigate the relationship between residues detected using laboratory bioassays and damage to susceptible crops in the field, and the relevance of these findings to current recommendations for sulfonylurea use in alkaline soils.

MATERIALS AND METHODS

The experiments were conducted at the Wimmera Research Station, Dooen (36° 41'S, 142° 18'E), which has an average annual rainfall of 410 mm. The soil was a self mulching grey clay with a pH of 8.0 (1:5 soil:water suspension method) in the top 0–10 cm increasing to 8.9 at 40–50 cm. Plots (15 × 2 m) were sprayed in winter 1993 or 1994 with triasulfuron (25 g ha^{-1}), chlorsulfuron (15 g ha^{-1}), and metsulfuron methyl (4.2 g ha^{-1}). Rates used were the maximum recommended for this soil type. The plots, including untreated controls, were arranged in a randomized block design with four replications.

Bioassays Soil was sampled to a depth of 50 cm at 6, 10 and 27 weeks after 1993 herbicide treatments and 6, 15, 32 and 48 weeks after 1994 treatments using a split core soil sampling tube. Root length reduction of field pea (*Pisum sativum* L. cv. Dundale) was used to measure herbicide residues in each 10 cm segment of soil using the bioassay technique described by Stork (1996).

Field experiment 1, 1994 The plots sprayed in 1993 were sown with medic at 12 kg ha^{-1}. Emergence of medic within four 0.1 m^2 quadrats was assessed 10 weeks after sowing. Dry weight of above ground medic growth within four 0.1 m^2 quadrats was taken 16 weeks after sowing.

Field experiment 2, 1995 All plots (both 1993 and 1994 herbicide applications) were divided into three sub-plots

(4.4 × 1.2 m). These were randomly sown with either canola (*Brassica napus* L. cv. Rainbow) (6 kg ha^{-1}), lentils (80 kg ha^{-1}), or medic (12 kg ha^{-1}). Emergence was assessed four weeks after sowing using three 0.1 m^2 quadrats for each sub-plot. Dry matter (above ground) within two 0.25 m^2 quadrats was measured 13 weeks after sowing. Canola seed was harvested 20 weeks after sowing.

Statistical analysis Data on emergence, dry matter, and seed yield of canola was analysed with a single factor ANOVA to test any differences between crops on treated and control plots.

RESULTS

Bioassay Results are presented as ηg herbicide g^{-1} dry soil. All the herbicides were found at a depth of 40–50 cm (chlorsulfuron; 0.7 ηg g^{-1}, triasulfuron; 0.7 ηg g^{-1} and metsulfuron; 2.5 ηg g^{-1}) six weeks after the 1993 application, and were present in the 0–50 cm depth (1.8 to 2.9 ηg g^{-1}) 27 weeks after application. The cumulative rainfall at these times was 56 and 315 mm, respectively. The 1994 application plots had residues of all herbicides (chlorsulfuron; 1.4 ηg g^{-1}, triasulfuron; 3.6 ηg g^{-1} and metsulfuron; 2.1 ηg g^{-1}) in the top 0–50 cm of soil 32 weeks after application while at 48 weeks only triasulfuron was detected in this zone (1.8 ηg g^{-1}). The cumulative rainfall was 134 and 235 mm, respectively.

Table 1. Dry weight (g m^{-2}) of crops sown one year after herbicide application, taken at 16 weeks (Experiment 1) and 13 weeks (Experiment 2) after sowing.

	Medic		Lentil	Canola
	Exp. 1	Exp. 2	Exp. 2	Exp. 2
Control	54.3	205.0	303.8	406.0
Chlorsulfuron	5.8[A]	29.2[A]	52.0[A]	254.5
Triasulfuron	21.7[A]	32.6[A]	70.0[A]	211.8[A]
Metsulfuron methyl	69.3[A]	182.9	309.0	326.4
LSD (P=0.05)	14.8	70.0	86.0	164.9

[A] Significant difference to control.

Table 2. Dry weight (g m^{-2}) of crops sown two years after herbicide application, taken at 13 weeks after sowing (Experiment 2).

	Medic	Lentil	Canola
Control	143.0	326.8	280.9
Chlorsulfuron	35.6[A]	177.0[A]	224.0
Triasulfuron	95.6	140.7[A]	245.1
Metsulfuron methyl	165.8	255.7	139.1
LSD (P=0.05)	74.2	93.7	153.6

[A] Significant difference to control.

Emergence In each experiment the herbicide treatments had no effect on emergence (data not shown).

Dry matter weight Triasulfuron reduced the dry matter of medic (Experiments 1 and 2), lentil and canola sown one year after herbicide application by 60, 84, 77 and 48%, respectively (Table 1). Chlorsulfuron reduced medic (Experiments 1 and 2) and lentil dry matter when sown one year after application by 89, 86 and 83%, respectively (Table 1). After one year metsulfuron methyl did not reduce dry matter in any crop, however in Experiment 1 medic growth was increased compared to the control (Table 1).

Two years after application chlorsulfuron caused reduction in dry matter of medics and lentils by 75 and 46%, respectively while triasulfuron reduced only lentil dry matter by 57% (Table 2). Metsulfuron methyl did not reduce the dry matter of any crop sown two years after application (Table 2).

Canola seed yield This was not reduced in crops sown one and two years after herbicide application (data not shown).

DISCUSSION

The laboratory bioassay results demonstrated that sulfonylureas leached rapidly to 40–50 cm with 56 mm of rainfall and persisted for up to 48 weeks in the 0–50 cm depth of soil. Damage to crops occurred up to two years after sulfonylureas were applied, but this varied with species and type of sulfonylurea. Chlorsulfuron reduced dry matter of medic and lentil two years after it was applied, while after the same period triasulfuron reduced the growth of lentil only. The laboratory bioassays detected only triasulfuron in the soil 48 weeks after the 1994 application, however, damage occurred to lentil and medic on both chlorsulfuron and triasulfuron treated plots one year after application. In this case the bioassay did not detect chlorsulfuron residues. There are two possible explanations for this; one is the unprecedented difference, compared to other herbicide groups, in sensitivity to chlorsulfuron among different plant species (Beyer *et al.* 1988), i.e. lentil and medic were more sensitive to chlorsulfuron than the peas used for the bioassays. Beyer *et al.* (1988) state that the soil residual activity which may continue for more than two years following some applications is due to the very high sensitivity of some species and not a failure of the herbicide to degrade appreciably in the soil. Secondly, the bioassay did not measure residues below 50 cm which, if present, would be accessible by crop and pasture roots. Metsulfuron methyl caused no damage in the year following application. This is consistent with laboratory bioassay results (unpublished data, GRDC sustainable use of sulfonylureas project) which found metsulfuron methyl to disappear more rapidly from the 0–50 cm depth of soil than chlorsulfuron or triasulfuron. The increase in dry weight of medic one year after application of metsulfuron methyl (Experiment 1) was possibly due to growth stimulation which can occur with many herbicides at sublethal doses (Beyer *et al.* 1988).

These findings reinforce the importance of following label recommendations when using these herbicides. The commercial formulation of chlorsulfuron is not recommended for use on soils of pH 8.6 and above. On soils with a pH 7.6–8.5 the minimum recropping interval for crops other than cereals is 24 months or longer (only if a field test strip of the planned crop has been successfully grown through to maturity in the previous season). Soil at the field experiment site had a pH of 8.0 in the top 10 cm which increased to pH 8.9 at a depth of 50 cm. This increase of pH with depth may result in chlorsulfuron persisting for longer than expected in these soils. The triasulfuron commercial formulation has a recommended replanting interval of 24 months for sensitive species on soils of pH 7.6 and above, however in the field experiment reduction of dry matter occurred in lentil sown two years after application. Dry matter reduction during the growing season may not indicate loss at harvest. Reduced canola dry matter (13 weeks after sowing) did not result in seed yield loss in crops sown one year after triasulfuron application. Experiments, which include seed yield assessment, will be carried out with susceptible species to help determine the most appropriate minimum recropping interval after chlorsulfuron and triasulfuron use in these situations. These experiments will assess crops sown two years and longer after herbicide application.

Bioassays are an important tool for studying sulfonylurea movement and persistence but may not predict crop damage due to differences in the sensitivity of susceptible species. Long term field experiments are essential to determine the potential damage of sulfonylurea residues to susceptible crops and pastures and to provide information on the appropriate use of these herbicides in sustainable agricultural systems.

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