Persistence of ALS inhibiting (Group B) herbicides in alkaline soils of south eastern Australia

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Summary The ALS inhibiting (Group B) herbicides (sulfonylureas, sulfonanilides and imidazolinones) are soil and foliar applied herbicides whose persistence threatens production of rotational crops. This study found that in alkaline soils of south eastern Australia persistence was as little as one month after treatment (MAT) under ideal conditions for metsulfuron or as long as 43 MAT for chlorsulfuron and imazethapyr. While they are prone to leaching the majority of herbicide remained in the top 20 cm of the soil profile at the low–medium rainfall sites used in this study. In general the product labels provide adequate guidelines for avoiding damage to rotational crops provided that the pH of the paddock is properly assessed.

Keywords ALS herbicides, sulfonylurea, leaching, persistence, residue, alkaline.

INTRODUCTION

The ALS inhibiting (Group B) herbicides (sulfonylureas, sulfonanilides and imidazolinones) are widely used in broadacre dryland cropping because they are cheap, effective against a wide range of weeds, easy to use and have low mammalian toxicity. However, there are concerns about leaching and persistence of ALS herbicide residues and their affect on following rotational crops such as oilseeds and pulses. Residues as low as 1% of applied chlorsulfuron have damaged sensitive crops in Canada (Moyer *et al.* 1989).

Stork (1995) studied sulfonylurea herbicides in the alkaline soils of SE Australia and found that chlorsulfuron and triasulfuron persisted for at least 18 months and moved beyond the 50 cm studied. Black *et al.* (1999) questioned whether the label recommendations were adequate to protect growers. This is in marked contrast to the minimal carryover found in Queensland (Walker and Robinson 1996).

This study extends previous work on the sulfonylureas in SE Australia by measuring the persistence of chlorsulfuron, triasulfuron and metsulfuron-methyl for up to five years and deeper in the soil profile than previously studied. The study also included the new herbicides flumetsulam (a sulfonanilide) and imazethapyr (an imidazolinone), whose persistence has been little studied in Australia. The influence of herbicide residues on rotational crops was also evaluated.

MATERIALS AND METHODS

Field trials were established at Dooen, Kaniva and Walpeup in Victoria and Port Kenny and Mount Hope in South Australia (Table 1). Herbicide treatments were sprayed on separate plots in year 1, 2 or 3 and sensitive species sown in year 4. The trial commenced in 1996 in Victoria and 1997 in SA.

Trials were sown with cereals during the first three years and sensitive crop species including canola (*Brassica napus* L.), lentil (*Lens culinaris* L.) or field pea (*Pisum sativum* L.), and medic (*Medicago* spp.) in year 4. Emergence, dry matter (DM), crop European Weed Research Council (EWRC) ratings and yield were measured for each plot.

Herbicides The herbicides applied were chlorsulfuron (as 15 g ha^{-1} Glean® in Vic; 20 g ha^{-1} in SA), triasulfuron (as 25 g ha^{-1} Logran® in Vic; 35 g ha^{-1} in SA), metsulfuron-methyl (as 7 g ha^{-1} Ally®), flumetsulam (as 25 g ha^{-1} Broadstrike®), and imazethapyr (as 300 mL ha^{-1} Spinnaker®). They were applied with a motorbike mounted boomspray in 65 L ha^{-1} water. Four replicates of each herbicide treatment and a control were arranged in a randomised block design with each plot at least 3 m × 20 m.

Table 1. Field sites, soil characteristics and herbicide treatments at each site.

Site	Soil type	Soil pH[1]	Herbicide applied[2]
Dooen, Vic	self mulching grey clay	8.6	C M F I
Kaniva, Vic	sodic clay	7.9	T M F I
Walpeup, Vic	mallee sand	7.4	T M F
Mt. Hope, SA	weakly structured sand	8.3	C T M I
Pt. Kenny, SA	weakly structured sand	8.6	C T M F

[1] Soil pH of top 10 cm using 1:5 water method.
[2] C – chlorsulfuron, T – triasulfuron, M – metsulfuron-methyl, F – flumetsulam, I – imazethapyr.

Measurements Soil samples for residue determination were taken throughout the growing season with a hydraulic sampler to a maximum depth of 2 m with at least three samples per plot. Sampling continued each year until no more herbicide could be detected or to a maximum of 51 months after treatment (MAT). Samples were dried at 40°C for 18 h and stored at 4°C in the dark before being ground to <2 mm, homogenised and herbicide concentrations analysed by bioassay or ELISA.

Lentil cv. Cobber or Digger or pea cv. Dundale were used for all herbicide bioassays except for imazethapyr which used canola cv. Rainbow. All bioassays measured root length reduction and were grown for 7 d in a controlled environment with 21/11°C day/night and 12 h daylength. Standard logistic dose response curves (Streibig 1988) were used to determine herbicide concentrations in soil samples. The method used is described by Hollaway *et al*. (1999).

Soil samples below 40 or 60 cm were highly sodic and not suitable for bioassay due to poor plant growth. Instead enzyme linked immunosorbent assay (ELISA) was used for selected samples treated with chlorsulfuron, triasulfuron and metsulfuron-methyl using the method described by Hollaway *et al*. (1999). This technology was not available for flumetsulam or imazethapyr.

Daily measures of rainfall were taken at each site. Total winter (May–Oct) and total summer (Nov–Apr) rainfall were used to compare years. The daily soil temperature and maximum and minimum ambient temperatures were collected from the nearest available Bureau of Meteorology site. The average daily temperature for winter (May–Oct) was calculated by summing the cumulative maximum plus minimum temperatures and dividing by the number of days.

Data analysis Residue concentrations for the top 40 cm (60 cm at Walpeup) were plotted against time and cumulative rainfall and examined for trends.

Emergence, EWRC, DM and yield of sensitive crops were analysed by ANOVA (P=0.05).

RESULTS AND DISCUSSION

All of the herbicides leached down through the root zone (bioassayed depth of 40 or 60 cm) within a few months of application (Table 2). Of the three herbicides tested below this depth (all sulfonylureas), chlorsulfuron and triasulfuron had moved down to 100 cm at the first sampling 4 MAT. Metsulfuron did not move beyond the top 40 to 60 cm. The vast majority of the residues were detected in the top 20 cm at all sites. This was mainly in the 10–20 cm depth but was more likely to be the 0–10 cm depth in drier years or at Kaniva where rainfall infiltration was impeded by sodicity.

All herbicides degraded rapidly after application, however, low concentrations of some herbicides persisted for several years and damaged sensitive rotational crops. Chemistry is clearly the main factor influencing persistence with metsulfuron persisting for as little as 1 MAT under ideal conditions and chlorsulfuron and imazethapyr persisting for up to 43 MAT.

Soil pH is the main factor determining persistence of individual sulfonylureas with metsulfuron persisting up to 2 MAT at Walpeup (pH 7.4) and up to 15 MAT at Dooen (pH 8.6). Imazethapyr persisted for at least 43 MAT at Dooen and Kaniva and only 15 MAT at Mt. Hope, reflecting the higher clay and organic matter content of the soil at Dooen and Kaniva (Goetz *et al.* 1990). The sulfonylureas were more persistent when rainfall was lower but temperature did not seem to have an effect. When pH and rainfall are accurately measured the label recommendations predict damage in the vast majority of cases.

Any herbicide that persisted produced crop damage with chlorsulfuron and imazethapyr most likely to cause problems as predicted on product labels.

However, metsulfuron persisted longer than expected at Dooen during an extended period of dry weather leading to reduced DM (68% of control) and grain yield (55%) of lentils and reduced DM of medic (62%) one year after treatment. Soil pH at this site is 8.6 which is just beyond the recommended label limit of 8.5. It is unlikely that the scenario would have been greatly different if the pH was 0.1 units lower demonstrating that there is some risk of carryover beyond label limits under very dry conditions. Clearly, when soil pH is high and/or rainfall is low there is a greater risk and care should be taken to have a clear understanding of soil pH including any variations within the paddock.

Canola was less likely to be damaged by herbicide residues than lentil, pea or medic. For instance at Dooen lentil grain yield was reduced by chlorsulfuron applied up to three years before sowing, while canola sown only one year after chlorsulfuron application suffered dry matter reduction but not yield loss.

There was no damage to sensitive crops sown at Mt. Hope in 2000, but this was a year of abundant rainfall. This would favour herbicide degradation and plants not under stress can better tolerate any residues.

Each herbicide will now be discussed in detail.

Chlorsulfuron persisted for at least 43 MAT at Dooen where the soil pH was 8.6. ELISA analysis of soil to 2 m depth in 1996 found herbicide down to 1.0 m with 0.14 g a.i. ha^{-1} (1.2% of applied) in the

Table 2. Summary of leaching, persistence and injury to sensitive crops for ALS herbicides.

Herbicide	Max depth[1] (cm) found (assayed)	Time persisted[2] (MAT)		Maximum crop injury for each species at any site[3]			
		min	max	pea	lentil	medic	canola
chlorsulfuron	100 (200)	18+–26+	35–43	1 y yield	3 y yield	3 y yield	1 y DM only
triasulfuron	100 (200)	6–18+	15–35	1 y yield	1 y EWRC	1 y DM	no effect
metsulfuron	40 (120)	1–4	2–17	no effect	1 y yield	1 y DM	1 y DM
flumetsulam	60 (60)	3–15	17–29	no effect	1 y yield (P=0.1)	no effect	1 y DM
imazethapyr	40 (40)	4–27+	15–43	n/a	n/a	n/a	3 y EWRC, 2 y DM, 1 y yield

[1] For example soil samples were analysed for chlorsulfuron to a depth of 200 cm and it was found at a maximum depth of 100 cm.

[2] Time persisted is expressed as the range across all sites, for some sites the minimum persistence time is actually the last time soil was sampled e.g.: 18+ means persistence beyond 18 MAT was not measured.

[3] Pea and lentil were never grown at the same site so direct comparison of crop injury is not valid, imazethapyr is routinely applied to legume crops and crop injury would not be expected for pea, lentil or medic.

0.8–1.0 m depth 4 MAT. The residue concentrations were lowest following the 1996 application which was the wettest winter season (May–Oct) of the three. Residue concentrations were highest following the 1998 application which was the driest of the three.

Of the three years, 1996 had the warmest average winter soil temperature (10.2°C at 10 cm at 9 a.m.) compared to 9.3°C in 1997 and 8.9°C in 1998 which correlated well with the lowest persistence in 1996. Dooen was the only site where reliable soil temperatures were available. It cannot be assumed that ambient temperatures at other field sites are a good indicator of soil temperatures as the trend for ambient temperatures at Dooen showed 1998 as having a higher temperature than 1997.

At Mt. Hope chlorsulfuron persisted for at least 35 MAT. The concentration of residues was lowest following the 1997 application which was also the wettest winter. 1998 and 1999 had similar residue concentrations and similar winter rainfall. Residues at Pt. Kenny followed the same trend.

Sensitive crops planted at Dooen in 1999 were damaged by residues remaining from all three application years. Lentil and medic were the most susceptible to residues with grain or burr yield reduced 3 years after treatment (YAT); and yield, DM and EWRC damaged up to 2 YAT. Canola was more resilient with DM and EWRC reduced 1 YAT but yield was unaffected. Emergence was not affected by any of the herbicides residues.

Triasulfuron generally broke down rapidly in the first year with little persisting into the second year. Persistence beyond the second year was highest at Pt. Kenny which had the highest pH of the triasulfuron sites at 8.6. ELISA analysis detected triasulfuron down to the 40–60 cm depth, at Kaniva 4 MAT at a concentration of 1.5 g a.i. ha^{-1} (8.0% of applied) and to the 80–100 cm depth at Walpeup with a concentration of 0.06 g a.i. ha^{-1} (0.3% of applied) which is just above the detection limit.

At Kaniva triasulfuron had similar rates of break down for each year of application. There did not appear to be any trends relating to the wet 1996, dry 1997 and average 1998 winters. Likewise, the winter temperatures were consistent.

Mt. Hope showed a similar trend of minimal differences between residues, despite differences in rainfall.

Both Walpeup and Pt. Kenny followed the trend observed for chlorsulfuron of wet years being associated with lower residue concentrations.

Port Kenny had the highest concentration of residues of any site when sensitive crops were sown and was also the site where the most crop damage occurred. Medic DM was reduced by 38% and pea DM and grain yield by 43% and 20% respectively 1 YAT. At Kaniva there was a slight reduction in the EWRC of lentil and medic sown 1 YAT.

Metsulfuron-methyl generally was not detected one year after application. However, at Dooen and Pt. Kenny, the two sites with the highest pH, residues were found in small concentrations in the second year. This caused damage to sensitive crops at Dooen as discussed earlier. No metsulfuron was detected at depth with the ELISA.

Flumetsulam behaved similarly to triasulfuron in that most of it broke down in the first season with much smaller residue concentrations persisting through the second year. It was rarely detected by the third year.

However, at Kaniva, flumetsulam from the 1998 application was found at the highest concentration of the three years and persisted well into the third season, reducing the yield (66% of control, P=0.1) of lentils sown 1 YAT.

Differences in rainfall or temperature did not explain differences in residues at any site indicating that these factors may be less important in the degradation of flumetsulam than for the sulfonylureas. However, Murphy and Shaw (1997) considered that high rainfall was important in reducing persistence of flumetsulam.

Imazethapyr persistence varied dramatically between sites. At Mt. Hope it only persisted for between 4 and 15 MAT depending on the year of application. At Dooen and Kaniva imazethapyr persisted for 43 MAT following the 1996 application and was detected throughout the trial for the other two years (>26 MAT).

Imazethapyr residues at Dooen and Kaniva did not reduce DM or grain yield of canola sown 3 YAT in line with label recommendations. Canola sown 2 YAT suffered reduced DM (78% of control at Dooen, 64% at Kaniva) with no significant reduction of yield. Canola sown 1 YAT suffered reduced DM (72% at Dooen, 5% at Kaniva) and yield (75% at Dooen, 0% at Kaniva). Total residue concentrations were 16.7 g a.i. ha^{-1} (23% of applied) at Dooen and 24.8 g a.i. ha^{-1} (34% of applied) at Kaniva prior to sowing sensitive species.

All three sites recorded the lowest residues in their wettest year. However, while residues in the drier years were greater there were vast differences between residues detected in drier years that was not reflected in the relatively small differences in rainfall. At Kaniva residues remaining after the 1998 application were about double those after the 1996 or 1997 applications yet the rainfall in 1998 was in between the wet 1996 and the dry 1997. Goetz *et al*. (1990) found that degradation of imazethapyr is enhanced by increased soil water but in these trials other factors also influenced degradation.

At Mt. Hope imazethapyr persistence was much shorter with residues only detected beyond the year of application in 1998. There are no obvious relationships with the weather data that could explain this short persistence. Clearly site specific factors, such as microbial biomass, are important in determining the rate of degradation.

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