Loss of bioavailable pendimethalin herbicide from soil under different seeding systems

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Abstract

A bioassay, based on the response of oat roots, was used to quantify the concentrations of bioavailable pendimethalin under different direct-drill seeding systems. The seeding systems used for sowing wheat were high soil disturbance tines (Ribbon seeder and knife point) and low soil disturbance discs (DayBreak and K-Hart). The bioavailability of pendimethalin was very similar across all seeding systems until 8 days after crop sowing. While 25 days after crop sowing, the bioavailability of pendimethalin was greater under high soil disturbance tines (83-84%) when compared with low soil disturbance discs (62-70%). These results demonstrate that reduced bioavailability of pendimethalin occurs in low soil disturbance seeding systems, which could have implications for the control of weeds that show a protracted germination pattern.

Key Words

Bioassay, herbicide bioavailability, disc, tine.

Introduction

Pendimethalin is a dinitroaniline herbicide used for the control of annual ryegrass (*Lolium rigidum* Gaud.) in field crops in Australia. Dinitroaniline herbicides were adopted in Australia for weed control, but fell out of favour following the introduction in the early 1990s of more convenient post-emergent selective herbicides. However, intensive and continuous use of these herbicides over a long period of time has resulted in the evolution of widespread resistance in weed populations (Llewellyn and Powles 2001). Consequently, dinitroaniline herbicides are now being widely used again for the control of annual ryegrass in cereal cropping systems. The resurgent use of these herbicides has coincided with the rapid adoption of no-till (NT) cropping and stubble retention systems (D'Emden and Llewellyn 2004) by grain growers in order to reduce costs and improve sustainability of crop production.

The significant increase in NT cropping systems in recent years in Australia has changed the environment in which dinitroaniline herbicides have to perform. Pendimethalin is an important dinitroaniline herbicide, which is now being used for the control of annual ryegrass under NT situations. Grain growers have responded to concerns about reduced soil incorporation and increased crop residue on the surface under NT by increasing the application rate. As grain farmers move further towards reducing soil disturbance at sowing by adopting disc systems, the lack of incorporation is likely to impact on the efficacy of pendimethalin in these systems. The present study was undertaken to quantify the impact of direct-drill seeding systems on the bioavailability of pendimethalin in the field.

Materials and methods

Field experiments

The experiment was conducted during the growing season of 2005 at Minlaton on the Yorke Peninsula of South Australia. The seeding systems comprised two disc systems (DayBreak and K-Hart) and two tine based systems (knife point and Ribbon seeder). No prior tillage was conducted before the application of the herbicide. Pendimethalin at 0.72 kg ai/ha was applied immediately before sowing wheat (*Triticum aestivum* cv. Krichauff) in all the seeding systems. The herbicide was applied by using a 5-m wide boom sprayer mounted on a 4-wheel motorbike that delivered 100 L/ha spray solution through flat fan nozzles at a spray pressure of 200 kPa. The experiment was arranged in the field in a randomised complete block design with three replications.

Soil sampling

The upper 0 to 5 cm soil layer was sampled from all replications, at different times after crop sowing (0, 4, 8, 14 and 25 days after sowing, DAS), taking ten 4.5-cm diameter cores randomly from each plot. As the seeding operations only disturbed the top few cm of soil, it was considered unlikely that any pendimethalin would have moved below 5 cm. During sampling in the field, the soil samples were placed in sealed-plastic bags and stored temporarily in styrofoam boxes containing ice. On returning from the field, the soil samples were frozen at -18 C until analysis.

Bioassay procedure

The bioassay experiment was conducted in a glasshouse at the Roseworthy Campus of the University of Adelaide, South Australia. Preliminary experiments were conducted to develop a suitable bioassay technique that was simple to use. Oat roots were found to be more sensitive to pendimethalin inhibition and with lower variability compared to shoots. Therefore, inhibition of root growth was selected as the bioassay criterion to study the bioavailability of pendimethalin.

The frozen soil samples were thawed for 6 hours at room temperature before placing in the pots. The soil sample from each plot was thoroughly mixed and 550 g samples were placed in 600 ml clear-plastic pots. The pots had holes at the bottom and aluminium foil was wrapped around the pots to eliminate light effects on the roots. At the same time, a standard curve was developed. For this, untreated soil from the same site was air-dried and used to prepare standards between 0 and 0.50 μg pendimethalin/g soil. Six oat seeds were planted in the pots at a depth of 0.5 cm and a thin layer of untreated soil was spread on the surface to prevent photodecomposition. The pots were then placed in a glasshouse and arranged in a randomised complete block design with three replications. The glasshouse temperature was set at 25/15 ? 5?C (day/night). Oat roots were washed from the soil 21 days after planting when seedlings in untreated soil had reached 2.5 to 3-leaf stage. From each pot, four most uniform seedlings were used for measuring their root length. Oat roots were scanned with a flatbed scanner and total root length determined with the WinRHIZO Program (version 5.0 a) and represented as root length per plant.

Statistical analysis

Each treatment was replicated three times. A quadratic curve of the form

y = ax? - bx + c [1]

was fitted to the mean root length of the plants grown at known herbicide concentrations (standards) by using SigmaPlot 2004 (version 9.0), where *y* represents the root length at bioavailable concentration of herbicide *x*; *a, b* and *c* are the fitted constants. Bioavailable concentrations of herbicide under different seeding systems over time were estimated by fitting the data for root length to equation (1). The estimated bioavailable concentrations of herbicide were then converted to the percent of the original applied amount of the herbicide remaining. Assuming a bulk soil density of 1.4 g/cm? (Rainbow 2000), the dose of the applied pendimethalin concentration was calculated to be equivalent to 0.48 ?g/g soil. The data were analysed by using two-way ANOVA in a randomised block design with seeding systems as one factor and time (DAS) as the other factor. Transformation of data did not improve homogeneity; thus, ANOVA was performed on nontransformed data (Genstat 5 Committee 1993).

Results and discussion

For weed control it is not the total amount of an herbicide that is important, but its bioavailability. Therefore, a bioassay could be a useful tool to provide information on the bioavailability of an herbicide (Johnstone et al. 1998). A bioassay for pendimethalin using oat root length was used to determine the bioavailability of this herbicide in the field. A standard curve was constructed contrasting increasing amounts of pendimethalin in soil samples collected from the same field site on oat seedling root lengths (Figure 1). Oat root length and corresponding bioavailable pendimethalin levels for the different seeding systems are shown in Table 1 and percent bioavailability of pendimethalin in Figure 2, respectively. The bioavailability of pendimethalin was very similar across all the seeding systems until 8 DAS after which there was lower bioavailable pendimethalin under the disc systems. At the last sampling period (25 DAS), bioavailable pendimethalin was greater under the high disturbance Ribbon seeder (84%) and knife point (83%) systems than under the low disturbance K-Hart (70%) and DayBreak (62%) disc systems.

Under low soil disturbance systems, most of the pendimethalin might remain on the soil surface even after the sowing operation, where it would be susceptible to loss through volatilisation and photodecomposition (e.g. Parochetti and Dec Jr. 1978; Savage and Jordan 1980). Conversely high soil disturbance seeding equipment due to the greater soil coverage of the herbicide in the inter-rows, would have reduced the losses due to volatilisation and photodecomposition in these systems. In a previous study, Walker and Bond (1977) found pendimethalin to be more persistent when incorporated (80% remaining after 20 weeks) than when applied to the soil surface (20% remaining). Similar results have been observed in persistence studies on another dinitroaniline herbicide, trifluralin, where incorporation increased the persistence of this herbicide (Savage and Barrentine 1969). Thus, seeding or tillage systems that incorporate these chemicals into the soil are likely to reduce the rate of herbicide loss caused by volatilisation and photodecomposition.

In our study, the loss of bioavailable pendimethalin was negatively correlated with the level of soil disturbance caused by different NT seeding systems. Herbicide losses of this magnitude could have implications for the control of weeds with a protracted germination pattern. In such situations, there may be insufficient pendimethalin remaining to control later emerging weeds in the crop. As the amount of soil disturbance decreases, particularly with disc systems, the level of control offered by pendimethalin can be expected to decrease. Increased application rates of pendimethalin may compensate for losses of pendimethalin bioavailabilty in very low soil disturbance systems. However, higher application rates will also increase the risk of crop damage in these systems.

Conclusions

The loss of bioavailable pendimethalin was found to be greater under low soil disturbance (e.g. discs) seeding systems as compared to the seeding systems that cause high soil disturbance (e.g. tines). As a result, there may be insufficient pendimethalin remaining in the low soil disturbance seeding systems to control later emerging weeds.

Table 1. Oat root length (cm/plant) and bioavailable pendimethalin (?g/g soil) determined by bioassay under Ribbon seeder (RS), knife point (KP), K-Hart (KH) and DayBreak (DB). The soil samples were taken at different times after crop sowing (DAS).

Time	Oat root length				Bioavailable pendimethalin			
	RS	KP	KH	DB	RS	KP	KH	DB
DAS	———— cm/plant————				————µg/g soil————			
0	39.3	39.1	39.8	39.1	0.49	0.49	0.48	0.49
4	41.2	40.4	40.5	41.0	0.47	0.48	0.47	0.47

8	43.1	42.4	43.9	43.7	0.45	0.45	0.44	0.44
14	44.2	45.7	46.5	54.5	0.43	0.42	0.41	0.35
25	47.4	48.2	57.8	64.3	0.41	0.40	0.34	0.30
LSD (P=0.05)	5.0				0.05			

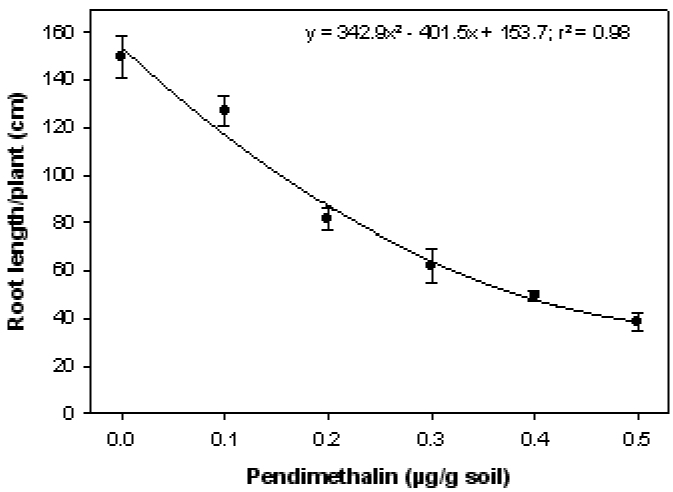

Figure 1. A quadratic relationship between the dose of pendimethalin (?g/g soil) and root length (cm/plant) of oats in the bioassay. Vertical bars represent standard error.

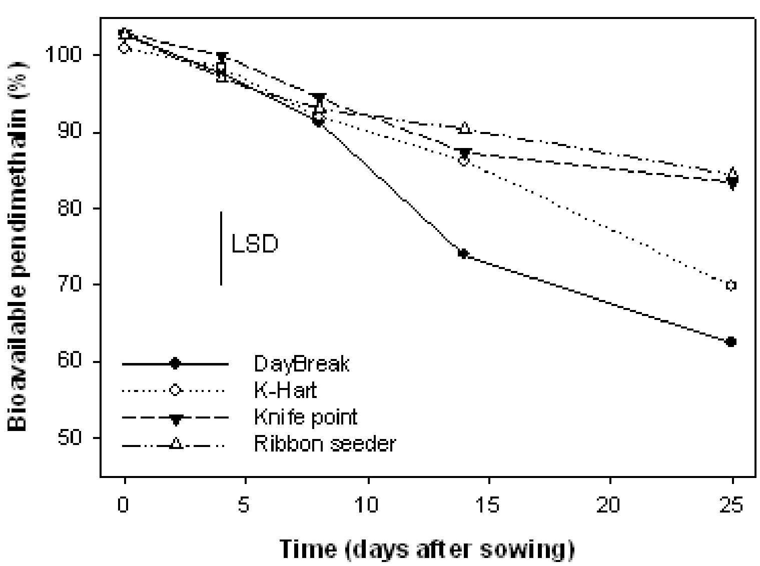

Figure 2. Bioavailability of pendimethalin (% of applied) under DayBreak, K-Hart, knife point and Ribbon seeder as determined by the oat bioassay. The applied pendimethalin concentration was equivalent to 0.48 ?g/g soil.

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