Physical and herbicide weed control in wide row lupins in Western Australia

Glen P. Riethmuller[1], Catherine P.D. Borger[1] and Abul Hashem[2]
[1] Department of Agriculture and Food Western Australia, PO Box 432, Merredin, WA 6415, Australia
[2] Department of Agriculture and Food Western Australia, PO Box 483, Northam, WA 6401, Australia
(glen.riethmuller@agric.wa.gov.au)

Summary Inter-row cultivation or shielded spraying can be used within wide row crops, in order to reduce weed growth between crop rows while causing minimal damage to the crop plants. However, this only kills weeds between the rows and weeds remain within the crop row (i.e. in-row weeds). Removing weed seed laden soil from the row (i.e. mechanical sweeps over the row) and spraying a narrow band of herbicide directly onto the crop row at seeding may help reduce the problem of in-row weeds. Metribuzin may be an effective herbicide to band over the row, for tolerant lupin (*Lupinus angustifolius* L.) varieties like Coromup. However, metribuzin is not registered for this practice.

The aim of the study was to assess the effect of over-the-row scraper sweeps and banded herbicides at seeding, and inter-row cultivation after lupin emergence, on weed numbers and lupin crop growth and yield.

Cultivation (sweeps at sowing and in-crop cultivation) combined with 300 g a.i. ha^{-1} of banded metribuzin gave 100% control of wild radish and a lupin yield of 2.0 t ha^{-1} at Merredin in 2013. Banded metribuzin also gave reduced ryegrass seed set in the wide row lupins. Shielded spraying (using paraquat/diquat) may be worth further investigation as it did reduce weed seed numbers without a great yield penalty (1.7 t ha^{-1}). Although unregistered for post sowing pre-emergent application, banded metribuzin over the row gave reduced weed numbers and still gave relatively high yield. Earlier application of paraquat/diquat in the shields may have reduced weed growth and therefore resulted in more soil water for crop growth and greater crop yields.

Keywords Lupins, wide rows, inter-row cultivation, shielded spraying, metribuzin, annual ryegrass, wild radish.

INTRODUCTION

Cultivation between crop rows is a common tool for weed suppression in Europe (Van der Schans *et al.* 2006), which is rarely utilised in Western Australian broad scale crops. Inter-row cultivation can be used within wide row crops (i.e. lupins), in order to disturb weed growth between crop rows while causing minimal damage to the crop plants. The degree of damage this technique causes to the weeds is influenced by weed species, soil moisture levels and the probability of post-cultivation rain. This method may cause damage to the lupin crop, which will be influenced by speed of cultivation, degree of soil throw, stage of crop development and crop density. It may prove to be an effective method of controlling herbicide-resistant wild radish in lupin crops, which is increasingly difficult to achieve with herbicides.

Banded over the row herbicides (i.e. herbicides sprayed directly onto the crop row during the seeding operation) may help reduce the common problem of in-row weeds. Coromup lupins are the most tolerant of metribuzin so an over the row pre-emergent application would be possible although is not registered for that purpose. Organic growers in other countries have used sweeps to scrap away the surface soil near the row to reduce in-row weeds (Liebman *et al.* 2004, Grubinger 2014).

Research is required to determine the success of cultivation or harrowing within young crops in Western Australia, in terms of weed control and crop damage. If successful, these techniques are likely to be useful to both organic and conventional growers.

MATERIALS AND METHODS

The experiment was conducted at the Merredin Research Station (31.48° S 118.29° E) on a sandy loam soil.

Treatments were:

1. Untreated control (no weed control).
2. Cultivate between rows three times three weeks apart.
3. Treatment two plus 500 g a.i. ha^{-1} simazine in a 22 cm band over the row at sowing.
4. Treatment two plus 1000 g a.i. ha^{-1} simazine in a 22 cm band over the row at sowing.
5. Treatment two plus 1500 g a.i. ha^{-1} simazine in a 22 cm band over the row at sowing.
6. Treatment two plus 150 g a.i. ha^{-1} metribuzin in a 22 cm band over the row at sowing.
7. Treatment two plus 300 g a.i. ha^{-1} metribuzin in a

22 cm band over the row at sowing.
8. Treatment two plus 450 g a.i. ha^{-1} metribuzin in a 22 cm band over the row at sowing.
9. Scraper sweeps to remove surface soil at sowing then cultivate between rows three times three weeks apart.
10. Treatment nine plus 300 g a.i. ha^{-1} metribuzin in a 22 cm band over the row at sowing.
11. 300 g a.i. ha^{-1} metribuzin in a 22 cm band over the row at sowing plus inter-row spray shield with Spray.Seed™ 3.0 L ha^{-1} at around early lupin budding.
12. 300 g a.i. ha^{-1} metribuzin in a 22 cm band over the row at sowing then post clethodim 36 g a.i. ha^{-1} and 10 days later 50 g a.i. ha^{-1} diflufenican plus 113 g a.i. ha^{-1} metribuzin.

Equipment A modified combine drill was used sowing five rows at a row spacing of 66 cm (Figure 1).

The plots were sown using 2 cm RTK autosteer on the tractor and the seed drill was also used for later inter-row cultivation of weeds by using two tines with 250 mm wide sweep points between the rows.

The herbicide band was applied behind a Janke™ press wheel using an even application Teejet™ AI95015EVS nozzle with coarse spray quality. A 150 mm ID 16 mm ring harrow was used to produce loose soil above the seed, to reduce soil drying (Figure 2).

The experiment was sown 9 May 2013 with 90 kg ha^{-1} cv. Coromup lupins and 37.5 kg ha^{-1} Double Phos™ (17.7% P, 16.2% Ca, 3.6% S) fertiliser banded 2 cm below the seed. All treatments had 40 mm wide cast points except treatment 9 which had 254 mm Agpoint™ No. 16310 sweeps with a specially designed soil scraper plate behind (Figure 3).

The lupin plant density was assessed by counting two 0.66 × 0.66 m quadrats per plot while annual ryegrass (*Lolium rigidum* Gaudin) and white oat (*Avena sativa* L.) head counts were measured in two 0.33 × 0.66 m quadrats per plot. The wild radish (*Raphanus raphanistrum* L.) plant number was low so all plants in each plot was counted.

The shielded sprayer applied 150 L ha^{-1} of water with Teejet™ DG95015EVS nozzles to improve coverage on the weeds (Figure 4).

The experiment was a randomised block design with three replications and analysed with Genstat 16th Edition.

RESULTS

The lupin density was fairly even and around the target density of 40 plants m^{-2} (Table 1).

An attempt was made to assess the in-row weed growth with a visual assessment on a scale of 1 be-

Figure 1. Modified combine seed drill.

Figure 2. Banding nozzle to apply herbicides and ring harrow on the press wheels.

Figure 3. Soil scraper plate behind sweep points.

Figure 4. Shielded sprayer between rows 20-8-2013.

ing low to 10 high. The sweeps with 300 g a.i. ha^{-1} of metribuzin (treatment 10) appeared to have lower weed growth than most other treatments (Table 1).

The lupin growth was similarly assessed and the treatments of nil, shielded sprayer (that had not been used at that stage) and clethodim + diflufenican appeared to have reduced control compared to the other treatments.

The annual ryegrass head density was variable but high on the clethodim + diflufenican treatment. Most other treatments reduced the annual ryegrass head number by around one quarter (Table 2). Sweeps plus 300 g a.i. ha^{-1} metribuzin killed all wild radish. There were some white oats in the experiment and clethodim

Table 1. Lupin density and in-row weed assessment with treatment.

Treat	Treatment	Lupins 13 June (pl m^{-2})	In-row weed rating 30 July* (1 low – 10 scale)	Lupin growth rating 30 July (1 low – 10 scale)
1	Untreated	37.1	9.2 ab	7.0 b
2	Cultivate	36.7	9.0 abc	9.0 a
3	Treat 2 + 500 g sim	36.3	7.7 bcde	8.7 a
4	Treat 2 + 1000 g sim	33.7	8.2 abcd	8.5 a
5	Treat 2 + 1500 g sim	36.7	8.5 abcd	8.3 a
6	Treat 2 + 150 g met	38.6	8.0 abcd	8.3 a
7	Treat 2 + 300 g met	42.1	8.2 abcd	9.0 a
8	Treat 2 + 450 g met	42.5	7.0 de	8.3 a
9	Treat 2 + sweeps	37.1	7.5 cde	8.8 a
10	Treat 9 + 300 g met	31.0	6.0 e	8.7 a
11	Shielded sprayer	40.6	9.3 a	6.7 b
12	Clethodim plus diflufenican	44.4	9.2 ab	7.2 b
	Average	38.1	8.1	8.2
	LSD	n.s.	1.76	0.887
	P value	0.068	0.020	<0.001
	C. of V%	12.0	12.8	6.4

* similar letters after are not significantly different (P <0.05).

Table 2. Weed density and lupin yield with treatment.

Treat	Treatment	Annual ryegrass head density 7 Nov (heads m^{-2})	Wild radish plant density 7 Nov* (√ plants per plot)	White oat density 7 Nov (heads m^{-2})	Lupin yield 27 Nov (t ha^{-1})
1	Untreated	405 a	2.97 (8.82) a	14.8	1.40 e
2	Cultivate	121 cd	2.68 (7.18) ab	2.6	1.72 d
3	Treat 2 + 500 g sim	113 cde	3.20 (10.20) a	1.0	1.88 abc
4	Treat 2 + 1000 g sim	125 cd	1.75 (3.06) abcd	1.0	1.81 cd
5	Treat 2 + 1500 g sim	108 cde	2.20 (4.84) abc	1.0	1.68 d
6	Treat 2 + 150 g met	137 c	1.41 (1.99) bcde	8.2	1.88 abc
7	Treat 2 + 300 g met	103 cde	2.06 (4.24) abcd	1.5	1.97 a
8	Treat 2 + 450 g met	82 cde	0.58 (0.34) de	3.6	1.97 a
9	Treat 2 + sweeps	104 cde	2.10 (4.41) abcd	6.1	1.81 bcd
10	Treat 9 + 300 g met	57 e	0.00 (0.00) e	6.1	1.96 ab
11	Shielded sprayer	66 de	0.80 (0.64) cde	4.1	1.70 d
12	Clethodim plus diflufenican	265 b	2.05 (4.20) abcd	0.0	1.70 d
	Average	140	1.82 (3.31)	4.2	1.79
	LSD	64.7	1.59	n.s.	0.157
	P value	<0.001	0.010	0.119	<0.001
	C. of V%	27.2	51.7	130.6	5.2

* back transformed squared in brackets and similar letters after are not significantly different (P <0.05).

+ diflufenican reduced their number to zero.

The lupin yield was surprisingly good for the season with the highest yielding treatment at 1.97 t ha^{-1} (Table 2). The 500 g a.i. ha^{-1} rate of simazine was higher yielding than the 1500 g a.i. ha^{-1}. There was no significant difference between all treatments with metribuzin applied. Interestingly the shielded sprayer gave 1.7 t ha^{-1} with low weed numbers. The sweeps alone appeared no better yielding than just cultivated but with metribuzin added the yield was better than just cultivated.

DISCUSSION

Although unregistered for post sowing pre-emergent application, a band of metribuzin over the row gave reduced weed numbers and still gave relatively high lupin yield.

The annual ryegrass head density was high on the clethodim + diflufenican treatment so these weeds were either resistant or too stressed at spraying time to respond to the herbicide.

The 500 g a.i. ha^{-1} rate of simazine was higher yielding than the 1500 g a.i. ha^{-1} so maybe 1500 g a.i. ha^{-1} caused simazine damage.

Previous work by the authors (Riethmuller *et al.* 2011) has shown that at least three inter-row cultivations are necessary for weed control with timing of the first one most critical to avoid weeds developing a large root system.

Shielded spraying may be worth further investigation as it did reduce weed seed numbers without a great yield penalty and would be more economically feasible than three inter-row cultivations for growers. Earlier application of paraquat/diquat in the shields may have reduced weed growth and therefore leaving more soil water for greater crop growth.

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