Wide row lupin (*Lupinus angustifolius* L.) cropping systems may sustain lupin production in Western Australia

Abul Hashem[1], Mike Collin[2] and David Bowran[1] and Paul Blackwell[3]

[1]Department of Agriculture and Food Western Australia, PO Box 483, Northam, WA 6401, Australia
Email: ahashem@agric.wa.gov.au
[2]WANTFA, Lot 12 York Road, Northam, WA 6401, Australia
[3] Department of Agriculture and Food Western Australia, PO Box 110, Geraldton WA 6531, Australia

Abstract

In 2003, five experiments evaluated alternative weed control options in lupins (*Lupinus angustifolius* L.) sown in 50-80 cm wide rows in WA to evaluate the efficacy of paraquat + diquat and tank mixes of knockdown herbicides with alternative molecules for inter-row weed control, and propyzamide and simazine for intra-row weed control. In Experiment 1, paraquat + diquat at 500 g a.i./ha controlled 93% of the blue lupin and 88% of the wild radish plants, giving 58% greater lupin yield than the untreated control. In Experiment 2, paraquat + diquat at 250 or 500 g a.i./ha controlled 95-100% annual ryegrass on the inter-rows and increased lupin yield by 11-43%. In Experiments 1 and 2, mowing followed by knockdown herbicide (glyphosate or paraquat + diquat) was equally effective on weeds but the effect of mowing time with regard to crop growth stage was not clear. In Experiment 3, propyzamide 1 kg a.i./ha or simazine 1 kg a.i./ha banded on lupin rows at sowing time reduced annual ryegrass density on lupin rows by 55-69%. In Experiment 4, alternative non-selective herbicide molecules from Group C, F, G, and N, as a tank mix with glyphosate or paraquat + diquat provided optimum control of inter-row annual ryegrass in wide row lupins. In Experiment 5 conducted at the farm scale, blue lupin control by glyphosate (94%) and paraquat + diquat (95%) was statistically similar to farmer practice. The trend in the grain yield of lupin was similar to that of weed control. Results clearly showed that inter-row weed control with paraquat + diquat provided optimum inter-row weed control and increased grain yields in wide row lupins.

Key Words

Weed management, row spacing, paraquat + diquat efficacy, sprayshields, tank mixes.

Introduction

One of the aims of wide row cropping is to control weeds by cultivation or non-selective herbicides. In the wake of an increase in the number of glyphosate-resistant annual ryegrass (*Lolium rigidum* Gaud.) populations in Australia (Preston 2008), farmers should use paraquat + diquat as an alternative to glyphosate or use tank mixes of knockdown herbicides with an alternative herbicide for inter-row weed control in wide row cropping systems. Little information is available on the efficacy of paraquat + diquat or knockdown based tank mixes on the inter-rows in wide row cropping systems within WA wheatbelt. The aim of this study was to evaluate the efficacy of paraquat + diquat and tank mixes of knockdown herbicides with alternative molecules for inter-row weed control.

Methods

Five experiments were conducted in 2003 to evaluate alternative weed control options in the inter-rows of lupins (*Lupinus angustifolius* L.) sown in 50-80 cm wide rows in WA. Experiment 1 was conducted on a lupin crop grown on a non-wetting yellow sand plain soil at Northampton (28? 20'S, 114?38'E). A lupin crop was sown in 55 cm wide rows (unit plot of 2 m x 20 m) in late May 2003. Simazine 1000 g a.i./ha was sprayed post-sowing pre-emergence (PSPE) over the experimental area. A mixture of paraquat + diquat (135 g a.i./L + diquat 115 g a.i./L), commercially known as Spray.Seed[?], was sprayed between lupin rows at 250 or 500 g a.i./ha at 7-leaf or flowering stage of lupin, using a new sprayshield. Experiments 2 and 3 were conducted on a Tamma sand plain field at the WA No-till Farmers Association (WANTFA) site, Meckering (31?38'S, 117?03'E). There were two, 78 cm wide rows in the centre of each plot, flanked by four rows at 68 cm, giving a plot size of 11.7 m x 30 m. The experiment was sown on 10 June 2003, using the a no-till commercial seeder of the cooperating farmer. . In Experiment 3, simazine and propyzamide were applied in a 15 cm band on lupin rows behind the seeder. Experiment 4 was conducted on a red sandy loam soil at York (31?52'S, 116?45'E) using the farmer's commercial sowing machine. Simazine 1 kg a.i./ha was uniformly applied over the experimental area before sowing... Experiment 5 which was conducted at the same site as Experiment 1, compared the efficacy of glyphosate and paraquat + diquat applied on the inter-rows with farmer's weed control practice at the farm scale. Inter-row herbicides were sprayed using sprayshields (Row Rocket or Red Ball). The main weed species were blue lupin (*Lupinus consetinii* Guss) and wild radish *(Raphanus raphanistrum* L) at Northampton and annual ryegrass at Meckering and York.

Results

Inter- and intra-row weed control

In Experiment 1, paraquat + diquat at 500 g a.i./ha sprayed at the 7-leaf stage of lupin controlled 93% of blue lupin and 88% of wild radish. Paraquat + diquat at 250 g a.i./ha sprayed at 7-leaf stage of lupin controlled 60% of blue lupin and 24% of wild radish (Table 1). In contrast, paraquat + diquat at 250 g a.i./ha sprayed 1 h after mowing weed plants between lupin rows at the flowering stage of lupin controlled 100% of blue lupin and 93% of wild radish. The same mixture, sprayed immediately after mowing at the 7-leaf stage, controlled 70% of blue lupin and 77% of wild radish. In Experiment 2, paraquat + diquat at 250 g a.i./ha with or without mowing controlled 92 to 100% of the inter-row annual ryegrass plants (Table 1). Increasing paraquat + diquat rate to 500 g a.i./ha sprayed at the flowering stage of lupin (6-leaf to stem elongation stage of annual ryegrass plants) controlled 100% of annual ryegrass.

Table 1. Effect of a mixture of paraquat + diquat at 250 g a.i./ha or 500 g a.i./ha sprayed between wide rows of lupins at its 7-leaf or flowering stage, with or without mowing, on the weed control and grain yields of lupin in Experiment 1 at Northampton and Experiment 2 at Meckering, WA in 2003. Weed control is expressed as percent of the untreated control. Rates of herbicides are expressed as g a.i./ha.

Treatments	Experiment 1 (Northampton)			Experiment 2 (Meckering)	
	Blue lupin control (%)	Wild radish control (%)	Lupin grain yield (kg/ha)	Annual ryegrass control (%)	Lupin grain yield (kg/ha)
1. Paraquat + diquat 250 g at 7 leaf stage of lupin	60	24	1381	98.0	1845
2. Paraquat + diquat 250 g at flowering stage of lupin	83	93	1783	97.0	1921
3. Paraquat + diquat 500 g at 7 leaf stage of lupin	93	88	2190	100.0	1531
4. Paraquat + diquat 500 g at flowering stage of lupin	83	93	1499	100.0	1817

5. Mowing/paraquat + diquat 250 g at 7 leaf stage of lupin	70	77	1274	95.0	2242
6. Mowing/paraquat + diquat 250 g at flowering stage of lupin	100	93	1360	92.0	1897
7. Mowing/paraquat + diquat 500 g at 7 leaf stage of lupin	69	74	1325	100.0	1919
8. Mowing/paraquat + diquat 500 g at flowering stage of lupin	98	97	1317	100.0	2139
9. Clethodim 60 g at 6-leaf stage of annual ryegrass	-	-	-	95.0	1755
10. Untreated control	0	0	913	0.0	1570
LSD(P=0.05)	27.3	20.5	413.7	6.2	414.2

In Experiment 3, intra-row annual ryegrass density was significantly reduced from 177 plants/m^2 in the untreated control to 69 plants/m^2 (61% reduction) by propyzamide banded on rows at 1 kg a.i./ha and to 55 plants/m^2 (68% reduction) by simazine banded on rows at 1 kg a.i./ha. There was no interaction between intra-row banding of herbicides and inter-row spraying on intra-row annual ryegrass control in Experiment 3 (data not presented). In Experiment 4, all mixtures of alternative herbicide molecules with glyphosate or paraquat + diquat provided 100% control of inter-row weeds in lupin. Inter-row mowing followed by spraying paraquat + diquat at 250 g a.i./ha controlled 75% of inter-row annual ryegrass plants (Table 2). Inter-row cultivation provided only 50% control of annual ryegrass. Tank mixes of glyphosate or paraquat + diquat with other non-selective herbicides from different modes of action provided 100% control of inter-row annual ryegrass. In Experiment 5, conducted at the farm scale, blue lupin control by glyphosate (94%) and paraquat + diquat (95%) was slightly greater than the boom spray used by the farmer (270 g a.i. /kg ethametsulfuron methyl + 595 g a.i./kg diflufenican) + metosulam, 960 g a.i./kg) but the difference was not statistically significant (data not presented). The average density of blue lupin in the untreated plots was 20 plants/m^2.

Lupin grain yields

In Experiment 1, paraquat + diquat at 500 g a.i./ha sprayed at 7-leaf stage of lupin without mowing produced the highest yield of 2190 kg/ha where inter-row blue lupin control was 93% and wild radish control was 88%. In Experiment 2, inter-row spraying with or without mowing produced an extra lupin yield of 185 to 672 kg/ha over the untreated control (1570 kg/ha) (Table 1) except in treatment 3. The highest lupin yield (2242 kg/ha) was obtained from paraquat + diquat at 500 g a.i./ha sprayed on the inter-rows 1 h after inter-row mowing at the 7-leaf stage, closely followed by paraquat + diquat at 500 g a.i./ha sprayed on the inter-rows after inter-row mowing at flowering stage of lupins. These treatments increased grain yield by 672 and 569 kg/ha, compared to the untreated control (Table 1). In Experiment 3 at Meckering, there was no significant effect of herbicide banding or interaction between banding treatments and post-emergence inter-row spraying treatments on the grain yield of lupins.

In Experiment 4 at York, lupin yield significantly increased in the inter-row spraying treatments compared with the untreated control (Table 2). Mowing followed by paraquat + diquat at 250 g a.i./ha controlled 75%

of the inter-row annual ryegrass plants resulting in 13% increase in lupin grain yield. Inter-row cultivation alone provided only 50% control of inter-row annual ryegrass with a 12% increase in lupin grain yield. The mixture of glyphosate 460 g a.i./ha + oxyfluorfen at 96 g a.i./ha sprayed on the inter-rows produced the highest grain yield of lupin followed by paraquat + diquat at 250 g a.i./ha.

In Experiment 5 at Northampton (Farm scale test) , the grain yield increased from 1230 kg/ha with conventional farm practice to 1440 kg/ha in paraquat + diquat treatment but the difference was not statistically significant. The trend in the grain yield of lupin was similar to that of weed control.

Table 2. Effect of mowing, inter-row cultivation and alternative herbicide molecules as a tank mix with knockdown herbicides on the inter-row annual ryegrass control, lupin pod numbers and grain yield in wide row lupin in Experiment 4 at York, WA in 2003. Rates of herbicides are expressed as g a.i./ha.

Treatments	Herbicide mode of action	Inter-row annual ryegrass control (%)	Lupin pods (Number/m^2)	Lupin grain yield (kg/ha)
1. Untreated control	-	0	131	736
2. Mowing followed by paraquat + diquat 250 g	Photosystem I-inhibitor	75	148	837
3. Inter-row cultivation	-	50	147	827
4. Glyphosate 460 g + oxyfluorfen 48 g	EPSP-inhibitor + protoporpyrinogen oxidase-inhibitor	100	179	1009
5. Paraquat + diquat 250 g + amitrole 200 g	Photosystem I-inhibitor + carotenoid biosynthesis-inhibitor	100	152	859
6. Glyphosate 460 g + glufosinate 400 g	EPSP-inhibitor + glutamine synthase-inhibitor	100	156	879
7. Glyphosate 460 g + prometryn 170 g	EPSP-inhibitor + Photosystem II-inhibitor	100	155	870
8. Glyphosate 460 g. + acifluorfen 34 g	EPSP-inhibitor + protoporpyrinogen oxidase-inhibitor	100	159	896
9. Glyphosate 460 g + dalapon 790 g	EPSP-inhibitor + lipid synthesis-inhibitor	100	135	762

10. Paraquat + diquat 250 g	Photosystem I-inhibitor	61	140	928
LSD (p=0.05)		15.3	21.2	170.6

Discussion

Results from the experiments in this study suggest that weed control by inter-row spraying of paraquat + diquat using sprayshields is feasible and can sustain productivity of lupin, particularly in situations where weeds have developed resistance to selective herbicides. However, in some situations, a wide row lupin crop (50 cm or wider) may not be as competitive with weeds as a normal lupin crop sown in 20-25 cm row spacing. Crabtree *et al.* (2002) found that increasing the lupin rows up to 42 cm did not penalise lupin grain yield but lupin yield declined at 84 cm wide row spacing when sown late. However, they postulated that wide rows would enable growers to use non-selective herbicides between rows and band more expensive selective herbicides on rows. French (2004) also postulated that lupin grain yield would be slightly reduced if row spacing was increased from 25 to 50 or even 74 cm in the northern wheatbelt of WA. These results should give confidence to growers wishing to grow lupins in wide rows to facilitate inter-row spraying or other novel methods of weed management in the central and northern WA wheatbelt, but not to the growers in the medium to high rainfall areas of southern WA wheatbelt where wide rows are likely to reduce lupin yield (French 2004). Effective weed control in wide row lupins using non-selective herbicides should sustain lupin production, as growers are likely to experience little or no yield decline from wide row lupins in most of the lupin growing areas within WA wheatbelt. Farm scale test using farmer's commercial machinery has also demonstrated that inter-row weed control with paraquat + diquat or glyphosate produced similar grain yields of lupin to farmer's normal weed control practice. However, in the wake of fast increases in the cases of glyphosate resistance in annual ryegrass in Australia, farmers should use paraquat + diquat for inter-row weed control. Use of a mixture of paraquat + diquat is also expected to minimise or delay the development of glyphosate resistance in weeds when the principles of double knockdowns are followed (Borger and Hashem 2007).

Conclusions

In the wake of widespread resistance of annual ryegrass to the main herbicide groups within the WA wheatbelt, it is necessary to manage annual ryegrass by incorporating alternative herbicide molecules or practices to minimise the impact of resistance. More research is needed to evaluate the efficacy of tank mixes of glyphosate with other herbicides such as prometryn, acifluorfen, oxyfluorfen, and glufosinate to control annual ryegrass on the inter-rows of wide row lupin.

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