Weed control in lupins using a new spray shield and other row crop techniques

Mike Collins and Julie Roche
Department of Agriculture, PO Box 483, Northam, Western Australia 6401, Australia

Summary Row-crop weed control methods, where totally different intra-row and inter-row treatments can be used, are examined, with lupin as the crop and annual ryegrass as the weed. Trials showed no yield decline out to 60 cm row spacing (the widest tried). The best results were obtained with intra-row control of ryegrass with seed-time band-spraying of propyzamide and inter-row use of knockdown herbicides with an improved (and patented) spray shield. Development is continuing.
Keywords Annual ryegrass, spray shield, row-crop, propyzamide, intra-row selective, inter-row non-selective, herbicide weed control, lupin.

INTRODUCTION

The world-wide trend to lower herbicide residues in food products and the general environment, together with the more local problem of evolving herbicide resistance in major weed species, requires research into alternative methods of controlling weeds. The 'row-crop' concept allows the definition of separate 'intra-row' and 'inter-row' zones, whereby quite different weed control methods can be used in the two zones. Typically this allows the use of non-selective methods inter-row, with the more expensive selective methods concentrated solely on the intra-row. This could have significant cost benefits for growers, as well as the gains from the use of less selective herbicide.

Because there is imprecision between the intra- and inter-row zones through a combination of variability in row formation and sprayer driving, there is overlap between the zones. Shields are normally mounted on a boom on a tractor, their lateral position in relation to the row being determined by the position of the tractor relative to the row, so that any steering error with the tractor affects the weed control efficacy and crop damage. The intra-row zone must be wide enough so that the shield can be far enough away from the row to not damage the crop when at its closest position to the row, yet not leave a gap between the zones when at it's furthest from the row. This leads to the overlap being determined by the precision of the system. The greater the precision, the narrower the intra-row zone and the overlap can be, and the narrower the row spacing before row cropping becomes uneconomic.

Wide row spacing in some pulse crops provides advantages for stubble handling and disease control as well as potential for row-crop weed control. Chickpeas in NSW showed no yield decline at row spacings up to 75 cm (Felton pers. comm.) and local trials have shown similar results with lupins (*Lupinus angustifolius*).

The aim of this research was to determine the effectiveness of various intra and inter-row weed control methods, including band spraying, shielded sprayers, cultivation, and flame weeding, as well as 'conventional' boom-sprayed selective herbicides.

Propyzamide, from Group K, has previously been too expensive for broad-acre use, and was commonly used for taking winter grass (*Poa annua*) out of couch grass (*Cyndon dactylon*) lawns, and for grass control in high value vegetable crops such as lettuce. It was considered to be potentially useful as an intra-row band herbicide for annual ryegrass (*Lolium rigidum* Gaudin), as the cost would be greatly reduced and it has residual properties, perhaps allowing one application to last until quite late in the season. Propyzamide was also used in 2001 as a 'layby' application. 'Layby' is a term to describe the operation of applying herbicide intra-row from additional nozzles (mounted on the side at the rear of the shield) while the inter-row zone is being sprayed by the shielded sprayer.

Joint work with Paul Blackwell at Mingenew in 2000 where both paraquat and glyphosate were sprayed intra-row as a layby treatment encouraged further work at Wongan Hills later that year, as the lupins seemed to tolerate these herbicides.

The relative success with inter-row shielded sprayer compared to inter row cultivation and other methods lead to a concentration on development of this method and an examination of its potential.

MATERIALS AND METHODS

Small plot (4–6 m wide, 25–40 m long) trials were conducted at Wongan Hills Research Station over the four years 1998–2001, in a heavily infested annual ryegrass) area, using narrow-leaved lupin as the crop.

Trial set-up Each year a site was selected where lupins were planned in the rotation, and the trial installed in May, after the 'break' (i.e., no trials were dry sown). Simazine and Spray.Seed™ were usually applied beforehand to reduce ryegrass numbers, and in-crop selective herbicides were used to control broadleaf weeds (predominantly wild radish, *Raphanus raphanistrum* L.).

Propyzamide was used as an intra-row grass selective herbicide. A 'dry' boom was mounted on the seeder behind the rear tines, with the nozzle mounts centred over the seeded row, applying 1.5 kg ha^{-1} initially, but 1 and 2 kg ha^{-1} as a treatment in 2001. The band width was adjusted by turning the fan nozzles at an angle to the direction of travel. The smallest nozzles readily available, Spraying Systems 8001E, were used delivering 268 L ha^{-1} for a 10 cm band.

Propyzamide was also used in 2001 as a 'layby' application (Table 5). The 'double knock' layby treatments were: glyphosate at 2.0 L ha^{-1} (7/9), followed by 2.0 L ha^{-1} of paraquat (22/9). Intra-row treatments were: paraquat at 2.0 L ha^{-1} (7/9), glyphosate 1.0 L ha^{-1} (22/9).

Inter-row weed control Weed wiping (with glyphosate applied 1 L ha^{-1}), glyphosate-impregnated foam (estimated similar rate), flame weeding (using shielded US-made 'Red Dragon' burners), cultivation (using 20 cm wide sweeps) and shielded sprayer treatments were all carried out in August, 1998, when the crop was vegetative and weeds were 3–4 leaf stage, and before any moisture stress (although that occurred only near harvest when the crop was drying off). Comparison was made to 'conventional' boom-sprayed selective herbicides (sethoxydim and haloxyfop). From 1999 onwards, treatments were reduced to cultivation (in the form of 'Lilleston' non-powered rotary hoes), various combinations of spray shield options, and 'conventional' boom sprayed selective herbicides.

RESULTS

The tables presented illustrate the major trial findings:

Row spacing See Table 1.

Table 1. Lupin yield (t ha^{-1}) with different row spacings.

Row spacing (cm)	1998	1999
18	1.569	1.610
36	1.500	1.710
50		2.047
54	1.539	
LSD (P=0.05)	ns	0.2549

Intra-row weed control Intra-row ryegrass numbers were reduced by over 90% in 2000 and 2001 by band spraying propyzamide at seeding time (Table 2), although the population was very variable. The results from the use of glyphosate and paraquat intra-row are presented in Table 3.

Table 2. Ryegrass numbers (per m^2) intra-row, with and without propyzamide intra-row banded treatment applied at seeding time.

Rate (kg ha^{-1})	1998	1999	2000	2001
0	3911	29	272	3763
1.0	–	–	–	731
1.5	2360	33	23	–
2.0	–		–	323
LSD (P=0.05)	ns	ns	120	1238

Inter-row weed control The trial in 1998 investigated many inter-row weed control options (Table 4).

Table 4. Ryegrass biomass, (kg ha^{-1}), and lupin grain yield (t ha^{-1}) with different inter-row weed control treatments, measured mid-October 1998.

Treatment	Ryegrass	Lupin
Selective herbicides	210	1.54
Shield, Spray.Seed, 1.0 L ha^{-1}	485	1.33
Shield, glyphosate, 1.0 L ha^{-1}	503	1.28
Cultivation	637	1.05
Glyphosate impregnated foam	886	1.20
Weed Wiper (with glyphosate)	826	1.11
Flame	931	1.18
LSD (P=0.05)	389.4	0.2186

Operation timing The trial in 2001 investigated both intra-row and inter-row weed control timing (Table 5).

DISCUSSION

Lupins row spacing The trial results of 1998 and 1999 found no decline in yield by having a row spacing up to 54 cm, in fact in 1999 the yield was greater at the widest row spacing. More recent work by Crabtree *et al.* (2002) suggested that lupins grown in harsher conditions yield more reliably on wider row spacings. This may be because of increased competition between the plants in the row encouraging flowering and seed set, a better phosphorous supply because of a greater concentration of fertiliser under the row, or possibly greater rationing of moisture in the inter-row

Table 3. Lupin yield 2000 results.

Treatment	Yield t ha^{-1}	Biomass t ha^{-1}	Harvest Index, %	1000 grain wt	Protein %
Propyzamide IR DKBR	0.690	4.241	16	146.3	32.175
Paraquat IR DKBR	0.603	3.366	18	136.5	31.375
Glyphosate IR and BR	0.672	3.116	22	135.7	Not tested
Nil IR Paraquat BR	1.018	2.781	37	145.3	Not tested
Conventional selective	0.422	3.996	11	142.5	33.025
Control – none	0.614	2.781	22	132.5	34.475
LSD (P=0.05)	0.3466	1.804	Not tested	7.062	0.6258

'DK' = double knock glyphosate followed by paraquat; 'IR' = intra-row; 'BR' = between-row.

Table 5. Trial results, 2001.

Treatment	Lupin biomass t ha^{-1}	Lupin yield t ha^{-1}	Ryegrass biomass t ha^{-1}
'Conventional Herbicide' = 250 mL 'Select', 11 July.	4.109	0.897	2.321
Early inter-row (2.0 L ha^{-1} glyphosate, 4 July), banded propyzamide 1.0 kg ha^{-1} at seeding, 17 May.	4.987	1.357	0.748
Early inter-row (2.0 L ha^{-1} glyphosate, 4 July), banded propyzamide 2.0 kg. ha^{-1} at seeding, 17 May.	5.629	1.560	0.680
Later inter-row (2.0 L ha^{-1} glyphosate, 16 August), banded propyzamide 1.0 kg ha^{-1} at seeding, 17 May.	4.108	1.100	1.305
Later inter-row (2.0 L ha^{-1} glyphosate, 16 August), banded propyzamide 1.0 kg. ha^{-1} at seeding, 17 May.	4.678	1.117	1.492
Early inter-row (2.0 L ha^{-1} glyphosate, 4 July), 'lay-by' propyzamide 2.0 kg ha^{-1} in-row, 27 June.	4.754	1.110	1.314
Early inter-row (2.0 L ha^{-1} glyphosate, 4 July), 'lay-by' propyzamide 1.0 kg ha^{-1} in-row, 4 July.	4.298	0.857	1.382
'Lilleston' rolling cultivator, 26 June and 13 July.	3.719	0.947	2.772
Early inter -row (2.0 L ha^{-1} glyphosate, 4 July), no intra-row treatment. Normal seed rate, 106 kg ha^{-1}.	4.163	0.907	1.439
Early inter -row (2.0 L ha^{-1} glyphosate, 4 July), no intra-row treatment. High seed rate, 147 kg ha^{-1}.	4.708	1.097	1.495
LSD (P=0.05)	ns	0.314	548.8

space (allowing more for grain filling) or perhaps less disease.

An example of the stress factor (for moisture) in lupin growth and production is illustrated in Table 3, where the treatment with no intra-row weed control has a similar biomass to the control treatment (no weed control), yet the best yield.

Intra-row weed control Results from the use of propyzamide as an intra-row band spray improved over the trial series (Table 2), although ryegrass numbers have always been very variable. Three factors could be involved in the improved results. The herbicide is a wettable powder and tends to block spray nozzles, later batches of the chemical being better in this respect. The match up of shields and row bands has greatly affected ryegrass numbers, as strips unsprayed between intra-row and inter-row zones (as little as 1 cm) have produced many ryegrass plants that have grown well and produced much seed. Moisture also seems to be a factor, with the herbicide being poorly active in dry conditions, such as the dry spell at seeding in 1999 and with the layby treatment in 2001.

The use of paraquat and glyphosate intra-row was not successful. Lesions developed on the base of crop stems, in some cases developing right around the stem, causing ringbarking. Yield, grain weight and protein were decreased. There is scope for screening of herbicides and rates for stem contact tolerance to perhaps find alternatives for layby use.

Inter-row weed control Cultivation was found to stimulate ryegrass germination. Two applications were not enough with sweeps in 1998, or twice with a 'Lilleston' rolling cultivator in 2000 or 2001 to give control. Cultivation may suit where the background ryegrass population is lower (there were up to over 5000 plants germinating per square metre at this site), but was regarded as an impractical inter-row treatment for high ryegrass populations.

The weed wiper and Roundup™ treated foam (both applied at 1 L ha^{-1} of Roundup) were tried as it was uncertain that the drift problem with spraying could be overcome. Results, however, were not as good as those from the shielded sprayer and development was not continued, although results were promising enough from the wiper to suggest that further development might improve performance. It may be possible to use the wiper under the shield to give a very low volume application method.

'Red Dragon' naked flame weed burners (made in Kansas, USA) were tried and found to be unsatisfactory in typical wheat-belt windy conditions. It was considered unlikely that an improved burner would be suitable for inter-row weed control, although a very narrow insulated burner may be practical for selective intra-row weed control. No tests have been made on the capacity of lupin plant stems to withstand such a treatment.

The inter-row spraying results were the best inter-row options in 1998 (Table 2), when both Spray.Seed and glyphosate were tested. Development of the design took the original idea of a trailed shield on wheels (as a means of maintaining the spray nozzle at the correct height and reducing steering errors, the wheels also reducing spray splash into the crop row) to one with a provisional patent. In this design the wheels were angled to the vertical to be parallel with the spray to allow closer treatment to the base of the crop plant. It was found that the wheels helped guide the shield by either running in the seeder groove when the crop plants were small, or along the base of crop stems when bigger. Fine adjustment to suit each row was found to be important to eliminate missed areas between the inter- and intra-row zones without resorting to wide overlaps, and to help the shields track well in the seeder grooves.

Operation timing In general, moisture limitations to yield were compounded by weed control timing. Table 5 (2001 data) illustrates this, and a 'critical' period trial in 2000 at another site (Southern Brook, near Northam) showed a consistent lupin yield decline as weeding became later, in a year and site where moisture was limiting from early July.

Shield development Full patenting occurred in 2002, with further testing and development to a commercial model continuing.

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