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Crop Updates 2010 - Weeds

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Herbicide control of slender iceplant

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Research conducted by L Hunt. A Blake completed this article after L Hunt's resignation from DAFWA.

KEY MESSAGES

- Pre-emergent herbicide treatments were more effective than post-emergence at controlling slender iceplant (*Mesembryanthemum nodiflorum*).
- The only fully registered option for controlling slender iceplant in WA is dicamba in a mix with 2,4-D amine in non-crop situations. The Liebe group also holds minor use permits for the use of Ally®, Glean® and atrazine for controlling slender iceplant in cereal and pasture paddocks valid until October 2010 (Permit number PER8226).

AIMS

Slender iceplant is a common weed of saline valley floor areas in the northern wheatbelt of WA but can also be found on non-saline areas. Registered options for controlling slender iceplant are limited. This research aims to identify treatments with potential to be registered for controlling slender iceplant in both crop and pasture situations.

METHOD

Four trials were conducted in 2008 at two sites, one site near Carnamah and one site near Morowa. The Carnamah site was red cracking clay and received 247 mm of April-October rainfall. The Morowa site was red clay-loam over a red-brown hardpan and received 241mm April-October rainfall. At each site one trial assessed pre emergent herbicide treatment and another trial assessed post emergent herbicide treatments aimed at controlling slender iceplant. The trials were designed as randomised blocks, each with three replicates. Spray strips (20 m x 3 m) were applied on 17 June for pre-emergent trials and on August 12 2008 for the post-emergent trials (60L water volume/ha with 11002 nozzles at 12 km/hr). Control of slender iceplant was visually assessed in August and November and expressed as a percentage reduction in iceplant biomass compared with the unsprayed control.

RESULTS

Table 1. **Percentage reduction in slender iceplant biomass visually assessed at two locations 63 days and 139 days after application of pre-emergent herbicide treatment.**

Pre-emergent herbicide (rate/ha)	Morowa		Carnamah	
	19 August	3 November	19 August	3 November
25 g/ha Broadstrike® (flumetsulam 800 g/kg)	89	90	98	99
15 g/ha Broadstrike® (flumetsulam 800 g/kg)	78	82	93	98
150 mL/ha diflufenican (500 g/L)	100	98	100	99
75 mL/ha diflufenican (500 g/L)	83	48	95	57
1 L/ha diuron (500 g/L)	58	7	99	90
500 mL/ha diuron (500 g/L)	8	0	80	7
3 L/ha Stomp® (pendimethalin 330 g/L)	93	62	100	93
2 L/ha Stomp® (pendimethalin 330 g/L)	73	13	97	85
1 L/ha Stomp® (pendimethalin 330 g/L)	23	0	92	33
200 mL/ha Goal® (oxyfluron 240 g/L)	83	13	93	10
500 mL/ha Goal® (oxyfluron 240 g/L)	100	97	100	98
200 g/ha Lexone ® (Metribuzine 750 g/L)	85	47	93	85
2 L/ha trifluralin (480 g/L)	40	0	83	13
500 mL/ha Dual Gold® (S-metolachlor 960 g/L)	20	0	47	0
1 L/ha Boxer Gold® (S-metolachlor 120 g/L + Prosulfocarb 800 g/L)	97	13	99	53
Control (unsprayed)	0	0	0	0

Table 2 **Percentage reduction in slender iceplant biomass visually assessed at two locations 83 days after application of post-emergent herbicide treatment.**

Post-emergent herbicide (rate/ha)	Morowa	Carnamah
	Rated 3 November	Rated 3 November
25 g/ha Broadstrike® (flumetsulam 800 g/kg) (+ 0.1% BS-1000)	40	63
25 g/ha Broadstrike® + 100 mL/ha diuron (+ 0.1% BS-1000)	65	57
1 L/ha diuron (500 g/L)	0	0
500 mL/ha diuron (500 g/L)	0	0
640 mL/ha 2,4-D amine (625 g/L) + 320 mL/ha dicamba (500 g/L)	99	100
640 mL/ha 2,4-D amine (625 g/L)	98	90
320 mL/ha dicamba (500 g/L)	5	13
1 L/ha MCPA LVE (500 g/L)	0	0
2 L/ha atrazine (500 g/L)	33	100
5 g/ha Ally® (metsulfuron-methyl 750 g/kg) (+0.1% BS-1000)	98	98
120 g/ha Lontrel® (clopyralid 750 g/kg) (+0.1% BS-1000)	0	0
500 mL/ha Goal® (oxyfluoron 240 g/L) (+0.1% BS-1000)	0	13
750 mL/ha bromoxynil (200 g/L) + 440 mL/ha 2,4-D amine (625 g/L)	5	20
Control (unsprayed)	0	0

CONCLUSION

Pre-emergence trials

Pre-emergent herbicide treatments were generally more effective than post-emergent treatments. Most pre-emergent treatments showed very good early control of iceplant, while only a few provided residual control right through the season. The top performing pre-emergent herbicides with long residual control were 150 mL/ha diflufenican, 500 mL/ha Goal® and 25 g/ha Broadstrike®. Pre-emergent iceplant control was consistently better at Carnamah compared to Morowa indicating how variable herbicide effect can be depending on factors including soil type, soil moisture and temperature.

Broadstrike® is registered for use in legume crops and pastures for post-emergent control of certain broadleaf weeds. Broadstrike® gave 40 to 63 per cent control of iceplant when used post emergence. When used pre emergence it was even more effective with up to a 98 per cent reduction in iceplant biomass achieved. Herbicide tolerance trials (Hunt and Blake 2010) found 25 g/ha Broadstrike® caused very little damage to the commonly grown fodder shrubs bluebush, oldman saltbush and river saltbush.

Diflufenican is registered for early post-emergent broadleaf control in legume crops such as lupins. Although not registered for pre-emergent use, results for pre-emergent diflufenican treatments were encouraging, with up to 100 per cent iceplant biomass reduction at a rate of 150 mL/ha. Herbicide tolerance trials indicated that diflufenican caused only minor damage to planted saltbush and bluebush when sprayed post-emergent (Hunt and Blake 2010).

Goal® has commonly been used as a knockdown spike in broadacre farming and is also registered at higher rates for pre-emergent control of some weeds in horticultural situations. Up to 100 per cent control was achieved using a pre-emergent application of 500 mL/ha Goal®. Herbicide tolerance trials also found only minor damage to saltbush and bluebush using 500 mL/ha Goal® (Hunt and Blake 2010).

Stomp® is generally used for pre-emergent control of grasses and some broadleaf weeds in cereals. Iceplant control improved with increasing application rate and was considerably better at the Carnamah site than at Morowa.

Boxer Gold® is registered for the control of annual ryegrass and toadrush in wheat and barley at 1.5–2.5 L/ha. At only 1 L/ha, Boxer Gold® provided up to 98 per cent biomass reduction of slender iceplant in the first 2 months. Activity dropped off by the end of the season, but residual activity may be greater at a higher application rate. Boxer Gold® contains a mix of the active ingredients, prosulfocarb and S-metolachlor. Dual Gold®, containing equivalent rates of only the S-metolachlor component was

trialled to assess the differences between the two products. This trial indicated that better iceplant control was achieved using the Boxer Gold® product than Dual Gold®.

Efficacy of diuron was variable but considerably better at the Carnamah site than at Morowa. The 1 L/ha rate was more effective than 500 mL/ha at both sites. Metribuzin was observed to have strong activity on slender iceplant.

Post-emergence trials

Herbicides with sufficient post-emergent activity were difficult to find. The fully registered option (in non-crop situations) of dicamba in a mix with 2,4-D amine was confirmed as effective but is known to cause serious damage to saltbush and bluebush (Hunt 2010). The Liebe Group holds a minor use permit for the use of 2 L/ha atrazine, which was effective at the Carnamah site in the 2008 trial, but only moderately effective at Morowa. Atrazine has also been shown to be damaging to both bluebush and saltbush (Hunt and Blake 2010).

Ally® was very effective in controlling iceplant, reducing biomass by 98 per cent at both trial sites. The Liebe Group holds minor use permits for the use of 5 g/ha Ally® and 15 g/ha Glean® to control slender iceplant. These products are known to be very damaging to legume pastures. Other trial work has found they are well tolerated by mature bluebush, but damaging to younger river and old man saltbush seedlings (Hunt and Blake 2010).

This research found that 1 L/ha of MCPA LVE® was insufficient for post-emergent iceplant control, along with the mix of bromoxynil + 2,4-D amine. 1 L/ha diuron, 300 mL/ha Lontrel® and 500 mL/ha Goal® also had poor post-emergent activity.

Not all the herbicides mentioned in this report are registered for slender iceplant control, nor have a minor use permit. Product selection will depend upon product labels, weeds spectrum and presence of desirable pasture species. Always consult product labels and seek professional advice, as these trials were intended as research only.

See also article ‘Herbicide tolerance of saltbush and bluebush’ by Hunt and Blake in Crop Updates 2010, Weeds Booklet.

KEY WORDS

slender iceplant, herbicide control

ACKNOWLEDGMENTS

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Herbicide tolerance of saltbush and bluebush

Lorinda Hunt, Department of Agriculture and Food, Western Australia, Three Springs, **Andrew Blake**, Department of Agriculture and Food, Western Australia, Geraldton

Research conducted by L Hunt. A Blake completed this paper after L Hunt's resignation from DAFWA.

KEY MESSAGES

- The three fodder shrubs tested varied in their tolerance to the applied herbicide treatments.
- The observed tolerances differed between the Buntine and Morowa sites

AIMS

River saltbush (*Atriplex amnicola*), old man saltbush (*Atriplex nummularia*) and small leafed bluebush (*Maireana brevifolia*) are fodder shrubs that are widely planted on saline areas in the northern wheatbelt of WA. Establishing perennial shrubs on saline areas can rehabilitate degraded areas and also provide profitable fodder reserves for livestock enterprises. Profitability of grazing salt tolerant shrubs is greater where there are improved annual pastures growing between the rows of shrubs. Slender iceplant (*Mesembryanthemum nodiflorum*) can dominate these areas making the establishment of other annual species difficult. Herbicide options are needed that effectively control slender iceplant but don't damage saltbush or bluebush. This trial aims to identify treatments that have potential to be registered for slender iceplant control where salt bush or bluebush are present.

METHOD

Two trials were conducted in 2008 at sites at Buntine and Morowa. Both trials assessed herbicide tolerance of the fodder shrubs small-leafed bluebush, river saltbush and old man saltbush. The trials were designed as strip plots with three replicates. Spray strips (20 m x 3 m) were applied on 11 and 12 August 2008 (60 L/ha water volume with 11002 air induction nozzles at 12 km/hr). The bluebush was a mature stand, but the river and old man saltbush were planted as tube stock in early winter 2008. Biomass reduction of the saltbush and bluebush were visually assessed on 3 November and expressed as a percentage reduction in biomass compared with the unsprayed control.

RESULTS

Table 1. **Percentage reduction in bluebush biomass based on a visual assessment at two locations rated 82 days after herbicide application.**

Herbicide treatment (rate/ha)	% Biomass reduction	
	Morowa	Buntine
25 g/ha Broadstrike® (flumetsulam 800 g/kg)	0	0
500 mL/ha Goal® (oxyflurofenen 240 g/L) (+0.1% BS-1000)	0	0
5 g/ha Ally® (metsulfuron-methyl 600 g/kg) (+0.1% BS-1000)	0	0
15 g/ha Glean® (chlorsulfuron 750 g/kg) (+0.1% BS-1000)	0	0
250 mL/ha Select® (clethodim 240 g/L) (+.05% Uptake)	3	0
7 g Eclipse® (metosulam 714 g/kg)	3	0
2 L/ha trifluralin (480g/L)	0	3
250 mL/ha diflufenican (500 g/L)	8	10
2 L/ha Stomp® (pendimethalin 330 g/L) (+0.1% BS-1000)	13	10
1 L/ha Spray.Seed® (paraquat 135 g/L + diquat 115 g/L)	19	20
1 L/ha diuron (500 g/L)	23	30
320 mL/ha dicamba (500 g/L)	30	50
800 mL/ha Gramoxone® (paraquat 250 g/L)	20	67
810 mL/ha Roundup PowerMAX® (glyphosate 540 g/L)	67	90
800 mL/ha 2,4-D amine (625 g/L)	77	97
1 L/ha atrazine (500 g/L)	99	80
Control (unsprayed)	0	0

Table 2. **Percentage reduction in the biomass of two saltbush species based on a visual assessment at two locations rated 82 days after herbicide application.**

Herbicide treatment (rate/ha)	River Saltbush		Old man Saltbush	
	Morowa	Buntine	Morowa	Buntine
25 g/ha Broadstrike® (flumetsulam 800 g/kg)	0	4	0	0
500 mL/ha Goal® (oxyflurofen 240 g/L)	4	4	8	0
5 g/ha Ally® (metsulfuron-methyl 600 g/kg)	29	4	33	4
15 g/ha Glean® (chlorsulfuron 750 g/kg)	63	42	88	79
250 mL/ha Select® (clethodim 240 g/L)	0	4	4	0
7 g/ha Eclipse® (metosulam 714 g/kg)	8	0	0	0
2 L/ha trifluralin (480 g/L)	0	8	0	0
250 mL/ha diflufenican (500 g/L)	0	4	0	0
2 L/ha Stomp® (pendimethalin 330 g/L)	21	4	13	0
1 L/ha Spray.Seed® (paraquat 135 g/L + diquat 115 g/L)	4	0	4	0
1 L/ha diuron (500 g/L)	8	0	0	0
320 mL/ha dicamba (500 g/L)	29	8	38	4
800 mL/ha Gramoxone ® (paraquat 250 g/L)	4	4	0	0
810 mL/ha Roundup PowerMAX® (glyphosate 540 g/L)	25	4	0	0
800 mL/ha 2,4-D amine (625 g/L)	25	17	25	0
1 L/ha atrazine (500 g/L)	4	13	0	0
Control (unsprayed)	0	0	0	0

Note: Adjuvants listed in Table 1 also applied with these treatments.

CONCLUSION

There were substantial differences in herbicide tolerance between the three plant species tested. There were also differences in tolerance between sites for the same treatments indicating how variable herbicide effect can be depending on factors including soil type, soil moisture and temperature.

All fodder shrub species showed good tolerance to Select®, Broadstrike®, trifluralin, Eclipse®, diflufenican and Goal®. Ally® and Glean® were well tolerated by bluebush, but damaging to both species of saltbush. Atrazine was very damaging to bluebush but tolerated by both species of saltbush. Gramoxone caused only minor damage except on bluebush at Buntine where it was very damaging. Both glyphosate and 2,4-D amine caused only minor to moderate damage to the saltbush, but were very damaging to bluebush. Dicamba was moderately damaging to all species at all sites. Diuron caused moderate damage on bluebush only. Spray.Seed® was well tolerated by saltbush and slightly damaging on bluebush.

The herbicides mentioned in this report are not registered for use in saltbush and bluebush pastures. Product selection will depend upon product labels, weeds spectrum and presence of desirable pasture species. Always consult product labels and seek professional advice, as these trials were intended as research only.

See ‘Herbicide control of slender iceplant’ by Hunt and Blake in Crop Updates 2010, Weeds Booklet.

KEY WORDS

river saltbush, old man saltbush, bluebush, herbicide tolerance

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Chemical control of windmill grass

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KEY MESSAGES

- Windmill grass growth in summer reduced yield of the following wheat crop by 26 per cent.
- Windmill grass, at all growth stages, can be controlled by Roundup Power Max® at 1 or 2 L/ha, Roundup Power Max® at 1 L/ha followed by Spray.Seed® at 1 L/ha or Verdict® at 400 mL/ha. Triflur Xcel® at 1 L/ha and Diuron® at 1.1 L/ha controlled windmill grass pre-seeding.
- These herbicides are not registered for control of windmill grass, but can legitimately be used to control other grass weeds, while also removing windmill grass.

AIMS

- To find out if the summer annual weed, windmill grass (*Chloris truncata* R.Br.), affects yield of the following wheat crop.
- To find chemical control options for windmill grass.

METHODS

Impact of windmill grass on wheat growth

A trial site was identified at Merredin, WA (616448 mE, 6515155 mN, Zone 50), on the Department of Agriculture and Food, Western Australia, Merredin Research Station. The trial design included four treatments: summer weed control or no summer weed control, followed by wheat sown at 18 or 36 cm row spacing (replicated four times, in a randomised block design). Two cohorts of windmill grass grew over the spring/summer of 2008/2009, in October 2008 and December 2008. In the weed control plots, both cohorts were killed directly after emergence with Roundup Power Max® at 2 L ha (a rate sufficient to kill all plants). In June 2009, Roundup Power Max® at 1.5 L/ha with Hammer® at 0.4 L/ha was sprayed over the whole trial site, to remove winter annual weeds before sowing. The crop was sown (at 18 or 36 cm row spacing) on 3 July 2009, using a 1.84 m wide plot seeder (plots were 4.5 m by 20 m, and each plot was sown twice). The crop was sown at 70 kg/ha, to a depth of 3 cm (115 kg/ha Agras fertiliser placed at 4 cm), using four inch wide bolt-on combine dart points cut down to 50 mm wide to penetrate the firm soil that had not been cropped for a number of years. No other in-crop herbicides were applied. The crop was harvested on 30 November 2009.

Prior to crop establishment, windmill grass density in one permanent quadrat (1 m^2) per plot was monitored from October 2008 (i.e. when windmill grass first emerged) to February 2009 (i.e. when all windmill grass in the no weed control plots had naturally senesced). Within the crop, four permanent quadrats per plot (of 0.25 m^2) were established to measure initial wheat density, wheat head number and biomass at the milk grain fill stage of the crop. Crop yield was assessed at harvest. ANOVA was used to assess the impact of the weed control and row spacing factors on the measured variables. Least significant differences were used to separate means (GENSTAT Version 12.1 2009).

Chemical control of windmill grass under glasshouse conditions

In October 2009, 99 pots (40 cm long by 16.5 cm wide by 14.5 cm tall) were filled with potting mix to within 2 cm of the top. Thirty windmill grass seeds per pot were planted by individually placing seeds on the surface of the potting mix. Pots were maintained in an open glasshouse (no temperature control) and exposed to a photosynthetically active radiation level of 550 $\mu Em^{-2} s^{-1}$. Water and fertiliser were applied as necessary to ensure healthy growth. Herbicide treatments (replicated three times, in a randomised block design) are shown in Table 2, and were applied with an overhead compressed air belt-driven glasshouse boom sprayer, calibrated to deliver 96 L/ha at 200 kPa. Treatments of Triflur Xcel®, Diuron® and Avadex Xtra® were applied directly to the soil surface two days after the seeds were planted (4 September 2009). The remaining 15 herbicide treatments were applied to a set of plants at the 2 to 4 leaf stage (13 October 2009) and to a second set of plants at maturity (i.e. producing seed heads) (1 December 2009). Plants were counted directly before and three weeks

after herbicide application. An ANOVA was used to assess survival (as a per cent of the control). Least significant differences were used to separate means (GENSTAT Version 12.1 2009).

Chemical control of windmill grass under field conditions

A trial was established directly to the east of the initial trial site described in 'Impact of windmill grass on wheat growth', in November 2009 (plots 2.5 m by 10 m). Windmill grass plants were evenly distributed within the site. Plants were at all development stages, but the bulk of the population was at seed head production. The ten herbicide treatments (replicated four times in a randomised block design) shown in Table 3 were sprayed using a spray boom mounted on a four wheel motorbike on 17 November 2009. The boom was approximately 40 cm above ground level. The bike was driven at 11 km/h, applying 80 L/ha of spray. Four Turbo Teejet nozzles (TT11002-VP yellow) were spaced 34 cm apart along the boom and each delivered 500 mL/min spray volume. Spray output and herbicide volume were calculated accordingly. Herbicides were sprayed following rainfall, so the plants at the site were actively growing. Number of surviving plants was assessed in five quadrats per plot (50 cm by 100 cm), on 15 December 2009. ANOVA was used to investigate plant survival (as a per cent of the control) and least significant differences were used to separate means (GENSTAT Version 12.1 2009).

RESULTS

Impact of windmill grass on wheat growth

Windmill grass grew from October 2008 to February 2009. The site contained other summer weeds (caltrop, spiny burrgrass, prickly saltwort) but density of other species was very low. In the summer weed control plots, average windmill grass density was 0 plants/m^2 and in the no summer weed control plots, average density was 11 plants/m^2 (from October 2008 to February 2009).

Initial wheat density was not affected by summer weed control, but was greater in the 18 cm row spacing treatments compared to 36 cm row spacing (Table 1). Wheat biomass and head number at the milk grain fill stage of crop development, and crop yield, were all significantly greater in the summer weed control plots, compared to the no weed control plots. Biomass, head number and yield were also greater under narrow row spacing. For all of these variables, the interaction between weed control and row spacing was not significant.

Table 1 **Initial wheat density following crop emergence, wheat biomass and wheat heads at the milk grain fill stage of crop development and wheat yield, averaged over the no summer weed control or summer weed control treatments, and the 18 cm or 36 cm row spacing treatments. The P and l.s.d. values indicate where means were significantly different.**

Measurement	Wheat density (/m^2)	Wheat biomass (g/m^2)	Wheat heads (/m^2)	Yield (t/ha)
No weed control	144	311	187	0.86
Weed control	143	370	210	1.16
l.s.d.	7.5	16.6	7.5	0.10
P	0.757	< 0.001	< 0.001	< 0.001
Row spacing: 18 cm	162	360	209	1.08
Row spacing: 36 cm	125	321	188	0.93
l.s.d.	7.5	16.6	7.5	0.10
P	< 0.001	< 0.001	< 0.001	0.007

Chemical control of windmill grass under glasshouse conditions

Roundup Power Max® or Spray.Seed® at 2 L/ha killed all windmill grass plants, as did Roundup Power Max® followed by Spray.Seed®. Roundup Power Max® or Spray.Seed® at 1 L/ha killed 90 and 89 per cent of plants. Verdict® was also effective (92 per cent control), as were Diuron® and Triflur Xcel® (100 per cent control, Table 2). When plants were sprayed at maturity, none of the herbicides were effective. Herbicide damage was clearly apparent, but plants recovered or re-sprouted, and produced new seed heads.

Table 2 **Average windmill grass survival (as a per cent of the untreated control), following application of herbicides pre-emergent (Triflur Xcel®, Diuron® and Avadex Xtra®), at the 2–4 leaf growth stage or at plant maturity (all other herbicides), in glasshouse conditions. Note: + indicates the second herbicide was applied one week after the first herbicide and – indicates that the herbicide was not sprayed.**

Herbicide	Survival of seedlings	Survival of mature plants at the seed production stage
Sprayed post emergent—at the 2–4 leaf stage or at plant maturity		
Roundup Power Max® 1 L/ha	10	97
Roundup Power Max® 2 L/ha	0	92
Spray.Seed® 1 L/ha	11	97
Spray.Seed® 2 L/ha	0	100
Roundup Power Max® 1 L/ha + Spray.Seed® 1 L/ha	0	96
Roundup Power Max® 2 L/ha + Spray.Seed® 2 L/ha	0	100
Verdict® 400 mL/ha	8	100
Decision® 1 L/ha	34	100
Lexone® 280 g/ha	34	97
Achieve® 430 g/ha	69	100
Axial® 250 mL/ha	95	98
Fusilade® 1.65 L/ha	41	95
Intervix® 750 mL/ha	100	94
Monza® 25 g/ha	91	90
Sprayed pre-emergent		
Triflur Xcel® 1 L/ha	0	–
Diuron® 1.1 kg/ha	0	–
Avadex Xtra® 1.6 L/ha	98	–
l.s.d. (P < 0.001)	23.0	Not significantly different

Chemical control of windmill grass under field conditions

All treatments with Roundup Power Max® were highly effective against windmill grass plants (86 to 95 per cent control). The surviving plants were very small and few had produced seed heads. Verdict® was also highly effective (71 per cent control). Decision®, Diuron® and Lexone® did not control plants, or result in any visual effect of herbicide damage. Spray.Seed® at 2 L/ha killed vegetative growth, but most plants re-sprouted and visual assessment indicated that seed head production was reduced but not prevented. Spray.Seed® at 1 L/ha had very little impact, again because plants successfully re-sprouted (Table 3).

Table 3. **Average windmill grass survival (as a per cent of the untreated control), following application of herbicides at all growth stages, in field conditions. Note: + indicates the second herbicide was applied one week after the first herbicide.**

Herbicide treatment	Survival
Roundup Power Max® 1 L/ha	14
Roundup Power Max® 2 L/ha	5
Spray.Seed® 1 L/ha	100
Spray.Seed® 2 L/ha	84
Roundup Power Max® 1 L/ha + Spray.Seed® 1 L/ha	7
Decision® 1 L/ha	97
Diuron® 500 g/ha	100
Lexone® 280 g/ha	100
Verdict® 400 mL/ha	29
l.s.d. (P < 0.001)	26.2

CONCLUSION

Growth of windmill grass over summer reduced crop biomass and head production, and reduced crop yield by 26 per cent. Therefore, control of this weed over summer (via herbicides or grazing) is beneficial to maximise crop yield (although not necessarily beneficial to maximise available stock feed over the summer/autumn feed gap). The impact of summer growing weeds on crop yield in 2009 may have been greater than would be apparent in other years because autumn of 2009 in Merredin was very dry and the season was short (Department of Agriculture and Food Western Australia 2009). The amount of winter rainfall will influence how much a crop relies on stored soil moisture from summer rainfall (Tennant 2000).

Crop growth (initial plant density, biomass, head production and yield) was greater under narrow rows, compared to wide rows. This has been found previously in wheat crops. Initial plant density is probably reduced in wide rows due to increased plant competition within the row, affecting subsequent crop yield (Amjad and Anderson 2006).

Windmill grass can be controlled with Roundup Power Max® at 1 to 2 L/ha, or Roundup Power Max® at 1 L/ha followed by Spray.Seed® at 1 L/ha, over the summer fallow. Diuron® or Triflur Xcel® (pre-seeding) successfully controlled this weed, but were only tested in glasshouse conditions. Verdict® killed plants in both glasshouse and field conditions and can be used to control this weed if it germinates within broadleaf crops. No herbicides were found that could be used to control windmill grass growing within cereal crops. None of these herbicides are registered to control windmill grass, but they can all be legitimately used for the control of other grass weeds, while coincidentally removing windmill grass.

Several herbicides were effective in the field, but did not kill a significant number of mature windmill grass plants in glasshouse conditions (Table 2 and 3). This indicates that windmill grass has an impressive ability to recover from herbicide damage in the presence of adequate water and fertiliser (such as are available to glasshouse plants). Therefore, when spraying mature plants in the field, it is important to ensure that rain will not follow the herbicide event to allow plants to recover and re-grow.

It should be noted that in this paper, specific herbicide products were referred to (rather than active ingredients). It has previously been found that windmill grass can have different reactions to different formulations of the same herbicide (Stewart 2002).

KEY WORDS

windmill grass, *Chloris truncata*, summer, weed, control, herbicide

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Use high water rates when applying pre-seeding herbicides to fields with high stubble density

Catherine Borger and **Abul Hashem**, Department of Agriculture and Food, Western Australia, Merredin and Northam

KEY MESSAGES

- High stubble biomass may reduce efficacy of pre-seeding grass selective herbicides.
- Where stubble biomass is high, increased water rates may improve herbicide performance.

AIMS

The minimum tillage system is causing increased reliance on pre-seeding herbicides like trifluralin for initial weed control. Further, the increased stubble density in a minimum tillage system reduces the efficacy of pre-seeding herbicides. A proportion of the herbicide binds to the stubble, rather than reaching the soil surface where it can successfully kill emerging weeds. However, this problem can be partially alleviated by increasing water rates. If pre-seeding herbicides are sprayed with course droplets, at high water rates, then more of the herbicide can leach through the stubble to reach the soil surface.

This research aimed to assess the impact of different stubble systems and water rates on pre-seeding herbicides.

METHODS

The trial

Two trials were conducted at the Wongan Hills and Merredin Department of Agriculture and Food Research Stations (soil at both sites was a light brown sandy loam with 5–10 per cent gravel). A split plot design was used, with stubble type as the main plot factor (four replications). Stubble treatments were established by harvesting the 2008 wheat crop to leave tall stubble (35 cm high) with chaff/straw removed into windrows (tall stubble-no chaff), short stubble (15 cm high) with chaff/straw removed into windrows (short stubble-no chaff) and short stubble (15 cm high) with chaff/straw spread (short stubble-chaff). Spreaders were sufficient to evenly spread chaff over the treatment plots. At the edge of the stubble plot, chaff from the spreaders was less dense than in the centre, but these areas of less dense chaff were designated as buffers (i.e. a buffer plot was placed to either side of every main plot). Harvest occurred on 28 November 2008 at Wongan Hills and 5 December 2008 at Merredin. Weed growth was controlled over the following summer/autumn, and Roundup Power Max® 1.5 L/ha was applied to both sites as a knockdown, prior to crop sowing in 2009.

The sub-plot factors were pre-seeding herbicides (Triflur Xcel® 1.5 L/ha, Sakura® 850 WG 118 g/ha, Boxer Gold® 2.5 L/ha, Stomp® 330 1.2 L/ha and an untreated control) sprayed with 50 or 100 L/ha of water. Herbicides were sprayed with Turbo TeeJets TT11002, at 2 bar pressure, to ensure coarse droplet size (plot size of 2 m by 20 m). Speed of spraying (11.5 and 5.8 km/h) was adjusted to deliver the two different water rates (nozzle type and pressure were kept uniform) to ensure that droplet size was similar between the treatments.

Herbicides were sprayed on 22 June 2009 at Wongan Hills and 2 July 2009 at Merredin. At Wongan Hills, initial annual ryegrass density was high enough that there was no significant difference between weed densities in the different stubble treatments. At Merredin, initial annual ryegrass density was very low across the site, and so annual ryegrass (cv Safeguard) was evenly spread using a Fertiliser Hand Spreader at 10 kg/ha. This likewise ensured that weed density was uniform between the stubble treatments. At each site, Wyalkatchem wheat 70 kg/ha (Macropro Plus fertiliser 80 kg/ha at Wongan Hills, Agras fertiliser 100 kg/ha at Merredin) was sown directly after herbicide application, to a depth of 3–4 cm. The crop was sown at 5 km/h, with 22 cm row spacing (using knife points and press wheels).

Measurements at each site included stubble biomass and soil moisture (to 10 cm) prior to sowing, density of wheat and annual ryegrass 2–3 weeks after crop emergence and crop yield. Wheat and annual ryegrass data were analysed using ANOVAs and means were separated using l.s.d. (GENSTAT Version 11.1 2008).

RESULTS

Pre-seeding conditions

Stubble biomass was lower in the short stubble-no chaff treatments (Table 1). However, at both sites, stubble biomass did not affect surface soil moisture directly prior to sowing.

Table 1 **Stubble biomass at Wongan Hills and Merredin, in the tall stubble-no chaff, short stubble-no chaff and short stubble-chaff treatments, (P and l.s.d. values indicate significant differences between stubble biomass at each site), and volumetric soil moisture (mm) in the top 10 cm of soil (averaged across stubble treatments).**

Location	Stubble biomass (kg/ha)					Soil moisture (mm)
	Tall-no chaff	Short-no chaff	Short-chaff	P	l.s.d.	
Wongan Hills	5350	3800	4720	0.026	1080	5.8
Merredin	1480	860	1490	< 0.001	260	9.7

Initial wheat emergence

At both locations, wheat emergence was not significantly affected by any of the treatments, and averaged 104 plants/m^2 at Wongan Hills and 102 plants/m^2 at Merredin.

Initial annual ryegrass emergence – Wongan Hills

At Wongan Hills, annual ryegrass density was high, with an average of 222 plants/m^2 in the control plots. Annual ryegrass density was high enough over the entire trial area that the stubble treatments had no impact on weed density. Annual ryegrass control (as a per cent of the annual ryegrass in the herbicide free plots), was greater in the short stubble-no chaff plots (76 per cent), compared to the short stubble-chaff plots (64 per cent) and the tall stubble-no chaff plots (70 per cent, P: 0.035, l.s.d.: 8.06). Annual ryegrass control was also generally higher when high water rates were used, with an average of 64 per cent of annual ryegrass killed by herbicides applied with 50 L/ha of water and 75 per cent killed with 100 L/ha of water (P: 0.004, l.s.d.: 5.3).

The interaction between herbicide, stubble treatment and water rate was also significant (Table 2, P < 0.001, l.s.d.: 9.7). Overall, Sakura® and Boxer Gold® gave better annual ryegrass control than Triflur Xcel®, and poorest control was provided by Stomp®. In the short stubble-no chaff plots (where stubble biomass was lowest), water rate did not have a large impact on annual ryegrass control, although Sakura® was more effective at the high water rate. In the short stubble-chaff plots, all herbicides were more effective at the high water rate. In the tall stubble plots, Sakura® and Stomp® were more effective at higher water rates than at low water rates.

Table 2 **The per cent of annual ryegrass controlled by pre-seeding applications of Triflur Xcel®, Sakura® 850WG, Boxer Gold® or Stomp® sprayed with varying water rates, onto different stubble treatments at Wongan Hills, and annual ryegrass control averaged over stubble treatment and water rate.**

Stubble treatment	Water rate (L/ha)	Triflur Xcel® 1.5 L/ha	Sakura® 118 g/ha	Boxer Gold® 2.5 L/ha	Stomp® 1.2 L/ha
Short stubble-no chaff	50	68	79	86	59
	100	72	96	82	62
Short stubble-chaff	50	49	74	70	3
	100	65	96	90	63
Tall stubble-no chaff	50	62	78	87	38
	100	63	92	88	53
Average		63	86	84	46

Initial annual ryegrass emergence – Merredin

At Merredin, annual ryegrass density (25 plants/m^2 in the control plots) was much lower than at Wongan Hills. Again there was no effect of stubble treatment on initial weed density, because annual ryegrass seed was spread prior to crop sowing to ensure even weed distribution. Water rate had no significant effect on annual ryegrass control. Likewise, herbicides were all equally effective. This was probably because stubble density and annual ryegrass density at Merredin was much lower than at Wongan Hills (Table 1). However, there was a slight effect of stubble biomass, with Stomp® and Boxer Gold® providing less effective control in the tall stubble, compared with the short stubble (P: 0.019, l.s.d.: 16.3, Table 3).

Table 3 **The per cent of annual ryegrass controlled by pre-seeding applications of Triflur Xcel®, Sakura® 850WG, Boxer Gold® or Stomp® 330, sprayed onto different stubble treatments (averaged over water rates of 50 or 100 L/ha) at Merredin, and annual ryegrass control averaged over stubble treatment.**

Stubble treatment	Triflur Xcel® 1.5 L/ha	Sakura® 118 g/ha	Boxer Gold® 2.5 L/ha	Stomp® 1.2 L/ha
Short stubble-no chaff	83	85	91	89
Short stubble-chaff	75	87	84	78
Tall stubble-no chaff	80	76	66	46
Average	79	83	80	71

Crop yield

At both Wongan Hills and Merredin, crop yield was significantly greater in the short stubble-no chaff treatments, probably due to the improved weed control in this stubble treatment (Table 4).

Table 4 **Yield of wheat at Wongan Hills and Merredin for each stubble treatment (averaged across water rate and herbicides). P and l.s.d. values indicate significant differences between wheat yields at each site.**

Location	Wheat yield (t/ha)				
	Tall-no chaff	Short-no chaff	Short-chaff	P	l.s.d.
Wongan Hills	1.85	2.03	1.97	< 0.001	0.087
Merredin	0.92	1.02	1.01	< 0.001	0.026

At Wongan Hills, crop yield was significantly greater following Sakura® (2.09 t/ha at 50 L/ha and 2.12 t/ha at 100 L/ha water) or Boxer Gold® (2.11 t/ha at 50 L/ha and 2.27 t/ha at 100 L/ha water), compared to Triflur Xcel® (1.91 t/ha at 50 L/ha and 1.96 t/ha at 100 L/ha water) or Stomp® (1.78 t/ha at 50 L/ha and 1.79 t/ha at 100 L/ha water) (P < 0.001, l.s.d.: 0.015). At Merredin, crop yield was not affected by herbicide or water rate treatment. As initial annual ryegrass density was low, the herbicide applications all provided reasonable control, and the remaining weed density was probably too low to have an impact on crop yield.

CONCLUSION

At Wongan Hills, Sakura® and Boxer Gold® provided more effective weed control than Triflur Xcel®. Stomp® was the least effective herbicide. There was less difference between herbicides at Merredin, because annual ryegrass density was low; allowing all herbicides to provide effective control.

For both trials, reduced stubble biomass resulted in improved weed control and greater yield due to reduced weed numbers, except for the short stubble-chaff treatment at Merredin (where yield was high in spite of higher biomass). Stubble did not influence soil moisture directly prior to seeding.

At Wongan Hills, increased water rate improved herbicide performance where stubble biomass was high, particularly in the short stubble-chaff treatment where a proportion of the stubble was lying flat on the ground, as compared to the tall stubble-no chaff treatment where all the stubble was standing upright. Where stubble biomass was low and stubble was standing upright (short stubble-no chaff), water rate did not have much impact on herbicide performance. At Merredin where stubble biomass and annual ryegrass density was low, water rate had no impact on herbicide performance.

Obviously stubble retention is important, particularly for erosion control (D'Emden et al. 2008). However, high stubble biomass (and chaff lying on the soil surface) can reduce the efficiency of pre-seeding herbicides, particularly where annual ryegrass density is high. Therefore, it may be worth assessing how much stubble will be left after harvest. If there is more stubble than is required to avoid erosion, then windrowing and burning the stubble will not only help control weed seeds at harvest (Walsh and Newman 2007) but will increase the efficacy of pre-seeding grass selective herbicides.

KEY WORDS

pre-seeding, herbicide, stubble, water rate, annual ryegrass

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Herbicide tolerance of lupins – influence of soil type and rainfall

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[1]Northam and [2]Geraldton

KEY MESSAGES

- Jenabillup showed poor tolerance to metribuzin compared to Mandelup.
- Frequent heavy rainfall during early crop growth stages could lead to crop damage due to concentration of soil active and residual herbicides like simazine in the furrow.
- High uptake of simazine following good soil moisture (due to heavy frequent rainfalls) could predispose the crop to damage by normally safe rates of post-emergent broadleaf herbicides.

AIM

To evaluate the herbicide tolerance of potential and recently released lupin varieties.

METHOD

Location and year	Eradu, 2008				Wongan Hills, 2008			
Soil Type, pH ($CaCl_2$) & OC (%)	Sandplain (Non wetting), 5.9 & 0.9.				Loamy sand, 4.6 & 0.9.			
Trial design	Criss-cross, every 7th plot was untreated control.							
Varieties	Jenabillup, Mandelup, WALAN2274 & WALAN2275							
Plot size (Net) and Replications	10 m x 1.8 m and 3				9.7 m X 1.8 m and 3			
Sowing date and seeding rate	30 May and 100 kg/ha				11 June and 100 kg/ha			
Seeding machinery and Seeding depth	Knife points and press wheels Combine, 3–4 cm seed depth				Knife points and press wheels DBS Seeder*, 3–4 cm, up to 10 cm seed depth			
Fertilizer	Super 1 100 kg/ha				Big Phos 80 kg/ha			
Soil moisture (%) at seeding 0–10 cm	3.0				Good			
(Gravimetric method) 10–20 cm	3.5				Good			
Rainfall (mm) with two weeks of seeding	13.8				7.8			
Herbicides application date: Before seeding, 2, 4, 6 and 8 leaves	30 May, 23 June, 26 June, 3 July and 6 July, respectively.				11 June, 17 July, 25 July, 12 August and 28 August, respectively.			
Visual Observation dates	26/6, 15/7, 27/7, 6/8/08				5/08, 9/10/08			
Plant Counts	5/11/08 (Data not shown)				5/08/08 (Data not shown)			
GreenSeeker® observations (NDVI)	20/8/2008 (Data not shown)				5/08/08 (Data not shown)			
Harvesting date	12 November				6 December			
Rainfall (mm) : May–November	May	June	July	Aug.	Sept.	Oct.	Nov.	**Total**
Eradu	8.6	63.2	124.2	10.2	43	22.4	9.8	**281.4**
Wongan Hills	12	33.4	121.4	19	48.4	28.2	3.8	**266.2**

* DBS= Deep Blade System Air Seeder, 250 mm spacing, 9.7 m wide. NDVI = normalized difference vegetative index. Crop emergence At Wongan Hills was poor and uneven due to deep seeding that resulted from complications with the combine.

RESULTS

Simazine at both 2.0 L/ha and the above label rate, and 2 L/ha Simazine + 1 L/ha Atrazine caused slight to moderate necrosis on leaves (10 per cent) within 4 weeks of seeding at Eradu. Simazine at above label rate caused 10–15 per cent biomass reduction (visible up to flowering stage) and had 20 per cent less flowers compared to untreated control and resulted in a significant yield reduction across all the varieties compared to both the control and the 2 L/ha Simazine treatment (Table 1).

None of pre-emergent treatments at Wongan Hills caused visual symptoms, biomass reduction or significant grain yield loss in any of the varieties tested at Wongan Hills (Table 2).

At Eradu, most of the post-emergent treatments caused 10–50 per cent biomass reduction (visible up to flowering stage) across all the varieties (Table 1). Brodal® + Lexone®, Brodal® + Lexone® + Simazine reduced plant density of WALAN2275 and Lexone® at higher than the label rate reduced plant population of Jenabillup, significantly (data not shown). These negative effect of post-emergent treatments resulted in significantly less grain yield across all the varieties.

At Wongan Hills, Brodal® + Eclipse® caused yellowing and 15 per cent biomass reduction during early growth stages across all the varieties. Brodal® + Lexone® and Lexone at higher rate resulted in leaf burning and significant biomass reduction in Jenabillup (NDVI data, data not shown). Brodal® + Lexone® + Simazine also caused 10 per cent biomass reduction in all the varieties. However, Brodal® + Eclipse® and Lexone at higher rate were the only treatments which resulted in significant yield loss in WALAN2274 and Jenabillup, respectively.

Jenabillup treated with Lexone® at above label rate caused a significant yield loss compared to the label rate of Lexone (150 g/ha) at both Eradu and Wongan Hills. All the other varieties had statistically similar grain yields at both the rates.

The differential response of varieties to herbicides (especially post-emergent) at Eradu and Wongan Hills could be attributed to difference in soil type, frequency and amount of rainfall around application timing. The soil was lighter (sand) and non-wetting at Eradu as compared to Wongan Hills (loamy sand). Within one month of crop seeding at Eradu 63.2 mm rain fall with 11 rainy days and one event of 21.8 mm. These rainfall events are likely to have filled the seeding furrows and increased the pre-emergent herbicide concentration in the seeding slots resulting in significant yield loss.

All the post-emergent treatments followed a basal 2 L/ha Simazine. Within one to two weeks of 2–4 and 6–8 leaf treatment application, around 38 mm rain fell at Eradu. It is likely that the wet conditions at the time of post-emergent herbicide treatment application, along with simazine phytotoxicity from the basal treatment resulted in significant yield reductions across all the varieties at Eradu. In contrast only 35 mm rain fell within one month of crop seeding at Wongan Hills. Two and 4 leaf treatments were applied shortly after 27.2 and 14.6 mm rainfall events, respectively, in July and no heavy rainfall events (> 10 mm) occurred for a month after application. In the previous trials, Mandelup has tolerated most of the herbicide treatments.

CONCLUSIONS

Interaction of soil active and residual herbicides and frequent heavy rainfall during early crop growth stages seems to be the main cause of severe crop damage from herbicides at Eradu on a lighter soil type. If necrosis is present from pre-seeding simazine, expect necrosis, biomass reduction and yield loss from post-emergent herbicides.

Jenabillup showed lower crop safety margins for metribuzin (Lexone®) as compared to other lupin varieties tested at both the trial sites.

Table 1 **Effect of herbicides on crop biomass (6 August – 9 WAS) and grain yield of lupin varieties at Eradu.**

No.	Herbicides/ha	Timing	Biomass reduction (%)				Grain yield (% of control)			
			Jenabillup	Mandelup	WALAN 2274	WALAN 2275	Jenabillup	Mandelup	WALAN 2274	WALAN 2275
0	Untreated control		0	0	0	0	100	100	100	100
	Grain yield (kg/ha)						2028	2119	1879	2104
1	Simazine 2.0 L (*)	Before	0	0	0	0	96	96	100	100
2	Simazine (above label rate)	seeding	20	15	15	10	**88**	**82**	**85**	**84**
3	Diuron 2.0 L	"	0	0	0	0	101	99	97	102
4	Simazine 2.0 L+ Atrazine 1.0 L	"	0	0	0	0	96	90	93	**93**
5	(*) Brodal® 200 mL	2 leaves	10	0	0	0	**86**	**88**	**90**	**88**
6	(*) Lexone® 150 g	"	30	20	20	20	**70**	**83**	**82**	**90**
7	(*) Lexone® (above label rate)	"	50	20	20	20	**52**	**74**	**87**	**86**
8	(*) Brodal® 100 mL+ Lexone® 150 g	4 leaves	10	10	10	10	**77**	**87**	**89**	**92**
9	(*) Brodal® 100 mL+ Eclipse® 6 g	"	0	0	0	0	**83**	**70**	**86**	**83**
10	(*) Brodal® 100 mL+ Simazine 0.5 L	"	10	10	10	10	**80**	**72**	**87**	**82**
11	(*) Brodal® 100 mL+Lexone® 100 g + Simazine 500 mL	6 leaves	15	15	15	15	**61**	**74**	**84**	**83**
12	(*) Eclipse® 10 g	8 leaves	0	0	0	0	**83**	**81**	**82**	**86**
l.s.d. (0.05) Control vs Herbicides (1-tail)							8	7	8	7
l.s.d. (0.05) Herbicides vs Herbicides (1-tail)							10	9	10	9

(*) indicates simazine 2.0 L/ha as a basal treatment. WAS = Weeks after seeding. • At 2 leaf treatments application time, 10, 60 and 20% of plants across all the varieties were at early 2, 2–4 and 4–6 leaf stage, respectively. At 4 leaf treatments application time, 30, 60 and 10% of plants across all the varieties were at 6, 4 and 2 leaf stage, respectively. At 6 leaf treatment application time, 30, 60 and 10% of plants across all the varieties were at 8, 6–8 and 6 leaf stage, respectively.At 8 leaf treatment application time, 30, 60 and 20% of plants across all the varieties were at 8–10, 8 and 6–8 leaf stage, respectively.

Biomass reduction was observed visually. Figures in **BOLD** are significantly lower yielding than the untreated control.

Table 2 **Effect of herbicides on grain yield (% of control) of lupin varieties at Wongan Hills.**

No.	Herbicides/ha	Timing	Jenabillup	Mandelup	WALAN 2274	WALAN 2275
0	Untreated control Grain yield (kg/ha)		100 1437	100 1479	100 1654	100 1508
1	Simazine 2.0 L (*)	Before	117	123	113	122
2	Simazine (above label rate)	Seeding	127	109	113	123
3	Diuron 2.0 L	"	104	110	96	118
4	Simazine 2.0 L +Atrazine 1.0 L	"	113	116	116	119
5	(*) Brodal® 200 mL	2 leaves	116	107	100	113
6	(*) Lexone® 150 g	"	93	108	106	114
7	(*) Lexone® (above label rate)	"	**62**	113	105	133
8	(*) Brodal® 100 mL + Lexone® 150 g	4 leaves	97	119	104	136
9	(*) Brodal® 100 mL + Eclipse® 6 g	"	95	110	**85**	116
10	(*) Brodal® 100 mL + Simazine 0.5 L	"	100	115	90	122
11	(*) Brodal® 100 mL + Lexone® 100 g + Simazine 500 mL	6 leaves	96	105	91	110
12	(*) Eclipse® 10 g	8 leaves	118	113	108	125
l.s.d. (0.05) Control vs Herbicides (1–tail)			15	14	13	14
l.s.d. (0.05) Herbicides vs Herbicides (1–tail)			18	18	16	18

(*) indicates simazine 2.0L/ha as a basal treatment. Figures in **BOLD** are significantly lower yielding than the untreated control.

Note: The results on potential new varieties WALAN2274 and WALAN2275 are published with permission from lupin breeder, Dr Bevin Buirchell, Department of Agriculture and Food, Western Australia.

KEY WORDS

lupins, varieties, herbicide, tolerance

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Response of new barley varieties to herbicides

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KEY MESSAGES

- The new barley varieties Commander and Oxford were tested for the first time in WA, in a herbicide tolerance trial at Katanning.
- The new barley varieties showed good tolerance to all the herbicides at maximum label rates.
- Both Baudin and Buloke seem to have low crop safety margins for Boxer® Gold and Buloke alone for Diuron + MCPA.

AIM

To evaluate the herbicide tolerance of recently released barley varieties.

METHOD

A field trial was laid out in a criss-cross design under weed free conditions at Katanning in 2009. Five barley varieties Baudin, Buloke, Commander, Hindmarsh and Oxford were sown on 18 June on a loamy sand soil ($CaCl_2$ measured pH 5.3 and OC 2.06 per cent) with three replications. The varieties were sown 2–3 cm deep in 12.13 m long by 0.96 m wide (4 rows at 24 cm row spacing) plots at a sowing rate of 75 kg/ha using coneseeder with knife points and press wheels. The varieties were randomised in each replication and 79 cm buffers were left between plots to allow herbicide applications without damaging the plots. Agstar Extra Plus was applied with the seed at 100 kg/ha.

The herbicides tested were those which had been found to reduce barley grain yield consistently across varieties in previous trials. The herbicides were applied at maximum label and higher rates, but only results of maximum label rates are presented here. The herbicide treatments (Table 3) were applied randomly in 1.5 metre wide strips using a spray shield on boom (air induction nozzles and 50L/ha water volume) across all the variety strips before seeding (16 June), at 4–5 leaf stage (3, 4 and 6 August) and 5–6 leaf stage (8 September). Trifluralin was incorporated on the same day of application using coneseeder. Every 5th plot was kept as an untreated control to assess the spatial variability. At the time of pre-emergent herbicide treatment application (16 June), gravimetric soil moisture content at 0–10 depth was 8.5 per cent and within 2 weeks of these treatments being applied, 103 mm more rain fell. The barley varieties were visually assessed for leaf spotting, yellowing, height and biomass reduction at 2–4 weeks after each treatment application and again at the heading stage using a 0 to 100 per cent scale, where 0 = no visible injury and 100 = complete plant death (3 September and 11 November). A hand held GreenSeeker® unit was used to record the effect of herbicide treatments on crop biomass, 3–4 weeks after each treatment application. GreenSeeker® is an integrated optical sensing system that measures crop health and vigour in terms of normalized difference vegetative index (NDVI). Due to large variation in the NDVI data taken on 30 October 2009, it was subjected to log Y*100 transformation. The trial was harvested on 6 December 2009 and net plot size was 10 m X 0.96 m. The grain yield data was subjected to Reml analysis (spatial) using Genstat.

Total rainfall from June to November was 348.2 mm. June was the wettest (36 per cent of total rainfall), July, August and September received 16–19 per cent of the total rainfall , October was dry, and again November received some rain (10 per cent) to give a soft/wet finish to the season. No frost effects were observed.

Note: Affinity® is also available in the liquid formulation as Affinity® Force (50 g of Affinity® is equivalent to 85 mL of Affinity® Force).

RESULTS

The effect of herbicides on barley varieties' NDVI/biomass (Table 1 & 2), and grain yield (Table 3) was as follows:

- 2.5 L Boxer® Gold, 670 mL Velocity® and 7g/ha Ally® had significantly lower NDVI values (reduced biomass) for Hindmarsh, 3 L/ha Triflur® X for Buloke and Hindmarsh, 50 g Affinity® + 0.5L/ha MCPA (Amine) for Oxford and 3 L/ha Hoegrass® for Baudin and Commander. However, these negative effects were not translated into significant yield loss in any of the varieties.
- 1.3 L/ha 2,4-D Amine reduced biomass of Baudin and Commander by 10 per cent (visually) which was noticeable up to crop maturity, but again this did not result into significant yield loss in any of the varieties.
- Boxer® Gold, and Diuron + MXPA (Amine) at the maximum label rates were safe on all the varieties tested. However, Boxer® Gold at higher than the label rate caused significant yield loss in Baudin and Buloke. Diuron + MCAP (Amine) at higher than label rate also caused yield loss in Buloke.
- Results for Commander and Oxford require confirmation in subsequent herbicide tolerance testing.

CONCLUSION

- All the varieties tolerated the herbicides at maximum label rates.
- Baudin and Buloke appeared to have low crop safety margins for Boxer® Gold and Buloke for Diuron + MCPA.

KEY WORDS

barley, herbicide, tolerance, grain yield

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Table 1 **Effect of herbicides on net NDVI (% of control) of barley varieties 10 WAS (3-09-09).**

No.	Herbicides/ha	Timing	Baudin	Buloke	Commander	Hindmarsh	Oxford
0	Untreated Control NDVI Readings		100 0.490	100 0.473	100 0.484	100 0.390	100 0.522
1	Triflur® X 3.0 L	Before	96	**88**	99	**86**	96
2	Boxer® Gold 2.5 L	seeding	102	96	100	**89**	97
3	Velocity® 670 mL	Z14-Z15	101	95	95	**77**	94
4	Ally® 7 g	"	94	92	95	**86**	92
5	Achieve® 380 g	"	97	94	95	92	95
6	Tigrex® 1.0 L	"	96	92	96	90	97
7	Affinity® 50 g + MCPA (Amine) 0.5 L	"	103	96	96	106	**90**
8	Hoegrass® 375 3.0 L	"	**91**	93	**91**	97	94
9	Diuron 0.4 L + MCPA (Amine) 0.5 L	"	104	101	105	97	101
l.s.d. (0.05) Control vs Herbicides (1-tail)			8	8	8	10	8
l.s.d. (0.05) Herbicides vs Herbicides (1-tail)			11	11	11	13	10
CV (%)			8	8	8	10	7

NDVI = normalized difference vegetative index measured by hand held GreenSeeker®. WAS = Weeks after seeding. Figures in **BOLD** are significantly lower than the Untreated Control.

Table 2 **Effect of herbicides on net NDVI (% of control) of barley varieties 17 WAS (30-10-09).**

No.	Herbicides/ha	Timing	Baudin	Buloke	Commander	Hindmarsh	Oxford
0	Untreated Control NDVI Readings (antilog)		100 0.163	100 0.195	100 0.212	100 0.149	100 0.153
10	2,4-D amine 625 1.3 L	Z15-Z16	94	108	97	92	91
l.s.d. (0.05) Control vs Herbicides (1-tail)			13	12	12	13	13
CV (%)			8	8	8	10	7

Table 3 **Effect of herbicides on grain yield (% of control) of barley varieties at Katanning (09GS29).**

No.	Herbicides/ha	Timing	Baudin	Buloke	Commander	Hindmarsh	Oxford
0	Untreated control Yield (kg/ha)		100 2198	100 2901	100 2540	100 3442	100 2341
1	Triflur® X 3.0 L	Before	94	88	87	90	92
2	Boxer® Gold 2.5 L	seeding	100	93	90	104	98
3	Velocity® 670 mL	Z14-Z15	118	120	123	114	126
4	Ally® 7 g X1	"	124	126	116	113	107
5	Achieve® 380 g	"	107	113	104	108	102
6	Tigrex® 1.0 L	"	101	99	114	101	102
7	Affinity® 50 g + MCPA (Amine) 0.5 L	"	120	104	108	111	119
8	Hoegrass® 375 1.5 L	"	99	92	93	93	86
9	Diuron 0.4 L + MCPA (Amine) 0.5 L	"	98	103	95	107	110
10	2,4-D amine 625 1.3 L	Z15-Z16	105	118	119	107	104
l.s.d. (0.05) Control vs Herbicides (1-tail)			17	12	15	11	16
l.s.d. (0.05) Herbicides vs Herbicides (1-tail)			22	16	21	15	21
CV (%)			16	12	15	11	15

Treatments 3+ Hasten® 1.0% v/v, 5 +Supercharge® 0.75% and 4 & 8+BS1000 0.25%. Treatment 3 was nominated to apply at Z12-Z13 and 4-9 at Z13-Z14. Due to frequent rains in July and late August, the trial site was almost waterlogged. The treatments were applied in August and September when the site became accessible.

Herbicide tolerance of new wheat varieties

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KEY MESSAGES

- The research results presented allow growers and agronomists to select safer herbicides for specific new wheat varieties, or select the more tolerant variety for their preferred herbicides/mixtures for specific weed control situations.
- Bumper seems sensitive to 200g/ha Hussar®, and Zippy to 3 L Triflur® X and 7 g/ha Ally®.

AIMS

To evaluate the herbicide tolerance of recently released wheat varieties.

METHOD

Location and year	Mullewa, 2008	Mullewa, 2009	Katanning, 2009
Soil type & pH (Cacl$_2$)	Red loam & 6.2	Red loam & 6.4	Loamy sand & 5.1
Trial design	Criss-cross with systematic untreated control plots.		
Plot size (Net) and Reps	10 m x 1.8 m and 3	10 m x 1.1 m and 3	10.1 m x 0.96 m and 3
Sowing date and rate	11 June, 75 kg/ha	3 June, 75 kg/ha	17 June, 75 kg/ha
Seeding machinery and Sowing depth (cm)	Combine (2008) and ConeSeeder (2009) fitted with knife points and press wheels and 3–4 cm deep.		
Fertilizer kg/ha (at sowing)	Agstar Extra, 70	Agstar Extra, 90	Agstar Extra Plus, 100
Soil moisture (%) 0–10 cm	6.4	5.5	5.6
at sowing 10–20 cm	7.4	7.8	3.9
Rainfall (mm) within two weeks of seeding	5.8	13.2	103
Harvesting date	12 November	12 November	2 December
Rainfall (mm): June– November	129.6	164.6	348.2

The herbicide tolerance of eight recently released wheat varieties along with Wyalkatchem is summarised in the table on the next pages using the following symbols. The herbicide and variety interactions are based on the yield response across herbicide crop tolerance trials detailed above.

– not tested or insufficient data.
√ **(Z)** no significant yield reductions at the label recommended rates in (Z) trials.
x% (w/z) yield reduction (warning), significant yield reduction at the label recommended rate in 1 trial only out of Z number of trials conducted.
x-y% (w/z) yield reduction (warning), significant yield reduction at the label recommended rate in w trials out of z trials conducted. Significant event occurring in w trials out of Z trials conducted. Eg (2/5) = tested in 5 trials, 2 trials returning a significant yield loss.

RESULTS AND CONCLUSIONS

Table 1 **Summary of wheat herbicide tolerance trials conducted at Mullewa and Katanning during 2008 to 2009.**

No.	Herbicides (Rate/ha)	Timing	Axe	Bumper	Espada	Fortune	Gladius	Mace	Magenta	Wyalkat	Zippy
1	Logran B Power® 50 g	Before	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	√ (3)
2	Stomp® 330 1.8 L	Seeding	6 (1/1)	√ (1)	√ (1)	√ (1)	√ (1)	–	√ (1)	√ (1)	√ (1)
3	Triflur® X 3 L	"	√ (3)	9 (1/3)	√ (3)	√ (3)	√ (3)	12 (1/2)	√ (3)	√ (3)	9 – 11 (2/3)
4	Dual® Gold 0.25 L	"	√ (3)	√ (3)	√ (3)	11 (1/3)	6 (1/3)	√ (2)	√ (3)	√ (3)	7 (1/3)
5	Diuron 1 L + Dual® Gold 0.25 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	7 (1/3)
6	Boxer® Gold 2.5 L	"	√ (3)	14 (1/3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	√ (3)
7	Glean® 20 g	Z12-Z15	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	6 (1/3)	6 (1/3)
8	Axial® 0.3 L	"	√ (1)	√ (1)	√ (1)	√ (1)	√ (1)	–	√ (1)	√ (1)	√ (1)
9	Jaguar® 1 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	√ (3)
10	Monza® 25 g	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	6 (1/3)	√ (3)
11	Velocity® 670 mL	"	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)
12	Hoegrass® 375 2 L	"	√ (1)	√ (1)	√ (1)	√ (1)	√ (1)		√ (1)	√ (1)	√ (1)
13	Cheetah® Gold 1 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	7 (1/3)	√ (3)	9 (1/3)
14	Hoegrass® (375) 200 mL + Achieve® 200g	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	7 (1/3)
15	Achieve® WG 380 g	Z13-Z15	√ (3)	17 (1/3)	√ (3)	√ (3)	√ (3)	13 (1/2)	√ (3)	√ (3)	5 (1/3)
16	Ally® 7 g	"	14 (1/3)	√ (3)	7 (1/3)	11 (1/3)	6 (1/3)	11 (1/2)	√ (3)	8 (1/3)	8 – 13 (2/3)
17	Atlantis® OD 0.33 L	"	5 (1/3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	10 (1/3)
18	Broadside® 1 L	"	√ (1)	√ (1)	√ (1)	√ (1)	√ (1)	–	√ (1)	√ (1)	6 (1/1)
19	Hussar® 200 g	"	12 (1/3)	9 – 13 (2/3)	√ (3)	7 (1/3)	10 (1/3)	√ (2)	√ (3)	√ (3)	8 (1/3)
20	Tigrex® 1 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	7 (1/3)
21	Buctril® MA 1.4 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	6 (1/3)	√ (3)
22	Affinity® 50 g + MCPA 0.5 L	"	14 (1/3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	√ (3)
23	Precept® 300 1 L	"	√ (1)	√ (1)	√ (1)	√ (1)	√ (1)	–	√ (1)	√ (1)	√ (1)
24	Eclipse® 5 g + MCPA LVE 0.5 L	"	√ (3)	√ (3)	7 (1/3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	5 (1/3)
25	Diuron 0.35 L + MCPA 0.4 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	7 (1/3)

Table 1 **Continued …**

No.	Herbicides (Rate/ha)	Timing	Axe	Bumper	Espada	Fortune	Gladius	Mace	Magenta	Wyalkat	Zippy
26	Paragon® 0.5 L	Z15-Z17	14 (1/3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	8 (1/3)
27	MCPA amine 50% 2 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	11 (1/3)
28	2,4-D amine 625 1.3 L	"	11 (1/3)	14 (1/3)	15 (1/3)	10 (1/3)	√ (3)	√ (2)	√ (3)	√ (3)	8 (1/3)
29	2,4-D LV ester 680 0.8 L	"	√ (3)	√ (3)	√ (3)	√ (3)	√ (3)	√ (2)	√ (3)	√ (3)	√ (3)
30	Kamba® 500 0.4 L	"	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)	√ (2)
31	Kamba® 500 0.5 L	"	14 (1/1)	√ (1)	√ (1)	9 (1/1)	7 (1/1)	–	√ (1)	√ (1)	8 (1/1)

Wyalkat = Wyalkatchem. The herbicide treatments were applied with the recommended wetters or adjuvants. During both the years at Mullewa, treatments 7-14 were applied at Z12-Z13, 15-25 at Z13-Z14 and 26-31 at Z15-Z16. The Katanning trial site received frequent rains in July and late August making well timed applications impossible. The treatments 7-25 were applied at Z14-Z15 and 26-31 at Z16-17 in early August and September when the site became accessible.

Note: Always follow label recommendations. The Department of Agriculture and Food, Western Australia, does not endorse the use of herbicides above the registered rate or off-label use of herbicides or off-label tank mixes. Crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

KEY WORDS

wheat, varieties, herbicides, tolerance

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Use of below label rate can lead to evolution of herbicide resistant weeds

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KEY MESSAGES

- Low herbicide rates can lead to resistance evolution in cross-pollinated species such as annual ryegrass.
- The potential for resistance evolution has been examined in annual ryegrass (*Lolium rigidum*) under low rate selection of diclofop-methyl, glyphosate and pyroxasulfone.
- Recurrent selection at low rates resulted in a different levels of selected resistance after three generations depending on the herbicide mode of action.
- Low herbicide doses should be avoided to minimize resistance evolution in cross-pollinated species such as annual ryegrass.

AIMS

1. Test the potential of low herbicide dose to select for resistance in ryegrass.
2. Quantify resistance level after three cycles of recurrent selection at low rates.
3. Compare results from different low dose selection studies with diclofop-methyl, glyphosate and pyroxasulfone.

METHOD

Plant material

A population of annual ryegrass (VLR1) was used in this study as a typical cross-pollinated grass weed species. VLR1 is known to be susceptible to all the registered herbicides used in Australia.

Recurrent selection and response to selection

Three cycles of recurrent selection at sub-optimal rates of herbicide were conducted on this herbicide-susceptible population VLR1. The known herbicide-susceptible annual ryegrass population was treated with sub-lethal doses of either diclofop-methyl or glyphosate or pyroxasulfone. Plants surviving the herbicide treatment were allowed to cross-pollinate with each other inside a pollination enclosure. The progeny was designated as P1 and was treated again with sub-lethal doses of either each herbicide with the surviving plants allowed to cross-pollinate to produce seed progeny, designated P2. The selection was again similarly repeated and surviving plants were grown to maturity and the seed progeny designated as P3.

Final herbicide study

Plants were grown outdoors during early winter to closely simulate paddock conditions (May-June). At the end of the three year recurrent selection all the selected progenies were evaluated in dose-response bioassays. The plant response of the selected progenies to each specific herbicide used in the selection was compared with the unselected parental population VLR1. For each herbicide at each dose there were four replicates. Dose-response bioassays were repeated at least once.

Statistics applied to dose-response studies

Plant survival data sets obtained in sigmoidal dose-response studies were analyzed by a three parameter log-logistic model. The response to selection in the selected progenies was measured as resistant index (i.e. the R:S (resistant:susceptible) ratio of estimated LD_{50} values between each selected progeny and the unselected parent population). Statistical difference was assessed by a t-test between the estimated LD_{50} values by using the SI function in the drc package (R Development Core Team) and P-values (*P*) are reported in tables.

RESULTS

The analysis of resistance indexes and the estimated LD_{50} values showed a very high level of resistance selected by three year cut rate selection with diclofop-methyl. The level of glyphosate resistance following low dose glyphosate selection was moderate. Similarly, the pyroxasulfone resistance level selected at low doses was significant but much lower than that selected by low doses of diclofop-methyl (Table 1).

Table 1 **Estimated LD50, relative resistance index and probability values (P) comparing the response to pyroxasulfone in the unselected parental populations VLR1 and the selected progenies after each cycle of recurrent selection at sub-lethal doses of herbicide, diclofop-methyl (Adapted from Neve and Powles 2005) and glyphosate (adapted from Busi and Powles 2009).**

Selection	Herbicide	LD_{50}	Resitance Index	*P*
P0	Pyroxasulfone	26	1.0	1.0
P1	Pyroxasulfone	27	1.0	0.77
P2	Pyroxasulfone	44	1.7	< 0.01
P3	Pyroxasulfone	24	0.9	0.46
P0	Diclofop-methyl	66	1.0	1
P1[1]	Diclofop-methyl[1]	132	2.0	< 0.01
P2[1]	Diclofop-methyl[1]	530	8.0	< 0.01
P3[1]	Diclofop-methyl[1]	1100	16.7	< 0.01
P0	Glyphosate	169	1.0	1
P1[2]	Glyphosate[2]	269	1.6	< 0.01
P2[2]	Glyphosate[2]	333	2.0	< 0.01
P3[2]	Glyphosate[2]	325	1.9	< 0.01

[1] Selected with diclofop-methyl only (see Neve & Powles, 2005).

[2] Selected with glyphosate only (see Busi & Powles, 2009).

CONCLUSION

Accumulation of minor resistance traits for herbicide resistance was possible under recurrent selection with the three different herbicides used at sub-lethal doses. A very high level of resistance was selected with the wheat-selective herbicide diclofop-methyl. Pyroxasulfone is a new selective herbicide for ryegrass control in pre-emergence in wheat and its selectivity in wheat is excellent. A significant shift towards pyroxasulfone resistance was achieved in comparison to the unselected parent population in two generations of pyroxasulfone selection. A similar resistance level was selected in this susceptible population with sub-lethal doses of glyphosate. We believe that use of full label rates would have minimized if not prevented such phenomena to occur.

It is well known the capacity of ryegrass to metabolize herbicides by a wheat-like resistance mechanism due to enhanced herbicide metabolism. Enhanced herbicide metabolism has been reported as the mechanistic basis for herbicide resistance across different herbicide modes of action. In the Australian wheat cropping system there are a number of ryegrass populations that are multi-resistant and may exhibit a much greater shift to resistance to yet-to-be released wheat-selective herbicides such as pyroxasulfone. A similar phenomenon to what was observed in this study with the wheat-selective herbicide diclofop-methyl may occur in different populations. The evidence we have accumulated from our studies in ryegrass leads us to the conclusion that herbicides should be used at the registered rate only. Do not cut the rate below the label rate. By ensuring diversity in herbicide use, maximizing rotation between herbicide modes of action and use of full label herbicide rates herbicide resistance can delay herbicide resistance to occur and herbicides will be more sustainable in Australian agriculture.

KEY WORDS

herbicide resistance, recurrent selection, low herbicide doses, herbicide selectivity, herbicide metabolism

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Herbicide mixtures can effectively kill herbicide-resistant weeds

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KEY MESSAGES

Using two populations of wild radish which have developed multiple resistance to herbicides, we showed that the mixtures diflufenican + simazine, diflufenican + metribuzin, picolinafen + simazine, and picolinafen + metribuzin were no longer effective in controlling the diflufenican + triazine - resistant population. However, the same population was effectively controlled using diflufenican + bromoxynil, diflufenican + MCPA ester, Affinity + MCPA amine, bromoxynil + MCPA and Glean + MCPA LVE. Bromoxynil + MCPA and diflufenican + metribuzin also effectively killed the population having multiple resistance to diflufenican + ALS herbicides.

AIM

To demonstrate that herbicide mixtures are a powerful tool for controlling herbicide—resistant weeds using wild radish as an example.

INTRODUCTION

There are many examples of herbicide mixtures killing herbicide-resistant weeds and these mixtures can make a substantial contribution to the management of herbicide-resistant weed populations. Research into the use of mixtures for controlling herbicide-resistant wild radish is on-going and this paper reports some of the work we have carried out.

METHOD

Glasshouse and field studies to confirm the efficacy of mixtures focusing largely on two wild radish populations one known to be resistant to diflufenican + ALS herbicides and the other resistant to diflufenican + triazines, have been carried out. Dose-response experiments were initially undertaken to confirm the resistance status of the populations. After these preliminary experiments, glasshouse and field evaluations were carried out to determine the efficacy of some selected mixtures which included bromoxynil + MCPA, diflufenican + metribuzin, diflufenican + bromoxynil, diflufenican + MCPA, picolinafen + MCPA, Affinity + MCPA and Glean + MCPA. Some of the other herbicides included in the studies are also shown in Table 1. A known susceptible population was used as a control in all the experiments.

Response to herbicides was recorded at various time intervals, starting 21 days after spraying the seedlings at the 2- to 3-leaf stage of development in both the glasshouse and field. Plants were recorded as alive if majority of their leaves remained green and their growing points remained alive or they strongly recovered after application of the herbicides. In some of the treatments, survivors were cut at ground level and dry weight determined after drying at 60° C for 72 hours as part of the evaluation of resistance.

RESULTS AND DISCUSSION

Only results of the field studies are presented in this paper (Table 1).

Table 1 **Efficacy of various herbicides on two populations of wild radish with multiple resistance**

Herbicide and rate/ha	Survival (%)	
	Resistant	Susceptible
Diflufenican + ALS - resistant population		
Diflufenican (Brodal 200 mL)	68.0	0
Bromoxynil + MCPA (Buctril MA at 1.4 L)	5.6	0
Diflufenican (Brodal 100 mL) + metribuzin (Lexone 100 g)	0.7	0
Diflufenican + triazine - resistant population		
Diflufenican (Brodal 200 mL)	55.1	0
Atrazine 2 L	100.0	0
Picolinafen (Sniper 50 g)	60.2	0
Diflufenican (Brodal 100 mL) + Simazine (1 L)	47.9	0
Diflufenican (Brodal 100 mL) + metribuzin (Lexone 100 g)	22.0	0
Picolinafen (Sniper 25 g) + Simazine (1 L)	52.3	0
Picolinafen (Sniper 25 g) + metribuzin (Lexone 100 g)	44.0	0
Diflufenican + bromoxynil (Jaguar 0.5 L)	0	0
Diflufenican + MCPA ester (Tigrex 0.5L)	74.1 (5.0)*	65.9 (6.0)
Picolinafen + MCPA ester (Paragon 375 mL)	81.3 (3.0)	63.9 (3.0)
Affinity (60 g) + MCPA amine (500 mL)	69.1 (11.0)	68.0 (9.0)
Bromoxynil + MCPA (Buctril MA 1.4 L)	0	0
Glean (5 g) + MCPA LVE (500 mL)	7.0 (2.0)	3.0 (2.0)
Untreated control	100.0 (104.0)	100.0 (103.0)

* Within brackets are fresh weights g/plant of survival.

Bromoxynil + MCPA (Buctril MA at 1.4 L/ha) and diflufenican (Brodal 100 mL/ha) + metribuzin (Lexone at 100 g/ha) were found to be effective in controlling the diflufenican + ALS-resistant population. Of interest was the mixture diflufenican + metribuzin which killed the population despite it being resistant to one of the components, diflufenican. The same mixture however, failed to control the diflufenican + triazine – resistant population, but effective control in terms of dry biomass was achieved when using the following mixtures: diflufenican + bromoxynil (Jaguar at 0.5 L/ha), diflufenican + MCPA ester (Tigrex at 0.5 L/ha), picolinafen + MCPA ester (Paragon at 375 mL/ha), Affinity at 60 g/ha + MCPA amine at 500 mL/ha, bromoxynil + MCPA (buctril MA at 1.4 L/ha) and Glean at 5 g/ha + MCPA LVE at 500 mL/ha.

The effectiveness of diflufenican + bromoxynil on the diflufenican + triazine-resistant population is of special interest. Since diflufenican and bromoxynil are classified under Group F and Group C, respectively under the present Australian Herbicide Mode of Action Groups classification system, one would be tempted to think that the mixture is unlikely to be effective on the population. However, under the international Herbicide Resistance Action Committee (HRAC) classification system, bromoxynil is placed under Group C3 and the triazines and metribuzin under C1. Unlike the triazines, bromoxynil has a different binding behaviour at the binding protein D1 in photosystem II. This protein is also called the herbicide or Q_B binding protein. Trebst (1987) grouped herbicides that bind in the Q_B niche into two families based on their interaction with amino acids at this site: the triazine/urea family which shows a strong interaction with Ser 264 and the phenol family that interacts strongly with His 215. Bromoxynil being a nitrile, belongs to the phenol family. According to Trebst, mutations in triazine resistance lead to increased sensitivity to phenol-type herbicides. This together with the fact that bromoxynil has an additional mode of action that involves membrane disruption probably accounts for the effectiveness of the bromoxynil + diflufenican mixture.

Another significant result was the effectiveness of the mixtures diflufenican + MCPA and picolinafen + MCPA, despite the resistance of the population to one of the components in the mixture. This was clearly evident in the suppression of the wild radish biomass rather than plant mortality. Therefore, once a herbicide is no longer effective on a population due to resistance, mixing it with an appropriate herbicide having a different mode of action may result in the control of the resistant population, as shown here. Therefore the use of mixtures is a powerful tool in controlling the resistant population.

As expected, the following herbicide treatments: diflufenican, diflufenican + simazine, diflufenican + metribuzin, picolinafen, picolinafen + simazine, picolinafen + metribuzin and straight atrazine were no longer effective for controlling the diflufenican + triazine-resistant population in lupin. Cross-resistance to picolinafen is not surprising since both diflufenican and picolinfen have the same mode of action, targeting the enzyme phytoene desaturase.

CONCLUSION

The use of herbicide mixtures for managing herbicide-resistant weed populations is still feasible as shown here using wild radish as an example.

KEY WORDS

herbicide mixture, wild radish, resistant

Paper reviewed by: JR Peirce

Selective spray-topping: Does it abort seed production of herbicide-resistant wild radish?

Aik Cheam and **Siew Lee**, Department of Agriculture and Food, Western Australia, South Perth

KEY MESSAGES

Selective spray-topping will not abort seed production of herbicide-resistant wild radish. Using Eclipse® as a selective spray-topping treatment, up to 98 per cent seed-set reduction was obtained in an Eclipse®-susceptible population. The same treatment was found to be ineffective in a population resistant to Eclipse®.

AIM

To determine whether effective seed-set control is achievable with a selective herbicide applied during the early reproductive phase of a wild radish population that is resistant to the herbicide.

INTRODUCTION

Selective spray-topping is the application of selective herbicides to the crop during the early reproductive phase of weed development to abort seed production. Registered herbicides are available for selective spray-topping of brassica weeds in cereals and wild oats in wheat. As a seed-set control technique, selective spray-topping can be applied as a follow-up treatment to early season control to effectively drive seedbank numbers down. According to Medd et al. (1995), it is possible to reduce the seedbank to extremely low levels using this technique.

Working on wild radish in wheat, Madafiglio et al. (1997) have shown that several herbicide groups are very effective at preventing the seed production when applied at the early flowering stage of weed development. However, with the widespread development of Group B resistance in wild radish populations in WA, it is not known whether this technique is still effective at preventing seed production.

This paper reports results from selective spray-topping work on a susceptible population in 2004 and a resistant population in 2005 of wild radish in a lupin crop using herbicides that are known to be effective at the seedling stages of growth of susceptible wild radish.

METHOD

The key herbicides evaluated in 2004 and 2005 at the Avondale Research Station, WA, are shown in Table 1.

The seed for establishing the 2004 wild radish population was initially tested to determine its resistance status and was found to be susceptible to all the herbicides used.

In 2005 a different population of wild radish known to be resistant to Eclipse® but susceptible to Brodal Options®, Sniper® and Lexone® was used.

The lupin variety sown in 2004 was Benara and the variety Mandelup was sown in 2005.

All the herbicides were applied immediately after crop flowering when most of the wild radish plants were at the pre-embryo stage of development when the seed pods were still green, squashy and watery and seed development was still at the ovule stage without embryo.

Assessments were made on the impact of the treatments on seed production of wild radish, crop yield and seedling vigour of the harvested crop seed.

RESULTS

Table 1 **Wild radish viable seed reduction per plant as per cent of control following selective spray topping of lupin in 2004 and 2005. Lupin yield, germination and seedling length were also expressed as per cent of control.**

Treatment	Wild radish viable seed reduction		Lupin[c]				
			Yield	Germination		Seedling length	
	2004[a]	2005[b]	2005	2004	2005	2004	2005[d]
Eclipse® 10 g	97.5	0.0	117.6	128.9	100.0	123.6	79.6
Eclipse® 10 g + Brodal Options® 100 mL	88.2	68.7	115.7	121.1	100.0	111.9	108.0
Eclipse® 10 g + Sniper® 33 g	88.0	38.6	128.7	110.5	100.0	100.0	86.2
Brodal Options® 200 mL	0	–	–	–	–	–	–
Brodal Options® 100mL + Lexone® 100 g	34.7	–	–	–	–	–	–
Sniper® 50 g	0	–	–	–	–	–	–
No herbicide control	0.0	0.0	100	100	100.0	100.0	100.0
			(1.08 t/ha)				

[a] 2004 wild radish was susceptible to Eclipse®.

[b] 2005 wild radish was resistant to Eclipse®.

[c] 2004 lupin variety was Belara and 2005 variety was Mandelup.

[d] There was water-logging in 2005, due to heavy rain.

Eclipse® on its own or in combination with Brodal Options® or Sniper® resulted in 88 to 97.5 per cent seed-set reduction of wild radish in the 2004 lupin crop. The best treatment was Eclipse® on its own, but it was not effective on the 2005 wild radish population which was resistant to Eclipse® but susceptible to Brodal Options®, Sniper® and Lexone®. However, there was partial seed-set reduction which ranged from 39 to 69 per cent when Eclipse® was mixed with Brodal Options® or Sniper®.

There was a loss in seedling vigour of the harvested lupin seed in 2005 in two of the treatments and water-logging of the plots could have contributed to this as there was no loss in vigour in the 2004 season.

CONCLUSION

Selective spray-topping as a technique for controlling seed-set of wild radish is quite promising with up to 98 per cent seed-set reduction after treating with Eclipse® if the wild radish is still susceptible to the herbicide. If the wild radish is resistant to Eclipse®, then selective spray-topping with the herbicide will be ineffective. Therefore, once wild radish has evolved resistance to a particular herbicide, the herbicide will no longer be effective even when used as a spray-topping treatment.

KEY WORDS

selective spray-topping, wild radish

Paper reviewed by: JR Peirce

The search for a new lupin herbicide

Peter Newman, Department of Agriculture and Food, Western Australia, Geraldton

KEY MESSAGES

Several years of research by DAFWA and UWA have not identified any novel herbicide options for wild radish control in lupins. This research has identified some new uses of old herbicides that show potential for future registration.

AIMS

Narrow leaf lupins *Lupinus angustifolius* are a relatively small crop on a global scale. Consequently, there is very little investment by chemical companies into the development of new herbicides for use in lupins. Wild radish is a major threat to the lupin industry as it is rapidly developing resistance to the small range of herbicides that are registered for its control. As a part of a new GRDC funded project, the search is on to find new herbicide options for wild radish control in lupins. In the event of finding a viable herbicide option, we will seek to collaborate with the relevant chemical company/s to have the product registered for wild radish control. The aim of this research is to identify some herbicide options that show promise to give good wild radish control with acceptable crop safety.

METHOD

Three trials were conducted at three separate sites evaluating a range of herbicides / timings.

Pre-sowing herbicide trial

Property of Andrew and Rod Messina, Eradu. Good Yellow sandplain soil. Weed free site. Pre sowing treatments applied to dry soil 12 May 2009. Mandelup lupins sown dry 13 May 2009. PSPE treatments applied 18 May. 25mm rain 21 May. Brodal and Brodal + Metribuzin treatments applied 26 June to 8 leaf lupins. Pre and PSPE treatments applied with AIXR11002 nozzles, 200 kpa, 66 L water/ha. Post-em treatments applied with DG11002 nozzles 200 kpa, 64 L water / ha. Strip plot design with three replications.

Post-emergent herbicides registered in lupins

Property of Brad McIroy, Pithara (Liebe main trial site). Crop 4 to 8 leaf at spraying on 3 July 2009. Wild radish 2 leaf (5 cm) to 6 leaf (30 cm) at spraying. Treatments applied with DG11002 nozzles 200 kpa, 63 L water / ha. Complete randomised block design with 3 replications.

Post-emergent – including un-registered herbicides

Property of Ian Broad, Mingenew. Yellow sandplain soil. Sprayed 25 June 2009. Mandelup lupins 8 leaf at spraying. Wild radish at spraying 30 per cent 2 leaf (5 cm); 65 per cent 4 leaf (10 cm); 5 per cent 6 leaf (15 cm). Treatments applied with resistance boom; 60 L water / ha; 02 flat fan nozzles, 200 kpa, 12 kph. Criss-cross trial design with 4 replications (plots 2 m x 2 m).

RESULTS

Pre-sowing herbicide trial – Messina

This trial was intended to evaluate efficacy and crop tolerance. However, as the site was sown dry we were unable to successfully choose a weedy site. Consequently the site was weed free. There were significant differences in yield between pre-emergent herbicide treatments ($P < 0.01$ l.s.d. 360 kg/ha). There was no significant difference between post-emergent treatments of Brodal 2921 kg/ha or Brodal + metribuzin 2868 kg/ha ($P > 0.05$). There was no significant interaction between pre-emergent and post-emergent treatments.

High rates of metribuzin (600 g/ha and 1200 g/ha) cause significant yield reductions. A high rate of Isoxaben (333 g/ha) pre-sowing and both rates of Isoxaben applied post sowing, pre-emergent caused significant yield reductions. There was no significant difference in yield between other treatments.

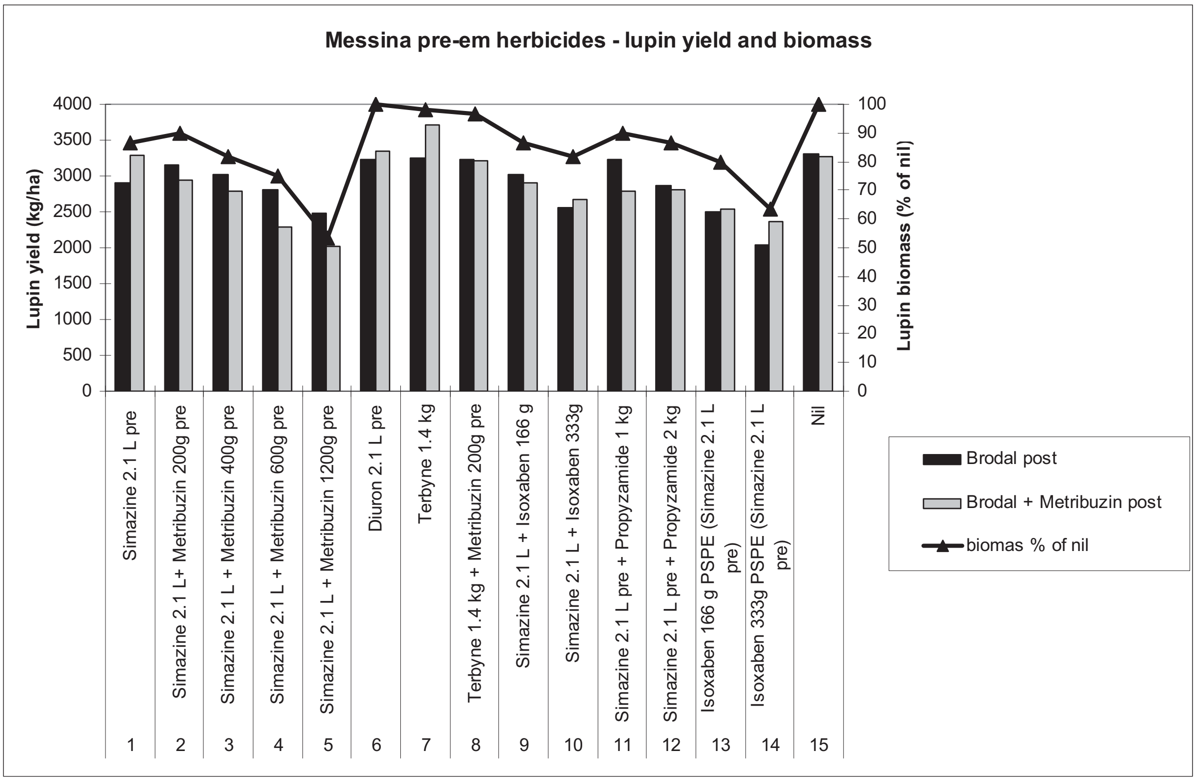

Figure 1 **Lupin yield (kg/ha) and visual lupin biomass rating on 26 June 2009 for a range of pre-sowing treatments with either Brodal or Brodal + metribuzin applied post-emergent – Messina 2009.**

Post-emergent herbicides registered in lupins – Liebe

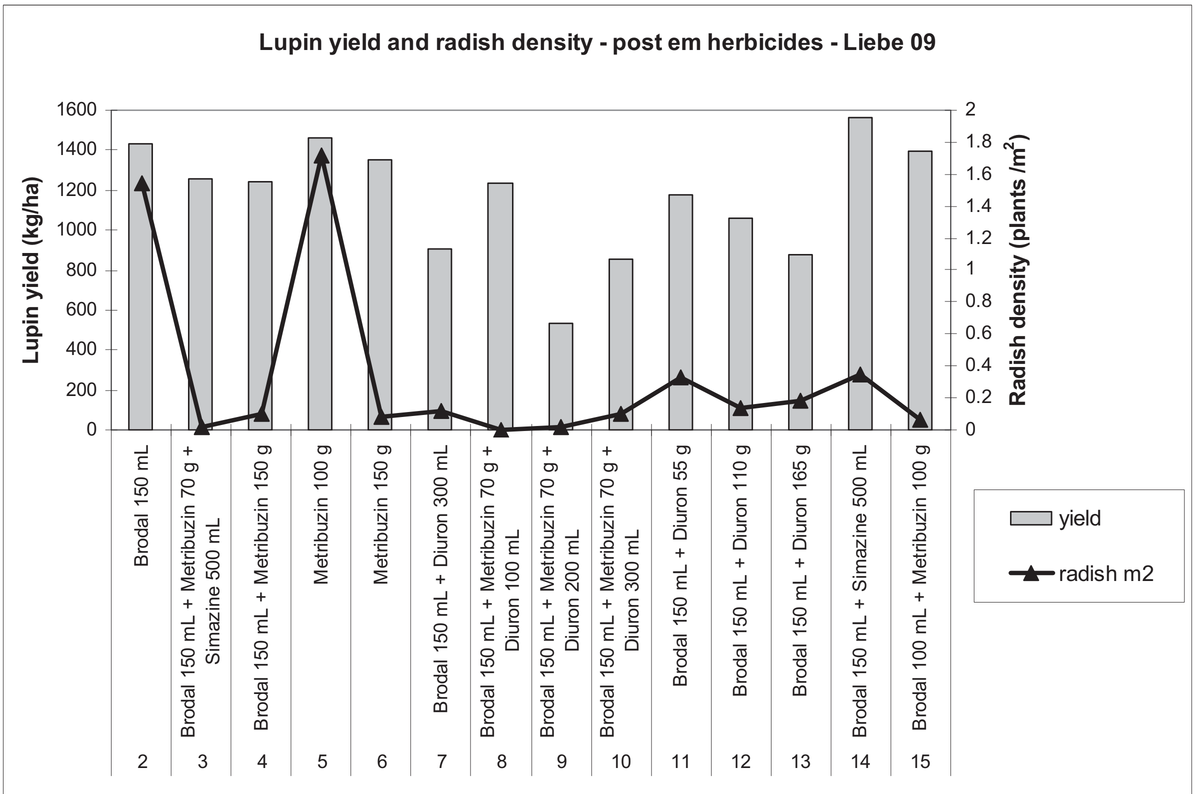

Figure 2 **Lupin yield (kg/ha) and wild radish density (plants /m^2) for a range of post-emergent herbicides applied at the 8 leaf stage of lupins – Liebe 2009.**

Very high levels of crop phyto-toxicity were observed at this trial approximately 7 days after spraying, which reduced crop biomass. Generally speaking, the treatments that caused the greatest crop phyto toxicity gave the best wild radish control. Crops did not recover from early herbicide damage, and so there was a very strong correlation between crop biomass (rated 12 August) and final lupin yield. There were significant differences in yield between treatments ($p < 0.01$; l.s.d. 340 kg/ha). There were significant differences in wild radish control between treatments ($p < 0.01$; l.s.d. 0.63 plants/m^2). Nil plots were sprayed out. Nil plots averaged 20 wild radish plants/m^2.

Post emergent – un-registered herbicides – Broad

Table 1 **Visual assessment (29 July 2009) of lupin biomass (% of nil) and wild radish control (% control) for a large range of treatments created by criss-cross spraying (2 m x 2 m plots).**

Herbicide treatment	Lupin biomass % of Nil	% radish control
Nil	100	0
Brodal 150 mL/ha	**97**	**93**
Brodal 100 mL + Metribuzin 100g	**87**	**98**
Metribuzin 150 g/ha	**85**	**87**
Diuron 300 mL/ha	86	38
Basagran (480) 2 L/ha	2	91
Isoxaben 300 g/ha	72	86
Brodal 300 mL/ha	**96**	**99**
Brodal 200 mL/ha + Metribuzin 200g/ha	**84**	**100**
Metribuzin 300 g/ha	70	96
Diuron 600 mL/ha	60	70
Basagran (480) 4 L/ha	0	97
Isoxaben 600 g/ha	38	99
Brodal 250 mL/ha + Metribuzin 100g/ha	**91**	**100**
Brodal 150 mL/ha + Metribuzin 150 g/ha	81	100
Brodal 150 mL/ha + Diuron 300 mL/ha	76	99
Brodal 150 mL/ha + Basagran (480) 2 L/ha	0	100
Brodal 150 mL/ha + Isoxaben 300 g/ha	68	99
Brodal 100 mL/ha + Met 250g/ha	73	100
Brodal 100 mL/ha + Met 100g/ha + Diuron 300 mL/ha	70	100
Brodal 100 mL/ha + Met 100g/ha + Basagran (480) 2 L/ha	0	100
Brodal 100 mL/ha + Met 100g/ha + Isoxaben 300 g/ha	53	100
Metribuzin 150 g/ha + Diuron 300 mL/ha	61	96
Metribuzin 150 g/ha + Basagran (480) 2 L/ha	1	99
Metribuzin 150 g/ha + Isoxaben 300 g/ha	58	98
Diuron 300 mL/ha + Basagran (480) 2 L/ha	0	94
Diuron 300 mL/ha + Isoxaben 300 g/ha	51	96
Basagran (480) 2 L/ha + Isoxaben 300 g/ha	1	99

This trial compared a large number of treatments in very small plots (2m x 2m). There are a large number of treatments that gave high levels of wild radish control but most of these were not well tolerated by the lupin crop. The safest treatments with the highest wild radish control were Brodal, Metribuzin and the combination of the two.

CONCLUSION

These trials unfortunately confirm what we have known for a long time. There is a large range of herbicide mixes that can control wild radish but lupins can not tolerate the majority of these herbicides/mixes.

Messina trial

The exciting result from the Messina trial was how tolerant lupins can be of herbicides applied pre-sowing. Mandelup lupins have demonstrated the ability to tolerate high rates of metribuzin pre-sowing in trials over the past four growing seasons. Previous trials have shown only minor yield reductions when metribuzin was applied at 600 g/ha in a mix with simazine pre-sowing. The high rates of 600 g/ha and 1200 g/ha metribuzin pre-sowing in a mix with simazine caused 18 per cent and 28 per cent yield reductions respectively. However, the low rates of 200 g/ha and 400 g/ha caused no significant yield reduction. Applying additional metribuzin (120 g/ha) in a mix with Brodal to the crop post-emergent did cause minor yield reductions compared to applying Brodal alone. This suggests that there is a limit to the total amount of metribuzin that a lupin crop can tolerate. This data will potentially be used to pursue registration of metribuzin (750 g/kg) at 150 to 200 g/ha, pre-sowing in lupin crops.

The Messina trial also demonstrated that lupins have excellent tolerance of diuron and Terbuthylazine applied pre-emergent. Isoxaben, on the other hand, was not tolerated well by the lupins. This may be the final straw in evaluating this herbicide for radish control in lupins. Isoxaben has proven to be soft on radish, hard on lupins and expensive. Lupins also tolerated propyzamide well, but future research is required to evaluate radish control before this product is considered for registration?

Liebe trial

This trial demonstrates just how difficult it is to develop new herbicide options in lupins. The herbicide brews that gave the greatest weed control also caused the greatest crop damage and the lowest yields. The old standards of Brodal + simazine, Brodal + metribuzin and the three way mix of Brodal + simazine + metribuzin gave the best weed control with the most acceptable crop damage. The very poor radish control with Brodal alone demonstrates just how important it is to mix this product with a group C herbicide for best results. All of the mixes containing Diuron post emergent were very damaging probably as a result of heavy rain in the weeks following spraying. The most surprising result in this trial was the high level of wild radish control achieved with metribuzin 150 g/ha alone. This was also observed at two other trials in 2009. Heavy rainfall after spraying may have contributed to this result.

Broad trial

This trial used a criss-cross spraying design with a resistance boom to create a large number of combinations of post-emergent herbicides. The resultant plots are very small (4 m^2) so these results should be viewed as preliminary results only. Once again, combinations of Brodal and Metribuzin gave the highest wild radish control with the least damage to the crop. Basagran (bentazone 480 g/L) was the most damaging herbicide and will take no further part in future evaluation. Isoxaben was disappointing both in terms of crop safety and efficacy and is unlikely to be evaluated further. Diuron was once again shown to be damaging when applied post emergent to lupins. Possibly the only thing that will make Diuron a post-emergent option in the future would be the breeding of a more tolerant lupin.

Conclusions

Ultimately, the lupin industry needs a new post emergent wild radish herbicide of novel mode of action. At the moment, indications are that this is unlikely to happen in the coming years. These trials demonstrate that while there are a number of herbicide options for wild radish control, the problem is that lupins have very poor herbicide tolerance. There is potential to pursue registration of some pre-sowing herbicides that may offer improved suppression of wild radish but are unlikely to offer high levels of control. Future research will continue to explore novel herbicides as well as investigate the possibility of crop safteners / plant breeding to enhance lupin herbicide tolerance.

KEY WORDS

lupin, herbicide, wild radish

ACKNOWLEDGMENTS

Many thanks to all of the growers involved and to Dave Nicholson and the Geraldton RSU for technical support. Thankyou to GRDC for supporting this research.

Project No.: DAW00123

Paper reviewed by: Catherine Borger

Colonisation of agricultural regions in Western Australia by flaxleaf fleabane

Catherine Borger, Greg Doncon and **Abul Hashem**, Department of Agriculture and Food, Western Australia, Merredin and Northam

KEY MESSAGES

- Flaxleaf fleabane seed can disperse at least 1800 metres in one season.
- Flaxleaf fleabane seems more likely to establish where disturbance is low.
- Summer weed control will control flaxleaf fleabane. However, seeds of this plant disperse very widely, and so it would not be possible to restrict the movement of herbicide resistance genes between fields.

AIMS

Flaxleaf fleabane (*Conyza bonariensis* (L.) Cronquist) is a common weed in Australia, being widespread in the eastern states and the south of WA (Wu 2007). Flaxleaf fleabane is found throughout the wheatbelt of WA, but is more commonly a weed of wastelands, roadsides and towns, rather than cropping fields (Hussey et al. 1997). The capacity of flaxleaf fleabane to infest agricultural areas in the central wheatbelt is unknown, and will depend on the colonisation rate of this species in agricultural ecosystems.

Dispersal of flaxleaf fleabane is likely to be widespread, as seeds are very light; allowing for broad scale seed dispersal (Wu 2007). Shields et al. (2006) used atmospheric seed sampling techniques to indicate that horseweed (*C. canadensis*) seed is likely travel up to 500 km. It is highly probable that flaxleaf fleabane achieves similar broad scale seed dispersal. However, this does not indicate how well flaxleaf fleabane can establish or colonise an area, i.e. how many seeds actually establish following dispersal. Colonisation rates of flaxleaf fleabane within a farming landscape has not been investigated, but will effect invasion rates of this species into new areas and spread of herbicide resistant genes through existing populations.

This research aimed to assess the potential of flaxleaf fleabane to become a weed of farms in the central WA wheatbelt, by examining colonisation rates within the farming system.

METHODS

Flaxleaf fleabane seed source

A population of flaxleaf fleabane plants was identified in Merredin, WA, during January 2007. The plants were spread in remnant vegetation.

Flaxleaf fleabane colonisation

An un-grazed annual ryegrass pasture field was identified, at the Department of Agriculture and Food WA Merredin Research Station on Great Eastern Hwy. The Research Station, and all farms and road verges within a 2 km radius of the Research Station, were searched for flaxleaf fleabane plants or other species of the *Conyza* genus during September and November 2007 and January 2008. No plants were discovered.

A total of one hundred seeds (20 from five individual plants) were collected from the Merredin population, in December 2007. Seeds were evenly spread over a 4 m^2 area, on 14 December 2007, in the centre of the pasture field. A cohort of eight seedlings emerged in January 2008. A single plant (Parent Plant) survived to produce 21 seed heads. Seeds were released from the seed heads via wind mediated dispersal, in April and May 2008. Further cohorts emerged in the trial area in the following spring/summer but were prevented from releasing seed.

Following seed release, establishment of flaxleaf fleabane plants on the Research Station and surrounding farms was monitored at intervals of three months, from September 2007 to March 2009. Monitoring occurred after major rainfall events when germination was likely to have occurred. Plants were identified at the seedling or rosette stage, the location was marked and the plants removed.

Location of rosettes was mapped and direction of each rosette from Parent Plant was subject to circular data analysis. Daily maximum wind speed and direction at the time of seed release from Parent Plant was obtained from the Merredin Research Station automatic weather station (Department of Agriculture and Food Western Australia 2009) and likewise subject to a CDESCRIBE analysis.

Flaxleaf fleabane seed production per head

A total of 15 flower heads (three heads per plant from five plants) were removed from both the Merredin population and the Research Station population during March and April 2009. The selected heads were fully formed but only partially open (to ensure no seeds had been lost due to dispersal). Seeds on each head were counted manually under a dissecting microscope. An ANOVA was used to investigate variation in seed production per head between the two populations. Population was the factor, plant number and seed head number were the blocking factors and seed number per head was the response.

RESULTS

Flaxleaf fleabane seed production per head

Seed production ranged from 189 to 385 per head, with a mean and standard error of 284 ± 13.8. Average seed production per head by plants at the Merredin and Research Station populations was not significantly different (P = 0.191, l.s.d.: 38).

Flaxleaf fleabane colonisation

From the average number of seeds per head and the number of seed heads produced by Parent Plant, an estimated 5965 seeds were released onto the Research Station in April/May 2008. In the following year, 366 rosettes were found growing on the Research Station. No rosettes were found on the farms/roads adjoining the Research Station. As a result, it was assumed that all rosettes found on the Research Station originated from seed produced by Parent Plant. Given this assumption, established rosettes only accounted for 6 per cent of the estimated 5965 seeds. The greatest proportion of rosettes was found within 20 m of Parent Plant (64 plants). The maximum distance a rosette was found from Parent Plant was 1842 m (Figure 1).

The direction of rosettes from Parent Plant was related to the direction of the strongest wind events that occurred when seed was being released (Figure 2). Flaxleaf fleabane rosettes were more likely to germinate along roadsides and fence lines than in the centre of fields. There were two areas in the middle of fields where fleabane was common, because no cultivation or weed control had occurred over spring and summer (i.e. when most of the rosettes were found).

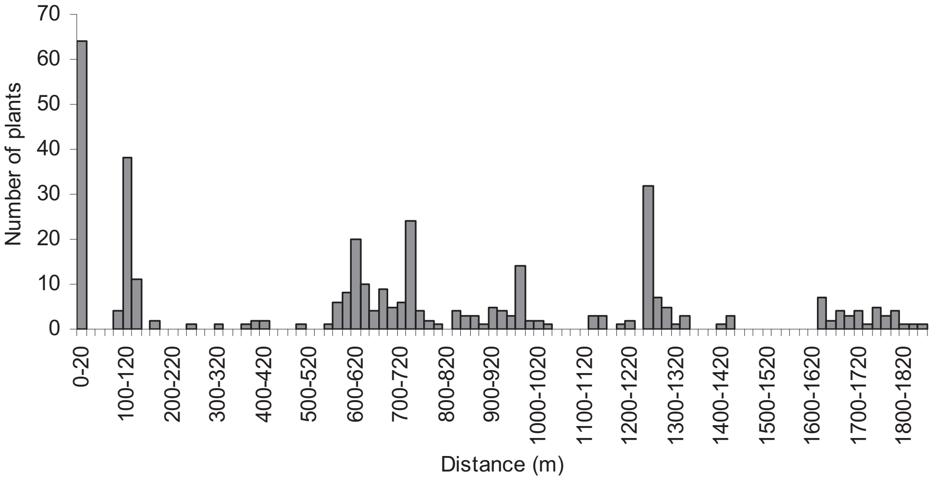

Figure 1. **The number of plants that established within a set radius (0–1860 m) of Parent Plant. Establishment was monitored from May 2008 to March 2009, following the release of an estimated 5965 seeds during April and May 2008.**

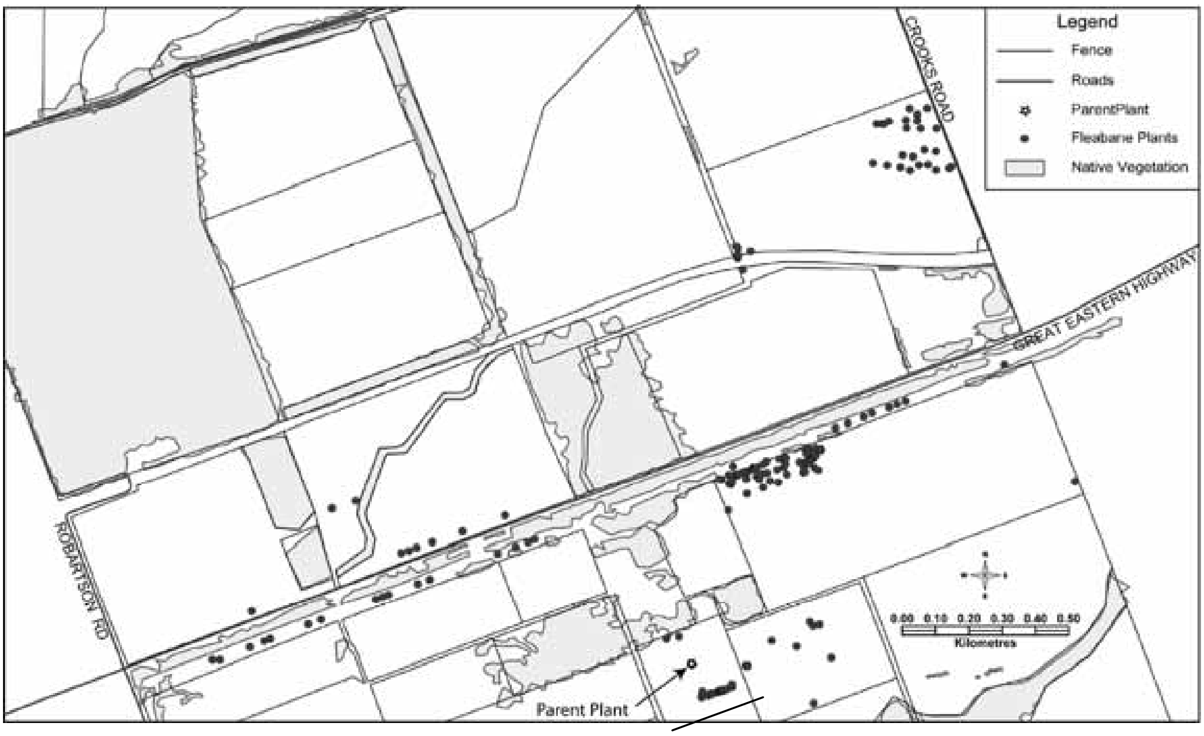

Figure 2 **Location of flaxleaf fleabane rosettes (grey circles) collected on the Research Station, from May 2008 to February 2009. Robartson and Crooks Road border the Research Station to the west and east. The legend indicates the location of Parent Plant, roads, fences and areas of native vegetation.**

CONCLUSION

The main conclusion from these results is that flaxleaf fleabane will spread to and successfully colonise farming systems in WA, given the successful spread of this species over the Research Station during one year. This work found that flaxleaf fleabane seeds can disperse a maximum distance of 1842 m.

Not surprisingly, more flaxleaf fleabane was found in sites where summer weed control did not occur. Flaxleaf fleabane plants also accumulated along roadsides and fence lines, possibly due to reduced disturbance or weed control measures.

Over the bulk of the Research Station, standard farm practices (including summer weed control) appeared to control plants. Therefore, thorough summer weed control (including fence lines) should successfully remove plants.

It may be possible to control or reduce the spread of fleabane in the central wheatbelt where on farm density is still low. However, once populations are dense it is probably not possible to prevent dispersal and gene flow. In California, horseweed developed resistance to glyphosate and wind mediated dispersal allowed the resistance genes to spread rapidly (Hanson et al. 2009). This highlights the need to avoid herbicide resistance development in WA.

KEY WORDS

flaxleaf fleabane, *Conyza bonariensis*, summer, weed, dispersal

ACKNOWLEDGMENTS

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Paper reviewed by: Dr Sally Peltzer, Department of Agriculture and Food, Western Australia

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Weed suppression by crop competition in barley, canola and wheat

Abul Hashem and **Catherine Borger**, Department of Agriculture and Food, Western Australia, Merredin and Northam

KEY MESSAGES

- Crop-competition processes are highly dynamic under field conditions. The competitive ability of cultivars of a single crop type (barley, canola or wheat) is highly variable, probably due to variation between seasons and sites.
- Barley and wheat cultivars appear to be more competitive than canola and have a greater ability to suppress formation of annual ryegrass heads.
- Within each crop some cultivars showed greater ability to produce grain yield and suppress formation of annual ryegrass heads.

AIMS

One way to suppress weeds such as annual ryegrass is to increase crop competitive ability by using competitive crop cultivars and manipulating seeding rate. In the recent years, many farmers have started using high seeding rates of wheat and barley to suppress weeds and manage herbicide resistant weeds. However, the competitive ability of recently developed crop cultivars under weedy situations is not well known to growers. The aim of this study was to examine the competitive ability of crop cultivars to suppress weeds in wheat, barley and canola grown under in-crop herbicide or no in-crop herbicides, with or without high seeding rate.

METHODS

This study was accomplished in two phases. In 2008, competitiveness of four cultivars of each crop (wheat, barley and canola) was examined under in-crop herbicide or no in-crop herbicide. In 2009, interaction of seeding rate and selected crop cultivars was examined under in-crop herbicide or no in-crop herbicide with or without high seeding rate. Four trials were conducted at Meckering WANTFA site and Wongan Hills Research Station in 2008 and 2009.

Methods 2008

Main plost: Crops (wheat, barley, canola).

Sub-plot: Weed control (herbicides or no herbicide).

Sub-sub-plot: Four crop cultivars per crop species. Crop cultivars were chosen to achieve variable grain size, early vigour, plant height, biomass, canopy structure, growth duration, yield potential, etc.

Wheat cultivars: Wyalkatchem, Yitpi, Calingiri, EGA Bonnie Rock.

Barley cultivars: Roe, Hindmarsh, Baudin, Buloke.

Canola cultivars: CB^{TM} Tanami, CB^{TM} Boomer, Bravo TT, Thunder (all TT canola).

Row spacing: 25 cm between rows of crops.

Methods 2009

Main plots: Crops (Wheat, barley, canola).

Sub-plot: Weeding (Herbicide or no herbicides).

Sub-sub-plot: Seeding rates (barley 75 or 150 kg/ha, canola 2.5 or 5 kg/ha and wheat 60 or 120 kg/ha).

Sub-sub-sub-plot: Crop cultivars

Wheat cultivar*:* EGA Bonnie Rock, Wyalkatchem.

Barley cultivar*:* Roe, Baudin.

Canola cultivar*:* CB^{TM} Tanami, Bravo TT.

Trial design: Split-slit plot design was employed in both years. In 2008, crop type was the main plot factor, weed treatment in the sub-plots and cultivar in the sub-sub-plots. In 2009, crop type was the main plot factor, weed treatment in the sub-plot, seeding rate in the sub-sub-plots and cultivars in the sub-sub-sub-plots.

Measurement: Canopy area (canopy height x width) and light interception through the crop canopy were measured at maximum tillering stage of wheat or barley and rosette stage of canola. The main weed species both at Meckering and Wongan Hills was annual ryegrass. Brome and barley grass were also present at Meckering. Grass weed heads were counted at anthesis of wheat. Floristic composition of crops and weeds was assessed visually in each plot at late flowering stage of crops in 2008 only. Grain yield was recorded at harvest.

Data analysis: Data were subjected to ANOVA and means were separated by l.s.d. For grain yield of crops, ANOVA was performed for each crop separately to minimise the confounding effects of crop species. For the ANOVA of other measurements such as crop canopy area and weed seed heads, crop species was used as the main factor.

RESULTS

Initial weed control

Initial in-crop weed control due to standard herbicides in each crop varied amoung crops, seasons and locations. Weed control was generally more effective in wheat and barley than in canola.

Grain yield of crops

Interaction of weed control and cultivars influenced grain yield of wheat and barley in all trials except at Meckering in 2008. In canola, a significant interaction effect of herbicide and cultivars was found at Meckering in 2008 and at Wongan Hills in 2009.

In barley, Roe and Hindmarsh yielded better than Baudin and Buloke at both locations in 2008 regardless of herbicide (Table 1). Under no in-crop herbicide, Hindmarsh at Meckering and Baudin at Wongan Hills produced lower yield than under herbicide.

In canola, Bravo and Thunder produced greater grain yield under herbicide than under no herbicide at Meckering in 2008. The other two cultivars did not respond to herbicide at Meckering in 2008 (Table 1). In 2009, herbicide significantly improved yield of Tanami and Bravo.

In wheat, Wyalkatchem yielded better under herbicide than no herbicide in two out of four trials and EGA Bonnie Rock yielded better under herbicide than no herbicide in three out of four trials. Other cultivars did not respond to weeding in either season or location.

Use of higher seeding rates in 2009 did not affect crop yield of canola and wheat at either location. Higher seeding rate of barley increased barley grain yield by 13 per cent at Meckering in 2009 but not at Wongan Hills where ryegrass density was greater.

Annual ryegrass heads

On average, barley and wheat cultivars had fewer annual ryegrass heads at maturity than canola cultivars (Table 2). Annual ryegrass head numbers were not recorded at Wongan Hills in 2008. In barley, herbicide reduced annual ryegrass heads in Buloke at Meckering in 2008, Roe at Meckering and Wongan Hills in 2009, and Baudin at Wongan Hills in 2009. However, annual ryegrass heads were not influenced by barley cultivar alone. In canola, herbicide reduced the number of ryegrass heads but cultivar alone did not influence annual ryegrass heads regardless of weed control.

In wheat, herbicide reduced annual ryegrass heads in most cultivars in all the trials. Under no herbicide, Wyalkatchem had more annual ryegrass heads than other cultivars at Meckering in 2008 and at Wongan Hills in 2009 (Table 2)

Canopy area

At maximum vegetative stage, barley had larger canopy area than wheat and wheat had larger canopy area than canola (data not shown). However, some cultivars of canola such as Thunder had greater light interception than wheat or barley probably due to larger leaf size and wider leaf angle than other

crops and cultivars. Regardless of crops, large canopy area and high light interception in most cultivars did not result in greater grain yield suggesting that there was a shift in the competiveness of cultivars of each crop.

Table 1 **Grain yield (kg/ha) of different crop cultivars grown under herbicide and no herbicide conditions at Meckering and Wongan Hills in 2008 and 2009[a].**

Crops/ Cultivars	Meckering				Wongan Hills			
	2008		2009		2008		2009	
	Herbicide	No herbicide	Herbicide	No herbicide	Herbicide	No herbicide	Herbicide	No herbicide
Barley								
Roe	2474	2443	3323	2987	2444	2379	2500	2253
Hindmarsh	2405	2189	–	–	2500	2611	–	–
Baudin	1817	1686	3264	2741	2203	1951	2419	2083
Buloke	1928	1981	–	–	2145	2015	–	–
l.s.d. .05	NS		453.5		216.9		187.9	
Canola								
CB™ Tanami	960	789	595	595	1104	1063	980	571
CB™ Boomer	817	717	–	–	972	889		
Bravo	863	540	618	530	1007	951	1057	637
Thunder	934	706	–	–	965	931	–	–
l.s.d. .05	211.8		NS		NS		82.2	
Wheat								
Wyalkatchem	1011	928	2441	1959	2396	2250	2319	1879
Yitpi	1323	1305	–	–	2194	2125	–	–
Calingiri	944	785	–	–	2326	2174	–	–
EG Bonnie Rock	1416	1409	2252	1902	2208	2424	2407	1960
l.s.d. .05	NS		431.5		150.4		174.2	

[a]'–' = This cultivar was not used in 2009 trials.

DISCUSSION

In barely, Roe produced higher grain yield both under herbicide and no herbicide conditions than Buloke at Meckering and Wongan Hills in 2008. Buloke appeared to have larger canopy area at maximum tillering stage than Baudin. However, this did not result in higher grain yield of Buloke, suggesting that there was a shift in the competitiveness of this cultivar.

In canola, the ranking of cultivars (based on the canopy area and light interception recorded at the rosette stage) did not correspond to the final grain yield. However, the ranking of cultivar competitiveness at the flowering stage (visual assessment of the floristic composition of canola cultivars and weed density) appears to correspond more closely to the grain yield of canola.

In wheat, Bonnie Rock had the largest canopy area and light interception at maximum tillering stage but did not appear to produce greater grain yield nor suppress more ryegrass heads than other cultivars except at Meckering in 2008. Of the remaining three cultivars, Calingiri showed higher canopy area and light interception at maximum tillering stage, but did not show a yield advantage in weedy or herbicide situations, suggesting that there was a shift in the competitiveness of this cultivar between vegetative and reproductive stages.

Seasonal and site conditions such as time of sowing, rate and speed of crop emergence, herbicide efficacy, herbicide toxicity, emergence time and type of weed present have a large influence on crop-weed dynamics. Even though there was not much difference in the suppression of annual ryegrass by crop cultivars, measurement of the amount of annual ryegrass seed production may indicate if cultivars do affect ryegrass seed production as a consequence of competition.

A small change in the competitiveness of the crop of the weeds between the vegetative and reproductive stage of the crop may have a large impact on the competitive interaction between crops and weeds (Hashem et al. 1998). Such a shift in the competitiveness of crop cultivars with age of crop and weed plants needs to be understood to allow improved predictions of crop yield.

Table 2 **Effect of herbicide and different crop cultivars on annual ryegrass heads (number/m^2) at Meckering and Wongan Hills in 2008 and 2009 seasons[a].**

Crops/Cultivars	Meckering				Wongan Hills	
	2008		2009		2009	
	Herbicide	No herbicide	Herbicide	No herbicide	Herbicide	No herbicide
Barley			–	–	–	–
Roe	1	11	16	40	36	145
Hindmarsh	3	9	–	–	–	–
Baudin	2	9	15	28	35	181
Buloke	1	19	–	–	–	–
Canola						
CB™ Tanami	7	34	20	51	175	426
CB™ Boomer	18	37	–	–	–	–
Bravo	17	24	24	53	80	465
Thunder	16	35	–	–	–	–
Wheat						
Wyalkatchem	1	25	18	47	32	204
Yitpi	3	11				
EG Bonnie Rock	2	13	14	37	26	140
Calingiri	1	15				
l.s.d. .05	11.5		20.6		111.9	

[a] Annual ryegrass head number is not available for Wongan Hills in 2008.

CONCLUSION

Crop-weed competition is highly dynamic under field conditions probably due to variation between seasons and sites. Barley and wheat cultivars appear to be more competitive than canola leading to greater suppression of annual ryegrass heads. Further studies on the interaction of seeding rate and row spacing should be undertaken to examine their impact on competitive ability of crops and crop cultivars.

KEY WORDS

barley, canola, wheat, cultivars, herbicide, seed rate, light interception, canopy area

ACKNOWLEDGEMENTS

We gratefully thank GRDC (Project DAW 00158), WANTFA, Avondale and Wongan Hills Research Station Support Units, and Glen Riethmuller. Special thanks are due to Chris Roberts, Barbara Sage and Aaron Middleton for technical assistance.

REFERENCE

Hashem, Abul, SR Radosevich & ML Roush 1998, Effect of proximity factors on competition between winter wheat (*Triticum aestivum*) and Italian Ryegrass (*Lolium multiflorum* Lam). *Weed Science*. 46: 181-190.

Project No.: GRDC project DAW00158

Paper reviewed by: Dr Dave Minkey

Mouldboard plough continues to kick goals

Peter Newman and **Dr Steve Davies**, Department of Agriculture and Food, Western Australia, Geraldton

KEY MESSAGES

Mouldboard ploughing across eight sandplain soil sites over three growing seasons has resulted in an average grain yield response of 320 kg/ha (for a range of crop types) and average weed control of 94 per cent. The key to success is to use this practice in the appropriate situation. This research (along with other research) is improving the ability to identify the appropriate soil types suited to mouldboard ploughing to achieve profitable and environmentally responsible results.

AIMS

(i) Evaluate mouldboard ploughing for paddock renovation at a number of sandplain soil sites.

(ii) Improve the ability to predict which soil types will give profitable responses.

(iii) Measure the long term effect of mouldboard ploughing on weed seed bank.

METHOD

Eight sites of varying size and degree of replication have been ploughed over the past three growing seasons. Sites were generally ploughed in June / July and sown immediately with a cover crop. They were then treated the same as the rest of the paddock in the following year/s. Where weeds were present they were assessed by conducting quadrat counts. Yield was assessed using either a small plot harvester, yield monitor or weigh trailer.

Table 1 **Summary of mouldboard plough trial and demonstration sites in the northern agricultural region of WA.**

Site	Design	Soil
Horwood	Un-replicated demo – 40 m x 10 m plot	Good yellow sand—low water repellence. Low weed seed bank.
Preston	4 rep small plot trial + lime treatments	Good yellow sand—low water repellence. Medium seed bank of ryegrass and radish.
Cosgrove	2 rep demo – 300 m long plots	Variable—weak sand to yellow sand to gravelly sand to duplex—1 t/ha to 4 t/ha yield range—severe water repellence. High seed bank of capeweed, ryegrass & radish.
Mitchell	3 reps long term radish trial – 50 m plots	Weak sand with large gravel stones—severe water repellence. High radish seed bank.
Holmes	2 rep demo 150 m long plots + 4 rep small plot trial with lime treatments	Good yellow sand—low to moderate water repellence. Moderate seed bank of ryegrass and radish.
Harding	300 ha ploughed – compared to nil area approximately 50 m away.	Water repellent / weedy top soil—good yellow sandy subsoil (5% clay). Very high seed bank of six weed species.
Ayers	2 rep demo plus deep rip and lime treatments – 200 m long plots	Water repellent / weedy top soil—good yellow sandy subsoil (5% clay). High ryegrass seed bank.
Forward	2 rep demo – 100 m long plots	Yellow sand—moderate water repellence. Moderate ryegrass and radish seed bank.

RESULTS

On average there was a 320 kg/ha grain yield response (of various crop types) to mouldboard ploughing across eight sites over three growing seasons. The range of yield response was from -127 kg/ha (Preston – canola) to 856 kg/ha (Harding – Wheat). The negative yield response of the canola at the Preston site in 2008 was due to poor canola establishment as a result of the seeder sinking in to the mouldboard plots and sowing the canola too deep.

On average there was 96 per cent control of annual ryegrass and 91 per cent control of wild radish across all sites. For some sites this is a single year result whereas for others this represents the weed control over two years following ploughing. For example, the ploughed plots of the Cosgrove site have been weed free since ploughing in 2007. The poor wild radish control at the Preston site in 2008 was due to poor site management as some wild radish was allowed to set seed in the 2007 cover crop.

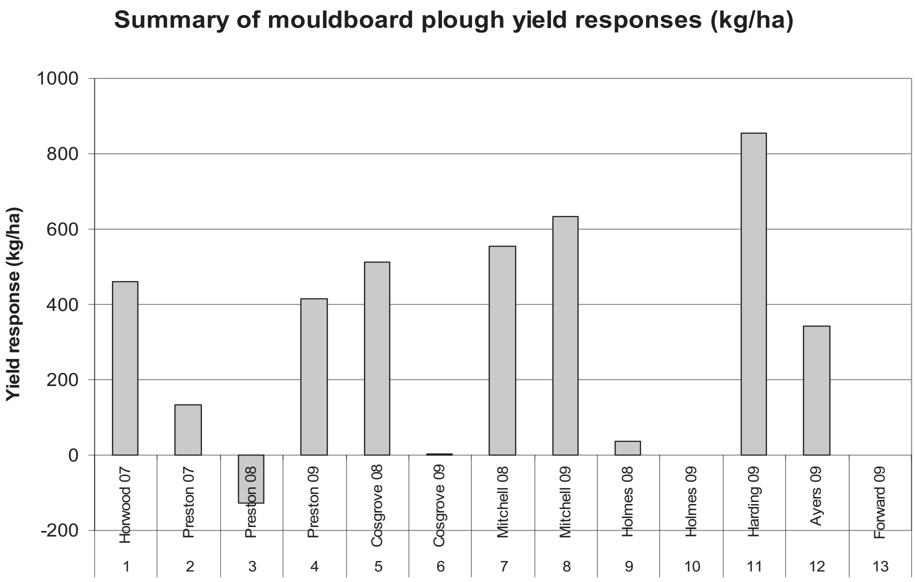

Figure 1 **Yield response to mouldboard ploughing (kg grain /ha) across seven sites near Mingenew.**

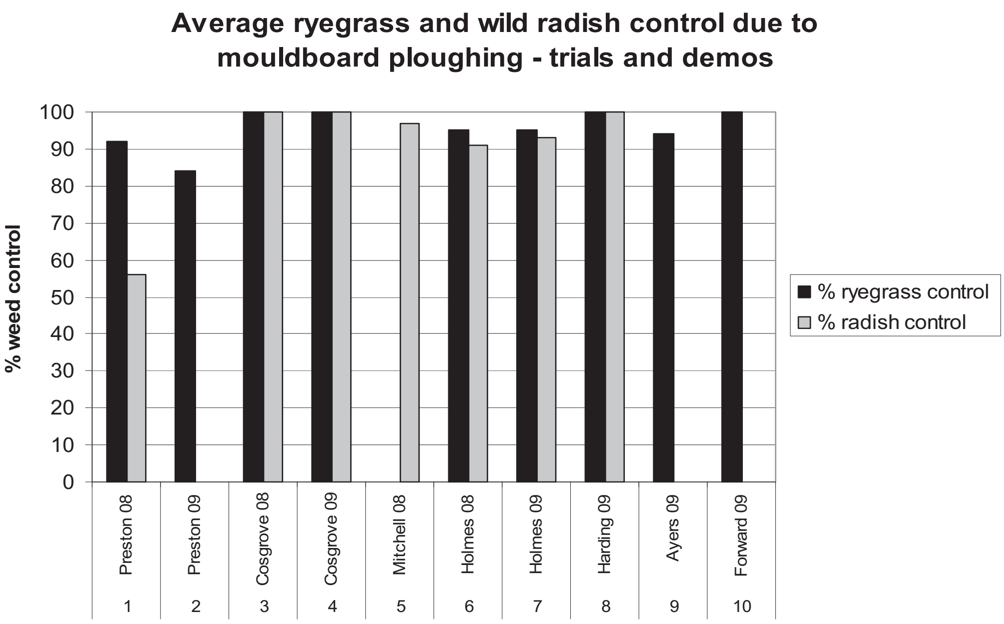

Figure 2 **Per cent weed control as a result of mouldboard ploughing across seven sites in the northern agricultural region of WA.**

DISCUSSION

The trials and demonstrations presented here should be considered as preliminary research in this area. In all cases excellent weed control has been achieved through the use of one-off mouldboard ploughing. The yield response to ploughing has been more variable. Some of this variability can be explained by site management, and soil type variability. There was an excellent break to the season in 2009 with all sites receiving at least 20 mm rain on 20 May. Consequently there was no difference in crop establishment observed between ploughed and nil treatments. Some of the interesting results from these sites are discussed below.

The Cosgrove site was ploughed by Rod Cosgrove in 2007 and cover cropped with wheat. In 2008 the whole site was sown to lupins and there was much improved establishment in ploughed areas and a 500 kg/ha yield response from ploughing. In 2009 the site was sown to wheat and there was no difference in yield between ploughed and non-ploughed. This site has variable soil types from weak white sand, to yellow sand to gravelly sand. In general, the yellow sand responded well to ploughing. The white sand did not respond to ploughing. The gravelly sand was high yielding (4.3 t/ha) and mouldboard ploughing slightly reduced this yield. So this is a good paddock to see where mouldboarding works well and where it does not. The weed control from mouldboarding was sensational. Ploughed plots are weed free. Nil plots have high levels of annual ryegrass, capeweed and wild radish. The plough brought up patches of hard setting clay at this site in a small area of shallow sandy duplex soil which was bare in the 2008 lupin crop. In 2009, these patches supported excellent growth of wheat.

Early research into mouldboard ploughing of sandplain soils in W.A. prompted Mingenew farmer, Tony Harding to import a large mouldboard plough and this machine ploughed 500 ha of sandplain soil in 2009. Tony’s machine is a nine furrow Kverneland plough fitted with skimmers. This plough is 4 m wide, works at a speed of 9 to 10 kph to a depth of 30 to 35 cm covering approximately 4 hectares per hour. The estimated cost of ploughing was $70 to $100 per hectare. Tony’s site was ploughed, rolled and sown to wheat on 5 June 2009. The site copped 90 kph winds three weeks after sowing that caused significant damage to the crop. The crop recovered from this wind event, however, the yields presented are from an area with less wind damage. The crop was not sprayed with any herbicides and was basically weed free. This is a great achievement given the massive seed bank of weeds in this paddock.

The Ayers paddock has been a poor performer for many years compared to neighbouring paddocks and the grower is looking for a solution. Mouldboard ploughing was compared to deep ripping and three rates of lime were applied perpendicular to the plots prior to ploughing and ripping. The lime response was not measured in 2009 although it will be measured in the future as the sub-soil pH is as low as 3.9. A yield response in the 2009 wheat crop of 342 kg/ha along with excellent weed control has prompted the grower to consider ploughing the entire paddock in years to come.

The Forward site is the one that has us puzzled. The site was ploughed in August 2008 and the mouldboard plots sown to barley for cover. The whole paddock was sown to wheat in 2009 and there was no significant yield response to ploughing. It is possible that there may be a difference in water / nutrient use of the 2008 barley cover crop compared to the surrounding 2008 lupin crop which has affected the 2009 wheat crop.

CONCLUSION

The trials and demonstrations here have demonstrated the potential of mouldboard ploughing of sandplain soil to increase crop yield through the reduction in the weed seed bank, alleviation of water repellence and potentially burying lime to correct sub-surface acidity. Future, more detailed research, will focus on improving the accuracy of selecting soils that are suitable to mouldboard ploughing.

KEY WORDS

mouldboard plough, renovation, annual ryegrass, wild radish, non-wetting sand

ACKNOWLEDGMENTS

Many thanks to all of the growers involved and to the Geraldton RSU for their straight driving and technical assistance. Thankyou also to Steve Davies for bringing his knowledge of soil science to this research.

Project No.: DAW00123

Paper reviewed by: Dr Steve Davies

The answer my friend is to burn in light wind

Peter Newman, Weeds Research Officer, Department of Agriculture and Food, Western Australia and **Michael Walsh**, Weeds Researcher, University of Melbourne

KEY MESSAGES

Many growers in the south west of Western Australia will be burning narrow harvest windrows for the first time this autumn. It is very important for these windrows to be burnt in the right conditions to achieve high levels of weed seed destruction while minimising fire escapes. Light wind (5 to 10 kph) during burning is critical to fuel the fire all of the way to the soil surface where the majority of weed seeds are.

AIMS

To inform growers and agronomists of the correct techniques for burning narrow windrows to maximise weed seed destruction while minimising the risk of fire escapes.

METHOD

This paper reports on research conducted between 2000 and 2007. The specific methodology of this research will not be quoted here in the interest of space. This research has been reported in previous crop updates. For specific research methodology please refer to previous update papers.

RESULTS

Burning temperatures to destroy weed seeds

Kiln studies conducted by Dr Michael Walsh determined that temperatures in excess of 400 °C for at least 10 seconds are needed to guarantee the death of ryegrass seed. The same study confirmed that 400 °C for 30 seconds is required to kill wild radish seed within their pod segments.

Standing stubble versus windrow burning

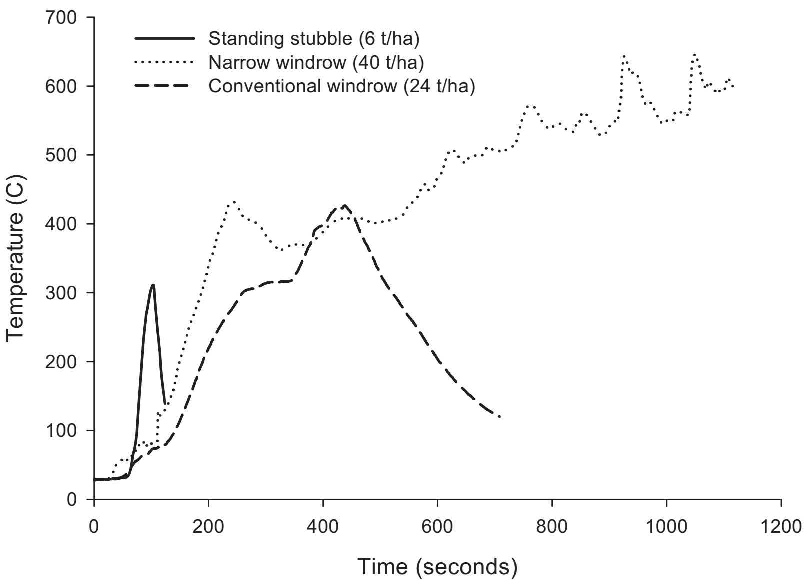

Figure 1 **Temperatures recorded during burning of standing wheat stubble, stubble in a conventional (wide) windrow and stubble in a concentrated (narrow) windrow at Konongorring in 2004.**

The conventional windrow and narrow windrow treatments burnt at higher temperatures over a much longer period than the standing stubble (Figure 1). The conventional windrow was created by simply removing straw spreaders from the rear of the header.

Wind speed effects on narrow windrow burning

The high wind speed treatment produced the highest burning temperature and the shortest burning duration. The medium wind speed burnt slightly hotter than the low wind speed treatment (Figure 2).

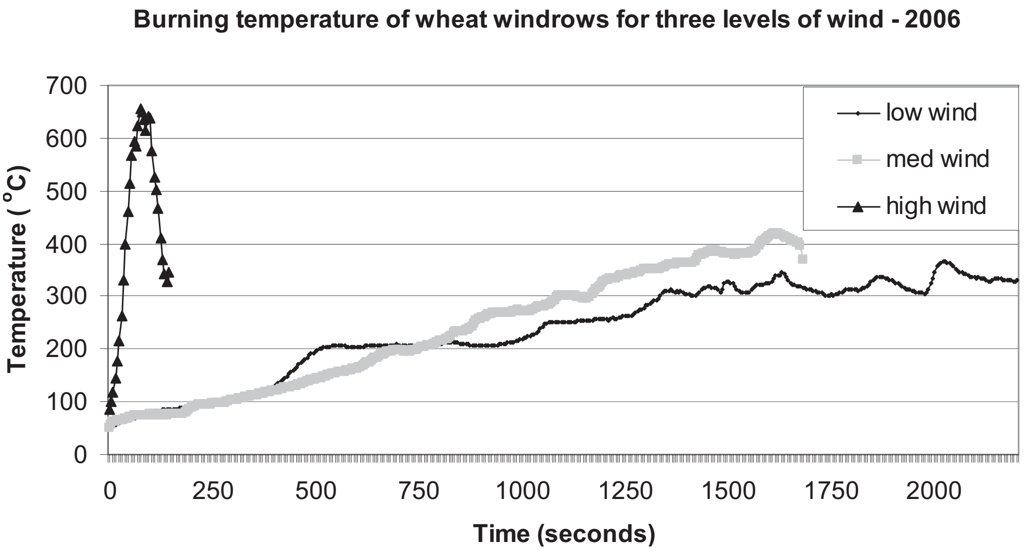

Figure 2 **Effect of wind speed on the burning duration and burning temperature at the soil surface of wheat stubble in narrow windrows. Low wind 0 to 5 kph; Med wind 5 to 15 kph; high wind 20 to 45 kph.**

Burning wet windrows

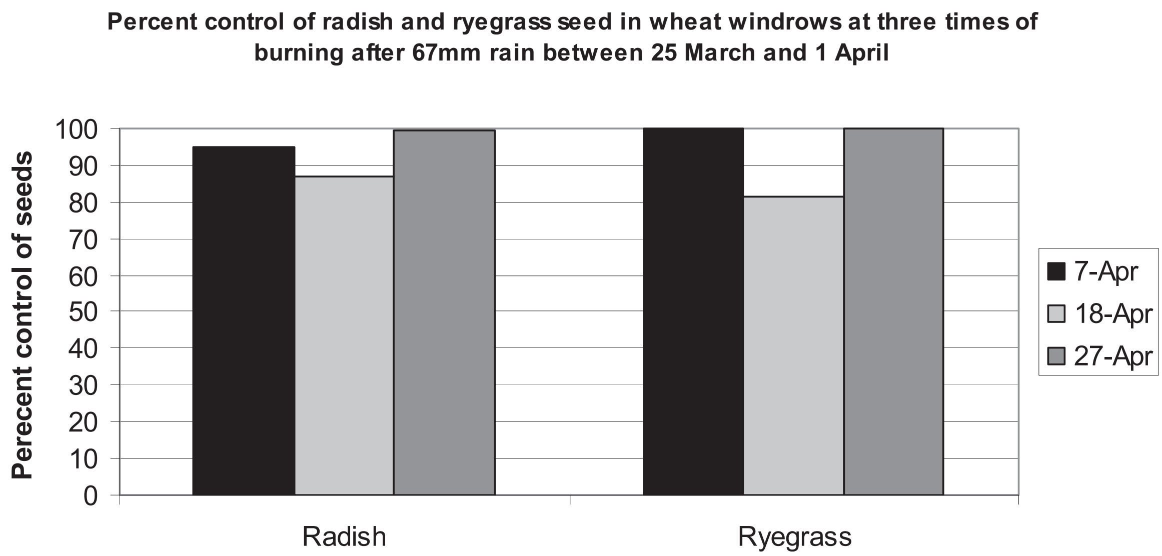

Figure 3 **Annual ryegrass and wild radish control (%) for three times of burning after 67mm rain fell between 25 March and 1 April 2005 near Mingenew.**

Annual ryegrass and wild radish control was measured by placing a known number of ryegrass and wild radish seeds on sand in aluminium pie dishes and placing them under the windrow. After burning, these seeds were recovered and germinated on agar to determine seed viability. Burning temperatures at the soil surface were measured for each burn but are not presented here.

What are the long term effects?

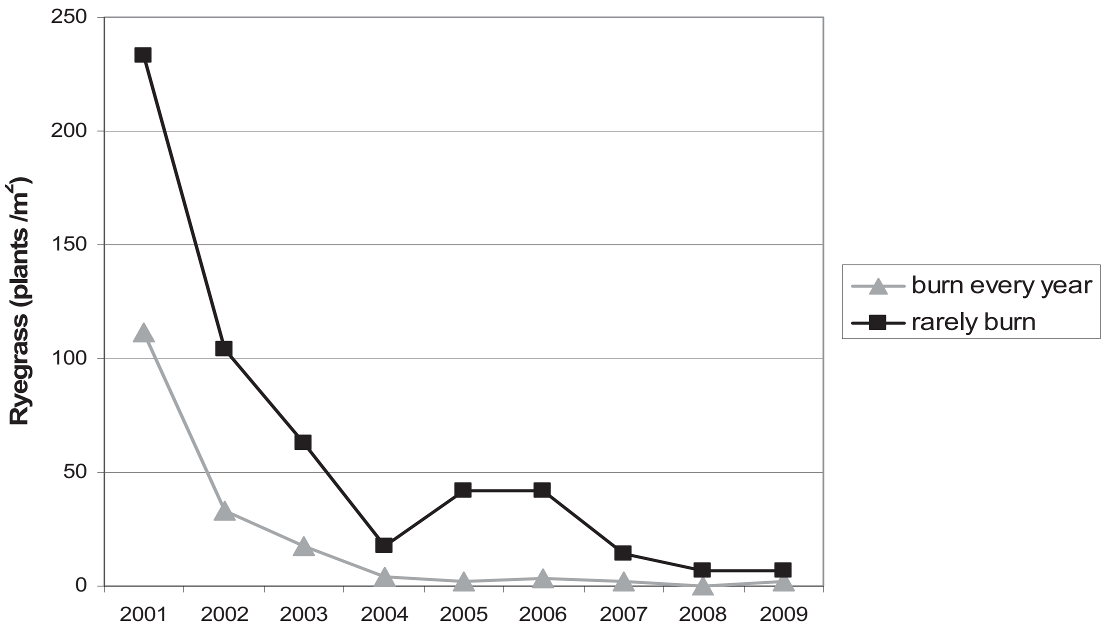

Figure 4 **Ryegrass density (plants / m2 counted in August each year) from focus paddocks of seven growers who burn windrows or tow a chaff cart at harvest every year compared to sixteen growers who rarely practice harvest weed seed management.**

CONCLUSION

The kiln studies conducted by Michael Walsh demonstrate that wild radish seeds require a longer burning time and/or hotter temperatures than annual ryegrass to guarantee that they are killed. Whole paddock burning will often create temperatures hot enough for long enough to destroy a high percentage of ryegrass (80 per cent) but will give un-satisfactory results for wild radish (10 per cent). Burning narrow windrows creates higher temperatures than whole paddock burning greatly increasing control of a range of weed seeds while leaving the majority of the paddock with adequate stubble cover to minimise wind erosion.

By the time the burning season begins in March / April, the vast majority of weed seeds have settled to the soil surface beneath the windrow. Therefore it is necessary to create high temperatures at the soil surface to destroy the weed seeds. Light wind (5 to 10 kph) is necessary during burning to facilitate this. There is research evidence showing that windrows burn hotter when there is light wind compared to burning in still conditions. Additionally, observations by researchers and growers during burning are that the complete burning of windrows is only achieved in a light wind. The main observation is that burning during still conditions leads to the fire smothering itself and the ash at the soil surface does not smoulder/glow red as it does when there is light wind. This results in a layer of un-burnt trash at the soil surface under the ash.

Grower case studies have demonstrated that harvest weed seed management is very successful at eroding the seed bank of resistant weeds in cropping situations. Growers who don't burn windrows or tow a chaff cart have still managed to erode ryegrass seed banks. However, this has been achieved largely through the use of trifluralin (often every year) and they continue to have a residual ryegrass seed bank. Growers who have burnt windrows or towed a chaff cart every year took only three growing seasons to severely erode their ryegrass seed bank and have had six seasons of very low ryegrass numbers since. It seems ironic that we would spend a growing season killing weeds with a number of herbicide applications only to go and spread the survivors evenly over the paddock at harvest. Narrow windrow burning has been very successful for a number of growers and is now widely adopted. However, it is not without its pitfalls and a future innovation such as the Harrington Seed Destructor will be a welcome successor to windrow burning. Such an innovation may facilitate harvest weed seed management of all crops as opposed to only burning windrows over a percentage of the farm.

The Art of Burning Narrow Windrows – tips for new players

Large wind erosion events that result from broad scale burning of paddocks are unacceptable. The art of burning is to burn only that fraction that contains weed seeds and leave the majority of the paddock with residues retained.

There are a few simple rules to follow:

- Consult you local shire/fire warden for burning regulations.
- Always have fire fighting equipment on hand.
- Harvesting up and back is ideal but not essential.
- Concentrate crop residues into a 600 mm to 700 mm wide windrow using a chute mounted to the rear of the header. Harvest low to minimise the risk of the fire spreading into adjacent stubble.
- To minimise the risk of escapes, commence burning in the late afternoon if permitted. Grower experience has been that most escapes occur while burning in the middle of the day where burning embers blow to adjacent paddocks/bush.
- Burn the outside two laps of the paddock first before commencing the remainder of the paddock.
- Burn in light wind—5 to 10 kph is ideal. Still conditions do not fuel the fire to the soil surface and are often associated with hot weather where willi willis can pick up burning stubble.
- A light cross wind is regarded by growers as being the ideal direction to fuel the fire to the soil surface.
- It is **not** necessary to burn on a hot day. The windrow will burn adequately if it is dry and there is light wind.
- Light up windrows every 200 m or so to burn out in reasonable time. If attempting to burn into the wind have a second person with a fire fighter following to extinguish the downwind fire.
- Lupin and canola windrows can be burnt with the wind as there is low risk of fire escapes, although a light cross-wind is ideal. The biggest risk of fire escape is two year old wheat stubble. If this is a problem, burn into the wind.
- Wheat windrows can be very challenging to contain to the windrow. Wheat crops over 2 to 2.5 t/ha are generally not recommended for windrow burning due to excess bulk. Wheat windrows should be burnt into the wind under cooler conditions eg. at night if permitted.
- Avoid barley stubbles. The extra leaf material makes it difficult to contain the fire to the windrow. If you have made barley windrows try a light graze to eat off excess leaf material prior to burning.
- If there is rainfall allow 10 to 14 days for the windrows to dry before burning. If there is a germination of green weeds in the windrow it may be necessary to spray prior to burning.
- Budget on additional fertiliser, particularly potash. Windrow burning is not recommended for fully matched tramline farming systems due to banding of nutrients in the same place each year.
- When harvesting with the chute attached to the rear of the header, if stopping in the crop it is necessary to reverse the header immediately to avoid blockages.

KEY WORDS

burning, narrow windrow, annual ryegrass, wild radish

ACKNOWLEDGMENTS

Many thanks to Michael Walsh for his collaboration on this research and to the growers involved. Many thanks to GRDC for supporting this controversial research.

Project No.: DAW00123

Paper reviewed by: Dr Michael Walsh

Using image analysis to detect three-horned bedstraw seed in grain samples

John Moore, Department of Agriculture and Food, Western Australia, Albany and **Murray Gillespie**, Lygil Holdings, Albany, Western Australia

KEY MESSAGES

Detecting three-horned bedstraw in grain samples using image analysis is a cost effective way to determine the extent of the bedstraw infestation in WA.

BACKGROUND

Three-horned bedstraw (*Galium tricornutum*) is a declared weed that is currently the focus of an eradication campaign in Western Australia. Knowing the extent of a weed infestation is required to justify a weed eradication program as this has a large influence on the benefit:cost ratio. Detecting weeds at low levels in the environment is both difficult and expensive and a large number of samples are required. For weeds that contaminate grain, large numbers of samples can be collected cheaply as the grain is delivered for sale and these samples can be screened for weed seed.

Using image analysis allows large numbers of samples to be screened quickly. This paper describes a system where a video camera is set up over a conveyor belt and the images are analysed for the presence of three-horned bedstraw seed.

AIMS

To provide a method of rapidly screening large numbers of grain samples for three-horned bedstraw seed.

METHOD

A machine was built based on an old conveyor belt pot sprayer. An accurate feeding mechanism delivers grain to the belt which then travels under a video camera and then on to a drafting gate mechanism where grain containing suspect seeds is directed into a separate container for further analysis (Figure 1).

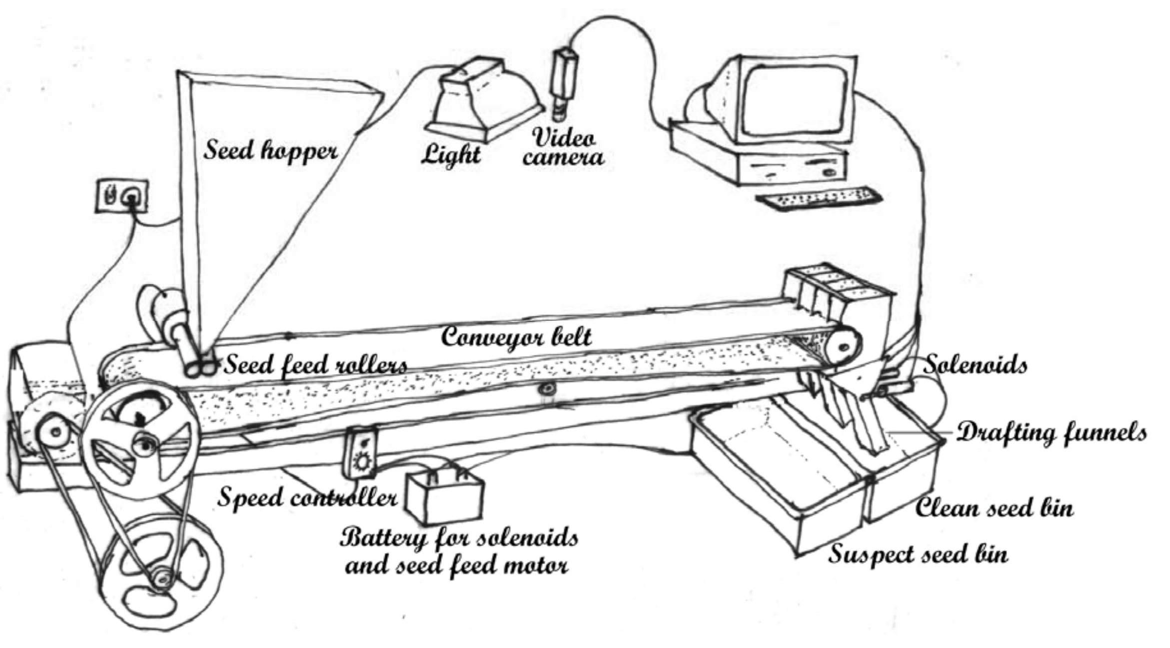

Figure 1 **The setup of the machine for detecting foreign seeds in grain samples.**

The video camera is attached to a computer running the Halcon 9 image analysis software. This returns 25 characters for each seed or object. These characters are captured by a program we developed and are used to determine if the object is similar to bedstraw. If so, the program sends a pulse to open the appropriate drafting gate to separate the seed from the bulk sample. The characters are also stored in a database.

To train the system, bedstraw seeds and a sample of bedstraw-free grain are passed under the camera in two separate runs and the 25 characters are recorded. Discriminant analysis (in Genstat) is used to produce a formula which best separates the bedstraw from the grain and other debris. This formula is entered into the program for analysing future samples potentially containing bedstraw.

Grain samples to be screened are passed through the machine. When a suspect seed is detected the grain is automatically diverted to a separate container. Grain from this container is then manually scanned or put through the machine again to further concentrate the sample.

RESULTS

An accuracy of 98 per cent detection is regularly achieved for bedstraw in the cereal grains. In canola the accuracy is typically around 90 per cent because the bedstraw seed is very similar in size and colour to canola.

A significant amount of programming was required to take the data captured by the Halcon software, store it and analyse it quickly enough to operate the drafting gates before the seed had arrived at the gates.

The throughput is about 100 kg per hour. About 100, one-kilo samples are typically processed in a day due to the time taken to load, dispose and record individual samples.

CONCLUSION

The system is suitable for detecting bedstraw large numbers of small samples where the sample can be fed through slowly enough to allow reasonable separation between individual seeds on the belt. Currently it is not suitable for deployment on commercial conveyor belt systems where there is a depth of grain on the belt.

It is estimated that the cost per sample is 90 per cent less than visual screening. The relative accuracy of the two methods under normal conditions has not been compared.

The system is also being tested to detect insects in grain from a GRDC project investigating insect contamination of grain.

KEY WORDS

Discriminant analysis, *Galium tricornutum*, grain samples, Halcon, image analysis, seed detection, three-horned bedstraw.

ACKNOWLEDGMENTS

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Project No.: DAFWA, PQZ/001/331

Paper reviewed by: Jennifer Westwood

Can we manage brome and barley grass in cereals?

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KEY MESSAGES

- The pre-emergent application of metribuzin, trifluralin or Boxer Gold® followed by Monza® reduced barley and brome grass by over 80 per cent with good wheat yields. The combination of metribuzin and Monza® is the cheapest to apply.
- Do not rely on the stand-alone usage of pre- and post-emergent herbicides to completely control barley grass and brome grass in cereals.
- These grasses need to be strategically managed prior to sowing to cereals.

BACKGROUND AND AIM

The last few seasons have had late starts prompting many farmers to sow directly on the break or even dry. The lack of effective pre-planting control (coupled with the adoption of conservation tillage) has resulted in widespread increases in barley grass (*Hordeum leporinum*) and brome grass (*Bromus diandrus* and *B. rigidus*) in cereals.

There is a lack of effective post-emergent herbicides for the control of barley grass and brome grass in traditional wheat varieties. Alternatives include using metribuzin-tolerant wheat varieties such as Eagle Rock or Clearfield varieties which can be sprayed with Midas® or Intervix®. Are these effective treatments for the control of brome and barley grass on their own? Do we also need to consider integrated weed management techniques such as the control of seed set in the previous season or one or two knockdowns prior to sowing?

This trial investigates the control of barley grass and brome grass in wheat using pre- and post-emergent herbicides.

METHOD

A site at Katanning (Great Southern Agricultural Research Institute) was selected in 2008 with a background population of barley grass (*Hordeum leporinum* Link.) and great brome (*Bromus diandrus* Roth). The trial was sown to Eagle Rock® wheat and Clearfield Janz® wheat on 3 June 2009, one week after the break of the season. The barley and brome grass was at the one-leaf stage. The trial had a randomised split-plot block design with 11 herbicide treatments and 4 replicates. The treatments were a range of pre-emergent herbicides either applied singly or in combination with a post-emergent herbicide. There were no knockdowns applied.

Measurements taken throughout the season included crop and weed densities, dry weights at anthesis and yield and grain protein.

This trial was repeated at Beverley on a heavy infestation of barley grass.

Herbicide treatments

Eagle Rock® wheat

1. Metribuzin (750 g/kg) at150 g/ha, IBS
2. Metribuzin (750 g/kg) at 200 g/ha, IBS + Monza® (sulfosulfuron) (750 g/kg) at 25 g/ha, PO
3. Boxer Gold® (S-metalochlor (120 g/L) + prosulfocarb (800 g/L)) at 2.5 L/ha, IBS
4. Boxer Gold® (S-metalochlor (120 g/L) + prosulfocarb (800 g/L)) at 2.5 L/ha, IBS + Monza® (sulfosulfuron) (750 g/kg) at 25 g/ha, PO
5. Trifluralin (480 g/L) at 2 L/ha IBS
6. Trifluralin (480 g/L) at 2 L/ha IBS + Monza® (sulfosulfuron) (750 g/kg) at 25 g/ha, PO
7. Diuron (900 g/kg) at 450 g/ha, IBS
8. Diuron (900 g/kg) at 450 g/ha, IBS + Monza® (sulfosulfuron) (750 g/kg) at 25 g/ha, PO
9. Monza® (sulfosulfuron) (750 g/kg) at 25 g/ha, PO
10. Untreated

Clearfield Janz® wheat

1. Intervix® (imazamox (33 g/L) + imazapyr 15 g/L)) at 500 mL/ha, PO (Z14–37)

(Note: IBS = incorporated by sowing, PO = post-emergent.)

RESULTS

A slow start to the season and non-wetting resulted in a staggered germination of the wheat but a good germination of barley grass. Early counts indicated that approximately 100 barley grass and brome grass plants (/metre^2) germinated across the trial. Barley grass was the predominant grass weed although brome grass and annual ryegrass were also present.

All of the pre-emergent herbicides resulted in some control (50–70 per cent) of barley grass in Eagle Rock® wheat, as shown by the head numbers, although none were completely effective (Figure 1). An additional post-emergent application of Monza® further improved barley grass control. The application of Monza® after metribuzin, Boxer Gold® and trifluralin controlled both grasses by over 80 per cent. Applied as a single application, Monza® only marginally reduced the number of barley heads but the size of the individual heads was decreased. It was sprayed 6 weeks after sowing and the grasses were possibly little too big. In Clearfield Janz®, Intervix® also controlled barley grass by over 80 per cent reducing the number and size of the barley grass heads and delaying their emergence. Similar results were found at Beverley.

Although the brome grass numbers were low across the trial, only metribuzin, Boxer Gold® and trifluralin in combination with Monza® reduced head numbers.

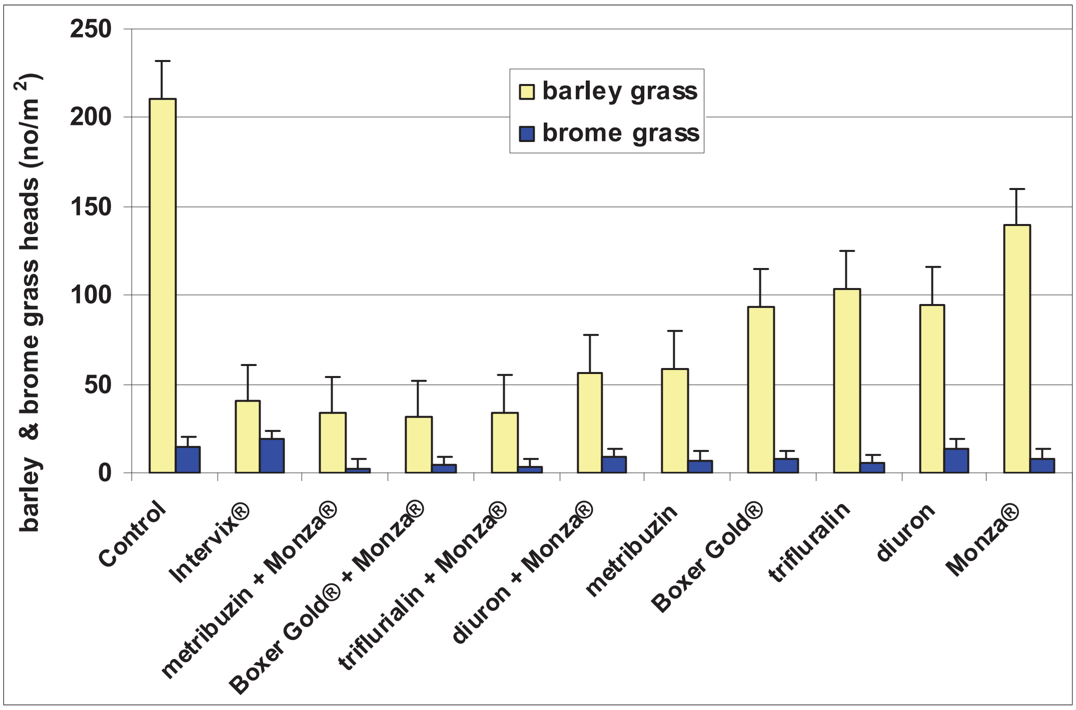

Figure 1 **The effect of 11 herbicide treatments on the number of barley and brome grass heads (heads/m^2) in Eagle Rock® and Clearfield Janz® wheat.**

The high numbers of grass weeds in the crop resulted in reduced wheat yields by over 60 per cent (Figure 2). The metribuzin and Monza® treatment had the highest yield and the lowest weed count but this was not significantly different than a range of other products. The greater the number of brome and barley grass present, the greater the reduction in yield. Clearfield Janz® was the exception however; producing poor yields despite reasonable control of barley grass. This variety seemed to struggle with the dry start to the season compared with Eagle Rock®.

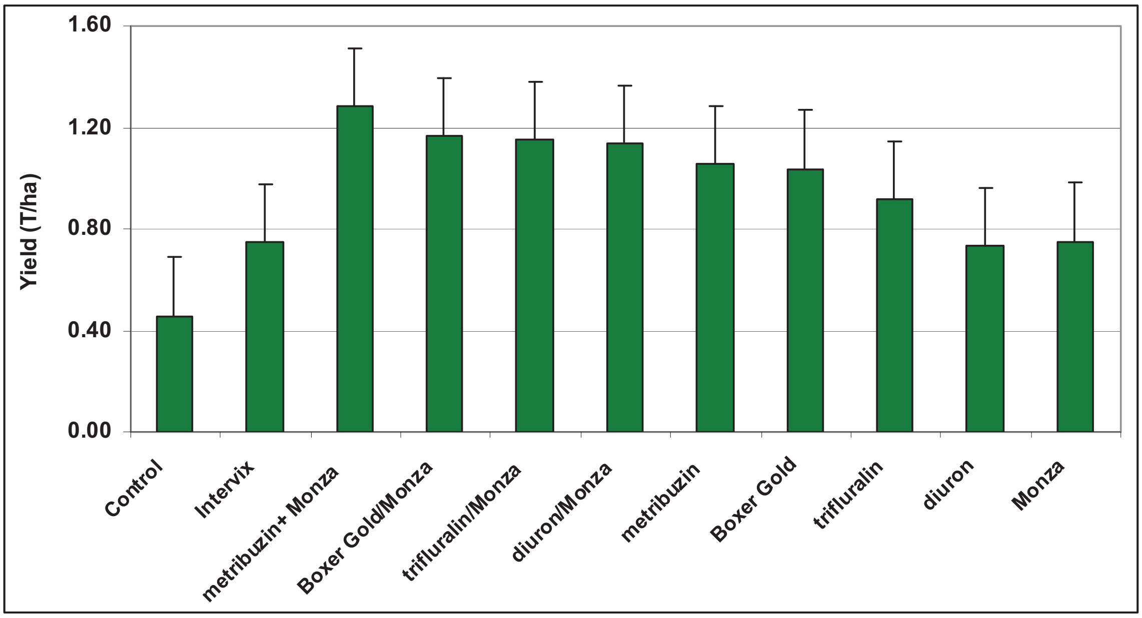

Figure 2: **The effect of barley and brome grass control by 11 herbicide treatments on the yield (t/ha) of Eagle Rock® and Clearfield Janz® wheat.**

CONCLUSIONS

- It is difficult to effectively control barley grass and brome grass in cereals with pre- and post-emergent herbicides alone. The pre-emergent application of metribuzin followed by Monza® reduced barley and brome grass by over 80 per cent and produced the best yield. Other pre-emergents such as trifluralin and Boxer Gold® in combination with Monza® also controlled the grass weeds and produced good yields but are more expensive to apply. The application of Intervix® also controlled barley grass to over 80 per cent but the yields of Clearfield Janz were poor. This variety struggled with the late start to the season.
- In this trial, some of the herbicide treatments reduced the number of barley grass heads by 80 per cent but there were still over 30 heads/m^2 produced. These heads can produce over 750 weed seeds/m^2 to compete with your crop in the following season.
- Integrated weed management should be employed to control barley and brome grass. Strategically-timed pasture spray-topping in the previous season can reduce both barley grass and brome grass seed set by over 85 per cent and should be considered when planning to crop after pasture. Over 99 per cent of barley grass and *Bromus diandrus* (the brome grass species in this trial) seeds germinate within 1–2 weeks of the break of the season. These seedlings can then be effectively controlled using knockdowns prior to sowing. The yield loss attributed to the delayed sowing is likely to be less than the yield loss due to weed competition. The use of other rotations, such as herbicide-tolerant canola, may effectively control these grasses.

KEY WORDS

brome grass, barley grass, herbicides, IT wheat, Clearfield wheat, Monza, metribuzin, trifluralin, Boxer Gold®, diuron, Intervix®

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Controlling mature fleabane

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KEY MESSAGES

- In summer, glyphosate or glyphosate + 2,4-D amine followed by a 'double-knock' with paraquat 7 days later kills 100 per cent of mature fleabane. Glyphosate or glyphosate + 2,4-D amine applied as a single dose also provides good control.
- In late spring, diquat can be used as a salvage spray in-crop provided the fleabane is small (less than 5 cm).
- Monitoring winter crops following spring rain will enable effective control of small fleabane before harvest.

BACKGROUND AND AIMS

Flaxleaf fleabane (*Conyza bonariensis*) is becoming more prevalent in Western Australia, spreading from the south coast to other parts of the wheatbelt. Tall fleabane (*C. sumatrensis*) is also prevalent, particularly in the wetter areas. There has been some indication of the two species hybridising in the field although this is as yet unconfirmed.

In WA, fleabane germinates in spring, often after the spray window for early post-emergent herbicides. The remaining opportunities for control are either late post emergent spraying, a salvage herbicide application prior to harvest or after harvesting is complete. Once the crop is removed, the fleabane has no competition for light or moisture and can grow rapidly, especially with further summer rain. By this time, the fleabane plants are often large, have an extensive root system and a reduced leaf area and are tolerant to most herbicides.

This paper presents the results of two trials to investigate the control of mature flaxleaf fleabane at two times of the year, late spring and late summer

METHOD

Trial 1, Frankland

The first field trial was in Frankland in February 2009, where flaxleaf fleabane had continued to grow after harvest. This trial investigated the control of large fleabane in stubble using a 'double-knock' strategy. Ten single dose herbicides were applied on 29 January followed by an application of paraquat across half the plot 7 days later. Visual assessments were made 21 and 47 days after the initial herbicide application. This trial was a randomised split-plot design with blocks and three replicates.

Initial Herbicide Treatments

1. Untreated
2. 2,4-D amine (625 g/L) at 2 L/ha
3. Amitrole (250 g/L) at 5 L/ha
4. Grazon Xtra® (aminopyralid + picloram + tricolpyr (8 + 11 + 300 g/L)) at 400 mL/ha
5. Glyphosate (540 g/L) at 2 L/ha
6. Pyresta® (2,4-D LV ester + pyraflufen-ethyl (421 + 2 g/L)) at 900 mL/ha
7. Raptor® (imazamox (700 g/kg) at 50 g/ha
8. Diuron (900 g/kg) at 2 kg/ha
9. Glyphosate (540 g/L) at 2 L/ha) + 2,4-D (625 g/L) at 2 L/ha
10. Diuron (900 g/kg) at 500 g/ha + 2,4-D amine (625 g/L) at 2 L/ha

(NB: All treatments with 1 per cent oil.)

Trial 2, Kendenup

The second trial was in Kendenup where flaxleaf fleabane had germinated in late August through September, 2009. The site had been sown to oats and was cut for hay in early November, after which the fleabane had flourished due to lack of competition. Six herbicide treatments were applied on November 9 to vegetative plants (3–10 cm rosette to early bolting). This trial was a randomised block design with four replicates.

Herbicide treatments

1. Untreated
2. Diquat (200 g/L) at 3 L/ha
3. 2,4-D amine (625 g/L) at 1.7L/ha
4. 2,4-D amine (625 g/L) at 1.7L/ha + metsulfuron (600 g/kg) at 5 g/ha
5. Fluroxypyr (200 g/L) at 750 mL/ha + metsulfuron (600 g/kg) at 5 g/ha
6. Metsulfuron (600 g/kg) at 5 g/ha

RESULTS

Trial 1, Frankland

Both glyphosate and glyphosate + 2,4-D amine followed by a ‘double-knock’ with paraquat seven days later (see Table 1) provided complete control of fleabane. Both of these herbicide treatments (glyphosate and glyphosate + 2,4-D amine) applied as a single dose also provided good control with no seed set and only a little evidence of green plant tissue. Amitrole and 2,4-D amine also provided good control but only after the double-knock with paraquat.

Table 1 **Visual assessments of herbicide treatments on mature flaxleaf fleabane in Frankland, 2009**

Initial herbicide	Visual assessment after 47 days	Visual assessment + paraquat after 47 days
Glyphosate	4.5	5
Glyphosate and 2,4-D amine	4.5	5
Amitrole	2.5	4.5
2,4-D amine	2	4.5
Diuron granules + 2,4-D amine	1.5	4
Grazon Extra®	1.5	4.75
Pyresta®	1	2.5 to 5
Diuron granules	1	2.5 to 5
Raptor®	1	2.5 to 5
Control	1	2.5 to 4

Scale

1 = no effect
2 = some herbicide damage
3 = marginal control
4 = good control
5 = dead

Trial 2, Kendenup

The best herbicide options for flaxleaf fleabane in late spring are diquat and 2,4-D plus metsulfuron, depending on the size of the plants (Table 2). Diquat was very effective at controlling small fleabane (less than 5 cm) but the larger ones grew out of the treatment and were growing rapidly at six weeks. 2,4-D plus metsulfuron had not completely killed the fleabane plants at 6 weeks after spraying but the plants were yellow and stunted and unlikely to set seed.

Table 2 **Visual assessments of herbicide treatments on flaxleaf fleabane at Kendenup in December, 2009**

Herbicde	Visual assessment at 6 weeks after spraying	Notes
Untreated	1	Flowering
Diquat	2 to 5	Small plants have died but larger ones have regrown
2,4-D amine	3	Yellow
2,4-D admine + metsulfuron	4	Yellow, unlikely to flower
Starane® + metsulfuron	3	Yellow
Metsulfuron	2	Slightly yellow but likely to flower

Scale

1 = no effect
2 = some herbicide damage
3 = marginal control
4 = good control
5 = dead

CONCLUSION

- Mature fleabane is difficult to kill especially in mid to late summer. The most effective treatment is an application of glyphosate (> 2 L/ha) or glyphosate + 2,4-D amine followed by a 'double-knock' with paraquat 7 days. Glyphosate (> 2 L/ha) or glyphosate + 2,4-D amine applied as a single dose also provides good but incomplete control.
- Fleabane is also difficult to control in late spring. Diquat is effective on small fleabane but larger plants tend to grow out of it. 2,4-D plus metsulfuron provides adequate control of fleabane in the late vegetative stage when the crop has been removed (in this case for hay). It is unlikely to control fleabane as well where the crop has not been removed and the crop shades the fleabane, reducing the amount of herbicide reaching its' target.
- Small fleabane are relatively easy to control. A late post-emergent herbicide application of a Group I herbicide (pre-flag leaf emergence) should easily control small fleabane in cereals. Monitoring following spring rain is essential however as the germination of fleabane often coincides with flag-leaf emergence, making it too late to spray.

KEY WORDS

Flaxleaf fleabane, herbicides, glyphosate, 2,4-D, amitrole, diuron, Pyresta®, Grazon Extra®, Raptor®, metsulfuron, Starane®, diquat

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