Chemical control of bedstraw (*Galium tricornutum* Dandy) in wheat, barley, field peas, chickpeas and faba beans in southern Australia

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Summary

Field experiments were carried out in Victoria between 1991 and 1994 to assess the efficacy of selective herbicides for the control of bedstraw in commercial field crops. Imazethapyr provided acceptable control of bedstraw in faba beans, field peas and chickpeas when applied pre-emergence, and in field peas post-emergence. Chickpea and faba beans were intolerant to imazethapyr applied post-emergence. Flumetsulam applied post-emergence gave effective control of bedstraw seed production in chickpeas and field peas. Faba beans were intolerant to flumetsulam. Bentazone, pyridate, diflufenican, simazine and metribuzin failed to give adequate control of bedstraw in pulse crops.

In wheat and barley, chemicals applied early post-emergence that provide acceptable crop safety and control bedstraw, include bromoxynil + MCPA ester + dicamba, flumetsulam, bromoxynil + diflufenican, fluroxypyr and amidosulfuron. Metsulfuron-methyl, metsulfuron-methyl + bromoxynil + MCPA ester, bromoxynil + MCPA ester and chlorsulfuron did not consistently control bedstraw in cereals. Bedstraw can be effectively controlled at later cereal growth stages with 2,4-D amine or fluroxypyr. Yield responses to chemical control of bedstraw were greater with herbicide applied earlier than later in the growing season.

The implication of chemical control options on potential herbicide resistance development in bedstraw is discussed.

Introduction

Bedstraw, *Galium tricornutum* (Dandy), has become a major problem weed in south-eastern Australia particularly in South Australia and the Wimmera region of Victoria (Amor and Kloot 1987, Black *et al.* 1994) and continues to spread through the movement of stock, contaminated seed and machinery.

There are limited data in the literature on the control of bedstraw in field crops under Australian conditions. Black *et al.* (1994) reported that options for bedstraw control with 90% or higher efficacy, and satisfactory crop tolerance in wheat and barley included fluroxypyr, dicamba, dicamba + MCPA ester, dicamba + MCPA ester + bromoxynil, chlorsulfuron, triasulfuron + terbutryne and diflufenican + MCPA ester. Imazethapyr post-sowing pre-emergence or post-emergence and imazethapyr + metribuzin post-emergence or flumetsulam were the most effective treatments for control of bedstraw in field peas achieving 80–90% control. Stephenson's (1992) report on the biology of bedstraw is based largely on the closely related species cleavers (*Galium aparine* L.) and highlights the limited information in the literature about bedstraw.

This paper reports the results of herbicide evaluation experiments carried out in wheat, barley, chickpeas, field peas and faba beans from 1992–1994 with the objective of developing recommendations for effective control of bedstraw in southern Australia.

Method

Field experiments (randomized complete block design) were conducted in commercial crops growing in self mulching grey clays with surface pH, in water, of 7.5–8.6 or on red sandy clay loams with surface pH, in water, of 7–8.5 in the western Wimmera (Table 1). Experiments consisted of four replicates with plots (either 2, 3 or 6 m wide and 20 m long) laid across the direction of sowing, and always including unsprayed controls. In each experiment control plots, and one herbicide treatment, were 6 m wide and were used for seedling recruitment studies (results not presented) and the yield experiments reported here. Buffers of 10–15 m were left around sites, to avoid spray drift onto the experimental area from co-operator applications to the rest of the paddock. Normal management practices, except for herbicide applications, were carried out by the co-operator as part of their crop maintenance program.

Herbicides and rates were chosen following discussions with chemical company representatives, resellers and grain

Table 1. Details of experimental sites.

Trial identification code	Year	Crop	Location	Soil type	Surface pH (water)
91W	1991	Wheat	Yearinga	sandy loam over clay with free limestone	8.6
92Wa	1992	Wheat	Yearinga	red / grey clay	8.0
92Wb	1992	Wheat	Serviceton	grey clay	8.3
93Wa	1993	Wheat	Serviceton	grey clay	8.4
93Wb	1993	Wheat	Yearinga	sandy loam over clay with free limestone	8.5
92Ba	1992	Barley	Yearinga	red sandy loan	7.2
92Bb	1992	Barley	South Lillimur	grey clay	8.3
93Ba	1993	Barley	Netherby	grey clay	8.1
93Bb	1993	Barley	South Lillimur	grey clay	8.6
92CPa	1992	Chickpeas	Yearinga	red / grey clay	7.5
92CPb	1992	Chickpeas	Kaniva	grey clay	8.4
93CP	1993	Chickpeas	South Lillimur	grey clay	8.2
91BE	1991	Faba beans	Serviceton	grey clay	8.6
92BE	1992	Faba beans	Serviceton	red sandy loam	7.5
93BEa	1993	Faba beans	Serviceton	grey clay	8.1
93BEb	1993	Faba beans	South Lillimur	grey clay	8.3
91P	1991	Field peas	Yearinga	sandy loam	7.6
92P	1992	Field peas	Serviceton	grey clay	8.4
93Pa	1993	Field peas	Kaniva	grey clay	8.5
93Pb	1993	Field peas	South Lillimur	grey clay	8.5

Table 2. Herbicide treatment effects on yields of bedstraw seed and wheat.

Treatment	Rate (g ha^{-1})	Wheat yield % of untreated control						Bedstraw seed yield % control					
Trial identification number		91 W	92 Wa	92 Wb	93 Wa	93 Wb	**Average**	91 W	92 Wa	92 Wb	93 Wa	93 Wb	**Average**
Pre-sowing													
Trifluralin	400	116					**116**	-25					**-25**
Trifluralin + Late post- emergence 2,4-D amine	400 + 850	149^{+}					**149**	99^{+}					**99**
Early post-emergence (Z14–23)													
Chlorsulfuron	11.25 or 18.75	266^{+}	157^{+}	128^{+}	129^{+}	136^{+}	**163**	92^{+}	99	97^{+}	51	84^{+}	**85**
Metsulfuron-methyl	4.2	196^{+}	164^{+}	127^{+}	133^{+}	115	**147**	82^{+}	96	100^{+}	69	68^{+}	**83**
Bromoxynil + MCPA ester + metsulfuron-methyl	200 + 200 + 4.2	199^{+}	156^{+}	128^{+}	135^{+}	129^{+}	**149**	95^{+}	83	91^{+}	74^{+}	63	**81**
Bromoxynil + MCPA ester	280 + 280		162^{+}	130^{+}	151^{+}	126^{+}	**142**		94	100^{+}	91^{+}	74^{+}	**90**
Bromoxynil + MCPA ester + dicamba	196 + 392 + 56	201^{+}	160^{+}	122^{+}	136^{+}	132^{+}	**150**	96^{+}	100	100^{+}	99^{+}	99^{+}	**99**
Diflufenican + bromoxynil	27.5 + 275		168^{+}	126^{+}	147^{+}	128^{+}	**142**		91	100^{+}	91^{+}	85^{+}	**92**
Flumetsulam + non ionic surfactant	16 + 0.6%		159^{+}	117^{+}	126^{+}	121^{+}	**131**		99	100^{+}	100^{+}	99^{+}	**99**
Flumetsulam + Uptake®	16 + 0.5%		153^{+}	116^{+}	112	131^{+}	**128**		99	100^{+}	100^{+}	100^{+}	**99**
Fluroxypyr	120		156^{+}	117^{+}	140^{+}	130^{+}	**136**		100	100^{+}	98^{+}	100^{+}	**99**
Fluroxypyr	200		135^{+}	110	143^{+}	130^{+}	**130**		69	100^{+}	100^{+}	100^{+}	**92**
Amidosulfuron	11.25				130^{+}	123^{+}	**127**				98^{+}	95^{+}	**97**
Amidosulfuron	15				141^{+}	131^{+}	**136**				98^{+}	100^{+}	**99**
Mid-tillering (Z 23–31)													
Dicamba	48	118					**118**	79^{+}					**79**
Diflufenican + bromoxynil	27.5 + 275	113	124^{+}		148^{+}	108	**123**		93		97^{+}	82^{+}	**90**
Diflufenican + MCPA ester	25 + 250	113	133^{+}				**123**	74^{+}	93				**84**
Fluroxypyr	120		143^{+}	98	126^{+}	122^{+}	**122**		98	70^{+}	100^{+}	100^{+}	**92**
Fluroxypyr	200	134	151	98	118	112	**123**	96^{+}	100	100^{+}	97^{+}	100^{+}	**99**
Fluroxypyr + MCPA amine	100 + 250		142^{+}	100			**121**		100	100^{+}			**100**
Fluroxypyr + diflufenican + MCPA ester	100 + 12.5 + 125			104			**104**			100^{+}			**100**
Fluoroglycofen-ethyl	750				107	120^{+}	**114**				47	67^{+}	**57**
Fluoroglycofen-ethyl	1500				113	125^{+}	**119**				51	67^{+}	**59**
Mecoprop-p	450				114	121^{+}	**118**				24	56^{+}	**40**
Mecoprop-p	900				116	127^{+}	**122**				31	50^{+}	**40**
2,4-D amine	850	115					**115**	99^{+}					**99**
Diuron + MCPA sodium	450 + 250	128					**128**	91^{+}					**91**
LSD (P=0.05)		43	20	11	19	16		12	NS	55	42	30	
Plant density of untreated control (plants m^{-2})		94	155	156	103	110	**124**	121	106	41	174	155	**119**
Yields of untreated control													
Wheat (t ha^{-1})		0.93	3.35	3.62	2.57	2.95	**2.68**						
Bedstraw (kg ha^{-1})								226	40	15	226	93	**120**

$^{+}$ Indicates records with significantly higher ($P<0.05$) crop yields or lower bedstraw seed yields than unsprayed controls.

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growers and included herbicides that have been shown to be effective against cleavers overseas. Not all the herbicides evaluated were commercially available in Australia.

Treatments were applied using a compressed air driven spray boom, mounted on a 4 wheel motorbike travelling at 6 km h^{-1} (Barnett *et al*. 1987). The application volume was 64 L ha^{-1} and was applied at a pressure of 250 kPa through Spraying Systems® 110015 nozzles at 50 cm spacings, adjusted to 35 cm above the crop canopy. Control plots were driven over by the motorbike at the most frequent application timing to negate wheel damage effects. Application timings were pre-sowing, post-sowing pre-emergence, early post-emergence (cereals Z 14–22, pulses 3–5 leaf stage approximately six weeks after sowing) mid-tillering (Z 23–29) and late post-emergence (Z 30+) (Zadoks *et al.* 1974).

Weed and crop densities were assessed by either 5 or 10, 0.1 m^{-2} quadrats and were recorded at application and between three and four weeks after application for each herbicide treatment.

To alleviate the problem with some chemicals causing the ‘green skeleton’ effect (Black *et al*. 1994) assessment of bedstraw control was made from seed production. Plots (1.42 m cutting width by 20 m long) were mechanically harvested at ground level with a Hege® harvester adjusted to capture all crop and bedstraw seed produced. Harvested samples were weighed and sub-sampled to determine production of bedstraw seed, crop yields and trash for each treatment. Results were analysed by ANOVA. $\mathrm{Log}_{10}(x + 1)$ transformations were made when deemed appropriate by plotting residual values. Treatment means were converted to percent of unsprayed control for presentation.

Reports of individual experiments are provided in Carter (1991, 1992) and Dowsley (1993). Further details are available from the author on request.

Results

Wheat and barley

Yield responses to herbicide applications in both wheat (Table 2) and barley (Table 3) were greater at early application timings (Zadoks 14–23) than at later

Table 3. Herbicide treatment effects on yields of bedstraw seed and barley.

Treatment	Rate (g ha^{-1})	Barley yields % of untreated control					Bedstraw seed yield % control				
Trial identification number		92Ba	92Bb	93Ba	93Bb	**Average**	92Ba	92Bb	93Ba	93Bb	**Average**
Pre-sowing											
Flumioxazin	50	123				**123**	-13				**-13**
Flumioxazin	100	140$^+$				**140**	-18				**-18**
Early post-emergence (Z14–22)											
Chlorsulfuron	16	161$^+$	118$^+$	123$^+$	111$^+$	**128**	99$^+$	82$^+$	84$^+$	100$^+$	**91**
Metsulfuron-methyl	4.2	150$^+$	111	115$^+$	105$^+$	**120**	99$^+$	55	65	61	**70**
Metsulfuron-methyl + bromoxynil + MCPA ester	4.2 + 200 + 200	166$^+$	123$^+$	127$^+$	106$^+$	**131**	99$^+$	85$^+$	89$^+$	99$^+$	**93**
Bromoxynil + MCPA ester	280 + 280	155$^+$	117$^+$	120$^+$	107$^+$	**125**	99$^+$	85$^+$	95$^+$	98$^+$	**94**
Bromoxynil + MCPA ester + dicamba	196 + 392 + 56	170$^+$	113	121$^+$	103	**127**	100$^+$	99$^+$	97$^+$	97$^+$	**98**
Flumetsulam + non-ionic surfactant	16	146$^+$	103	120$^+$	101	**117**	100$^+$	97$^+$	92$^+$	100$^+$	**97**
Flumetsulam + Uptake®	16	134	106			**120**	100$^+$	98$^+$			**99**
Flumetsulam + non-ionic surfactant	20		115$^+$			**115**		95$^+$			**95**
Diflufenican + bromoxynil	27.5 + 27	177$^+$	122$^+$		103	**134**	100$^+$	92$^+$		100$^+$	**97**
Fluroxypyr	120		111	125$^+$	102	**113**		98$^+$	93$^+$	100$^+$	**97**
Fluroxypyr	200	161$^+$	119$^+$	116$^+$	105$^+$	**125**	100$^+$	100$^+$	100$^+$	100$^+$	**100**
Amidosulfuron	11.25			127$^+$	105$^+$	**116**			93$^+$	100$^+$	**97**
Amidosulfuron	15			130$^+$	104	**117**			93$^+$	100$^+$	**97**
Fluoroglycofen-ethyl	750			119$^+$	104	**112**			44	53	**49**
Fluoroglycofen-ethyl	1500			127$^+$	107$^+$	**117**			78$^+$	99$^+$	**89**
Mecoprop-p	450			108	100	**104**			-8.7	34	**13**
Mecoprop-p	900			117$^+$	101	**109**			33	20	**27**
Mid-tillering (Z 23–31)											
Diflufenican + bromoxynil	25 + 250	132	103	98	90	**94**	84	-7.7	67	97$^+$	**60**
Diflufenican + MCPA ester	25 + 250		94			**94**		-23			**-23**
Fluroxypyr	120			121$^+$	107$^+$	**114**			100$^+$	57	**79**
Fluroxypyr	200	140$^+$	105	115$^+$	93	**113**	100$^+$	94$^+$	98$^+$	100$^+$	**98**
Fluroxypyr + MCPA amine	100 + 250		95			**95**		100$^+$			**100**
LSD* ($P=0.05$)		37	13	66	5		BTD	BTD	BTD	BTD	
Plant density of untreated control (plants m^{-2})		96	213	74	108	**123**	119	6.7	83	63	**68**
Yields of untreated control											
Barley (t ha^{-1})		1.94	2.52	2.99	4.15	**2.90**					
Bedstraw (kg ha^{-1})							157	13	45	7.6	**56**

$^+$Indicates records with significantly higher ($P<0.05$) crop yields or lower bedstraw seed yields than unsprayed controls.

* BTD indicates that the LSD is inappropriate for back-transformed data.

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application timings (>Z 23). For the same herbicide treatment the yield response in wheat was consistently higher than that observed in barley. Bedstraw seed production was consistently reduced by 99% or more by early post-emergence applications of bromoxynil + MCPA ester + dicamba, flumetsulam, fluroxypyr and high rates of amidosulfuron (15 g ha^{-1}) and later applications of fluroxypyr (200 g ha^{-1}), fluroxypyr + MCPA ester and 2,4-D amine with or without trifluralin pre-sowing. Treatments that consistently provided 90–98% control of bedstraw seed production included early post-emergence applications of bromoxynil + MCPA ester, diflufenican + bromoxynil, fluroxypyr and amidosulfuron (11.25 g ha^{-1}) and late post-emergence applications of diflufenican + bromoxynil, fluroxypyr (120 g ha^{-1}) and diuron + MCPA sodium.

Eighty to 90% control of bedstraw seed production was achieved with early post-emergence applications of chlorsulfuron, metsulfuron methyl, metsulfuron methyl + bromoxynil + MCPA ester and late post-emergence applications of diflufenican + MCPA ester. Herbicides with less than 80% control of bedstraw seed production included trifluralin, dicamba, fluoroglycofen-ethyl, mecoprop and flumioxazin (Table 3).

Chickpeas

Post-sowing pre-emergence applications of imazethapyr, alone or in mixtures with simazine, resulted in consistent and significant increases in chickpea yields of >170% (Table 4) and average reductions in bedstraw seed production of >85% in six out of nine treatments. Chickpea yields increased by an average of >120% when flumetsulam was applied post-emergence and bedstraw seed control was slightly higher and more consistent with this than with the imazethapyr treatments (Table 4). Under the highest bedstraw densities (142 plants m^{-2}) yields from flumetsulam treatments were not significantly different from imazethapyr treatments.

Post-sowing pre-emergence applications of clomazone, sulfentrazone and flumetsulam (16 g ha^{-1}) reduced bedstraw seed production by an average of 69, 72 and 56% respectively, which is considered to be a less than commercially acceptable level of control (Black *et al.* 1994). Simazine alone or in mixtures with atrazine or prometryne provided no reduction of bedstraw seed production and did not decrease chickpea yields, indicating satisfactory tolerance of chickpeas to these herbicides. No herbicide achieved 100% seed reduction of bedstraw in chickpeas; the best that could be reliably expected was about 90%. Chemical options, with acceptable crop safety, for bedstraw control in chickpeas include post-sowing pre-emergence imazethapyr (30 or 40 g ha^{-1}) alone or in mixtures with simazine and post-emergence flumetsulam (12–16 g ha^{-1}).

Table 4. Herbicide treatment effects on yields of bedstraw seed and chickpeas.

Treatment	Rate (g ha^{-1})	Chickpea yield % of untreated control				Bedstraw seed yield % control			
Trial identification number		92CPa	92CPb	93CP	**Average**	92CPa	92CPb	93CP	**Average**
Post-sowing pre-emergence									
Simazine	900	189^{+}	138^{+}	119	**149**	43	2	-28	**6**
Simazine + prometryne	450 + 450			118	**118**			-15	**-15**
Simazine + atrazine	450 + 450			111	**111**			-28	**-28**
Simazine + imazethapyr	750 + 30	253^{+}	142^{+}	204^{+}	**199**	91^{+}	-35	99^{+}	**52**
Simazine + imazethapyr	750 + 40	284^{+}	132^{+}		**208**	86^{+}	93		**90**
Simazine + flumetsulam	750 + 12			120	**120**			10	**10**
Imazethapyr	40	235^{+}	114	169^{+}	**173**	88^{+}	72	79	**80**
Imazethapyr	60	278^{+}			**278**	96^{+}			**96**
Flumetsulam	12	167^{+}	117^{+}	155^{+}	**146**	28	-18	50	**23**
Flumetsulam	16	142	117^{+}	143	**134**	59	54	50	**56**
Clomazone	240			200^{+}	**200**			69	**69**
Sulfentrazone	6000^{A}			172^{+}	**172**			72	**72**
Split application									
Simazine pre-emergence + flumetsulam post-emergence	750 + 12			209^{+}	**209**			96^{+}	**96**
Post-emergence (3–6 node)									
Pyridate	675	150	122^{+}	183^{+}	**152**	15	52	51	**43**
Pyridate	900	189^{+}	103		**146**	46	11		**32**
Flumetsulam	12	130	93	174^{+}	**132**	81^{+}	82	98^{+}	**88**
Flumetsulam	16	129	82^{0}	157^{+}	**123**	90^{+}	85	99^{+}	**92**
LSD (P=0.05)		58	16	34		56	NS	26	
Plant density of untreated control (plants m^{-2})		52	23	29		2.3	1	142	
Yields of untreated control									
Chickpeas (t ha^{-1})		1.26	2.26	0.53	**1.17**				
Bedstraw (kg ha^{-1})						284	54	497	**278**

^{A} Developmental product, rates recorded as mL ha^{-1} of product provided for evaluation.

* Indicates records with significantly higher ($P<0.05$) crop yields or lower bedstraw seed yields than unsprayed controls.

^{0} Indicates records with significantly lower ($P<0.05$) crop yields than unsprayed controls.

Faba beans

Post-sowing pre-emergence applications of flumetsulam alone or in mixtures with metribuzin or simazine and post-emergence applications of imazethapyr or flumetsulam with non-ionic surfactant or Uptake® crop oil resulted in yield decreases of faba beans in the order of 40% (Table 5). Faba bean yields responded well to post-sowing pre-emergence applications of imazethapyr (30 or 40 g ha^{-1}) alone or in mixtures with simazine in three out of four experiments.

Reductions in bedstraw seed production in the order of 90% were consistently observed under moderate to low (<25 plants m^{-2}) bedstraw plant densities with imazethapyr at rates of 30 or 40 g ha^{-1}. Under higher plant densities (67 plants m^{-2}) all treatments involving simazine alone or in mixtures with imazethapyr, flumetsulam, atrazine or metribuzin resulted in increases in bedstraw seed production, 67% of these significant. This finding is inconsistent with other experimental results obtained in chickpeas and field peas and appears to be an anomaly with the trial conducted in 1991 (91BE).

Bentazone did not give consistent control of bedstraw across the three years of experiments. Yield increases with clomazone and sulfentrazone were significant; sulfentrazone gave, on average, 90% control of bedstraw whilst control with clomazone was on average 59%.

Bedstraw control in faba beans could be achieved with post-sowing pre-emergence imazethapyr (30 or 40 g ha^{-1} alone or with mixtures of simazine 750 g ha^{-1}) or with sulfentrazone. Suppression of faba bean yields indicate that faba beans do not show adequate tolerance to any treatment containing flumetsulam or post-emergence imazethapyr.

Field peas

Flumetsulam (12 or 16 g ha^{-1}) applied post-emergence and imazethapyr (30 or 40 g ha^{-1}) applied post-sowing pre-emergence or post-emergence (40 or 60 g ha^{-1}) provided on average 79% control of bedstraw seed production in field peas (Table 6). The addition of non-ionic surfactant to flumetsulam did not enhance bedstraw control. Flumetsulam did not significantly ($P=0.05$) affect pea yields. Field pea yields were significantly increased when clomazone or sulfentrazone were used in one experiment (93Pb) in 1993. Bedstraw seed yields in field pea crops were reduced by an average of 85% with sulfentrazone and by 75% with clomazone. This level of reduction is consistent with reductions observed in chickpeas and faba beans (Tables 4 and 5). Pre-emergence application of flumetsulam and post-emergence applications of bentazone, diflufenican and pyridate all gave less than 70% control of bedstraw seed production.

Imazethapyr (30 or 40 g ha^{-1}) applied post-sowing pre-emergence or (40 or 60 g ha^{-1}) applied post-emergence and flumetsulam (12 or 16 g ha^{-1}) post-emergence are therefore effective options in field peas. Clomazone, sulfentrazone and flumioaxazin provide useful reductions of bedstraw seed production and warrant further evaluation. Bentazone provided variable but consistently less than 70% reduction in bedstraw seed production and is unlikely to be reliable enough for bedstraw control in pulse crops.

Discussion

The best options to control bedstraw seed production with herbicides are in cereal crops. This study, along with Black *et al.* (1994), has identified a variety of reliable herbicide options and application timings in wheat and barley crops. Early control results in significant yield increases but

Table 5. Herbicide treatment effects on yields of bedstraw seed and faba beans.

Treatment	Rate (g ha^{-1})	Faba bean yields % of untreated control					Bedstraw seed yield % control				
Trial identification number		91 BE	92 BE	93 BEa	93 BEb	**Average**	91 BE	92 BE	93 BEa	93 BEb	**Average**
Post-sowing pre-emergence											
Simazine	900	103	92	131[+]	208[+]	**134**	-25	35	-103	-85[0]	**-45**
Simazine + atrazine	450 + 450	98			112	**105**	-65[0]				**-65**
Simazine + atrazine + imazethapyr	500 + 300 + 30	99				**99**	-69[0]				**-69**
Simazine + flumetsulam	750 + 16		60[0]	63[0]		**62**		-137[0]	-304[0]	12	**-143**
Simazine + imazethapyr	750 + 30	94	91	158[+]	435[+]	**195**	-65[0]	38	91	86[+]	**38**
Simazine + imazethapyr	750 + 40	109	73[0]	158[+]	558[+]	**225**	-40	89[+]	95	88[+]	**58**
Imazethapyr	40	97	79	147[+]	380[+]	**178**	35	94[+]	86	95[+]	**78**
Imazethapyr	60		86	136[+]	504[+]	**242**		79	27	94[+]	**67**
Metribuzin	216	96				**96**	-2.9				**-2.9**
Metribuzin + imazethapyr	72 + 30			148[+]	415[+]	**282**			89	93[+]	**91**
Metribuzin + imazethapyr	96 + 40			150[+]	338[+]	**244**			94	93[+]	**94**
Metribuzin + imazethapyr	216 + 16	86[0]				**86**	9.8				**9.8**
Metribuzin + flumetsulam	96 + 16			44[0]	54	**49**			-151[0]	36	**-58**
Metribuzin + simazine	96 + 750	106				**106**	-94[0]				**-94**
Clomazone	240			155[+]	342[+]	**249**			73	44	**59**
Sulfentrazone	8000[A]			129[+]	319[+]	**224**			88	92[+]	**90**
Post-emergence (5–6 node)											
Bentazone	840–864	125[+]	78[0]	81[0]	131	**104**	9.2	27	24	74[+]	**34**
Imazethapyr	40	115	64[0]			**90**	21	57			**39**
Imazethapyr	60		54[0]			**54**		61			**61**
Flumetsulam + non-ionic surfactant	12	101	58[0]	45[0]	46	**63**	92[+]	-20	96	93[+]	**65**
Flumetsulam + Uptake®	12			44[0]	42	**43**			98	95[+]	**97**
Flumetsulam + non-ionic surfactant	16		58[0]			**58**		79			**79**
Simazine + flumetsulam	500 + 12		54[0]	52[0]	58	**55**		-8.5	98	92[+]	**61**
LSD* (P=0.05)		21	21	19	100		61	89	133	BTD	
Plant density of untreated control (plants m^{-2})		26	30	14	12	**20**	67	19	23	12	**30**
Yields of untreated control											
Faba beans (t ha^{-1})		1.50	2.91	1.78	0.26	**1.61**					
Bedstraw (kg ha^{-1})							173	142	51	12	**94.5**

[A] Developmental product, rates recorded as mL ha^{-1} of product provided for evaluation.

[+] Indicates records with significantly higher ($P<0.05$) crop yields or lower bedstraw seed yields than unsprayed controls.

[0] Indicates records with significantly lower ($P<0.05$) crop yields than unsprayed controls.

* BTD LSD are inappropriate for back-transformed data.

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may not completely stop bedstraw seed production. Later control will stop seed production of bedstraw but will not result in significant yield increases. Producers should be encouraged to control bedstraw early in cereals for yield response and budget for a late application of herbicide to completely stop bedstraw seed production if desired. In some situations the later application of herbicide may not be required.

No treatment gave 100% reduction of bedstraw seed production in chickpeas, faba beans or field peas supporting the conclusion of Black *et al.* (1994) that the management of bedstraw in crops preceding pulses will play a major role in the long term management of this weed. The best opportunity to control bedstraw in pulse crops is in chickpeas or field peas with the application of flumetsulam later in the season. Additional options in chickpeas and field peas include imazethapyr post-sowing pre-emergence and in field peas post-emergence. Faba beans have one option, namely post-sowing pre-emergence imazethapyr.

Producers should be encouraged to maintain flexibility in the pulse rotations and capitalize on the chemical management options available to them to reduce seed production of bedstraw. Under high bedstraw burdens (100 plants m^{-2}) chickpeas or field peas allow the strategic use of post-emergence flumetsulam to give over 90% seed control. Under lower plant densities post-sowing pre-emergence use of imazethapyr in chickpeas, field peas or faba beans will give control in the order of 90%. This level of control cannot be expected under higher weed burdens.

There have been no reports of bedstraw resistant to effective herbicides in Australia. In order to reduce the potential for herbicide resistance development in bedstraw, producers should be encouraged not to use group B herbicides in cereal crops for bedstraw management as herbicides from group B (flumetsulam and imazethapyr) are the only effective chemicals for bedstraw control in pulse crops. Chemical options in cereals offer the producer different modes of actions, and higher levels of seed control of bedstraw (group C: diuron, bromoxynil, group F: clomazone, group I: 2,4-D, MCPA, fluroxypyr, mecoprop-p, dicamba) than achieved in pulse crops. Reducing producers reliance on group B herbicides (metosulam, chlorsulfuron, metsulfuron-methyl) in cereals, for bedstraw control, will allow flumetsulam and imazethapyr to be used in pulse crops without increasing pressure for resistance build-up. If producers wish to use group B herbicides in cereals for other reasons then they need to be aware of the potential for development of herbicide resistance.

Wheat and barley are important crops to make significant reductions to seed bank inputs in an integrated management approach. Targets for bedstraw control should be in the order of 95–100% control to reduce seed inputs into the seed bank and reduce the pressure for higher levels

Table 6. Herbicide treatment effects on yields of bedstraw seed and field pea.

Treatment	Rate (g ha^{-1})	Field pea yield % of untreated control					Bedstraw seed yield % control				
Trial identification number		91P	92P	93Pa	93Pb	**Average**	91P	92P	93Pa	93Pb	**Average**
Post-sowing pre-emergence											
Simazine	900	74^{0}				**74**	-11				**-11**
Simazine + atrazine	600 + 300	85				**85**	-19				**-19**
Simazine + imazethapyr	750 + 9.6	105				**105**	7.9				**7.9**
Simazine + imazethapyr	750 + 19.2	112				**112**	8.8				**8.8**
Simazine + metribuzin	750 + 96	81				**81**	-6.1				**-6.1**
Flumetsulam	16		74^{0}	111	106	**97**		60^{+}	64	11	**45**
Imazethapyr	30	149^{+}	90	102	178^{+}	**130**	37^{+}	99^{+}	88^{+}	91^{+}	**79**
Imazethapyr	40	138^{+}	103	117	170^{+}	**132**	33^{+}	96^{+}	96^{+}	98^{+}	**81**
Metribuzin + imazethapyr	72 + 30			91	149^{+}	**120**			93^{+}	93^{+}	**93**
Metribuzin + flumetsulam	96 + 16			68^{0}	103	**86**			62	63^{+}	**63**
Clomazone	115.2			110	149^{+}	**130**			75	75^{+}	**75**
Sulfentrazone	6–8000^{A}			100	145^{+}	**123**			80^{+}	90^{+}	**85**
Post-emergence (5–6 node)											
Flumetsulam	12			110	114	**112**			78^{+}	95^{+}	**87**
Flumetsulam	16	100		90	120	**103**	82^{+}		71	95^{+}	**83**
Flumetsulam + non-ionic surfactant	12		84	103	88	**92**		92^{+}	65	95^{+}	**84**
Flumetsulam + non-ionic surfactant	16		83	108	110	**99**		95^{+}	84^{+}	97^{+}	**92**
Imazethapyr	40	125^{+}	98	86	139^{+}	**112**	64^{+}	78^{+}	98^{+}	92^{+}	**83**
Imazethapyr	60		100	100	142^{+}	**114**		93^{+}	99^{+}	95^{+}	**96**
Bentazone	840 or 864	76^{0}	95	111	126^{+}	**102**	38^{+}	85^{+}	79^{+}	68^{+}	**68**
Diflufenican	100		87	110	112	**103**		64^{+}	-11	-23	**10**
Diflufenican + imazethapyr	50 + 50		90	94	133^{+}	**106**		82^{+}	60	80^{+}	**74**
Pyridate	675		30^{0}			**30**		59^{+}			**59**
Flumioxazin	30		70^{0}			**70**		97^{+}			**97**
LSD* (P=0.05)		19	18	29	25		18	47	BTD	BTD	
Plant density of untreated control (plants m^{-2})		35	47	37	12.5	**33**	896	2	49	28	**244**
Yields of untreated control											
Wheat (t ha^{-1})		1.29	2.06	1.84	0.92	**1.53**					
Bedstraw (kg ha^{-1})							896	35	92	99	**281**

^{A} Developmental product, rates recorded as mL ha^{-1} of product provided for evaluation.

$^{+}$ Indicates records with significantly higher ($P<0.05$) crop yields or lower bedstraw seed yields than unsprayed controls.

^{0} Indicates records with significantly lower ($P<0.05$) crop yields than unsprayed controls.

* BTD indicates that the LSD is inappropriate for back-transformed data.

of control in pulse crops. A strategic approach to bedstraw management will include both cereals and pulse crops.

Conclusion

Cereal crops offer the widest choice of chemical management options for bedstraw control (bromoxynil + diflufenican, bromoxynil + MCPA + dicamba, chlorsulfuron, flumetsulam, 2,4-D amine, dicamba + MCPA ester, fluroxypyr) with efficacy of up to 100% control of seed set. There is limited chemical choice in pulse crops, with imazethapyr and flumetsulam the two effective chemicals. Control of over 95% seed production is rare in pulse crops. Management options in pulse crops are greatest in peas (imazethapyr post-sowing pre-emergence or post-emergence; flumetsulam post-emergence) and chickpeas (simazine + imazethapyr post-sowing pre-emergence; flumetsulam post-emergence) but are limited in faba beans to imazethapyr post-sowing pre-emergence.

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