Spray-topping of wild oats (*Avena* spp.) in wheat with selective herbicides

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Summary

Seed production is the critical factor which allows wild oats (*Avena* spp.) to persist as an important weed of winter cropping systems in Australia. To attack this mechanism, four selective herbicides registered for use on wild oats in wheat were applied late post emergence at two field sites, with the specific aim of reducing seedset. The majority of wild oat plants were between stem elongation and booting when sprayed with recommended or lower rates of diclofop-methyl, fenoxaprop-ethyl, flamprop-methyl or tralkoxydim.

The herbicides, except diclofop-methyl, significantly reduced both the emergence of inflorescences (by up to 99%) and seed production (by up to 96%). However, fenoxaprop-ethyl and flamprop-methyl reduced the formation of wild oat inflorescences and seed production significantly more than did tralkoxydim. Whilst there was some phytotoxic damage visible in one of the crops, this did not affect the density of wheat heads or wheat grain size.

From these preliminary tests it is considered that the tactic of applying low doses of selective herbicides during stem jointing could be useful for preventing seed production of wild oats. Other advantages and aspects to be considered, in developing this form of spray-topping for use in cropping, are discussed.

Introduction

Wild oats (*Avena* spp.) are distributed across the Australian wheat belt and are amongst the industry's most important weeds. They caused losses estimated at $42 million in 1987 (Medd and Pandey 1990) due to their propensity to reduce wheat yields through competition (Martin *et al.* 1987, Poole and Gill 1987) and to the cost of herbicides applied to control them.

A number of pre and post emergence herbicides are registered for wild oat control in wheat. Although effective in reducing competition, both research and grower evidence has highlighted the ineffectiveness of herbicides in preventing the build-up of wild oat populations. Seed banks of wild oats increased four to six-fold over a three year cropping cycle using diclofop-methyl (Medd 1990) and eight to twelve-fold using flamprop-methyl or tri-allate (Martin and Felton 1990). The population increases in both studies occurred irrespective of whether conventional or conservation tillage techniques were used to prepare seedbeds. A recent survey of farmers interviewed by Hoechst Australia Ltd. found that wild oats occur on two out of three farms throughout winter cereal growing areas, are increasing on over 40% of the infested farms and the managers of more than one third of these farms find it difficult to control wild oats (Howat, personal communication 1990). The difficulty in controlling wild oats in wheat had likewise been shown in a previous farmer survey reported by Martin *et al.* (1988), and in the evaluation of herbicides (Reeves *et al.* 1973, Paterson 1977, Wilson 1979).

There is mounting evidence that the persistence of wild oat populations within crops is due more to the input of new seed, rather than to seed longevity in the soil (as is widely believed). Seed dormancy is a mechanism that bestows longevity, allowing seeds to accumulate in the soil (Banting 1966, Simpson 1983). However, proliferation of wild oat populations through this means seems highly unlikely given that its seeds are generally short-lived (Quail and Carter 1968) and seed banks decline annually at a rate of 70% or greater (Medd 1990). The practical achievement of excellent wild oat control through a one or two year rotation with summer crops, particularly sorghum (Philpotts 1975, Wilson *et al.* 1977, Purvis 1990), further refutes the dormancy/longevity/carryover belief, due to the rapid depletion of seed banks (Martin and Felton 1990). This rotational practice would not work if a predominance of dormant seeds were persisting in the seed bank.

Consequently, if tactics which reduce seed production could be developed they would enable populations of wild oats to be better managed. Along that line, this paper reports on two pilot experiments undertaken to examine the impact of four selective herbicides applied late post emergence with the specific aim of reducing the seedset of wild oats growing in wheat.

Methods and materials

Experiments were established in two commercial wheat crops naturally infested with wild oats, one at Moree Lat. 29°28'S, Long. 149°51'E, the other at Inverell Lat. 29°46'S, Long. 151°07'E in northern N.S.W. The crops were treated late post emergence with fenoxaprop-ethyl (racemic mixture) (60 g a.i. ha^{-1}), flamprop-methyl (225 and 450 g a.i. ha^{-1}), tralkoxydim (150 g a.i. ha^{-1}), diclofop-methyl (562.5 g a.i. ha^{-1}) or left untreated. Three replicates of each treatment were layed out in 4 × 10 m plots arranged in a randomized block. Treatments were applied along the central 3 m of plots leaving a 0.5 m buffer. Both sites were typical of wild oat infestations in continuous wheat cropping systems in north western N.S.W. in having a history of pre and post emergence herbicide usage for wild oat control. Few other weeds were present at either site, although the Moree crop had been sprayed with 2,4-D amine (700 g a.i. ha^{-1}) nine days prior to the application of treatments.

Herbicide treatments were applied at both locations when the majority of wheat and wild oat tillers had advanced to stem elongation/booting (Zadoks 30 to 50); considerably later than recommended for seedling kill. The development of wild oat plants was particularly uniform at Inverell, whereas at Moree it was more variable, due perhaps to staggered recruitment. Tiller development (means for 10 wheat and 18 wild oat plants selected at random from each location) and environmental data recorded at the time of treatment are presented in Table 1 along with other agronomic and spray application details.

The density of wild oat inflorescences was assessed approx. 10 and 35 days after treatment. Phytotoxicity of the treatments on the crop was visually rated (zero = no damage to five = no grain formation) at the same time. Scores above two are considered commercially unacceptable (McMillan and Cook 1987-89). At harvest, wheat head density, 100 grain weight and wild oat seed production were measured.

Results

Ten days after treatment few wild oats heads had fully emerged at either site but a significant reduction in inflorescence density from 3.1 to 0.8 m^{-2} (74% reduction) at Moree and from 4.4 to 0.2 m^{-2} (96% reduction) at Inverell was evident (Table 2). At the later assessment, when most inflorescences had fully emerged, the greatest reduction in inflorescence density was from 65.0 to 1.7 heads m^{-2} (97% reduction) at Moree and from 110.3 to 1.1 heads m^{-2} (99% reduction) at Inverell (Table 2). All treatments, except diclofop-methyl at Inverell, significantly reduced the number of inflorescences which emerged at both sites; fenoxaprop-ethyl and both rates of flamprop-methyl were significantly more effective than tralkoxydim and diclofop-methyl at Moree whereas all were better than diclofop-methyl at Inverell.

Table 1. Plant growth stage of wild oats and wheat along with spraying details at the time of applying treatments at Moree and Inverell.

	Moree	Inverell
Plant growth stage[1]		
Wheat	22-29/37-41	23-29/31-33
Wild oats	23-29/34-61	22-29/31-45
Wild oat tillers (no. $plant^{-1}$)	6.7	8.2
Wild oat tillers - vegetative (%)	8	32
Wild oat tillers - elongating (%)	62	68
Wild oat tillers - reproductive (%)	30	1
Crop and spraying details		
Wheat cultivar	Hartog	Owlet
Seeding rate (kg ha^{-1})	45	40
Sowing date	14.06.90	23.06.90
Date of spraying	28.08.90	27.09.90
Temperature	19°C	22°C
Humidity	44 %	56 %
Spraying method/pressure	Hand held boom/240 kPa	
Nozzle type/spacing	8002 Teejet® flat fan @ 50 cm	
Spray volume (L ha^{-1})	160	150

[1] Assessed using the decimal code of Zadoks *et al.* (1974). All tillers on each plant were scored, not just the most advanced one as stipulated in the code.

Seed production in wild oats was significantly reduced by fenoxaprop-ethyl and both rates of flamprop-methyl at each location, and by tralkoxydim at Moree although it was significantly less effective than the fore-mentioned treatments. The largest reductions were from 1333 to 51 seeds m^{-2} at Moree (96.2% reduction) and from 2369 to 269 seeds m^{-2} at Inverell (88.6% reduction) (Table 2). Treatment with diclofop-methyl did not significantly affect seed production.

No visual phytotoxic symptoms were evident in the Inverell crop and although herbicide treatments caused significant visual crop damage at Moree, this was not considered to be commercially unacceptable (Table 3). Damage was evident 10 days after spraying, and after five weeks more phytotoxicity resulted from fenoxaprop-ethyl and each rate of flamprop-methyl than from tralkoxydim and diclofop-methyl. Phytotoxicity symptoms consisted of mild chlorosis and/or slight height reduction and were most severe in the flamprop-methyl treatments. Although yields were not recorded at harvest, there were no significant treatment effects on the density of wheat heads or 100 grain weight (Table 3).

Discussion

At present, few practical methods are available to directly attack the production of weed seeds in crops. The results from these preliminary experiments offer a very encouraging indication that some selective herbicides may be used as a spray-topping tactic in wheat to reduce the production of wild oat seed. With both fenoxaprop-ethyl and flamprop-methyl the reduction in seed production was consistently of a high order: up to 89% at Inverell and 96% at Moree. Further investigation to develop the technique as a form of spray-topping thus seems warranted. With a view to registering the technique, these studies should concentrate on: evaluating application timing and dose rates; establishing herbicide residue levels in grain to satisfy with-holding periods; and appraising the economics of the tactic.

A critical factor in the control of wild oats is the timing of spray application. One reason for poor control of populations in practice is the characteristically staggered pattern of seedling emergence, which results in variable age and maturity within stands. Such variation could also affect the efficacy of spray-topping. The wild oat infestation at Inverell was, in this respect, atypically uniform at the time of treatment, with approximately one third vegetative tillers and the remainder undergoing stem elongation (Table 1). At Moree a minority of tillers were vegetative, with the majority elongating, some booting and others with the inflorescence emerged (Table 1). Despite the considerable variation in plant development at the Moree site, seed production was reduced by up to 96%, whereas a reduction of up to 89% was achieved at Inverell. This indicates that there is some latitude in the time of spray application, with the optimum stage of development being from stem elongation to booting (since treatments were less effective at Inverell where there was a higher proportion of vegetative tillers). In contrast to these results, the stage of tiller development is critical, and needs to be synchronized, for effective spray-topping of grass weeds in pastures (Jones *et al.* 1984, Leys *et al.* 1991). It is fortunate that the apparent application window in crops is not so specific, for it would not be possible to modify tiller development by slashing or grazing, as is necessary in pastures to maximize efficacy.

Besides preventing crop losses by controlling weeds, herbicides may cause phytotoxic damage to crops. Phytotoxicity is potentially a problem with selective spray-topping since crop tolerance decreases with age. Although the visual damage was not unacceptable at one site, and negligible at the other, further studies are required because greater damage would normally be expected from later than recommended application of post emergence herbicides. One way to offset phytotoxicity would be to cut herbicide rates since damage is also strongly dose dependent. In this study, only flamprop-methyl and fenoxaprop-ethyl were used at rates below those recommended for seedling kill. As there was no significant difference in wild oat seed production for half and full dose rates of flamprop-methyl, there could be scope for reducing the dose rate of this herbicide, at least, to circumvent possible crop damage.

By enabling control of seed production, it is envisaged that the tactic could provide advantageous new management options in cropping. For example, it has been predicted that a combination of methods, which result in reduced seed production in addition to the death of plants to alleviate yield losses through competition, would lead to more effective control of wild oat populations (Medd and Ridings 1990). This might be achieved for instance by split application, with half the dose of herbicide applied at the conventional time to reduce competition and half applied later to reduce seedset. This combined attack would appear to be one way of reducing the overall input of herbicides into cropping (Pandey and Medd 1990). Secondly, in seasons where weather conditions prevent weed control during the vegetative phase, or where there is a delayed flush of weed recruitment, spray-topping could at least minimize seedset. Likewise, where economics preclude early season weed control due to low grain prices or low weed densities, spray-topping with low rates of herbicides may be a profitable alternative in the long term by reducing future infestations. The tactic may also be useful in managing herbicide resistant weeds, and furthermore, could be applicable to other weeds besides wild oats, and be used in crops other than wheat. In all cases, the intended use of the tactic is **not** to prevent yield loss from the competitive effects of the weed in the current crop, **but rather to minimize seed production and replenishment of seed banks** - a preventative measure which would have its benefit through lowering expenditure on weed control in future years, as illustrated by Pandey and Medd (1991).

If the tactic is successfully developed, we suggest it should be referred to as

Table 2. Effect of herbicides (g a.i. ha^{-1}) applied late post emergence on the emergence of inflorescences and seed production of wild oats at Moree and Inverell.

	Fenoxaprop-ethyl (60)	Flamprop-methyl (450)	Flamprop-methyl (225)	Tralkoxy-dim (150)	Diclofop-methyl (562.5)	Untreated control	S.E.D.	Sig. level
Moree								
Wild oat fertile tillers (heads m^{-2}) 7.9.90 (10 DAT)	1.4	1.7	1.7	0.8	1.7	3.1	0.5	$p < 0.05$
Wild oat fertile tillers (heads m^{-2}) 2.10.90 (35 DAT)	6.2	1.7	3.7	30.8	38.3	65.0	10.4	$p < 0.001$
Wild oat seed weight (g m^{-2}) 12.10.90 (45 DAT)	5.0	2.4	4.1	32.2	59.3	61.3	10.3	$p < 0.001$
Wild oat seed production (seeds m^{-2}) 12.10.90 (45 DAT)	108.0	51.0	90.0	700.0	1290.0	1333.0	222.8	$p < 0.001$
Inverell								
Wild oat fertile tillers (heads m^{-2}) 8.10.90 (11 DAT)	0.2	1.0	1.2	0.7	3.4	4.4	1.2	$p < 0.05$
Wild oat fertile tillers (heads m^{-2}) 29.10.90 (32 DAT)	7.7	1.1	2.0	15.5	93.8	110.3	7.2	$p < 0.001$
Wild oat seed weight (g m^{-2}) 16.11.90 (50 DAT)	15.0	17.3	23.7	88.0	103.0	132.2	23.8	$p < 0.05$
Wild oat seed production (seeds m^{-2}) 16.11.90 (50 DAT)	269.0	311.0	424.0	1577.0	1846.0	2369.0	427.4	$p < 0.05$

Table 3. Phytotoxicity of herbicides (g a.i. ha^{-1}) applied late post emergence to control seed production in wild oats at Moree and effects on wheat production at Moree and Inverell.

	Fenoxaprop-ethyl (60)	Flamprop-methyl (450)	Flamprop-methyl (225)	Tralkoxy-dim (150)	Diclofop-methyl (562.5)	Untreated control	S.E.D.	Sig. level
Moree								
Wheat phytotoxicity rating (0 to 5) 7.9.90 (10 DAT)	0.8	1.6	1.1	0.8	0.6	0.0	0.2	$p < 0.001$
Wheat phytotoxicity rating (0 to 5) 2.10.90 (35 DAT)	1.6	1.5	1.3	0.8	0.7	0.3	0.2	$p < 0.001$
Wheat fertile tillers (heads m^{-2}) 12.10.90 (45 DAT)	109.3	111.0	133.7	93.0	86.7	107.7	14.1	n.s.d.
Wheat 100 grain weight (g) 12.10.90 (45 DAT)	2.4	2.4	2.4	2.4	2.6	2.2	0.2	n.s.d.
Inverell								
Wheat fertile tillers (heads m^{-2}) 16.11.90 (50 DAT)	115.0	76.3	98.7	120.3	73.7	91.7	20.1	n.s.d.
Wheat 100 grain weight (g) 16.10.90 (50 DAT)	2.9	2.8	2.8	2.7	2.6	2.8	0.2	n.s.d.

"selective spray-topping" to differentiate it from existing practices. The term spray-topping describes the use of sub-lethal rates of non-selective herbicides, applied around anthesis or the early dough stages of floral development, specifically to prevent viable seed production of annual grass weeds in pastures. It is mainly applied to weeds, which are tolerant of in-crop herbicides, in the final year of a pasture or clover ley rotation to reduce regeneration in following crops, e.g., Dowling (1988). Consequently the approach to preventing wild oat seedset differs in a number of respects to pasture spray-topping. Firstly, selective herbicides were used; secondly, they were applied prior to inflorescence emergence of the majority of tillers; and thirdly, no attempt was made to synchronize floral development in order to maximize efficacy. Nevertheless, we feel vindicated in using the term since both approaches have the common objective of preventing the setting of viable seed in order to reduce inputs to the seed bank and seedling regeneration in subsequent years.

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