Chemical weed management of wild oats

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Introduction

A range of selective herbicides are currently registered for the control of wild oats (*Avena* spp.) in Australian cereal and broadleaf crops (Table 1). Of these, the Group A herbicides (aryloxyphenoxypropionates (APP's) and cyclohexanediones (CHD's)) are the most widely used for post-emergence applications in field crops, whilst triallate and simazine are the key pre-emergence herbicides for winter cereal and lupin crops, respectively. The efficacy of these herbicides is reviewed in relation to: crop yield responses; ability to reduce wild oat seed production; and the development of herbicide resistance in wild oat populations.

Yield response

Wild oats are highly competitive against a range of crops and a compelling reason for using avenacides is to restrict crop yield losses. The severity of yield loss depends on several factors, including the choice of herbicide and timing of herbicide application. Medd (in press) analysed a range of experimental data from the northern grain region to determine the importance of application timing and profitability of various avenacides (triallate, trifluralin, difenzoquat, diclofop-methyl, flamprop-methyl and barban) in wheat. Pre-emergence herbicides had a mean plant control efficacy of 70.5% ± 16 compared with 65% ± 18 for early post-emergence herbicides. These investigations indicated that herbicide application was potentially most profitable for pre- and early post-emergence avenacides when wild oats were reduced to <20 plants m^{-2}, or <10 plants m^{-2} respectively. Assuming average efficacy, this equates to maximum anticipated densities of approximately 70 plants m^{-2} for pre-emergence treatments, and pre-spraying densities of 30 plants m^{-2} for early post-emergence treatments. Treatments that failed to reduce densities below 100 plants m^{-2} were at most risk of being uneconomic.

Pre-emergence herbicides tended to be more consistently profitable than early post-emergence avenacides. This agrees with the knowledge that wild oats which emerge with the crop are regarded as being the most competitive, particularly at high densities, supporting the argument for early removal (McNamara 1976).

Studies in southern New South Wales, South Australia and Western Australia have shown that wheat and barley cultivars vary in their tolerance to avenacides. Varietal cereal yield reductions have been recorded to barban, diclofop-methyl, difenzoquat, flamprop-methyl and tralkoxydim (Lemerle *et al.* 1981, 1985, Bowran 1993, Wheeler *et al.* 1995). Yield losses have also been recorded for tralkoxydim under waterlogged conditions, and when used in conjunction with a wetter or adjuvant (Madin and Martin 1990). In comparison, clodinafop-propargyl, fenoxaprop-*p*-ethyl and flamprop-methyl have not induced major yield losses. Where losses were observed, cultivar tolerance was strongly influenced by seasonal conditions and to a lesser extent by soil type (diclofop-methyl has induced zinc deficiency in some cases, and where zinc is not limiting slight yield increases have sometimes been recorded).

Trends in the northern hemisphere have indicated considerable weed control savings can be made by applying herbicides at lower than recommended rates. In Australia, dose response information is generally undertaken during development of products but is rarely reported. Often only a single dose rate is recommended. Lemerle and Verbeek (1995) found that lowering dose rate is unlikely to be a practical option for clodinafop-propargyl, diclofop-methyl, fenoxaprop-*p*-ethyl, or tralkoxydim, especially when soil moisture is limiting. Because herbicide potency can sometimes be increased by the addition of surfactants or oils (Gilmour *et al.* 1989, Anderson 1990, Moerkerk *et al.* 1992), this offers a further possibility for reducing herbicide dose rates, but as mentioned above, increased potency can mean greater phytotoxicity. Martin and Pannell (1990) developed a model to determine the optimum economic rate of tralkoxydim and Pandey and Medd (1990) used dose response curves for diclofop-methyl in their bioeconomic simulation of seed kill.

Table 1. Selective herbicides adapted for control and suppression of wild oats (from Chambers 1995).

Group	Active constituent
A (APP's)	Clodinafop-propargyl, diclofop-methyl, fenoxaprop-*p*-ethyl, fluazifop-*p*, haloxyfop, propaquizafop, quizalofop-*p*-ethyl
A (CHD's)	Clethodim, sethoxydim, tralkoxydim
B	Imazethapyr
C	Atrazine, diuron, metribuzin, simazine
D	Pendimethalin, trifluralin
E	Triallate
F	Amitrole
K	Flamprop-methyl, Flamprop-*m*-methyl

Seed production

The development of technology that directly controls seed production would enable wild oat populations to be more efficiently regulated within winter crops (Medd and Pandey 1993). Because wild oats shatter, seed capture is not an option. One of the main failings of early application of avenacides is their inability to control seed production, in part due to the staggered germinating habit of wild oats. To this end, the use of post-emergence herbicides applied late (early wild oat tiller elongation stage) in northern New South Wales was found to be a promising strategy to minimize wild oat seed production and the replenishment of seed banks (Medd *et al.* 1992 and 1995). Flamprop-methyl, flamprop-m-methyl and fenoxaprop-ethyl were the most effective herbicides, reducing seed production by up to 96%. Nietschke *et al.* (1996b) reported similar results for late applications of flamprop-*m*-methyl, with seed production reduced by an average of 97% over two sites in South Australia. It has been suggested this method be referred to as 'selective spray-topping'.

The practice of 'crop-topping' using paraquat has recently been registered to limit annual ryegrass seed production in pulse crops. Research recently undertaken by in South Australia (Matthews *et al.* unpublished data) found that paraquat applied for three successive years (at the beginning of wild oat seed shed), reduced the wild oat seed bank by 53% in a wheat-field pea rotation. Alternative research in South Australia evaluated flamprop-*m*-methyl as an early crop-topping control method in wheat (Nietschke *et al.* unpublished data). It was determined that seed production was reduced by up to 72% when flamprop was applied to wild oats at the late booting growth stage.

Where a pasture or winter fallow phase is incorporated into a cropping rotation, knockdown herbicides (glyphosate and paraquat) provide an ideal opportunity to eliminate seed set. By reducing the input of new seed, the seed bank can be significantly depleted before reverting to a crop. For example, Mansooji (1993) reduced the wild oat seed bank by 97% in 3.5 years with annual applications of glyphosate. These well established techniques are termed 'pasture topping' or 'spray-topping' when used to control seed set in pastures, and 'winter cleaning' when used to spray-out pastures or fallows.

Population management

Weed management aims to minimize weed populations and maximize economic benefits. Short-term (yearly or current crop) economic decision making concepts are the norm, with little regard to costing the future consequences of seed production, development of herbicide resistance, effects from herbicide residues in the soil, and shifts in the botanical composition of the weed flora. Consequently, expenditure on weed control and rotations should ideally be evaluated as a long-term investment to account for ongoing and possibly more serious future weed problems. As discussed by Auld and Tisdell (1987), uncertainties about crop loss functions and potential weed densities, along with farmers attitudes to risk also need to be considered.

Will long term policy decision making lead to lower weed populations and cheaper weed control, and if so, will farmers adopt such policies?

Herbicide resistance in wild oats

To achieve wild oat control in Australian cropping systems, there is widespread and persistent use of Group A herbicides. This has resulted in the appearance of resistant wild oat populations (Mansooji *et al.* 1992). In north eastern Victoria, 6% of 1992 cropping paddocks contained diclofop-methyl resistant wild oats (Walsh 1995), compared with 4% of 1993 cropping paddocks in the mid-north of South Australia (Nietschke *et al.* 1996a). In southern New South Wales the level of diclofop-methyl resistant wild oats had increased from 3% in 1991 to 5% in 1994 (J. Broster personal communication). Given the continued reliance on Group A herbicides, the incidence of herbicide resistant wild oats throughout southern Australian cropping zones will undoubtedly increase.

Mansooji *et al.* (1992) recorded variable patterns of resistance to Group A avenacides. Most populations exhibit either one of two patterns: resistance only to diclofop; or a high resistance to all APP's and a low resistance to CHD's (Holtum 1992). To date there have been no reports of cross or multiple-resistance in wild oats in Australia, although this can reasonably be expected given the experience in Canada (Morrison *et al.* 1995).

These patterns have implications for the chemical management of wild oats. To help slow the onset of resistance and ensure long term herbicide effectiveness, heavy importance must be placed on the rotation between herbicide groups. A variety of non-Group A avenacides can be utilized in field crops (Table 1). The most important options include triallate (cereal and broadleaf crops), flamprop-methyl (wheat, triticale and safflower), simazine (lupins and faba beans), imazethapyr (faba beans and field peas) and diuron (lupins and field peas). Furthermore, simazine and atrazine can be utilized for wild oat control in triazine resistant canola, although this may only be attractive at relatively high wild oat densities because of the yield penalties associated with resistant canola plants (Forcella 1987). Note, however, that residue persistence of herbicides such as atrazine (Walker *et al.* 1994) and trifluralin (Jolly and Johnstone 1994) can be a serious crop rotation constraint that must be considered when designing herbicide rotations.

Minimal CHD resistance of wild oats has so far been reported in Australia and therefore the use of CHD's at recommended rates is effective on most APP resistant populations. Thus, the long term usefulness of CHD's (and other herbicide groups) must be conserved through prudent herbicide choice and use, to minimize selection pressure towards resistance.

Whilst herbicide rotation is a 'state of the art' recommendation, a sobering word of caution comes from Morrison *et al.* (1995) in relation to the Canadian experience:

"… farmers who identified the problem were rotating herbicides with the expectation that they could avert the resistance problem on their farm. Herbicide rotation in itself did not provide the intended result. This does not invalidate the practice of avoiding or delaying the onset of single target site resistance. However it does serve as a reminder that herbicide rotation is a stop-gap, medium term solution to the problem and reinforces the need for longer-term, more integrated approaches to weed management."

Conclusion

Herbicides will continue to be the most potent component of any integrated management system for wild oats. Few economically attractive cultural techniques currently exist in southern Australian cropping systems (Nietschke 1996). Herbicide management must be a balance between: minimizing crop yield loss and phytotoxic damage; minimizing wild oat seed production; minimizing the selection pressure for herbicide resistance; and minimizing populations. The greatest chance of achieving high yield increase results from reducing wild oats to low densities, whilst seed production can be successfully minimized by choosing a spray-topping technique appropriate for the situation. Triallate is best utilized to control medium to heavy weed infestations while flamprop is most effective under low density infestations. Both herbicides have the added advantage of being non-Group A avenacides. From a herbicide resistance management perspective, this is valuable since a range of herbicides can be rotated between classes, thus slowing the onset of herbicide resistance. Additionally, the pasture or winter fallow phase of a rotation offers an important option for total seed kill through the use of a non-selective herbicide.

Possible research emphasis

Practical techniques for minimizing wild oat populations are now feasible but it remains to be demonstrated if these can be economically implemented. Expenditure on weed control is mostly based on short term (yearly or current crop) economic decision making concepts, with little regard to future consequences. Medd (in press) argued that short term weed management policies generally use more resources, require repeated intervention to treat successive infestations, fail to contain weed populations and are as a consequence probably more costly than a long term approach to population management. The advantage of adopting a long term policy to manage populations has been illustrated for wild oats by simulation (Pandey and Medd 1990), but remains to be validated.

Extensive research in northern New South Wales has examined the use of both pre-emergence and late post-emergence herbicides as important tools for the management of wild oats in winter cereal rotations, but little work of a similar nature has been undertaken in southern Australia.

Weeds often occur in mixtures e.g. wild oats and barley grass (Poole and Gill 1987). Survey (Nietschke *et al.* 1996a) and widespread observations indicate that wild oats and annual ryegrass also regularly coexist in southern Australian cropping systems, but little is known of the effect herbicides and other weed management practices have on the dynamics of each species under these circumstances. Research recently undertaken in South Australia, demonstrated that both pre-emergent (triallate / trifluralin) and crop-topping (paraquat) herbicide application has a greater impact on annual ryegrass than wild oats when present as a mixed field infestation (Matthews *et al.* unpublished data). Additionally, cultural techniques such as weed seed collection at harvest, crop stubble burning and delayed seeding impact less on wild oats, thus contributing to their ongoing persistence if present with annual ryegrass.

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