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Integrated weed management strategies for delaying herbicide resistance in wild oats

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Résumé de l'article

Les biotypes de folle avoine (*Avena fatua*) résistants aux herbicides infestent les principales régions céréalières de l'Ouest américain et de l'Ouest canadien. Cet article passe en revue les stratégies de lutte intégrée contre les mauvaises herbes qui peuvent être utilisées pour empêcher ou retarder le développement de la résistance aux herbicides chez la folle avoine. Une stratégie de lutte intégrée contre la folle avoine, destinée à retarder ou à empêcher le développement de la résistance, devrait être basée sur la prévention de l'introduction des grains de folle avoine dans le sol. Deux façons d'y arriver sont d'empêcher l'immigration de graines dans le champ à partir de sources externes, et de réduire ou éliminer la production de graines par la folle avoine déjà présente au champ. Il est de plus en plus évident que le recours à l'utilisation continuelle d'herbicides comme seul moyen de lutte contre les mauvaises herbes n'éliminera pas la folle avoine ni les autres graines de mauvaises herbes de la banque de graines du sol. Au contraire, tout porte à croire que cette pratique va sélectionner des biotypes résistants aux herbicides utilisés, particulièrement là où des herbicides ayant le même mode d'action sont utilisés de façon continue. Il est essentiel, cependant, que les herbicides soient considérés seulement comme une composante d'un système intégré global incluant la lutte culturale et d'autres stratégies de gestion, et que les principes agronomiques soient considérés lors du développement de ce système.

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Integrated weed management strategies for delaying herbicide resistance in wild oats

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Herbicide-resistant biotypes of wild oats (*Avena fatua*) infest most major cereal producing regions in the western United States and Canada. This paper reviews potential integrated weed management strategies that can be used to prevent or delay selection of herbicide-resistant wild oats plants. An integrated wild oats management strategy to delay or prevent the development of herbicide resistance should be based on preventing the movement of wild oats seed into the soil. Two ways to achieve this are by preventing the immigration of seed into the field from external sources, and by reducing or eliminating seed production by wild oats already in the field. It is becoming increasingly clear that reliance on continuous herbicide use as the sole means of weed control will fail to eliminate wild oats and other weed seed from the soil seedbank. On the contrary, evidence is mounting that this practice will select for biotypes that are resistant to the herbicides used, especially where herbicides of the same mode of action are used continuously. It is essential, therefore, that herbicides be considered as just one component of an overall integrated system together with cultural control and other management strategies, and that agronomic principles be considered when developing this system.

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Les biotypes de folle avoine (*Avena fatua*) résistants aux herbicides infestent les principales régions céréalières de l'Ouest américain et de l'Ouest canadien. Cet article passe en revue les stratégies de lutte intégrée contre les mauvaises herbes qui peuvent être utilisées pour empêcher ou retarder le développement de la résistance aux herbicides chez la folle avoine. Une stratégie de lutte intégrée contre la folle avoine, destinée à retarder ou à empêcher le développement de la résistance, devrait être basée sur la prévention de l'introduction des grains de folle avoine dans le sol. Deux façons d'y arriver sont d'empêcher l'immigration de graines dans le champ à partir de sources externes, et de réduire ou éliminer la production de graines par la folle avoine déjà présente au champ. Il est de plus en plus

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évident que le recours à l'utilisation continuelle d'herbicides comme seul moyen de lutte contre les mauvaises herbes n'éliminera pas la folle avoine ni les autres graines de mauvaises herbes de la banque de graines du sol. Au contraire, tout porte à croire que cette pratique va sélectionner des biotypes résistants aux herbicides utilisés, particulièrement là où des herbicides ayant le même mode d'action sont utilisés de façon continue. Il est essentiel, cependant, que les herbicides soient considérés seulement comme une composante d'un système intégré global incluant la lutte culturale et d'autres stratégies de gestion, et que les principes agronomiques soient considérés lors du développement de ce système.

Nomenclature of chemical names cited in the text:

Chlorotoluron: *N'-(3-chloro-4-methylphenyl)-N,N'-dimethylurea;* diclofop: *([±-2-(4-(dichlorophenoxy) phenoxy)propanoic acid;* difenzoquat: *1,2-dimethyl-3,5-diphenyl-1H-pyrazolium;* flamprop-isopropyl-L: *N-benzoyl-N-(3-chloro-4-fluorophenyl-L-alanine;* imazamethabenz: *[+/-]-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-4(and 5)-methylbenzoic acid (3:2);* sethoxydim: *2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one;* triallate: *S-(2,3,3-trichloro-2-propenyl)bis(1-methylethyl)carbamothioate.*

INTRODUCTION

Over 100 weed biotypes have developed resistance to 14 classes of herbicides during the past 25 to 30 yr (LeBaron 1991). Many of the cases have been reported during the past 10 yr in cereal production systems in the United States and Canada. Examples include kochia [*Kochia scoparia* (L.) Schrad.], Russian thistle (*Salsola pestifer* A. Nels.), prickly lettuce (*Lactuca scariola* L.), annual ryegrass (*Lolium rigidum* Gaud.), chickweed [*Stellaria media* (L.) Vill.], and slender foxtail (*Alopecurus myosuroides* Huds.) resistant to acetolactase-inhibitor herbicides (Saari *et al.* 1994), wild oats, Italian ryegrass (*Lolium multiflorum* Lam.), annual ryegrass, and slender foxtail resistant to acetyl-CoA carboxylase-inhibitor herbicides (LeBaron 1991); chlorotoluron-resistant slender foxtail (Moss 1992), dinitroaniline-resistant green foxtail [*Setaria viridis* (L.) Beauv.] (Morrison *et al.* 1991), triallate-resistant wild oats (O'Donovan *et al.* 1992), triazine-resistant downy brome (*Bromus tectorum* L.) (LeBaron 1991), and wild mustard [*Brassica kaber* (DC.) Wheeler] resistant to auxin-type herbicides (Heap and Morrison 1992). There also have been reports of cross resistance to more than one herbicide group. For example, triallate-resistant wild oats is resistant to difenzoquat (O'Donovan *et al.* 1992), diclofop-resistant annual ryegrass is resistant to nine other herbicide classes (Powles and Matthews 1992), and chlorotoluron-resistant slender foxtail shows varying degrees of resistance to 23 different herbicides (Moss 1992).

In virtually all reported cases, herbicide-resistant weeds have occurred where herbicides are the major or only component of the weed control program and where integrated weed management strategies have not been used. Integrated weed management strategies can reduce selection pressure and prevent or delay resistance. For example, triazine-resistant weeds have not appeared in the midwestern section of the United States where appropriate crop and herbicide rotations are used frequently.

Current recommendations for managing herbicide resistance tend to concentrate on modifying herbicide use strategies (*e.g.* rotating herbicides of different modes of action or applying herbicides in mixtures). Integrated approaches to weed management are sometimes mentioned, but rarely discussed in any detail. To be successful, management practices to delay or prevent selection of herbicide-resistant weeds must be part of an integrated weed management plan for a specific production system.

Herbicide-resistant weed management strategies can be adapted from strategies used by entomologists to manage insecticide resistance (Forrester 1990). A herbicide resistance management program should include weed management programs for arable and non-arable lands, be regional with local adaptability, and should be integrated in such a way as to include weed management in all parts of the production system. It also should be designed for a farming system rather than a herbicide marketing program, be proactive rather than reactive, and should be able to fit into government-based farm programs. Strategies to prevent or delay the occurrence of herbicide-resistant weeds in crop production systems rarely have been implemented. For example, there has been little or no integration of weed management strategies for cropland with those for adjacent sites such as rights-of-way. A recent survey in Idaho showed that over 50% of croplands sampled contained resistant kochia, even though sulfonylurea herbicides had not been applied repeatedly to the land (Mallory-Smith *et al.* 1993). Roadsides continuously treated with sulfonylurea herbicides likely served as the seed source that infested the adjacent cropland.

The likelihood of selecting for herbicide-resistant weed biotypes should be minimal if an effective integrated weed management plan is part of a crop production program. Integrated weed management has been defined as the integration of effective, environmentally safe, and sociologically acceptable control tactics that reduce weed interference below the economic injury level (Thill *et al.* 1991). An integrated weed management strategy must be included in all parts of a crop production system (Swanton and Weise 1991). This includes a consideration of tillage system, critical period of weed interference, alternative methods of weed control, enhanced crop competitiveness, crop rotation, weed seedbank dynamics, and modeling of crop-weed interference. Overall, weed management strategies should be flexible to adjust to changing environmental, technological, economic, and social factors, while incorporating the long-term impacts of specific control measures (Swanton and Weise 1991). This includes management practices to prevent or delay the appearance of herbicide-resistant weeds.

The objective of this paper is to review potential integrated weed management strategies that could be used to delay or prevent the selection of herbicide-resistant weed biotypes. It focuses on wild oats, one of the most serious weeds of field crops in Canada and the United States (Holm *et al.* 1977).

COMPONENTS OF A MANAGEMENT STRATEGY

The overall goal of a wild oats management program to prevent or delay the development of resistance should be to reduce the movement of wild oats seed into the soil. This can be achieved by preventing wild oats immigration into a field, and by management of wild oats already in the field.

Prevention of immigration

Immigration of herbicide-resistant wild oats seed into a field can lead to a rapid buildup of the resistant population, particularly if the same herbicide (or class of herbicides) that selected for the resistance continues to be used. Immigration of most wild oats seed into a field can be prevented by planting clean seed, cleaning harvest and tillage equipment between fields, covering grain trucks used to transport grain, avoiding transfer of soil from roadsides to cropland, and controlling wild oats infestations along roadsides, fence rows, and waste areas. Mowing, burning, and spraying with herbicides will control wild oats plants and minimize or prevent seed production in these non-crop areas. Herbicides should be used only in combination with cultural control methods, and should have a different mode of action than the herbicides used to control wild oats in the field during any part of the crop production system. For example, do not use acetyl-CoA carboxylase inhibitor herbicides to control wild oats in non-crop areas if diclofop, sethoxydim or other similar herbicides are used to control it in crops. Harvesting wild oats plants for green forage before plants shed seed effectively controlled wild oats (Cussans and Wilson 1976). Mowing non-crop areas to prevent wild oats seed production should be an equally effective control strategy. Burning, at best, will be partially effective (Wilson and Cussans 1975) and may increase wild oats establishment due to suppression of perennial species and reduced surface plant residues in non-crop areas. Immigration of herbicide resistant wild oats seed into a field can be minimized if these strategies are implemented by growers.

Management of wild oats

A number of factors will influence how effectively wild oats is managed in a field, and how much wild oats seed is returned to the soil. These include weed control practices such as herbicide use, tillage, stubble burning and roguing, as well as agronomic factors such as choice of crops and cultivars, type of crop rotation, relative density and time of emergence of weeds and crop, row spacing, fertility level and fertilizer placement.

Herbicides

Rotating herbicides is a frequently mentioned strategy for delaying herbicide resistance. This topic is discussed as part of the paper presented by Jasieniuk and Maxwell (1994). Thus, we do not discuss this strategy here. Our discussion will focus on the effects of herbicides on wild oats population dynamics.

Numerous experiments have shown that herbicides effectively can reduce wild oats infestations, wild oats seed production, and crop yield loss due to wild oats. However, most of these experiments have been short-term, usually lasting only one growing season. A few have measured the effects of herbicides on wild oats seed production. In a 4-yr study, wild oats in plots treated with triallate and difenzoquat produced 80-95% less seed compared to the untreated control in continuous wheat (*Triticum aestivum* L.) (Fernandez-Quintanilla *et al.* 1987). Flamprop-isopropyl-L reduced seed production by 59-72%. Herbicide-treated plots had 61-81% less seed in the soil at the end of the 4-yr experiment compared to initial seed populations, and 92-95% fewer seeds than plots not treated with herbicides. However, the populations were still high enough to require some form of control, even after 4 yr of herbicide use. In another study in spring barley (*Hordeum vulgare* L.), 118 wild oats plants m^{-2} treated with imazamethabenz at 0.46 kg a.i. ha^{-1} produced 670 seeds m^{-2} compared to 3300 seeds m^{-2} produced by untreated plants (D. Thill, unpublished data). Even though control in the treated plots was greater than 90%, wild oats seed production exceeded initial plant populations by five times.

A population dynamics model for sterile oats (*Avena sterilis* L.) in dryland cereal cropping systems showed that seedbank populations continued to increase over a 10-yr period when control with herbicides was less than 85%, and the long-term effect of herbicides on wild oats populations was relatively small (Gonzalez-Andujar and Fernandez-Quintanilla 1991). About 95% control was required to cause an asymptotic reduction in the seedbank over time.

These studies suggest that continuous herbicide applications alone will rarely, if ever, eliminate wild oats from the soil seedbank. However, any weed management practices that reduce wild oats seed numbers, including herbicide application, should reduce the probability of selecting for a herbicide-resistant biotype. It is important to note that continuous use of herbicides with the same mode of action should be avoided even though they initially may reduce wild oats seed production. Eventually, continuous use of herbicides with the same mode of action will select for herbicide-resistant biotypes.

Tillage

In continuous winter wheat, wild oats populations increased dramatically in shallow-tine cultivation treatments compared to plowing, direct drilling, and deep-tine cultivation during a 4-yr experiment (Pollard and Cussans 1981). Plowing, and to a lesser extent, deep cultivation, buried wild oats seed and reduced the number germinating in any one year. Direct drilling left wild oats seed on the soil surface where natural mortality was greater. Shallow tillage mixed the seeds into the surface layer of soil and provided an optimum environment for survival and germination. Tine cultivation also resulted in more wild oats seedlings in the first year of a 4-yr study in continuous spring barley (Wilson 1981). By the second year, plowing resulted in a greater wild oats seedling population because deeply buried seeds were brought to the soil surface. Wild oats plants were not allowed to produce seed during the study and regardless of tillage method, few wild oats seeds persisted in the soil beyond 4 yr, which falls within the 2-5 yr range often reported for wild oats seed (Chancellor 1976b). Populations of wild oats likely can be reduced by occasional deep plowing (once every 4 yr) if increased soil erosion can be avoided. However, spring cultivation, compared to no cultivation or plowing, hastened wild oats seed decline in soil when surviving plants were not allowed to produce seed (Peters 1991).

Relative emergence time

The competitive ability of a weed, relative to a crop, depends largely on time of emergence. Usually, early emerging wild oats plants are most competitive (O'Donovan *et al.* 1985) and more likely to survive and produce the most seed (Chancellor and Peters 1974). Later emerging wild oats plants tend to be less competitive, but can reduce grain yield of cereals, especially at high plant densities.

In greenhouse studies, wild oats plants that emerged 3 and 6 wk after wheat had combined root and shoot dry wt that were 47 and 75% less, respectively, than plants that emerged with the wheat (Martin and Field 1988). Additionally, the late-emerging plants did not produce panicles and, thus, no seed. Field experiments in Canada with wild oats densities ranging from 50-100 plants m^{-2} showed that grain yield loss increased by about 3% for every day wild oats plants emerged before wheat or barley (O'Donovan *et al.* 1985). This simple multiple regression equation also showed that yield loss gradually diminished by the same amount for every day wild oats emerged after the crops. Yield loss for barley generally was less than yield loss for wheat. This model was further refined by Cousens *et al.* (1987). Unfortunately, the effect of emergence time on wild oats plant growth and seed production was not reported. In a modeling study, Gonzalez-Andujar and Fernandez-Quintanilla (1991) reported that the contribution of late-emerging wild oats plants to the overall dynamics of the population was small and could be disregarded. This may not always be the case, especially in a weakly competitive crop. Wild oats plants that emerge late relative to strong competitive crops such as barley may not require control with herbicides. Omitting herbicide application in these situations would delay or prevent selection of herbicide-resistant wild oats biotypes.

Relative crop and wild oats densities

Crop yield losses due to wild oats generally have been shown to increase with increasing wild oats density (Bell and Nalewaja 1968; Bowden and Friesen 1967; Chancellor and Peters 1976; Dew 1972; Hussain *et al.* 1985; Morishita and Thill 1988). Few studies have investigated the effects of crop density on the competitive interactions between wild oats and crops, or the impact of crop density on wild oats seed production. Wheat yield losses due to wild oats decreased as wheat seeding rate increased (Carlson and Hill 1985), but the effect of wheat density on wild oats seed production was not measured. When winter wheat density was increased from 60 to 195 plants m^{-2}, wild oats seed production was reduced 52% (Wright 1993). Wild oats seed production was reduced 52% (to 1450 seeds m^{-2}) when barley seeding rate was increased from 94 to 188 kg ha^{-1} (Elliot 1972). Similarly, a more recent study showed that increasing barley density from 135 to 415 plants m^{-2} and from 170 to 625 plants m^{-2} reduced wild oats seed production over a wide range of wild oats densities by approximately 70% (Evans *et al.* 1991). At the highest barley plant populations, however, wild oats plants still produced 1300-2800 seeds m^{-2}. These studies suggest that although increasing crop density can alleviate the affects of wild oats on crop yield, and reduce wild oats seed production considerably, long-term wild oats control using this practice alone is unlikely. It may be more feasible when used in combination with other weed control measures such as limited herbicide use (Barton *et al.* 1992).

Row spacing

Cereal seed distribution may or may not affect crop competitiveness with weeds. For example, wild oats growth and seed set were greatest in barley seeded at 94 kg ha^{-1} in 20-cm spaced rows, and were least in barley seeded at 188 kg ha^{-1} in 10-cm spaced rows (Bate *et al.* 1970). Averaged over barley seeding rate, wild oats seed production was reduced 46% (to about 1570 seeds m^{-2}) when barley was planted in 10-cm compared to 20-cm spaced rows. Kirkland (1993) has reported similar findings in the absence of herbicides. When barley was seeded at 180-535 seeds m^{-2} in 9- and 18-cm spaced rows, wild oats biomass was not different between row spacing treatments (Barton *et al.* 1992). Wild oats plant counts and biomass were not affected by row spacing when no-till spring wheat was seeded at 95 kg ha^{-1} in 20-, 30-, and 40-cm spaced rows (Reinertsen *et al.* 1984). Likely, the effect of crop row spacing on wild oats productivity interacts with several other agronomic and environmental factors. It can be concluded, though, that narrowly spaced rows of crop plants will be equal to or more competitive with wild oats than widely spaced rows of crop plants.

Fertility level and fertilizer placement

Reports vary regarding the effect of fertilizers on reducing wild oats competition in cereal crops. Effects range from a 50% reduction in wild oats stem number in fertilized wheat to a 16% increase in wild oats population in fertilized barley (Chancellor and Peters 1976). A recent 3-yr study showed that the number of wild oats seeds per plant increased from 555 to 826 to 1115 to 1195 as nitrogen fertilizer rate increased from 0 to 50 to 100 to 200 kg ha^{-1} in winter wheat (Wright 1993).

There were 27-57% less wild oats plants in no-till spring wheat early and late in the growing season, respectively, when nitrogen fertilizer was band-applied in the seed row compared to broadcast-applied before seeding wheat (Reinertsen *et al.* 1984); however, late in the growing season, wild oats biomass was the same between fertilizer treatments. Fertilizer placement did not interact with crop row spacing or herbicide treatments. In spring barley, there were 28 - 60% fewer wild oats stems m^{-2} when nitrogen fertilizer was band-applied compared to broadcast-applied (J.Lish and D. Thill, unpublished data). Wild oats seed production was not measured in either study. It would be important to know if fertilizer banding compared to broadcast applications reduced wild oats seed production. It appears that broadcasting fertilizer favors wild oats growth, while banding generally favors the crop. However, excessive levels of nitrogen fertilizer banded with the crop seed can injure the crop, which will reduce its competitiveness against weeds.

Nitrogen fertilizer also has been shown to stimulate germination and emergence of wild oats (Agenbag and De Villiers 1989). In this case, a broadcast application of nitrogen fertilizer could stimulate seed germination and seedling emergence of wild oats before planting. The emerged wild oats plants could be controlled easily with cultivation or a non-selective herbicide before planting the crop. This technique would work only in production areas with longer growing seasons and where fertilizer can be broadcast-applied well before spring tillage.

Competitive crops and cultivars

Winter-planted cereals are more competitive with spring-germinating wild oats than spring-planted cereals (Chancellor and Peters 1976). Spring barley usually competes better with wild oats than spring wheat, oats (*Avena sativa* L.), or rye (*Secale cereale* L.) (Bell and Nalewaja 1968; Carlson and Hill 1985; Chancellor and Peters 1976) and barley is more competitive than wild oats (Bate *et al.* 1970; Bell and Nalewaja 1968; Evans *et al.* 1991). Peas (*Pisum sativum* L.) and flax (*Linum usitatissimum* L.) are poor competitors (Chancellor and Peters 1976). In pot experiments conducted outdoors, it was shown that barley cultivars differ in their ability to compete with wild oats and that competitiveness of individual cultivars could be affected by phosphorus fertilizer level (Konesky *et al.* 1989). Growing competitive crops as part of the normal crop rotation should reduce wild oats productivity (seed output), especially if the crop is more competitive than wild oats and if locally adapted cultivars are planted.

Crop rotation

Several studies suggest that combining crop rotations with herbicide use can effectively reduce wild oats populations over time. A weed population dynamics model projects that continuous herbicide use over 10 yr in continuous winter wheat would result in a gradual increase in wild oats population (Gonzalez-Andujar and Fernandez-Quintanilla 1991). Wild oats populations were nearly eliminated in 9-10 yr in a fallow-winter wheat or a fallow-winter wheat-spring barley rotation when herbicides were used only in crops. This shows the benefit of crop rotation in reducing wild oats populations over time.

In a 6-yr field experiment, wild oats populations in soil decreased 21% in a continuous wheat rotation and 41% in a winter wheat-spring barley-spring pea rotation (D. Thill, unpublished data). In the latter experiment, herbicides were applied to achieve low, medium, and high levels of wild oats control. In the continuous wheat rotation, low, medium, and high control levels resulted in a 55% increase, and a 49 and 74% decrease, respectively, in wild oats seed in the soil after 6 yr. A similar trend was observed in the wheat-barley-pea rotation. The low, medium, and high levels of control resulted in a 32% increase and a 63 and 84% decrease, respectively, in wild oats seed in the soil. Thus, wild oats seed populations in soil were reduced more in the diverse crop rotation compared to continuous wheat at any level of wild oats control with herbicides.

Failure to control wild oats in continuous wheat resulted in wild oats populations increasing from an initial 12 plants m^{-2} or less to over 200 plants m^{-2} after 4 yr (O'Donovan 1988). In continuous barley or a barley-canola (*Brassica napus* L.) rotation, populations increased to only about 40 plants m^{-2}. In a study in the United Kingdom, wild oats populations were reduced to a greater extent when non-cereal crops were rotated with cereals than when cereals were grown continuously (Phipps and Roebuck 1980).

The viability of wild oats seed in the soil in a perennial crop, such as grass, is about the same as in fields tilled annually (Chancellor 1976a). However, the rate of decline usually was faster in soils cultivated annually because soil disturbance encouraged seed germination. Wild oats seed produced in a perennial crop are left on the soil surface where natural mortality is greater than for deeply-buried seeds (Pollard and Cussans 1981), which should hasten the depletion of seed reserves in soil.

Other agronomic factors

About 33% of newly-shed wild oats seeds on the soil surface can be destroyed by stubble burning that follows soon after grain harvest (Wilson and Cussans 1975). Combined with other control strategies, stubble burning could be used to reduce initial seed populations in areas of a field severely infested with wild oats as a form of zone management. The self-burial mechanism of wild oats seed into the soil allows many seeds to escape if burning is delayed until later in the fall (Cussans and Wilson 1976).

Late-planted spring crops and early-planted fall crops generally have fewer wild oats plants than early-planted spring crops and late-planted fall crops (Chancellor and Peters 1976). Wild oats populations have been reduced 36-97% by late-planting spring wheat or barley. The disadvantage of delayed planting is reduced crop yield or quality, which can be substantial depending on how long planting is delayed. However, since not all fields on a farm can be planted at the same time, those fields with the worst wild oats infestation could be planted last.

Roguing fields with sparse wild oats infestations will prevent population increases in future years (Cussans and Wilson 1976). Wild oats plants should be rogued near the heading stage, but well before viable seeds are produced. Where dense stands of wild oats exist in a field, cutting the crop and wild oats for hay or silage before seed shed can greatly reduce seed rain. Also, a chaff collector used at harvest will collect many wild oats seeds and remove them from the field.

CONCLUSION

The development of an integrated wild oats management strategy to delay or prevent the development of herbicide resistance should be based on preventing the movement of wild oats seed into the soil. It is becoming increasingly clear that reliance on continuous herbicide use as the sole means of weed control will fail to eliminate wild oats and other weed seed from the soil seedbank. Evidence is mounting that this practice will select for biotypes that are resistant to herbicides, especially where herbicides of the same mode of action are used continuously. It is essential, therefore, that herbicides be considered as just one component of an overall integrated system, together with cultural control and other management strategies, and that agronomic and ecological principles be considered when developing this system.

Competitive interactions between wild oats and crops are a very complex issue. Several agronomic factors will influence the extent to which crop yield is reduced by wild oats, and the amount of wild oats seed produced and returned to the soil. Manipulating these factors to favor the crop against the weed and integrating them with reduced herbicide use and cultural control measures has the potential to reduce wild oats competition and seed production.

Farmers should prepare individual field maps that show the boundaries and infestation level (none, low, medium, high) of wild oats for all of their fields. Maps should be updated annually, preferably before crop harvest when wild oats plants are highly visible. They need to keep accurate records of all cultural practices and chemical applications made to the field and record changes in wild oats population levels and boundaries. This will allow them to assess the long-term effects of their management program. Zone or area management of wild oats within a field should be used if infestations are confined to certain areas of the field. Over time, integration of these practices combined with a diverse crop rotation should reduce wild oats seed populations, and reduce the need for herbicide application every year. At the same time, the risk of selecting for herbicide-resistant biotypes would be reduced considerably compared to situations where herbicide use was the dominant weed control practice.

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