STRATEGIES TO COMBAT HERBICIDE RESISTANCE WITH PARTICULAR REFERENCE TO ANNUAL RYEGRASS, *LOLIUM RIGIDUM*, IN SOUTH-EASTERN AUSTRALIA

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Summary. A national policy on herbicide use which emphasises their importance as part of a total weed control program is required. Management strategies which have been developed to combat herbicide resistant ryegrass in southern New South Wales and north-eastern Victoria are outlined and responsibilities for their adoption are suggested.

INTRODUCTION

Herbicide resistant weeds have been slow to develop, especially in Australia. However, since resistance was identified in annual ryegrass, *Lolium rigidum*, in 1982 (5), there has been a steady increase in the number of cases and there are now about 300 reported farms with herbicide resistant ryegrass in south-eastern Australia (J. Dellow, pers. comm.). Indications suggest that the number of cases will continue to increase. There is now an urgent need to develop management strategies to counter herbicide resistance and to have these strategies incorporated into modern farming practices.

This paper discusses the need for a national policy on herbicide use and describes management strategies which have been developed to combat herbicide resistant ryegrass (HRR) in southern New South Wales and north-eastern Victoria. We intend it as a discussion paper and do not see it as a final treatise.

NATIONAL POLICY ON HERBICIDE USE

In the current decade when environmental issues are receiving extensive media coverage and legislation to reduce herbicide use has been enacted in at least one country (4), it is timely to re-think our philosophy on the use of herbicides with a view to prolonging their life and effectiveness.

With this in mind there is a need for a national policy on herbicide use which emphasizes their importance as part of a total weed control program. One of the major objectives of this policy should be to delay the development of herbicide resistance. This part of the policy should include:

1. An awareness campaign to publicise the potential for resistance with ad hoc herbicide applications and the implications of herbicide resistance for future farming options.

2. Development of strategies for herbicide use with the aim of minimising the potential forresistance.

3. Appropriate, co-ordinated, technology transfer programs to enhance the adoption of these strategies.

While the national policy needs to be uniform, strategies to combat specific herbicide resistance in individual species probably need to be developed on a regional basis to allow for differences in farming practices, herbicide use and possibly weed ecotype. As examples, farming systems in dryland southern NSW and north-eastern Victoria are very similar and uniform strategies may be developed for these two areas. This may well be the case in most of southern Australia. Farming systems in southern and northern NSW are however very different and the strategies

for southern NSW may not be appropriate in northern areas. Irrigation areas may also require different strategies.

STRATEGIES TO COMBAT HRR IN SOUTHERN NSW AND NORTH-EASTERN VICTORIA

Agriculture on the slopes of southern NSW and north-eastern Victoria involves a close relationship between crops and livestock which co-exist in winter crop-clover ley rotations. The clover ley is based on subterranean clover but annual grasses, especially annual ryegrass, are also important. Because of this we envisage three distinct parts to the strategy:

1. A strategy for herbicide use in pastures which minimises the chance of selecting resistant ryegrass.

2. A strategy for herbicide use in crops which minimises the chance of selecting resistant ryegrass.

3. A strategy for farms which already have HRR.

In developing these strategies the following assumptions have been made:

1. The resistant biotype is present at very low frequencies throughout the susceptible population and only becomes obvious through herbicide selection.

2. Because of the variety available and volume used, aryloxyphenoxypropionates (AOPP eg diclofop-methyl) are the herbicides most likely to develop resistance. Cyclohexanediones, (CHD eg sethoxydim) and AOPP herbicides are however likely to be similar in selecting for resistance and are grouped together when considering possible options on farms without HRR.

3. Trifluralin based herbicides, chlorsulfuron, triasulfuron and simazine are considered a lower risk. To date these herbicides have only been implicated in resistance on a few farms in South Australia (trifluralin and chlorsulfuron) and along railway tracks in Western Australia repeatedly sprayed with mixtures of atrazine and amitrole (simazine).

4. It takes several years of AOPP/CHD use to select resistant ryegrass from the susceptible population and non-selective herbicides such as paraquat and glyphosate can be used with little risk of selecting HRR.

The concept of levels of resistance was not considered because of the difficulty of determining the level present (specific testing is required) and because resistance is already at a high level by the time farmers seek advice.

Herbicide use in pastures. The pasture phase provides the best opportunity to use non-selective methods of controlling ryegrass. Numerous reports have shown that populations of annual ryegrass decrease during the pasture phase in response to increasing competition from less palatable species such as barley grass (*Hordeum* spp.), brome grass (*Bromus* spp.), and Vulpia (*Vulpia* spp.) (2,7).

Set stocking at moderate to high grazing pressures can dramatically reduce the proportion of annual ryegrass in the sward (3). Spraytopping and cutting for hay or silage can also be used to reduce seed banks prior to cropping (9).

While there is less herbicide used in pastures than in crops, the amount of AOPP's used in pastures is increasing. To minimise the selection pressure, herbicides should be used sparingly in pastures and, where possible, non-selective treatments such as spraytopping or cleaning with paraquat should be preferred.

Thus for pasture cleaning where complete control is not necessary (eg early years of the pasture phase) products such as simazine and paraquat should be used in conjunction with grazing and agronomic management practices which favour clover dominance (6). These techniques, along with spraytopping, are recommended in pastures where broad-leaved crops start the cropping phase. When wheat is to be the first crop, maximum control of grasses in the year prior to cropping is vital to control root diseases. Therefore, the best choice is an AOPP herbicide or, when Vulpia is present, a mixture of AOPP+simazine. When AOPP herbicides are used in this way the pasture should also be spraytopped or cut for hay or silage to reduce seeding of resistant plants which may have survived (Table 1).

Table 1. Strategies to minimise the risk of developing HRR in the pasture phase of the rotation.

Pasture situation	Preferred options	Other options or comments
1. Early years of the pasture phase.	Grazing and agronomic management. Paraquat, or simazine+paraquat.	May have to accept less than perfect result. Spraytopping can be used but may reduce sub-clover seed production.
2. Pasture to break crop (eg canola, lupins or field peas).	Paraquat, or simazine +paraquat. Long fallow. Spraytop.	Complete grass control is not required as disease break before broad-leaved crops is not important.
3. Pasture to oats.	Spraytop then paraquat or simazine+paraquat. Long fallow.	Must obtain maximum control of Vulpia and barley grass if oats is to act as a disease break.
4. Pasture to wheat.	AOPP + spraytop, or AOPP/Simazine+spray-top. Long fallow.	Cutting may be substituted for spraytopping.

The strategies outlined above only apply to the cropping-livestock zone. In permanent pastures on the tablelands, herbicide use and cropping will be less frequent and hence there is little chance that HRR will become a problem. Therefore, no restrictions are envisaged in these areas.

Herbicide use in crops. The aim is to rotate both the crops and the herbicides to combine the most economic crop sequence with herbicide variety (Table 2). Wherever possible, the strategies involve the use of canola as the first crop following pasture. If canola cannot be grown, wheat should be grown after winter cleaning the pasture with AOPP, or long fallowing using non-selective herbicides or cultivation. Fallowing should only be considered where it is normally practised for storing water.

Trifluralin should be used with the first crop as this is usually sown into a cultivated seedbed. If canola or another broadleaved crop is sown, trifluralin should be applied at 2 L/ha. The cropping sequence which follows should be: wheat, lupins or field peas, then another cereal. The advantage of lupins over field peas or canola is that simazine+trifluralin or simazine+Yield^{R} can be used. Where wild oats is not a problem triasulfuron or chlorsulfuron should be used to control annual ryegrass in wheat.

In addition to rotating crops and carefully choosing herbicides the following management practices are non-selective and should be adopted:

1. In general, direct drilling is the most appropriate way of establishing crops with minimum weed problems. However, for lupins minimal soil disturbance seems beneficial (1) and will also allow trifluralin or Yield^R to be used.

2. When AOPP herbicides are used in cereals, stubble should be burnt to kill surviving seed (8) and therefore reduce the input of the resistant biotype into the seed bank.

3. A three to four year cropping sequence is the preferred maximum with seven years as the absolute maximum. If AOPP herbicides are applied to pastures prior to cropping this should be considered part of the cropping sequence when determining the maximum number of crops before returning to pasture.

Table 2. Strategies to minimise the risk of developing HRR in the cropping phase of rotations commonly used in southern NSW and north-eastern Victoria.

Crop year	Preferred options	Other options or comments
1.First crop.	Canola (preferred), lupins or field peas (trifluralin).	Wheat (trifluralin) or oats after winter cleaning or long fallow.
2.Second crop	Wheat direct drilled or minimum tilled (diclofop-methyl, chlorsulfuron or triasulfuron).	Lupins (see 3b) or peas.
3.a.Third crop (end of rotation).	Undersown, direct drilled cereal (no herbicide).	The use of a cereal in a continuing rotation is not recommended except after lupins, because of the restricted range of herbicides in cereals.
b.Third crop (continuing).	Minimum tilled lupins (simazine, or simazine+ rifluralin).	AOPP if required.Field peas or other alternative crops.
4.Fourth crop.	Direct drilled cereal (diclofop-methyl, chlorsulfuron or triasulfuron).	Steps 3b. and 4 can be repeated. Maximum crop rotation seven years.

Strategies for farms with resistant ryegrass. The first step is to confirm if suspected populations are resistant. A farmer checklist should be compiled and widely distributed to help farmers determine if they have HRR. This checklist will allow the farmer to eliminate other causes of herbicide failure and check previous herbicide history before notifying the reseller and the relevant Department of Agriculture or private agronomist of the problem. The possibility of resistance should always be confirmed by a test which also identifies which herbicides may still be useful.

The general strategy is to return the area to pasture as soon as possible while minimising or preventing seed production of the resistant biotype. While in pasture non-selective techniques to reduce the seed bank of annual ryegrass should be used annually. After a number of years of pasture the area can be cropped again using non-selective seedbed preparation and crop/herbicide combinations which result in high returns and maximum control of ryegrass. This strategy is similar to that outlined by Powles and Howat (9).

IMPLEMENTATION OF STRATEGIES

The adoption of strategies to combat herbicide resistance will require the co-operation of everyone involved in offering herbicide advice. However, different bodies should take responsibility for implementing various parts of the strategy. A suggested breakdown could be:

1. General publicity on herbicide resistance should be the responsibility of Advisory Officers of State Departments of Agriculture, but agribusiness should also make mention of the phenomenon whenever possible. This publicity should be directed at media and events with high farmer credibility.

2. Strategies to combat specific herbicide/weed resistance problems should be developed regionally by agribusiness in conjunction with research and extension agronomists from Departments of Agriculture, Universities and CSIRO. As part of this strategy development there should be opportunities for industry and community consultation and an on-going review process to ensure the strategies remain relevant with changing technology.

3. The actual transfer of strategies to minimise the risk of developing resistance should be the responsibility of agribusiness using the reseller network as the major outlet for advice and publications. This may require specific training for resellers and possibly a general upgrading of the skills and qualifications of representatives. Extension agronomists of Departments of Agriculture should follow these strategies when making herbicide recommendations and should also promote non-chemical methods of weed control for minimising/overcoming resistance.

4. The development of management plans for individual farms should be undertaken by consulting agronomists. Farmers with problems should be referred to individual advisors by resellers.

The risks of herbicide resistance developing and the implications for future cropping plans, should be considered when farm management decisions are being made. Strategies to minimise the risk of developing HRR should not be considered in isolation but should be incorporated, where possible, into normal husbandry practices.

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