Western Australia. *Australian Journal of Experimental Agriculture* 35, 67-72.

Gill, G.S. (1996). Ecology of annual ryegrass. *Plant Protection Quarterly* 11, 195-8.

Gill, G.S., Cousens, R.G. and Allen, M.R. (1996). Germination, growth and development of herbicide resistant and susceptible populations of rigid ryegrass (*Lolium rigidum*). *Weed Science* 44, 252-6.

Heap, I.M. (1988). Resistance to herbicides in annual ryegrass (*Lolium rigidum*). Ph.D. Thesis, University of Adelaide, South Australia, pp. 123-36.

Lemerle, D., Verbeek, B. and Coombs, N. (1995). Losses in grain yield of winter crops from *Lolium rigidum* competition depend on crop species, cultivar and season. *Weed Research* 35, 503-9.

Matthews, J.M., Llewellyn, R., Reeves, T.G. and Powles, S.B. (1996). Integrated management for the control of herbicide resistant ryegrass. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, pp. 417-20.

Mayfield, A. and Edwards, R. (1992). Survey of weeds in SA, pp. 2-3. (Crop Science Society of SA, Adelaide).

Medd, R.W., Auld, B.A., Kemp, D.R. and Murison, R.D. (1985). The influence of wheat density and spatial arrangement on annual ryegrass *Lolium rigidum* Gaud. competition. *Australian Journal of Agricultural Research* 36, 361-71.

Nietschke, B., Llewellyn, R., Matthews, J.M., Reeves, T.G. and Powles, S.B. (1996). Survey of herbicide resistance in ryegrass and wild oats. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, p. 691

Pearce, G.A. (1975). The effect of burning on the viability of annual ryegrass seed. *Australian Weeds Research Newsletter* 22, 37-9.

Pearce, G.A. and Holmes, J.E. (1976). The control of annual ryegrass. *Journal of Agriculture Western Australia* 17 (4th series), 77-81.

Penfold, C. and Miyan, M.S. (1996). Non chemical post sowing weed control in broadacre cropping. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, p. 698.

Pratley, J.A., Graham, R. and Leys, A. (1993). Determination of the extent of herbicide resistance in southern NSW. Proceedings of the 10th Australian and 14th Asian-Pacific Weed Conference, Brisbane, pp. 286-8.

Purvis, C., Jessop, R.S. and Lovett, J.V. (1985). Selective regulation germination and growth of annual weeds by crop residues. *Weed Research* 25, 415-21.

Reeves, T.G. and Smith, I.S. (1975). Pasture management and cultural methods for the control of annual ryegrass (*Lolium rigidum*) in wheat. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15, 527-30.

Reeves, T.G. (1976). Effect of annual ryegrass (*Lolium rigidum*) on the yield of wheat. *Weed Research* 16, 57-63.

Umbers, A. (1996). Canola again or plant more wheat? Australian Grain, Volume 6 (1), vii.

Chemical management of annual ryegrass

J.M. Matthews, Co-operative Research Centre for Weed Management Systems, Faculty of Natural Resources, University of Adelaide, Glen Osmond, South Australia 5045, Australia.

Introduction

There has been a high level of adoption of herbicides for ryegrass (*Lolium rigidum* Gaudin) control since their introduction in the early 1970s. Farming systems have continually changed with the availability of new herbicide products, such that pre-planting tillage has been replaced by non-selective herbicide use and crop selective products on many farms. Ryegrass has been a particular target of selective herbicides due to its widespread distribution.

The application of selective herbicides to annual ryegrass has seen the development of many populations resistant to a range of selective herbicides. Several surveys have been undertaken to determine the extent of resistance. Gill (1992) in Western Australia reported a high incidence of resistance following a voluntary survey and Pratley *et al.* (1993) in New South Wales also reported high incidences of resistance. In South Australia, a random survey showed that about 40% of ryegrass populations sampled displayed levels of resistance that are considered to pose management difficulties (Nietschke *et al.* 1996). Resistance is now so widespread that a discussion of herbicide use for the management of ryegrass should differentiate between herbicide susceptible and resistant ryegrass.

Chemical control of herbicide susceptible ryegrass

There are 52 herbicides registered for the control of annual ryegrass in Australia. These herbicides are from twenty chemical groups when classified according to chemical structure and 12 groups when classified according to primary mode of herbicide action. Classification of herbicides into mode of action groups has been recently adopted by the AVCARE Ltd. as an aid to managing herbicide resistance in annual ryegrass (AVCARE 1996).

Of the mode of action groups (which will be the basis of grouping used here) A, B, C, D and K contain products which are selective in cereals. Selectivity is achieved through physiological differences between the crops and the weed, or other factors such as depth or growth differences. Eight groups (groups A, B, C, D, E, J, K and L) have members with herbicides which are selective in legume and other broadleaf crops. Non-selective herbicides from groups M and N are commonly used in broadacre agriculture.

In 1995, the expenditure on herbicides which are largely targeted against ryegrass, was approx. $66.7 million which was about 46% of the selective herbicide market. Diclofop-methyl (group A) commanded about 60% of the market for cereal selective herbicides in 1995. From the group B herbicides, triasulfuron is probably the most widely used against ryegrass, although usage is targeted at other weeds as well. Its market share is 56% of a $44 million market. Of the group C herbicides, simazine has about 74% of a $23 million market, and has largely followed the increase in lupin area in the last 12 years. Trifluralin is also largely used against annual ryegrass. Value in 1995 was $22 million. These figures (sourced from Solutions Research) are only a guide to usage due to the use of these products against other weed species.

Although there are many herbicides registered for the control of annual ryegrass, seven are registered for selective removal of ryegrass from cereal crops and the sales indicate that two dominate the market. More herbicides are available for use in broadleaf crops, but again the market is dominated by a few and these are drawn from the same chemical and mode of action groups as the cereal selective herbicides.

The use and effectiveness of herbicides for management of herbicide susceptible ryegrass

Pre-sowing herbicide application

The use of the non-selective herbicides glyphosate or paraquat on seedling ryegrass for pre-sowing weed control in reduced tillage systems is a widespread and effective practice. The use of pre-sowing herbicides trifluralin and triasulfuron or chlorsulfuron for ryegrass control (and other weeds) in legumes and cereals has doubled in market share over the past 10 years. These products usually give an economic yield response in the year of application but do not restrict weed seed output adequately to suppress populations over time. The ryegrass seed bank following two years of trifluralin pre-sowing was 22% of the control but 26 times greater than the initial seed bank (Matthews *et al*. 1996). Limitations to continued efficient use of trifluralin are poor performance due to poor incorporation in minimum tillage systems, late emerging ryegrass, and in the case of the group B herbicides, poor incorporation and resistance or cross resistance.

Other pre-emergent selective herbicides are mainly from groups C and D and are widely used in broadleaf crops. The increase in the area planted to such crops has necessarily increased the use of all selective herbicides as it is very difficult to grow a profitable legume crop without effective herbicides. These are less successful than in cereal crops due to the reduced crop competition. The efficacy of group C herbicides are at risk from herbicide resistance.

Early post-emergence herbicide application

The cereal selective group A herbicides, diclofop-methyl and tralkoxydim are usually very effective on susceptible ryegrass populations at the recommended rate, but the use of selective post-emergent herbicides in cereals has declined since 1988, perhaps due to extensive resistance, changes in crop agronomy and drought. Selective herbicides from group B are used as both pre- and post-emergence products and control is suggested to be adequate. However in the field control, is often variable due to poor incorporation by rainfall. Group C products are sometimes used for selective weed control in cereals and are limited by poor selectivity and risk of crop damage.

Group A herbicides which are selective in broadleaf crops are effective on ryegrass when used correctly on susceptible populations. All group A herbicides are foliar uptake at the rates used in Australia and poor weed control can result from late germinating ryegrass emerging after herbicide application. The group B herbicide imazethapyr has short term suppression only on the label.

Late post-emergence herbicide application

The increased use of the non-selective herbicides glyphosate and paraquat (spray-topping) to reduce seed production of maturing weeds in the preceding pasture phase, has improved management of ryegrass (and other grasses) in the year before crop or pasture establishment (Dowling 1988). Timing of application for all weed species present is the major practical issue, however, spray-topping with paraquat or early glyphosate fallow can reduce seed banks by up to 95% in one year, typically about 75%. The same approach has been adopted with the application of paraquat to maturing ryegrass (crop-topping) to reduce viability of seed being set, in various legume crops. The use of paraquat has become registered for use in peas, chickpeas, lupins, faba bean and vetch. In South Australia, work by Mayfield (1995) (Table 1.) has shown the crop damage potential to be variable (0–18% at appropriate rates and timing). Crop-topping reduced the ryegrass seed bank in crop by 70% in each of two years (Matthews *et al*. 1996).

Table 1. Crop damage and ryegrass control from crop-topping treatments in a range of pulse crops. (Mayfield 1995).

Crop growth stage at application	Crop yield (% of untreated)	Ryegrass control (% killed)
Beans – upper pods forming	80–87	83–90
Peas – upper pods 1/2 filled	68–86	65–83
Lupins – top pods 3/4 filled	85–90	80–85
Chickpeas – dough stage	65–90+	60–85

Chemical management of herbicide resistant ryegrass

For populations that are resistant to a herbicide or to many herbicides, the prospects for herbicide use can be limited. The propensity for a population of annual ryegrass to develop cross resistance to a range of herbicides that have not been applied to that population is the reason for the development of resistance to many herbicides. Gill (1992 and 1995) has documented the onset of resistance and cross resistance in Western Australia, and the distribution of resistance within resistant populations; Pratley *et al.* (1993) and Heap and Knight (1990), in populations from other areas. From these reports it is apparent that susceptibility to herbicides can vary between herbicide resistant populations and specific herbicide choices are required for each population. From Gill (1992), the proportion of group B resistance in Western Australia was 70%; Group A aryloxyphenoxypropionates (‘fop’) resistance 48% and cyclohexanediones (‘dim’) resistance 15%. Resistance to all three herbicide groups was 11% of the surveyed populations. This pattern of resistance may be different for populations where different herbicides predominate during the selection processes. Resistance to the PS II inhibitor simazine is widespread, whereas the herbicide trifluralin is effective on many populations. Many farmers have used ‘Herbicide Resistance Testing Services’ to describe the herbicides which are still effective on ryegrass populations and herbicides are still being used on resistant populations.

No resistance has been detected yet to the non-selective herbicides, glyphosate or paraquat. Methods of management for herbicide resistant populations have been a focus of many extension programs. Most include use of glyphosate and paraquat and many farmers have instituted integrated weed management for the control of populations with complex herbicide resistance.

Research needs

The rapid onset of herbicide resistance has challenged the crop agronomy sector and the crop protection sector of Australian agriculture to consider the interactions of weeds and crops in the absence of effective selective herbicides. However, resistance is not the only driving force for changed agronomy practices leading to better and more durable weed control. If the trend to minimum tillage and stubble retention is maintained with the current reliance on selective herbicides, then it is important to understand the interactions of the crop and the weed in this changed environment. There is very little information about the interactions of current crop species and crop varieties, and crop planting density and row spacing with and without pre- and post-emergent herbicides, across the range of environments that have herbicide resistance.

The failure of selective herbicides due to resistance or by species replacement is a response to the consistent selection pressure imposed by herbicide use. The options for dealing with herbicide resistance have shown considerable creativity and in many cases a return to managing basic weed/crop interactions were forced by the absence of selective herbicides. Control of weed populations by herbicides early in the season have given agronomic benefits in the short term but failed in the longer term as weed populations were not suppressed over time. Reduction of seed set by late application of herbicides or by other means has the prospect of reducing population increases and thereby increasing the durability of weed management in high intensity crop rotations.

References

AVCARE (1996). Herbicide mode of action information and media release, March 1996.

Dowling, P.M. (1988). Effect of pre-season management and in-crop herbicides on weed seedling numbers and triticale grain yield. *Australian Journal of Agricultural Research* 39, 783-92.

Gill, G.S. (1992). Herbicide resistance in WA. Proceedings of the National Herbicide Resistance Extension Workshop, Adelaide, pp. 8-13.

Gill, G.S. (1995). Development of herbicide resistance in annual ryegrass (*Lolium rigidum* Gaud.) in the cropping belt of Western Australia. *Australian Journal of Experimental Agriculture* 35, 67-72.

Heap, I.M. and Knight, R. (1990). Variations in herbicide cross resistance among populations of annual ryegrass (*Lolium rigidum*) resistant to diclofop methyl. *Australian Journal of Agricultural Research* 41, 121-8.

Matthews, J.M., Llewellyn, R., Reeves, T.G. and Powles, S.B. (1996). Integrated management for the control of herbicide resistant ryegrass. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, pp. 417-20.

Mayfield, A. (1995). Controlling escape ryegrass in legume crops. GRDC Report AMC 1, pp. 9-20.

Nietschke, B., Llewellyn, R., Matthews, J.M., Reeves, T.G. and Powles, S.B. (1996). Survey of herbicide resistance in ryegrass and wild oats. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, p. 691.

Pratley, J.A., Graham, R. and Leys, A. (1993). Determination of the extent of herbicide resistance in southern NSW. Proceedings of the 10th Australian and 14th Asian-Pacific Weed Conference, Brisbane, pp. 286-8.

Why vulpia is a problem in Australian agriculture

G.R. Code, Agriculture Victoria, Institute of Integrated Agricultural Development, RMB 1145, Rutherglen, Victoria 3685, Australia.

Certain species of the *Vulpia* genus constitute a significant problem to Australian agriculture due to their widespread occurrence, their adaptable life cycle and to various 'weedy' characteristics.

Distribution and abundance

Five species of *Vulpia* are recorded in Australia (Willis 1970, Ross 1990, Leys and Dowling 1992). Of these, three occur commonly as a problem in agriculture. These are:

V. bromoides (L.) Gray (squirrel tail fescue);
V. myuros (L.) C.C. Gmel. (rat's tail fescue);
V. fasciculata (Forssk.) Gray (sand fescue).

Although previously referred to collectively as silvergrass, the generic name *Vulpia* has recently been recommended as the accepted common name to avoid confusion with certain other grasses.

The vulpias occur as common weeds in all southern states. In New South Wales they are significant weeds of permanent pastures on the northern, central and southern tablelands and in annual pastures in cropping rotations in the eastern wheat belt south of Dubbo (Jones and Whalley 1993, Leys and Dowling 1992, McIntyre and Whalley 1990). *V. bromoides* and *V. myuros* are the main species and these often occur together (Leys and Dowling 1992, McIntyre and Whalley 1990).

In Victoria, vulpia occurs commonly in all districts except on the black self-mulching soils of the Wimmera. Again, *V. bromoides* and *V. myuros* are the main species (Willis 1970, Velthuis and Amor 1983, Hamilton 1993). *V. fasciculata* may occur in the Victorian Mallee.

In South Australia, *V. fasciculata* was reported as the only significant problem species in the mid-eighties, mainly in the Mallee region of South Australia (Heap and Stephenson 1986). But more recently, *V. bromoides* and *V. myuros* have been reported as significant weeds of pastures (Stephenson 1993).

In Western Australia, vulpia is a problem in all districts in the wheat belt. It is a significant weed of pastures and of crops where they are direct drilled. *V. bromoides* and *V. myuros* are the problem species, which commonly occur together. *V. myuros* is possibly the most dominant (Poole 1986, A. Wallace personal communication).

Significance in pastures

The *Vulpia* species are significant in pastures for several reasons. They reduce carrying capacity due to: poor winter production; low palatability in spring; and low nutritive value of dry residues. They are prolific producers of fine pointed barbed seeds which cause vegetable fault in wool, and cause mouth, eye and hide damage to stock (Jones and Whalley 1993, Leys and Dowling 1992, Leys *et al.* 1991a). In addition, the vulpias can severely compete with newly sown or regenerating pasture (Leys and Dowling 1992, Hamilton 1993). This competition can be increased due to allelopathic effects if dry vulpia residues are present (Pratley and Ingrey 1990, Scott and Blair 1987). Total loss caused to the wool industry by vulpia in pasture has been estimated at $30 million yr^{-1} nationally (Leys and Dowling 1992, Sloane *et al.* 1988).

Effective control of vulpia in pastures can be obtained with application of simazine in winter (Leys *et al.* 1991b, Leys and Plater 1993, Stephenson 1993), or by seed set reduction with spring application of paraquat or glyphosate (Leys *et al.* 1991a, Madin 1986a). However, these treatments have not provided long term control and in addition, the simazine treatment can reduce subterranean clover vigour and winter feed availability (Jones and Whalley 1993, Dowling *et al.* 1992, Hamilton 1993, Leys and Dowling 1992).

The rapid re-invasion of pasture with vulpia after these treatments is due in part to its prolific seed production and consequently large seed banks. Seed banks in excess of 1 million m^{-2} have been recorded in the northern tablelands of New South Wales (Jones and Whalley 1993). This means there is frequently sufficient seed to re-establish an infestation despite the implementation of effective control in one season. The ability of vulpia to compete well with establishing subterranean clover in autumn / winter would also contribute to this re-invasion. Vulpia will successfully invade pastures where presence of other grasses is low. Therefore, control measures need to be combined with establishment of a competing sward of annual or perennial grasses (Dowling *et al*. 1993, Leys and Dowling 1992, Leys *et al*. 1993).

Seedling grass species, particularly phalaris, are poor competitors with vulpia, due to direct competition and to allelopathic affects from residues (Pratley and Ingrey 1990, Scott and Blair 1987,