The management of annual ryegrass (*Lolium rigidum* Gaud.) in southern Australian broadacre farming systems is lacking in diversity

Peter J. O'Connell[1] and Jean-Louis Allard[2]
[1] Syngenta Crop Protection Australia Pty Ltd, PO Box 249, Wentworthville, New South Wales 2145, Australia
[2] Syngenta Asia Pacific Pty Ltd, 250 Northbridge Road, #39-00 Raffles City Tower, Singapore 179101

Summary Australian winter broadacre crops have been planted on 19.4 million ha on average, over the five years 1999 to 2003. The cropped area is dominated by cereals and in particular wheat. Annual ryegrass (ARG), (*Lolium rigidum* Gaud.) is the most widespread, difficult to control and important weed of Australian winter broadacre farming systems, and is arguably the greatest threat to sustainability of these systems. Alemseged *et al.* (2001) calculated that it infests about 6 million ha. Syngenta's analyses of herbicide sales suggest that the area treated for annual ryegrass could be as high as 8 million ha.

Herbicide sales have been used to estimate the area treated for ARG control. This analysis focuses on herbicides for which there is not yet widespread ARG resistance. Grain producers are heavily dependant on two groups of herbicides. Group M (glyphosate) is applied as a non-selective burn-down treatment prior to planting and is applied to as much as 25 million ha (applied up to 132% of the winter crop area). The Group D herbicides, especially trifluralin, are used for pre-emergent weed control on nearly 7 million ha, 36% of the cropped area, up from 25% in 2001. There is circumstantial evidence that Group D herbicides are mostly applied for the management of ARG, and there is a high risk of over-use.

Minimum- and no-tillage are used on 76% of the cropped area, while burning as a weed control technique (hot burn) is used on just over 10% of the area. In view of the current willingness of grain growers to rely heavily upon herbicides for weed control, a greater burden is placed on ensuring herbicide rotational strategies are carefully thought through and implemented. This has resulted in extension of double-knockdown techniques with Spray.Seed® to reduce the likelihood of glyphosate resistant ARG in reduced tillage environments.

A similar education program needs to be directed towards Group D herbicides and alternatives promoted. Group K herbicides, including S-metolachlor (Dual® Gold), are potential alternatives. Group K herbicides are generally well tolerated by barley, oats, legumes and canola and can be used at higher rates in these crops. Wheat is less tolerant at the rates required to manage ARG effectively. Rotating to Group K herbicides outside wheat is proposed.

The grains industry could evaluate the model the Australian cotton industry has established for the very successful management of insecticide resistance. A better way to manage herbicide use and rotation needs to be found, particularly as fewer new active ingredients are expected to be developed than in the past.

Keywords Annual ryegrass, diversity, double-knockdown, Dual Gold, glyphosate, herbicides, *Lolium rigidum*, resistance, rotation, Spray.Seed, trifluralin.

INTRODUCTION

Annual ryegrass (ARG) (*Lolium rigidum* Gaud.) is the most important, widespread and difficult to control weed of southern Australian broadacre farming systems (Alemseged *et al.* 2001). Alemseged *et al*. calculated through a survey that it infested about 6 million ha of winter grown crops.

Random surveys of annual ryegrass conducted in Western Australia and South Australia in the late 1990s found a large proportion of populations with resistance to herbicides belonging to the mode of action Groups A or B, acetyl-CoA carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors. ARG is the world's most significant case of herbicide resistance and exhibits multiple resistance to a range of herbicide modes of action (Llewellyn and Powles 2001). Most recently, resistance to glyphosate has been confirmed in ten cases in broadacre cropping systems.

By necessity, some farmers are moving to integrated weed management (IWM) practices as multiple and cross-resistance results in the failure of herbicides for weed control. However, questions remain in respect to how wholeheartedly IWM practices are being adopted. Pannell (2003) argued that there is no compelling case for reducing the reliance on herbicides in order to delay the time when they will be lost to resistance. Farmers will maintain herbicide-based weed management until forced to change by the full development of resistance, because strategies to limit the use of herbicides in order to preserve their useful life can involve substantial economic cost.

Syngenta Crop Protection can offer an insight into weed control practices by providing information on herbicide sales. In this paper we present how herbicides, for which widespread ARG resistance is not yet reported (Table 1), are being used. Opinion on improving herbicide rotational strategies is provided.

MATERIALS AND METHODS

Sales figures of Syngenta Crop Protection herbicides used for the control of ARG, within or prior to planting of winter broadacre crops, have been compiled. Estimates of herbicide sales made by other major Crop Protection manufacturers have been included.

The estimates of product volumes for competitor products are gained through several means. Firstly, ACNeilson collects product sales information from companies including BASF, Bayer, Dow, DuPont and Syngenta, and these figures are available to the participants. Some important non-participants are Nufarm, Crop Care and Farmoz.

Further information was obtained from product (brand) metric studies initiated by Syngenta but conducted by independent research companies. Amongst other things, these studies aim to find what products are being purchased by customers and why. In addition, personal communication between the market participants also plays a part in estimating the sales of competitor products.

The area treated by a particular product is derived from the volume of product sold, estimates of average use rates and by extrapolation from brand metric studies. These figures are the estimates that Syngenta Crop Protection uses for planning.

The crops planted and methods of ground preparation, tillage practices and stubble management are collected by the Australian Bureau of Statistics (ABS).

RESULTS

The total area planted to winter-sown broadacre crops ranged from 14 million ha in 1991–92 to 19.5 million ha in 1999–2003 (Table 2). The trend is toward increasing area sown to crops with a 37% increase over this period. This is in part a response to low wool prices as farmers reduce their sheep numbers.

Glyphosate (Group M) use on a per hectare basis is significantly greater than for any other herbicide group. Syngenta estimates that average glyphosate use is equivalent to every planted hectare receiving an application at least once per season. In 2000, the area treated was equivalent to 132% of the planted area (Table 3).

Paraquat and diquat (Group L) are used for preplant burndown and to a much lesser extent for crop-topping. A 2003 market survey indicated that 34% of Spray.Seed is applied as part of a double-knockdown treatment. This equates to 1 million ha of double-knockdown with Spray.Seed.

Trifluralin and pendimethalin are the Group D herbicides considered (Table 1). Syngenta estimates that they were applied to 6.9 million ha in 2003. The dinitroanilines are registered for use in nearly all the major broadacre crops (barley, canola, chickpeas, field peas, lentils, lupins and wheat).

Table 1. Herbicide mode of action groups for ARG, for which widespread resistance is not yet reported.

Group	Active Ingredients
C	atrazine, simazine, diuron
D	trifluralin, pendimethalin
K	S-metolachlor, metolachlor
L	paraquat, diquat
M	glyphosate

Table 2. Crop area planted ('000s ha) for five year average (1999–2003).

Crop type	Area planted ('000s ha)
barley	3,273
oats	716
triticale	271
wheat	11,852
canola	1,406
chickpeas	206
fababeans	159
field peas	313
lupins	1,120
lentils	130
Total	19,446

Source: ABS (2001a) and (2001b).

Group C herbicides include atrazine, simazine and diuron. Atrazine use is restricted to TT-canola (triazine-tolerant *Brassica napus* var. *napus*) and lupins. In addition to these crops, simazine can be used in chickpeas and fababeans. Diuron can be applied both pre-emergent and post-emergent in cereals and lupins. All together Group C herbicides are applied to 4.2 million ha for grass and/or broadleaf weed control.

Syngenta estimates that 6.5 million ha of cereals are treated pre-emergent with Group B herbicides (triasulfuron and chlorsulfuron). Much of it is applied in tank mixtures with another pre-emergent herbicide for ryegrass control.

Cropland preparation statistics taken from the 2001 census for the production year 2000 revealed that preparation of 76% of cropland is defined as no-tillage or minimum-tillage (one to two cultivations) (Table 4).

DISCUSSION

Grain growers use glyphosate extensively. With the high acceptance of minimum tillage practices in Australia, glyphosate is an important component of most broadacre farming operations.

Grain producers are turning to Group D herbicides (mostly trifluralin) as the primary herbicide for the selective control of ARG in many crops. The

dinitroanilines can be used in all the broadacre crops in Table 2, except oats (*Avena sativa*). Trifluralin applied to winter grown crops controls few weeds, namely ARG, annual phalaris (*Phalaris* spp.), wireweed (*Polygonum aviculare*) and fumitory (*Fumaria* spp.). It does offer useful suppression of some other weeds.

Syngenta estimates that the use of Group D herbicides in winter broadacre crops has grown from less than 1 million ha in 1990 to about 6.9 million ha (36% of the cropped area). Growth in the area of winter broadacre crops treated with Group D herbicides coincides with ARG resistance and the failure of herbicide modes of action, acetyl-CoA carboxylase (ACCase) and acetolactate synthase-(ALS) inhibitors, to adequately control it.

The growth in the area treated by dinitroanilines over the past 14 years is 6.0 million hectares, coinciding with the development of ARG resistance. Dinitroanilines control ARG but few other weeds. It is probable that at least 80% of the growth from Group D herbicides is targeted towards ARG, equating to 4.8 million ha.

Simazine, atrazine, (S-)metolachlor + diuron are also used to control ARG. The triazines, simazine and/or atrazine are applied to approximately 1.7 million ha of TT-canola and lupins. They control a broad range of weeds. Because of the predominance of ARG in the areas where lupins and canola are grown (mostly WA and southern NSW), as much as 40% of the use may include ARG as a target, an area of 0.7 million ha.

Group K herbicides are registered for the management of only two weeds, ARG and a weed of much lesser importance toadrush (*Juncus bufonius*). They are used predominantly for the management of ARG often in mixture with diuron, and to a lesser extent for control of toadrush. Syngenta estimates that at least 80% of Group K herbicides are used for ARG management. This equates to 1 million ha.

Together these assumptions suggest there is as much 6.5 million ha of ARG treated with the selective herbicides from Groups C, D and K. Alemseged *et al.* (2001) estimated that ARG infests approximately 6 million ha of winter grown crops. This figure may be too low.

While Group A and B herbicides are mostly used in mixture or sequence with the previously mentioned selective herbicides, they are used alone in some fields where resistance is not prevalent. Market research indicates Hoegrass® (diclofop-methyl) was applied to 0.5 million ha in 2000 (ACNielson 2001) and Syngenta estimates 6.5 million ha of cereals were treated pre-emergent with triasulfuron and chlorsulfuron in 2003.

It does appear as a result of the survey by Alemseged *et al.* (2001) and these calculations of herbicide use, that the area infested by ARG is at least 6 million ha. But, it may be as much as 8 million ha.

Table 3. Herbicide mode of action group and estimates of winter broadacre crop treated ('000s ha).

Group	2000	2001	2002	2003
C	5,117	3,935	2,167	4,244
D	5,117	4,919	6,140	6,945
K	205	394	1,084	1,351
L	614	2,952	3,251	4,244
M	25,790	16,332	17,518	21,415

Table 4. Cultivation practices in 2000 ('000s ha).

	No. of cultivations			
State	nil	1–2	>2	Planted area (ha)
WA	4,455	1,763	1,645	7,863
NSW	1,012	2,272	1,341	4,625
SA	747	2,480	425	3,652
VIC	640	1,245	1,087	2,972
Total	6,854	7,760	4,498	19,112

Source: Neil Clark and Assoc. adapted from ABS (2001b).

Table 5. Stubble management in 2000.

Treatment	% area	Remarks
Left intact	32%	mostly WA
Cool burn	11%	NSW, SA and northern WA
Ploughed in	23%	NSW and Vic
Hot burn	14%	NSW, Vic, SA and northern WA
Baled or grazed	11%	mostly WA and SA
Mulched	9%	Qld, NSW, Vic and SA

Source: ABS (2001b).

Non-herbicide weed control resulting from cropland preparation appears to be relatively unimportant, with 76% of winter broadacre crop land prepared with no- or minimum-tillage. In stubble management, 32% of stubble is left intact, 11% receives a cool burn and 9% is mulched (Table 5). Therefore on at least 50% of the land stubble is not managed in a way that would significantly reduce weed seed numbers. While these techniques are appropriate solutions for soil structure and soil water management, it does mean that there is a greater burden placed upon careful selection of herbicide rotations and mixtures as a means of delaying herbicide resistance.

Pannell (2003) found no compelling economic case for reducing the reliance on herbicides in order to delay the time when they will be lost to resistance. In this respect he appears to be consistent with the judgment of many farmers, whom despite loss in performance of Group A and B herbicides are very reliant on glyphosate and trifluralin and appear to be running the risk of over

using these at the expense of greater resistance issues.

Awareness of the risk of glyphosate resistance and the key factors leading to it (intensive use, exclusive use and lack of tillage) is growing. It has resulted in the adoption of double-knockdown techniques as a means to reduce the likelihood of glyphosate resistant ARG surviving in reduced tillage environments. Double-knockdown is a combination of non-selective herbicides applied to control ARG and other weeds. Llewellyn (2003) confirmed that three quarters of respondents to a survey of Western Australia's wheat belt growers would expect to use double-knockdown in the next four years. Syngenta's market research indicates 34% of Spray.Seed volume is being used as part of a double-knockdown. Therefore, on approximately 5% of the area planted to winter crops in 2003, a double-knockdown of non-selective herbicides was applied.

Assuming that within winter grown crops, Group D herbicides are mostly applied for the control of ARG, then they are being over-used. Group D herbicides are applied to 6.9 million ha and there are 6 to 8 million ha of ARG. AVCARE's (Agricultural and Veterinary Chemicals Association) herbicide resistance guidelines recommend their use be limited to every second year. Warnings of over-use are emerging from advisors including Newman and Adam (2003) in Western Australia.

The education and awareness programs directed towards glyphosate resistance and the development of alternative practices such double-knockdown or rotation with Spray.Seed may help preserve glyphosate. Likewise similar programs are required if dinitroanilines are to be preserved. Extension programs could support the use of Group D herbicides in rotation with other modes of action and raise awareness of treatment alternatives, particularly those likely to be readily adopted in the short-term.

Group K includes a number of very effective graminicides that are best known internationally for grass control in corn (*Zea mays*). They are an under utilised resource in Australia, having potential to be used as a rotational alternative. S-metolachlor (Dual Gold) is Syngenta's Group K herbicide and is well tolerated by barley, oats, legumes and canola. Wheat is less tolerant at the rates required to effectively manage ARG. Most effective use for ARG resistance management can be made with higher rates in dicot crops, barley and oats. Group D herbicides could be used preferentially in wheat and Group K as a rotational alternative in other crops, subject to registration.

The lack of alternative herbicide modes of action is in contrast to the great range of brands available. In Australia, 31 brands of trifluralin and 14 brands of metolachlor are registered. It is with this diversity that the industry struggles to provide common recommendations for herbicide rotations. The cotton industry in Australia is a unique example of what an industry can do to manage resistance, in this case managing resistance to the insect *Helicoverpa* spp. by having one resistance management strategy that provides clear guidelines for the use of any mode of action for the control of *Helicoverpa* spp.

For the international research-based companies, ARG has been a lesser target compared with the major European and North American grass weeds, *Setaria* spp., *Avena* spp. and *Alopecurus myosuroides*. With widespread ARG resistance, a new mode of action herbicide with similar performance to the Group A and B herbicides could be worth US$120 million in sales/annum in Australia. This may make it more attractive to companies like Syngenta. Unfortunately, much fewer new active ingredients are expected to be developed and we need to preserve what we have.

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