MANAGEMENT OF HERBICIDE RESISTANT RYEGRASS IN WESTERN AUSTRALIA – RESEARCH AND ITS ADOPTION

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Summary Herbicide resistance in ryegrass (*Lolium rigidum*) has forced some farmers to abandon the lupin–wheat rotation in order to manage ryegrass in the pasture phase. Technique of pasture-topping with paraquat or glyphosate is generally valued for its effectiveness against ryegrass and is now widely used in pasture paddocks ear-marked for cropping. However, in some areas of the wheatbelt, the economics of pastures is unattractive and farmers have endeavoured to manage resistant ryegrass by using several innovative methods of weed control within the cropping phase. In the lupin phase, one of these techniques involves capture of weed seeds during the harvesting operation. The seeds captured can be used as animal feed or destroyed by burning. Although the technique is effective against ryegrass, its adoption has been rather limited. In contrast, crop-topping grain legume crops with paraquat, which was registered for on-farm use in 1995, has been rapidly adopted by growers. It is likely that the high cost of the seed-capture machinery has limited its use on WA farms. Development of resistance in ryegrass has also had a major impact on the choice of herbicides used by farmers. Trifluralin has regained its popularity, with its use increasing nearly 10-fold over the last four years. Cultural weed control options such as delayed sowing, cultivation and stubble burning have not been widely accepted by farmers as viable options for the management of herbicide resistant weed populations.

INTRODUCTION

Herbicide resistance in annual ryegrass (*Lolium rigidum* Gaud.) has confronted Western Australian farmers as a major management issue for the last 10 years. Resistant populations have been documented in all cropping areas of the state with resistance confirmed to all major selective herbicide groups (Gill 1995). Resistance to sulfonylurea herbicides has usually become evident after only 3–4 applications of the herbicide group. In a farmer survey in 1993, 31% of Western Australian farmers stated that their selective herbicide had failed to control ryegrass for no apparent reason, possibly due to resistance (Martin *et al*. 1993).

Widespread development of resistance in weeds has highlighted vulnerability of selective herbicides as a tool of weed management. There is little doubt that integrated weed management techniques are required to reduce our reliance on selective herbicides. A range of chemical and non-chemical weed management techniques have been evaluated in the crop and pasture phases of the rotation. The adoption of various techniques by farmers has not depended solely on their effectiveness and has varied between different regions and even between farms in the same district. In this paper, data are presented on the effectiveness of the various integrated weed management (IWM) techniques against ryegrass and their adoption by farmers.

RESEARCH RESULTS AND ON-FARM ADOPTION

Pasture management Pasture phase, due to grazing pressure and use of non-selective herbicides (‘spray-topping’), presents an excellent opportunity to reduce the seed-bank of ryegrass. Pearce and Holmes (1976) recorded 29–80% reduction in ryegrass density in different field experiments with pasture-topping in WA. In a field experiment at Wongan Hills, heavy grazing in spring or normal grazing pressure combined with spray-topping with paraquat reduced ryegrass density in the pasture next year by 69–86% (Gill unpublished). In Victoria, Davidson (1992) showed that pasture-topping combined with grazing reduced ryegrass density in the subsequent year by 85%. There is a general consensus among researchers that, if adequate grazing pressure is maintained, pasture-topping can reliably give about 80% control of ryegrass.

Farmers also regard pasture-topping very highly for its ability to control resistant ryegrass. In our survey in 1993 (Martin *et al*. 1993), effective pasture-topping and grazing before cropping was rated number one (highest value) for controlling herbicide resistant ryegrass by farmers and consultants alike. Therefore, lack of adoption of pastures by farmers for resistance management, especially in the northern districts, is not due to ignorance of its value but more likely to be due to its unattractive gross margins. Unfortunately, the period of rapid expansion in resistance has coincided with a big decline in the wool price, forcing some farmers to cope with resistant ryegrass in the cropping phase.

Alternative herbicides Widespread development of resistance to group A and group B herbicides has caused a huge surge in the use of dinitroaniline herbicides in

Western Australia. Sales of dinitroaniline herbicides have jumped from 95 000 L in 1990 to more than 850 000 L in 1993 (J.E. Holmes personal communication). Apart from usage over a much larger area there is also evidence that farmers are increasing use rate per hectare. Extensive development research with this group was conducted in early 1970s and farmers have been able to draw on that experience to enable such a rapid change. An example of results that can be obtained with dinitroaniline herbicides, if used correctly, are presented in Table 1.

In some districts of the state, ryegrass populations are only resistant to the SU herbicides giving farmers the choice between fop/dim (group A) and dinitroaniline (group D) herbicides. However, there are practical constraints to the use of post-emergent fop/dim herbicides on heavy soils that are prone to mid-season water-logging. In wet seasons these farmers are forced to use aerial application of the herbicides, which is much more expensive.

Resistance has not yet been confirmed to triazine herbicides in Western Australia. This group is not noted for its effectiveness on ryegrass particularly under extended periods of dry soil surface, which are not uncommon in the northern districts. Release of new lupin varieties with superior tolerance to this group, has enabled farmers to increase triazine use thereby improving its efficacy on ryegrass.

Delayed sowing Delaying sowing after the break in season allows a greater proportion of the weed seed-bank to emerge before the crop is sown. This emerged component of the weed population can then be killed by the application of a non-selective herbicide or by pre-sowing cultivation. Delayed sowing in weedy paddocks used to be a common method of weed control before the release of selective herbicides. However, its effectiveness tended to be variable, depending largely on weather conditions during the delay (Morgan 1988). In most seasons, a substantial germination of ryegrass seeds takes place after

Table 1. The effect of triasulfuron and dinitroaniline herbicides on the production of ryegrass spikes and grain yield of wheat (Wongan Hills 1994).

Treatment	Ryegrass spikes m^{-2}	Grain yield t ha^{-1}
Trifluralin 400 g ha^{-1}	189	1.36
Oryzalin 250 g + trifluralin 250 g ha^{-1}	118	1.63
Triasulfuron 25 g ha^{-1}	71	1.83
Unsprayed control	390	0.53
LSD (P=0.05)		0.30

the crop has been sown. As McGowan (1970) found in his studies in Victoria, 12–23% of seasonal germination of *L. rigidum* seed occurred after June, by which time most crops would have been sown.

In an experiment at Wongan Hills in 1993, a 10 day delay after the break in combination with an autumn-tickle gave a large reduction in ryegrass density in the crop which was reflected in a 57% increase in the grain yield of wheat. In the following year at the same site, there was a long dry period after the break, a five week delay in seeding was required to detect a significant decline in ryegrass density in the crop. Such variable performance of this weed management option makes it unattractive for most farmers in WA. In our survey, delaying seeding was rated quite poorly by farmers and even lower by farm-advisers for its value in managing resistant weed populations (Martin *et al.* 1993).

High-yield packages developed over the last 5–10 years have had a strong focus on early sowing for high yields. Under weed-free conditions this is highly desirable, utilizing maximum available moisture for crop growth. Some trials have shown yield losses as high as 37 kg ha^{-1} d^{-1} for delays in sowing during the first four weeks after the break in season (Perry and Hillman 1991). The combination of perceived yield advantages from early sowing and erratic performance of delayed sowing have caused a big decline in the use of this technique in WA.

Burning Seeds of ryegrass and other weeds can be destroyed by burning the stubble. The effectiveness of burning however, depends on the physical location of the seed and the temperature and duration of the fire, which is largely dependent on the amount of available fuel (stubble). Pearce and Holmes (1976) found effectiveness of autumn burn in terms of ryegrass reduction in the subsequent crop to range from 20–90%. Mason *et al.* (1968) reported doubling or better of the wheat yield due to burning of ryegrass infested paddocks. Although there were visual differences in ryegrass density between the burnt and unburnt plots, actual ryegrass densities were not recorded. In a more recent study, Davidson (1994) reported that more than 90% of the surface seed-bank of ryegrass was destroyed by burning. However, the effectiveness of the treatment declined if the paddock had been grazed during the summer, possibly due to an insulating effect of soil on the seed buried by trampling and reduction in the amount of fuel available for the burn.

Burning crop and pasture stubbles used to be a relatively common method of weed management up to mid-1970s. Since then, there has been a concerted push to develop more sustainable methods of farming which have largely precluded burning, particularly on erosion-prone soils. In spite of relatively low cost of burning as a method of weed control, farmers have become reluctant to use it. In our 1993 farmer survey, burning the crop and pasture stubble was ranked second from the bottom for perceived value to weed management.

Hay making and green manuring Cutting of the crop for hay is one option for preventing seed set of ryegrass and may be the only option a farmer has in the season herbicide resistance becomes evident in the paddock. Hay-cutting in pasture was found to reduce weed density in the following crop by 70–85% (Reeves and Smith 1975). In a later study in WA, cutting a wheat crop for hay was estimated to reduce ryegrass density in the subsequent crop by 67% (Stewart 1993). Income from hay however, tends to vary from season to season and also depends on the proximity of the farm to the city. Cutting the crop for hay or chemical hay-freezing was ranked fifth from the top (moderate value) for perceived value to weed management (Martin *et al.* 1993).

Practice of green manuring is relatively rare in Western Australia. Limited data available suggest that it is an extremely effective strategy against ryegrass. Stewart (1993) estimated that green manuring a lupin crop reduced ryegrass density in the following wheat crop by 87%. It is however, important to monitor regrowth of ryegrass after cutting and spray the paddock if required, with a non-selective herbicide. We have recorded similar control of ryegrass with green manuring over three different seasons at Wongan Hills (Gill unpublished).

Table 2. The effect of seed capture at harvest on the ryegrass density in the subsequent lupin crop (Wongan Hills 1993).

Wheat phase treatment in 1993	Ryegrass plants m^{-2} in lupins phase in 1994
Conventional harvest	89
Redekop® harvest	24

Table 3. The effect of crop-topping treatments on the production of viable seeds by ryegrass and grain yield of lupins (Wongan Hills 1992).

Treatment	Ryegrass seeds $spike^{-1}$	Lupin yield t ha^{-1}
Untreated control	12.3	1.42
Paraquat 100 g ha^{-1} Time 1[A]	1.7	1.37
Paraquat 200 g ha^{-1} Time 1	1.0	1.18
Paraquat 100 g ha^{-1} Time 2	9.0	1.56
Paraquat 200 g ha^{-1} Time 2	4.0	1.17
Paraquat 100 g ha^{-1} Time 3	11.7	1.29
Paraquat 200 g ha^{-1} Time 3	8.7	1.58
LSD (P=0.05)	7.0	0.34

[A] Time 1 = ryegrass late flowering to milky dough stage.
Time 2 = ryegrass soft to firm dough stage.
Time 3 = ryegrass hard dough stage.

Capture of weed seeds at harvest Ryegrass is a prolific seed producer, with seed production estimated at times to exceed 30 000 seeds m^{-2} (Rerkasem *et al.* 1980). It has been estimated that in excess of 75% of these seeds pass through the harvesting machinery and are normally returned to the soil seed-bank (Davidson 1992). Preventing replenishment of the weed seed-bank by capturing them during harvest could be a vital tool in an integrated weed management program.

There are several different types of seed capture equipment now available in Australia. In Western Australia, Redekop®, a Canadian designed machine is the main method of weed seed capture operating in the wheat belt. Our research has shown that 60–80% of the total ryegrass seed production can be removed from the paddock, consequently reducing the level of weed infestations in the subsequent crop (Table 2).

In another study, in-crop ryegrass density declined by 44–68% due to different seed capture treatments in the previous wheat or lupin crop (Stewart 1993).

Although the first seed capture units were introduced in to WA more than five years ago, the rate of adoption of this technique has been extremely slow. It is likely that the high initial outlay (~ $A20 000), slower speed of harvest and higher fuel bills have been major deterrents to its adoption. In our survey in 1993, farmers ranked use of seed catchers to be of low value in the management of resistance (Martin *et al.* 1993). Whether this perception has changed since then, is not known.

Paraquat for seed-set control in grain legume crops (crop-topping) Use of non-selective herbicides such as paraquat for the prevention of seed production in grasses has been practiced widely in pastures at least for the last 10 years. However, use of paraquat for this purpose in grain legume crops is relatively new, granted official registration only in 1995.

Research carried out with crop-topping has generally shown large reductions in ryegrass seed production. However, timing of paraquat application appears to be critical, not just for seed-set control but also for damage to lupins. In our studies, use of paraquat at the milky dough stage of ryegrass was extremely effective in reducing seed-set of ryegrass (Table 3). When used at the correct timing, lupin yield losses have varied from 0–10%. Physical losses from pod damage by the sprayer, have been estimated to be around 3%. Although these losses are considerable, crop-topping has allowed some farmers to persist with continuous cropping which is considerably more profitable than pastures especially in low-medium rainfall areas.

Research to date has shown that there is usually about a two week window in a season within which effective ryegrass control can be achieved without sacrificing grain yield. In order to spray within this period farmers need to monitor their crops regularly. Spraying too early has resulted in greater than 50% yield loss and, as expected, spraying too late has resulted in absolute crop safety but only 10–20% seed-set control of ryegrass.

Adoption of crop-topping by farmers has been extremely rapid. According to Crop Care estimates, more than 15 000 ha of lupins in WA were sprayed with paraquat in the first year of its registration for this purpose (P. Nilson personal communication).

Development of resistance has undoubtedly complicated weed management. Several weed control methods now have to be combined to achieve acceptable weed control which could earlier be achieved by the single application of a selective herbicide. If increases in the area under cropping and average grain yields in WA are any indicators, farmers appear to be coping with the problem of resistance quite effectively. Use of alternative herbicides, pre-sowing weed control, crop-topping, burning stubble where appropriate, and capture of weed seeds during harvest have all contributed to the management of resistant ryegrass populations. In the higher rainfall districts in the south-west, short-term pasture phases have been used effectively to deplete weed seed-banks.

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