Herbicide Resistance in Ryegrass: Stochastic Evaluation of Management Strategies

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HERBICIDE RESISTANCE IN RYEGRASS
STOCHASTIC EVALUATION OF MANAGEMENT STRATEGIES

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ABSTRACT

Annual Ryegrass is a significant weed in cereal production in Western Australia. Herbicide resistance is increasing and is a major concern to producers. Long-term, field scale trials are being conducted on a number of sites in the state. The apparent costs and benefits of different management strategies are dependent on seasonal conditions and markets for inputs and products. This paper presents the results of a simulation model of alternative strategies under a wide range of historic conditions. A conceptual framework for selecting an optimal strategy is explored.

BACKGOUND

Western Australia produces a significant proportion of Australia's cereal crop. Approximately 12 million tonnes of grains are harvested from roughly 6 million hectares. The largest single crop is wheat, and more than 90 percent of this is exported. Traditionally wheat has been produced in rotations with a substantial proportion of leguminous pastures grazed by sheep. Relatively poor markets for wool and sheepmeat during the 1990s have led to a marked decline in livestock numbers, and substitution of other harvested crops for pastures in rotations.

Increased cropping has led to a rise in the occurrence of herbicide resistant annual ryegrass (*Lolium rigidum*) throughout Western Australia. Many herbicide groups that have been relied upon for years are no longer effective on resistant populations of annual ryegrass. As a result, farmers have had to use alternative weed management systems that are less (or not) reliant on selective herbicides. These systems are referred to as Integrated Weed Management (IWM), and use a diverse range of weed control treatments ranging from cultivation, burning and seed catching to green or brown manuring, cutting hay and grazing.

A four-year study was initiated in 1996 to investigate the viability of using IWM systems to overcome the problems associated with herbicide resistant ryegrass populations. Bill Roy of Agricultural Consulting and Research Services conducted the study at four trial sites in the wheatbelt of WA. The trials were conducted on large blocks that allowed application of field scale operations. Results from a site at York, on the western edge of the wheatbelt, were used as a source of data for this evaluation of IWM strategies.

The trials produced a rich source of data concerning integrated weed management strategies. In addition to monitoring weed control, gross margins were calculated by Bill Roy for the different strategies. However difficulties arise when assessing the merits of IWM strategies based on only three to four years of trial data. Results in the short term can be influenced substantially by year-to-year fluctuation in prices, production and quality. Other factors also distort results, such as disease resistance of particular crop varieties and crop establishment problems on some trial blocks and not others.

In addition, results from particular strategies may have been entirely different if other management decisions had been implemented. There was therefore a need to standardise the results of these trials and investigate the longer-term implications of IWM strategies on profits and ryegrass control.

This paper discusses two avenues of research into IWM strategies that build on these field trials. The first issue to be discussed concerns the effects of historic prices on the choice of preferred IWM strategy. The second issue concerns the trade-off between weed control and profits.

PRICES AND PREFERRED CONTROL STRATEGIES

Average gross margins (GM) for different weed control strategies may be used to compare strategies. However GMs are dependent on input and product prices which vary over time. Thus a particular strategy may have a high GM due to fortuitous markets for the sequence of crops grown in particular years, rather than because of the level of weed control or crop and livestock productivity. Comparison of more ‘normal’ GMs can be made by using a range of historic prices in @RISK simulations of actual trials. These simulations also show the variability of financial performance of different strategies. This type of analysis provides better ranking of strategies as well as allowing individuals to include their own attitudes to risk in their selection of a strategy.

The aim of this part of the study was to calculate the distribution of discounted three-year GMs for ryegrass management strategies using a range of historic input and product prices. The simulations were based on trials conducted at York, Western Australia.

Method

Data from three years of trials conducted at Northbourne near York from 1997 - 1999 were supplied by Bill Roy (Table 1). The trials comprised 15 blocks that received different treatments. @RISK simulations were run using the actual yields and product qualities, the levels of inputs used and the ryegrass populations recorded in these trials.

Historic prices for all products and costs of some inputs were collected. The number of years of data available varied. Most cultivation and contract costs were assumed to be at contract rates. All prices and costs were allocated a probability distribution and range. Probability distributions were triangular, uniform or normal. Gross margins for the three years were discounted at eight percent to give a net present value (NPV) for each strategy. The simulation was run once using 1000 iterations.

Results

Two principal results emerged. First, the average NPV from the simulation can be compared with the actual NPV calculated over the period of the trials using contemporary prices (Table 1). The ***simulated NPV*** represents the average value of the strategy under a 1000 combinations of possible prices and costs, whilst the ***actual NPV*** represents the value of the strategy using the precise prices and costs in the years in which they actually occurred.

Table 1. Effects of prices on NPV for each treatment

Trial block[1], crop/pasture rotation and treatment[2]	Aggregated Ryegrass[3] (m^{-2})	Actual NPV ($/ha)	Simulated NPV ($/ha)	Change in NPV	Change in rank
1A Stirling T2 (NB/C/D) Hyola T1 (SB/C/A) Amery T2 (WB/C/-)	124	373	299	-74	0
1B Merrit T1 (NB/-/C) Hay T1 (SB/C/A) Dundale T2 (WB/C/-)	184	183	88	-95	-2
1C Pasture T1 (NB/-/C) Brookton T1 (SB/C/A) Arrino T1 (WB/C/-)	13	217	284	67	0
1D Pasture T1 (NB/-/C) Pasture (NB/-/-) Amery T2 (WB/C/-)	3	163	249	86	+1
1E Pasture T1 (NB/-/C) Pasture (NB/-/-) Pasture (NB/-/-)	0	36	100	64	+1
2A Stirling T2 (NB/C/D) Karoo T1 (SB/C/C,A) Dundale T2 (WB/C/C)	631	230	153	-77	-2
2B Merrit[4] T1 (NB/-/C) Amery T2 (NB/C/BD) Karoo T1 (SB/C/C)	38	115	174	59	+1
2C Pasture T1 (NB/-/C) Westonia T2 (NB/C/BD) Arrino T1 (SB/C/-)	6	192	262	70	+1
2D Pasture T1 (NB/-/C) Pasture (NB/-/-) Westonia T2 (NB/C/-)	8	375	486	111	0
2E Pasture T1 (NB/-/C) Pasture (NB/-/-) Pasture (NB/-/-)	5	36	100	64	0
3A Stirling[4] T2 (NB/C/D) Karoo T1 (SB/C/C,A) Dundale T2 (WB/C/C)	179	-149	-160	-11	0
3B Merrit[4] T1 (SB/-/C) Stirling T2 (SB/C/CD) Hay T1 (SB/C/-)	396	-50	24	74	0
3C Pasture T1 (SB/-/C) Hay T1 (SB/C/-) Stirling T2 (NB/C/-)	208	124	170	46	0
3D Pasture T1 (SB/-/C) Pasture (NB/-/-) Merrit[4] T2 (NB/C/C)	48	-105	-65	40	0
3E Pasture T1 (SB/-/C) Pasture (NB/-/-) Pasture (NB/-/-)	83	36	100	64	0

1Blocks 1a-e low initial ryegrass seedbank; blocks 2a-e medium; blocks 3a-e high. **2**Treatments in brackets: SB = stubble burn, WB = windrow burn, NB = no burn. Middle characters, – = no cultivation, C = cultivated. Last letters denote herbicide groups used for ryegrass control other than non-selectives. T1 = seeded early, T2 = seeded late. **3**AR = Aggregated ryegrass in 3rd year. **4**Crop brown manured.

Stirling = barley; Hyola, Karoo = canola; Merrit = lupin; Westonia, Brookton, Amery, Arrino = wheat; Dundale = field pea.

Clearly there can be substantial absolute (eg $110/ha on block 2D) or relative differences (170% on block 3E) between actual and simulated NPVs. In some instances actual NPVs overstate the value of a strategy compared to 'normal' years (eg block 1B), in other cases the returns are understated (eg block 2D). In only one instance did a loss become a surplus (block 3B).

Whilst these changes in gross margins are occasionally substantial, they may not affect a farmer's choice of weed control strategy. It is probably of more importance to look at any changes in the ranking strategies. In some instances changes in ranking are substantial. In the first zone, block 1B goes from being ranked third to being ranked fifth, and in the second zone, block 2A goes from second to fourth.

The second result to emerge was the differences in distribution of possible NPVs. Figure 1 shows two strategies having similar mean NPVs but very different distributions of possible returns. The shape of the distribution about the mean is an indication of a strategy's riskiness with regards to prices and costs. Block 1A shows a wider and flatter distribution than block 1C.

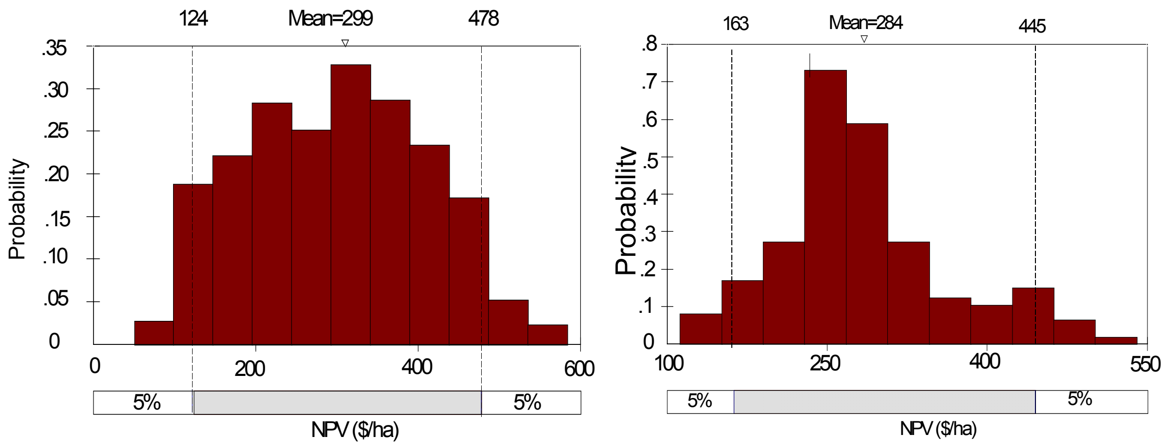


Figure 1. Distributions of NPV of 3-year GMs for blocks 1a and 1c ($/ha)

In this context it is important for farmers and their advisers to be aware of the economic climate in which they are making their weed control decisions. An actual NPV based on calculated prices and costs at precise points in time is perfectly valid but may disguise a strategy's true long-term merits. Apart from effectiveness of weed control, strategy choices will also be influenced by factors such as individual attitudes to risk and the overall financial strength or weakness of the farm business

RYEGRASS CONTROL AND ECONOMIC PERFORMANCE

Farmers have a wide array of tools to control weeds. These tools have a cost, such as the cost of the input, the cost of physical operations or income forgone either through incorporating low return crops in the rotation or through other operations. Herbicide-resistant weeds are more difficult and costly to control. Short-term sacrifices of income (e.g. croptopping, green manuring, pasture phases, fallow) are often part of long-term ryegrass control when severe herbicide resistance is encountered.

This trade-off between weed control and long-term profit is shown in Figure 2. Each point represents a long-term weed control strategy. High weed numbers can lead to low or negative returns (point a). However achieving very low weed numbers may incur high costs and also lead to low returns (point b). The frontier represents the most profitable strategies for particular weed counts. Some strategies produce lower returns for a particular weed count (e.g. strategy d is less profitable than c). Some strategies produce the same returns but with different weed counts (points e and f). Strategy c represents the optimum, producing the highest profit even though it does not minimise the weed count.

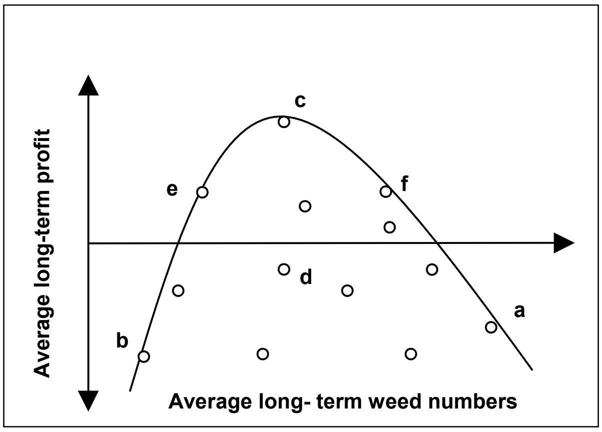


Figure 2 Conceptual example

This part of the study was designed to investigate the relationship between profitability and ryegrass control under different IWM strategies within the rotation.

Method

The computer simulation, RIM99, was used to investigate the long-term profitability and weed control effectiveness of a range of ryegrass management strategies. The simulation model was calibrated using data from the above trials. Rotations and weed control treatment from each of the fifteen strategies were entered into RIM99 and repeated another four times to represent a 20-year programme. This enabled a strategy's merits to be tested over a long planning horizon and removed some of the seasonal and varietal distortions typical of short-term field trial results. A range of alternative weed-control strategies were devised and applied to each block. Details of these strategies are given in Annex 1. These four-year strategies were also repeated to produce 20-year programmes. Average profits and ryegrass densities over the 20 years were plotted for each block. Three examples are shown in Figures 3 – 5.

Results

Block 1A (Figure 3) typifies strategies involving continuous cropping and using green manuring and/or croptopping as the major ryegrass control options. These strategies give results in line with the conceptual model. Financial losses are evident at both low and very high ryegrass densities. Strategy 2 involved frequent green manuring and Strategy 3 continuous cropping with inadequate control measures which resulted in financial losses in both cases. The base strategy that was actually applied in the trials appears to be close to optimal.

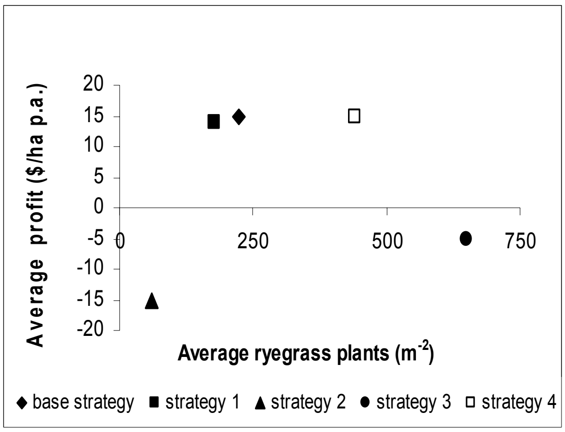
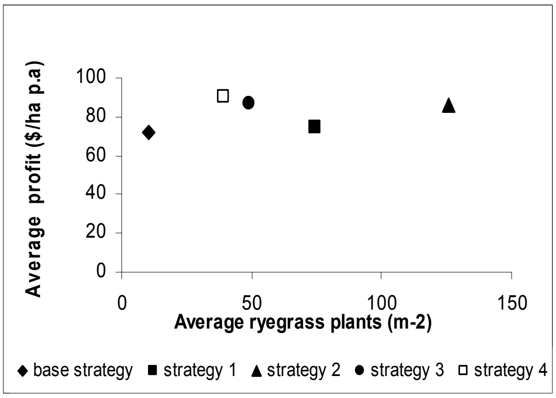
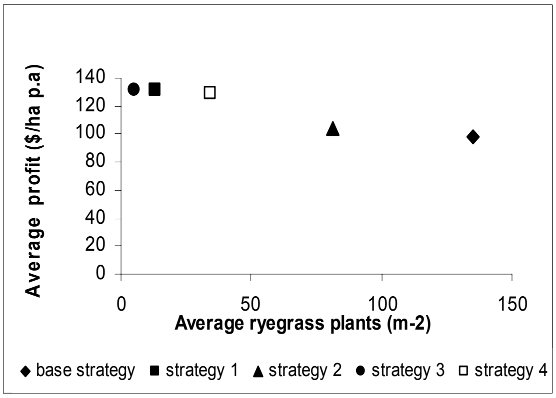


Figure 3 Profit and ryegrass nos – Block 1a

Results for Block 3B (Figure 4) show that in some instances similar profits can be attained in the long term through entirely different management strategies of ryegrass infestations. It should be noted that the average ryegrass populations are substantially lower than in Block 1A.

A clover-clover-wheat-wheat rotation used in Block 2D (Figure 5) with high intensity grazing and spraytopping in the clover phase provided excellent ryegrass control and also high profits.





Figures 4 and 5 Profit and ryegrass no (Block 3B and Block 2D)

In general, the most profitable strategies included control options that were both highly effective on ryegrass and did not involve a large sacrifice of income. High intensity grazing with spraytopping and cutting crops for hay were both profitable options. They both offer a large reduction in ryegrass seed set while also generating a positive gross margin. The most profitable strategy (Figure 5) involved two years of heavily grazed and spraytopped clover pasture followed by two consecutive wheat crops (with no selective herbicides). While rotations including green manure were not as profitable, they were still profitable and would be more so if costs are reduced. An option to reduce costs of green manuring is to plan it. In this study the crop was manured if in-crop ryegrass density reached a particular threshold. Thus manuring occurred after input costs for a full crop had been incurred. The high costs of green manuring used in this study are reflected in the relatively low profits generated by strategies examined in Block 1A (Figure 3).

Continual grain harvesting, while maintaining higher ryegrass densities, was still quite profitable when lupins were croptopped and combinations of high seeding rates, seed catching and burning are used within the rotation. Within individual farms, restrictions with livestock numbers, machinery availability, labour and time would mean that a combination of approaches to ryegrass control may be necessary. Other weeds also exist in the system and effective control of one species may allow another to dominate.

CONCLUSIONS

This study demonstrates that the use of single, contemporary commodity and input prices to evaluate weed control strategies that are to be applied in the future is unlikely to provide as detailed information for decision making as using a series of simulations. Individual farmers can incorporate their own subjective probabilities of prices into this type of analysis and the graphical output demonstrated in Figure 1 provides the opportunity for more informed decision making.

In a number of scenarios, the lowest ryegrass populations achievable do not represent the most profitable strategies. High populations can drastically reduce profitability. If selective herbicides are no longer effective then a break from continuous cropping is needed. Intensive grazing or hay appear to be very effective and profitable control strategies. However the issue is complex as the optimum strategy will change with different prices, weed control efficacy, crop yields and other management-related issues.

ACKNOWLEDGMENTS

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@RISK is an add-in to Excel, Microsoft Corporation.

RIM99 is a 'decision tool for integrated management of herbicide-resistant annual ryegrass' © University of Western Australia and Agriculture Western Australia.

BIOGRAPHY

Alister Draper is a recent graduate of Muresk Institute of Agriculture, Curtin University. He conducted this study as part of his honours research. Alister now works for the Western Australian Herbicide Resistance Initiative at the University of Western Australia, Nedlands, WA.

Dr Martin Bent is Senior Lecturer in Farm Management at Muresk Institute of Agriculture. He has extensive experience of farm economics, production and marketing in Europe and Western Australia.

ANNEX 1 – WEED MANAGEMENT STRATEGIES

Tables below give the details of the management strategies modelled for the different blocks. Results are shown in Figures 3 - 5. Abbreviations used in the tables are listed in the key below. In each table the 'Base Strategy' describes the treatment applied in the field which was used to calibrate the models. The treatments shown for each of the other strategies list the variations from the base strategy.

Key:

- 2 knocks: a sequential application of glyphosate and sprayseed before seeding
- tickle (10): shallow cultivation followed by sowing 10 days later
- tickle (20): shallow cultivation followed by sowing 20 days later
- SB: burn crop stubbles or pasture residues
- WB: windrow burn
- HSR: high seeding rate
- GM: green manure
- GT: gramoxone top lupins or pasture
- HIG: high intensity grazing
- RG: ryegrass
- SC: seed catch – total burn

Weed control strategies for Block 1A

Strategy	Treatment
Base	**Yr 1 Barley** – 2 knocks, trifluralin, tickle (20), SB **Yr 2 Canola** – sprayseed, tickle (20), WB **Yr 3 Wheat** – 2 knocks, HSR, tickle (20), SB **Yr 4 Lupins** – 2 knocks, HSR, tickle (20), GM
1	GM in barley (yr1 only), then only GM lupins if in-crop early spring RG>200/m^2 (yr 4, yr 7, yr 11, yr 15, yr19). GT lupins if not GM
2	GM in any crop (bar canola) when in-crop early spring RG>200/m^2 (yr 4, yr 7, yr 11, yr 15, yr19). GT lupins if not GM
3	Harvest grain every year and GT lupins
4	Harvest grain every year and GT lupins; HSR in barley and canola

Weed control strategies for Block 2D

Strategy	Treatment
Base	**Yr 1 Clover** – sprayseed, simazine pre-emerge, grazing, GT **Yr 2 Clover** – grazing, GT **Yr 3 Wheat** – 2 knocks, HSR, tickle (20), SB **Yr 4 Wheat** – 2 knocks, HSR, tickle (20)
1	HIG in clover
2	SC in first wheat after clover
3	HIG in clover, SC in first wheat after clover
4	HIG in clover, SC in first wheat after clover, only GT in 2^{nd} yr clover

Weed control strategies for Block 3B

Strategy	Treatment
Base	**Yr 1 Lupins** – 2 knocks, simazine pre-emerge, HSR, GM **Yr 2 Barley** – 2 knocks, trifluralin, HSR, tickle (20), SB **Yr 3 Wheat** – 2 knocks, tickle (10), cut for hay then glyphosate, SB **Yr 4 Canola** – 2 knocks, HSR, tickle (20), select, SB
1	GM lupins (yr1 only), then GM lupins if in-crop early spring RG>200/m^2 (yr 13, yr 17)
2	Always GT lupins instead of GM and SB lupin stubble instead of canola stubble
3	Sow barley at first chance to seed
4	Sow barley at first chance to seed and WB in canola