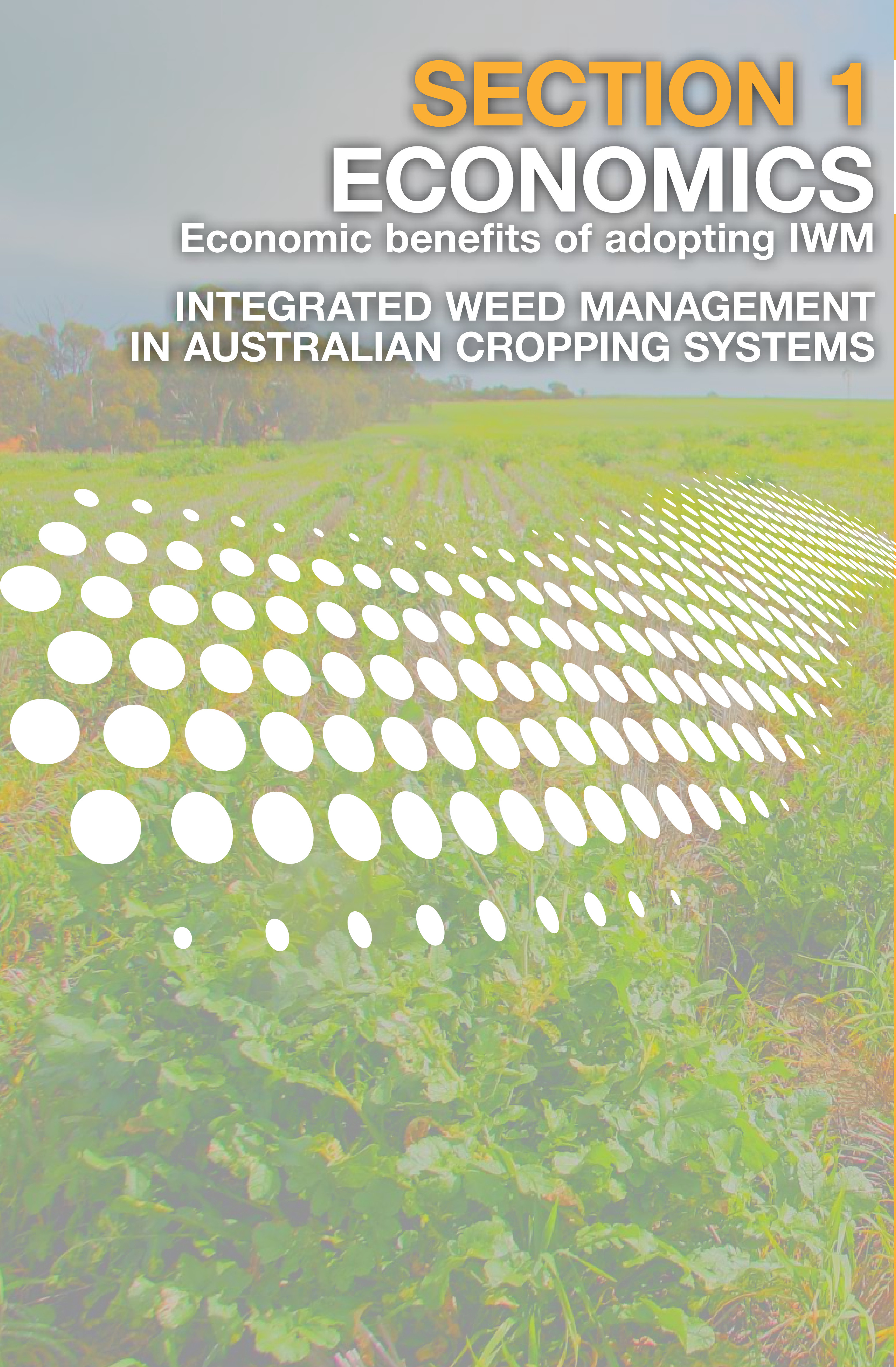
SECTION 1

ECONOMICS

Economic benefits of adopting IWM

INTEGRATED WEED MANAGEMENT IN AUSTRALIAN CROPPING SYSTEMS



SECTION 1: ECONOMIC BENEFITS OF INTEGRATED WEED MANAGEMENT

Adoption of integrated weed management (IWM) is economically beneficial in many Australian cropping systems. Not only is IWM essential for the management of herbicide resistance but it also plays an important role in minimising the size of weed seedbanks over time and has clear benefits for managing the risk of weed control failure due to adverse seasonal conditions. Using a range of tactics in an IWM plan is essential for the effective, long-term management of weeds.

IWM has short-term costs and short- and long-term benefits, including positive impacts on weed numbers and crop production. The challenge is to realise and estimate the long-term benefits, both physical and fiscal, rather than focus on the short-term financial pressures.

Short-term returns of individual enterprises are usually measured by a gross margin budget. This is determined by subtracting factors such as the cost of weed control (both herbicide and non-herbicide) and other inputs (e.g. seed and fertiliser) from gross income (calculated as crop yield multiplied by grain price). Crop yield is directly influenced by weed density, which itself is a function of weed control.

With the widespread and increasing problem of herbicide resistance, growers are forced to change both the short-term and long-term view of weed management. The new paradigm is that weed populations need to be managed to ensure a decrease in the weed seedbank over time and the actions taken now to reduce the weed seedbank will affect the profitability of crops for years to come. As small numbers of weed survivors are often sufficient to increase the weed seedbank, few surviving weeds can be tolerated. As a result, the use of economic thresholds of weed numbers based on their yield impact in the current crop alone is irrelevant!

Key finding #1

Weed seed carryover in the soil seedbank has a huge impact on returns in future years

Determining the optimal level of herbicide and non-herbicide inputs for a given weed density that will maximise the crop gross margin does not consider the longer term impacts of weed seedbanks on profitability. Each weed control decision not only affects returns for the current crop, but changes in the weed seedbank that result from decisions made in the current year also impact on future crop options, yields and the cost of weed management in later years.

Key finding #2

Calculating returns over the long term (e.g. 10 years) will help determine the real value of weed management options

Net present value (NPV) is one measure of calculating returns over the long term. In this instance future gross margins are summed and discounted back to a present day value. The discounted average annual return, obtained by dividing the NPV by the time period, can also be used. The term 'discounting' means converting future gross margins to a present day dollar value so as to account for factors such as inflation and the opportunity cost of capital.

This approach is able to account for important economic factors such as changes to the weed seedbank from one year to the next due to weed management actions and herbicide resistance. The benefits of agronomy targeting weed control (e.g. a change in crop sequence) and IWM tactics (e.g. green manuring where there is a loss of income in the year of activity) can be included.

TABLE E1 Elements of the economic costs and benefits for some individual tactics.

Tactic Group	Tactic	Average annual application cost ($/ha)	Elements of economic cost	Element of economic benefit^
1. Deplete weed seed in the target area soil seedbank	1.1 Burning residues	12	Fire risk, high erosion risk, nutrient and moisture losses	20–90% weed control
	1.2 Encouraging insect predation of seed	#	Stubble management, reduced tillage practices	20–80% weed control
	1.3 Inversion ploughing	20	Mechanical operation, high erosion risk	Up to 100% weed control, increased soil fertility and crop yield if soil constraints removed
	1.4 Autumn tickle	6	Mechanical operation, erosion risk, moisture loss	Stimulate weed emergence
	1.5 Delayed sowing	#	Mechanical operation, 5–30% crop yield penalty for each week of delay	Increase early weed control
2. Kill weeds in the target area	2.1 Fallow and pre-sowing cultivation	3	Mechanical operation, soil degradation, moisture loss	80% weed control
	2.2a Knockdown (non-selective) herbicides for fallow and pre-sowing control	12	Herbicide use, spray pass	95% weed control, easy weed control
	2.2b Double knockdown or 'double knock'	25	Herbicide use, spray pass	Nearly 100% weed control, delay resistance risk
	2.2c Pre-emergent herbicide	10–40	Herbicide use, spray pass, medium/high resistance risk, phytotoxicity	50–90% weed control
	2.2d Selective post-emergent herbicides	15–35	Herbicide use, spray pass, high resistance risk, phytotoxicity	85–95% weed control
	2.3 Weed control in wide-row cropping	#	Herbicide use, mechanical operation, low resistance risk, root pruning or crop damage	90% weed control, small yield loss
	2.4 Spot spraying, chipping, hand roguing and wiper technologies	#	Herbicide use, mechanical operation, low resistance risk	Target weed control / eradication
	2.5 Weed detector sprayers	#*	Machinery investment, herbicide use, spray pass, potential herbicide residue patches	High levels of control on low density, difficult to control weeds, reduces fallow spray costs by 80–95%
3. Stop weed seedset	3.1a Spray-topping with selective herbicides	5–20	Herbicide use, spray pass, high resistance risk, phytotoxicity, harvest withholding periods	Up to 90% weed control
	3.1b Crop-topping with non-selective herbicides	7	Herbicide use, spray pass, yield loss, phytotoxicity	Approximately 75% weed control, low resistance risk
	3.1c Wiper technology	8	Herbicide use, mechanical operation, phytotoxicity	50–98% weed control, low resistance risk
	3.1d Crop desiccation and windrowing	3–5	Machinery investment, herbicide use, mechanical operation, fire risk (if burn dumps on rows)	40–50% weed control
	3.2 Pasture spray-topping	5	Herbicide use, spray pass	75–90% weed control, low resistance risk
	3.3 Silage and hay – crops and pastures	#*	Herbicide use, mechanical operation, spray pass, contract labour, crop loss	90–98% weed control, fodder value, harvest savings
	3.4 Manuring, mulching and hay freezing	#*	Herbicide use, mechanical operation, spray pass, crop loss, contract labour	98% weed control, increased soil fertility, 10% yield boost in next crop, fodder value
	3.5 Grazing – actively managing weeds in pastures	#*	Running sheep, seed burial/spread	10–45% weed control
4. Prevent viable weed seeds within the target area being added to the soil seedbank	4.1 Weed seed control at harvest	5–17	Initial investment, mechanical operation, harvest delays, fire risk	60–95% weed seed removal of some weeds, reduced spread of resistant weeds, contain weed seedbank
	4.2 Grazing crop residues	#	Running sheep, seed burial/spread	10–45% weed control, fodder value
5. On-farm hygiene	5.1a Sow weed-free seed	#*	Prevention of new weed infestations requires extra time and labour	Minimisation of new species or resistant weeds being introduced to the farm
	5.1b Manage weeds in non-crop areas	#*		
	5.1c Clean farm machinery and vehicles	#*		
	5.1d Manage livestock feeding and movement	#*		
	5.1e Monitor paddocks following flood for new weed incursions	#*		

* Values vary between systems. ^ Weed control ranges correspond to the average percentage weed kill/seedset reduction across a range of weeds, crops and pasture types. # No specific cost item

ESTIMATING THE ECONOMIC BENEFITS AND COSTS OF IWM

Guidelines illustrating the economics of individual IWM practices can be provided based on a realistic IWM scenario, although the true economics will vary significantly between and within regions, farms and seasons. A summary of the elements of the economic costs and benefits of the IWM tactics identified in this manual is presented in Table E1 (page 17).

The net value of individual tactics is the difference in the 20-year equivalent annual profit for the base IWM strategy. This is calculated by including or excluding that particular tactic. A series of model simulations based on Ryegrass Integrated Management (RIM) led to the identification of the base IWM strategy, which was the most profitable combination of tactics over a 20-year period.

For further information on the RIM model, see the Australian Herbicide Resistance Initiative (AHRI) website (www.ahri.uwa.edu.au/RIM), related publications (Lacoste 2013; Pannell *et al* 2004) and *Simulation model 3: RIM model*, page 20.

Key finding #1

Herbicides are the most cost-effective weed management option, providing the most reliable weed control

When considering the economic value of individual tactics (Table E1, page 17) the use of herbicides was by far the most economically valuable tactic. The problem is that many of these selective herbicides are no longer effective in many regions.

Both high-intensity pasture grazing and high crop sowing rates also proved to be profitable tactics. Furthermore, windrowing, inversion ploughing, delayed sowing and pasture spray-topping, seed collection at harvest and encouraging seed predation and crop-topping to prevent seedset were all of positive value, as most provided very effective weed control. All other tactics were slightly unprofitable, with green manuring and silage/hay crops the least valuable .

This is consistent with the findings of Monjardino *et al* (2004b), who concluded that non-cropping phases, such as haying and manuring of crops, were generally found to reduce profits due to the high cost of sacrificing the entire crop, despite excellent weed control. The most promising prospects for such tactics appear to be in cases of well-established herbicide resistance involving the ineffectiveness of all selective herbicides, which is becoming more common. Here, a simple break-even analysis on the sale price of hay indicates that it would have to increase from $40/tonne to $85/tonne for the hay scenario to be as profitable as the base strategy.

See *Tactic 3.3 Silage and hay – crops and pastures* (section 4, page 190) and *Tactic 3.4 Manuring, mulching and hay freezing* (section 4, page 195) for real life examples of where these tactics are being used to manage resistance while making a profit for the grower.

ESTIMATING THE ECONOMIC BENEFITS OF IWM USING SIMULATION MODELS

This example discusses a number of published studies that have considered the economic benefits of IWM and their key findings. There is a strong Western Australian focus in these case studies due to the high incidence of herbicide resistance in that state.

Simulation model 1:
Net present value of adding crop competition and seed destruction

Key finding #1

Net present value (NPV) was determined by modelling a wheat–lupin rotation with different inputs and assumptions on resistance (Gorddard *et al* 1995)

A continuous cropping system was assumed until the herbicide resistant weed population increased to a point where cropping was no longer economically feasible, at which time the system converted to pasture production. The study did not consider issues such as rotating herbicide groups or rotation of crop and pasture between years.

The results of the analysis were reported for herbicide resistant and herbicide susceptible scenarios, and for chemical-only control (non-IWM) and non-chemical plus chemical control (IWM), as shown in Table E2 (below). The results are reported in terms of NPV calculated over 30 years using a 5 per cent real discount rate. In addition to the economic returns, the number of years before cropping was abandoned in favour of pasture. This is also presented in Table E2.

The model suggests that the presence of resistance at the rate of one plant per million (for annual ryegrass) in the first year substantially reduces the NPV by $678/ha for non-IWM after seven years and $594/ha for IWM scenarios after 12 years. Where resistance does not exist, cropping can continue indefinitely.

TABLE E2 Benefits of non-chemical weed control options (Gorddard *et al* 1995).

	NPV[a] ($/ha)	Years of cropping[b]
Herbicide susceptible weeds, chemical-only control	1445	30
Herbicide susceptible weeds, non-chemical and chemical control	1445	30
Resistant, chemical-only control	767	7
Resistant, non-chemical and chemical control	851	12

a Net present value (NPV) over 30 years using 5% real discount rate
b Number of years before resistance reaches a level where cropping is less profitable than pasture

A large number of strategies involving combinations of these tactics with post-emergent herbicides were examined. Of the control strategies investigated, a strategy which integrated six different tactics provided the highest NPV (Table E3, below). The strategies with the highest average NPV included a broader combination of tactics than is currently used in mainstream agriculture. The last two strategies in Table E3 highlight the importance of employing a combination of several non-chemical control methods.

TABLE E3 Net present values (NPV) of alternative weed control strategies in a 20-year continuous cropping (wheat–lupin) rotation in the central wheatbelt of Western Australia (Schmidt and Pannell 1996).

Modelling (target weed – annual ryegrass)	NPV ($/ha)
Model 1 • pre-sow glyphosate in wheat • simazine in lupins • increase crop plant densities (lupins from 40 to 60 plants/m^2, wheat from 100 to 200 plants/m^2) • crop-top lupins with paraquat • windrow lupin and wheat crops • burn windrows in autumn	985
Model 2 • pre-sow glyphosate in wheat • simazine in lupins • increase crop plant densities (lupins from 40 to 60 plants/m^2, wheat from 100 to 200 plants/m^2) • crop-top lupins with paraquat • windrow lupin and wheat crops • collect crop residue (seed-catch) at harvest	955
Model 3 • pre-sow glyphosate in wheat • simazine in lupins • crop-top lupins with paraquat • windrow lupin and wheat crops • burn windrows in autumn	159
Model 4 • pre-sow glyphosate in wheat • simazine in lupins • increase crop plant densities (lupins from 40 to 60 plants/m^2, wheat from 100 to 200 plants/m^2) • total autumn burn	255

Simulation model 2:
Combining a range of IWM tactics targeting annual ryegrass

Key finding #1

A strategy which integrated six different tactics provided the highest NPV according to the simulation model developed by Schmidt and Pannell (1996)

Key finding #2

Growers who wish to remain in a continuous cropping system must include a wide range of weed control methods, as no single method provides the optimal solution

The RIM simulation model included a much larger number of IWM tactics than was considered in simulation model 1. The weed control tactics included delayed sowing, shallow cultivation, cutting crop for hay to remove weed seed-heads, green manuring, seed-catching at harvest, crop-topping and increased crop densities.

Simulation model 3:
RIM model – herbicide resistance, annual ryegrass and IWM

Key finding #1

The benefits of IWM extend beyond herbicide resistance management, also applying to the case of long-term weed population management

The RIM (Ryegrass Integrated Management) model was developed from the earlier models, 1 and 2, and is described by Pannell *et al* (2004). This model expanded the number of chemical and non-chemical tactics available and also included the effects of different pasture phases on herbicide resistance and economic returns. The model allowed for resistance to herbicides with different modes-of-action, represented by the herbicide groups. Each group was allocated a number of applications, or 'shots', before full herbicide resistance was assumed to have developed.

TABLE E4 Consequences of restricting usage of selective herbicides over 10 years (assuming a Western Australian lupin–wheat rotation) (Pannell *et al* 2004).

Applications of selective herbicide available	Profitable treatments (other than selective herbicide) forming part of the integrated strategies[a]	Equivalent annual profit ($/ha)
2	• use high crop sowing rates (10) • crop-top lupins with paraquat (5) • use seed-catching cart, burn dumps (10) • delay seeding 20 days and apply glyphosate (10)	64
4	• use high crop sowing rates (10) • crop-top lupins with paraquat (5) • use seed-catching cart, burn dumps (10) • delay seeding 20 days and apply glyphosate (6)	76
6	• use high crop sowing rates (10) • crop-top lupins with paraquat (4) • use seed-catching cart, burn dumps (10) • delay seeding 20 days and apply glyphosate (2)	83
8	• use high crop sowing rates (10) • crop-top lupins with paraquat (2) • use seed-catching cart, burn dumps (10) • delay seeding 20 days and apply glyphosate (1)	91
10	• use high crop sowing rates (6) • crop-top lupins with paraquat (1) • use seed-catching cart, burn dumps (10)	93

[a] The number of years in which this treatment was applied is shown in parentheses.

A number of scenarios with differing levels of availability of a selective herbicide were evaluated over a 10-year period for a wheat–lupin rotation in Western Australia (Table E4, page 20). Included in the results are the non-herbicide options of:

- increasing crop sowing rates
- seed-catching at harvest
- shallow cultivation with delayed sowing
- crop-topping (a non-selective application of the herbicide paraquat to lupins during grain fill).

As herbicide availability increases, the total number of weed treatments other than selective herbicides falls. However, it is apparent from the results that it is economical in the long term to include IWM options when herbicide resistance is not an issue, so as to achieve a high level of control of weed populations.

Simulation model 4: Multi-species (annual ryegrass and wild radish) RIM model

Key finding #1

The most promising of the strategies examined appeared to be three years of pasture ('phase farming' in Western Australia), rather than the more commonly practised one year of pasture between crops

Monjardino *et al* (2003) extended the original single species (annual ryegrass) RIM model to include wild radish and added additional weed management practices to control this species (i.e. a multi-species RIM model).

The implications of several rotational sequences with different crop–pasture phases, where the level of selective herbicide availability was held constant, were evaluated (Table E5, below). The first two rotations are continuous cropping based on wheat (with either lupins or canola), and the last rotation is a wheat–wheat–lupin sequence with a three-year French (pink) serradella pasture phase in years 9 to11 of a 20-year simulation.

TABLE E5 Choice of crop–pasture rotation sequence and weed control practices over a 20-year period in Western Australia (Monjardino *et al* 2003).

Rotation[a]	Profitable control options other than selective herbicides[b]	Equivalent annual profit ($/ha)
WWL	• delayed sowing (1) • high sowing rates (19) • crop spray-topping (6) • windrowing (3) • seed-catching + burning (11) • windrowing + burning (6)	137
WWC	• delayed sowing (2) • high sowing rates (19) • crop spray-topping (0) • windrowing (6) • seed-catching + burning (10) • windrowing + burning (9)	114
WWL+PPP	• delayed sowing (0) • high sowing rates (16) • crop spray-topping (9) • seed-catching + burning (10) • windrowing + burning (3) • burning (1) • grazing (1) • high-intensity grazing (2)	124

a Abbreviations: W – wheat; L – lupin; C – canola; P – pasture (French serradella).
b The number of years in which this treatment was applied is shown in parentheses.

The IWM options were selected as optimal for each rotation system considered. All three rotations provided good weed control. The control methods selected for the two cropping-only rotations were broadly similar, although practices such as delayed sowing, windrowing and seed-catching were slightly less attractive in the lupin rotation. The rotation that included pasture had a different mix of control options, as the pasture phase itself allowed for grazing as an additional weed control method. Importantly, the inclusion of a pasture phase with these extra weed control options made it economically optimal to use fewer applications of selective herbicide.

In a different study by Monjardino *et al* (1999), the inclusion of pasture in a cropping rotation increased the attractiveness of a long-term herbicide conservation strategy (versus rapid exploitation of the same selective herbicide) by reducing the early net losses that occur when cropping is continued with minimal use of herbicides.

Monjardino *et al* (2004a) evaluated the net value of a broader range of crop–pasture sequences against different factors such as initial weed seed densities, level of herbicide use, pasture phase length and frequency. The most promising of the strategies examined appeared to be the so-called 'phase farming', involving occasional three-year phases of pasture rather than shorter, more frequent and regular pasture phases. This approach was competitive with the best continuous cropping rotation in a number of scenarios, particularly where herbicide resistance was at high levels.

Simulation model 5: Multi-species (annual ryegrass and wild radish) RIM model and GM glyphosate resistant canola crop

Key finding #1

In the absence of glyphosate resistant weeds, the value of glyphosate resistant canola as a break crop to manage weeds is significantly higher than that of triazine resistant canola

Key finding #2

The glyphosate resistant canola technology package needs to be highly effective in order for its use to be justified in the management of annual ryegrass and wild radish infestations

The multi-species RIM model was again used, this time to evaluate the economic value of including a genetically modified (GM) crop in the system. The example used was glyphosate resistant canola to replace triazine resistant canola in a typical Western Australian cropping system (Monjardino *et al* 2005). The analysis focused on a continuous croppingt rotation of wheat–wheat–canola–wheat–lupin.

The assumption was that glyphosate can be sprayed in-crop once or twice, and that this may reduce reliance on, and thus help prolong the life of, selective herbicides to which annual ryegrass and wild radish can be highly resistant. Glyphosate resistant canola was also assumed to have a yield advantage compared to triazine resistant canola, although its seed is likely to cost more due to a technology fee.

Evaluation of these trade-offs led to the conclusion that the value of glyphosate resistant canola is significantly higher than that of triazine resistant canola, which currently dominates Western Australian plantings (Table E6, below). The benefits of glyphosate resistant canola accrue from its yield advantage relative to triazine resistant canola (10 to 20 per cent) and from the inexpensive, effective weed control obtained with glyphosate.

TABLE E6 Equivalent annual profits and weed densities for two scenarios, and net value of glyphosate resistant canola ($/ha/year), for a wheat–wheat–canola–wheat–lupin rotation over a 20-year period in Western Australia.

	Equivalent annual profit ($/ha/yr)	Annual ryegrass density (plants/m^2)	Wild radish density (plants/m^2)
Scenario with glyphosate resistant canola	153	< 1	1
Scenario with triazine resistant canola	142	< 1	2
Net value of glyphosate resistant canola	11		

Note: the presence or selection of glyphosate resistant weeds was not considered in this modelling

However, the results of this analysis indicate that the glyphosate resistant canola technology package needs to be highly effective in order for its use to be justified in the management of annual ryegrass and wild radish infestations. This estimate would be higher if wild radish alone had been considered in the analysis and lower if the focus were on annual ryegrass.

The adoption of glyphosate resistant canola could result in a substantial increase in farm profit, as well as greater flexibility in managing weeds and the likely extension of the life of selective herbicides.

Despite public debate on the potential impacts of genetically modified crops, the risks of gene flow from glyphosate resistant canola, the development of 'super weeds' and the potential problems with volunteer weeds have all been found to be very low or negligible. Furthermore, the impact on the environment of growing glyphosate resistant canola is likely to be positive as a result of reduced usage of residual triazine herbicides in favour of glyphosate.

However, if glyphosate resistant canola is widely adopted there is a threat of increased evolution of resistance to glyphosate in a range of weed species, as glyphosate will be used in-crop as well as during the fallow phase, thus reducing its profitability and availability to farmers over time.

The impact of GM canola products on human health is not expected to be significant as no traces of GM material are usually found in canola oil. Nevertheless ongoing risk assessment research is required in these areas.

Grower and adviser experience with early releases of glyphosate resistant crops, which have a limited application window for glyphosate, have found issues with later season weed germinations which, if not addressed at harvest by seed capture or other means, will lead to an unacceptable increase in the weed seedbank for following crops.

Simulation model 6:
WeedRisk model – inclusion of variability and uncertainty

The simulation studies already discussed assume certainty with respect to efficacy of the weed control options. However, variability in seasonal conditions is an important source of risk to farmers in terms of yields and potential impacts on the efficacy of weed control.

Key finding #1

Using multiple weed management tactics seeks to spread the risk of control failure and increase the probability of success

Farming and weed management practices both have elements of seasonal risk and are affected by seasonal conditions. Jones and Medd (2005) used a climate and biological simulation model (WeedRisk) to determine the impact of IWM options on weed seedbanks, plant densities and crop yields for different population densities of wild oats and wild radish.

The strategies in this simulation model involved the use of a post-emergent herbicide plus various combinations of the IWM options of pre-season tillage (e.g. autumn tickle), increased competition (e.g. increased sowing rate, competitive crops) and late season herbicide application (e.g. crop-topping, selective spray-topping).

Key finding #2

IWM options that stop weed seedset had the greatest impact on reducing weed seedbanks

The use of post-emergent herbicides was found to be critical when trying to minimise wild oats density and maximise crop yields in any given year. Similar results were obtained in the case of wild radish.

Using the same mix of weed control options, Jones *et al* (2006) estimated the economic benefits of IWM under deterministic (i.e. zero risk) and stochastic (i.e. full risk) assumptions. The benefits of a non-IWM scenario (i.e. post-emergent herbicide only) for wild oats over a 20-year simulation period were a gain in NPV of 6 per cent. However, when variability in seasonal conditions and the efficacy of the alternative options were taken into account, the NPV of the IWM scenario was 80 per cent greater than the non-IWM scenario.

Key finding #3

The benefit of the IWM scenario was largely due to options that reduced the seedbank (e.g. crop-topping, selective spray-topping). These tactics were able to compensate for the failure of post-emergent herbicides in years when they failed due to adverse seasonal conditions

To explore the benefits of IWM further, the WeedRisk model was tested for a range of rotational and IWM options over a 20-year period for three key cropping weeds: wild oats, wild radish and annual ryegrass (Table E7, below). The systems included a continuous cropping system and a rotation involving a four-year crop phase followed by a three-year perennial pasture phase for a southern New South Wales cropping system. The calculated benefits from IWM are conservative, as the analysis does not consider the impacts of development of herbicide resistance from continual use of post-emergent herbicides.

Wild radish effectively ‘crashes the system’ when relying solely on herbicides in a continuous cropping system due to the difficulty in controlling the staggered germinations throughout the year along with its ability to set viable seed whenever conditions are favourable. Wild radish seed will be harvested each year and re-sown with farmer-saved seed.

TABLE E7 The economic impact ($/ha) of different crop and IWM systems on mean[a] annualised discounted returns for wild oats, wild radish and annual ryegrass in a southern New South Wales cropping system.

	Economic return ($/ha)					
	Wild oats		Wild radish		Annual ryegrass	
Continuous cropping						
No IWM	268	± 35	-9	± 27	284	± 34
IWM	332	± 38	315	± 37	335	± 38
Crop + pasture rotation						
No IWM	288	± 29	157	± 25	284	± 28
IWM	319	± 32	300	± 30	320	± 31

a The values following ± are the standard deviation.

Key finding #4

The economic returns averaged over a 20-year period for IWM are greater than for non-IWM in all cases, usually by a considerable margin, primarily due to lower seedbank numbers in IWM systems.

Contributors

Randall Jones and Marta Monjardino

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