The Economic Benefits of Glyphosate-Tolerant Canola and Lupin in Controlling Annual Ryegrass (*Lolium rigidum*)

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Abstract

Herbicide resistance in problematic weed species such as annual ryegrass (*Lolium rigidum*) can eventually place major constraints on weed control in cropping systems. Using the dryland cropping system in Western Australia as an illustration, this study examines how the possible introduction of genetically modified varieties of canola (*Brassica napus*) and narrow-leafed lupin (*Lupin angustifolius*) with resistance to the broad-spectrum herbicide glyphosate may assist in increasing farm profits through higher yields, lower herbicide costs and improved weed control. The bioeconomic model RIM which simulates the population dynamics of annual ryegrass over a 20 year period was used to investigate the value of including these glyphosate-tolerant (GT) crop varieties compared to the non-GT varieties. The economic value of including GT canola and GT lupin was consistently found to be higher than reliance on their non-GT variety alternatives. More effective weed control with lower costs was also achieved when both these GT crops were grown. The economic benefits of including both GT canola and GT lupin in farm rotations could be as high as $A46/ha/year when they are used intensively. However, a major threat to the technical and economic efficacy of these GT crops is the possible emergence of glyphosate-resistant weed populations. The introduction of both GT lupin and GT canola therefore needs to be accompanied wherever possible with strategies known to reduce this risk.

Key Words

Herbicide resistance, annual ryegrass, glyphosate, weed control

Introduction

Canola (*Brassica napus*) and narrow-leafed lupin (*Lupin angustifolius*) are the two most important broad-leafed crops grown in the grainbelt of Western Australia (WA). One of their rotational benefits has been the opportunity they provide to selectively control grass weeds. However this role as a grass weed break, particularly for annual ryegrass (*Lolium rigidum*), is diminishing due to the growing problem of herbicide resistance. Widespread resistance to group A herbicides (ACCase-inhibitor) and group B herbicides (ASL-inhibitor) (Owen et al. 2007) has forced new weed-control methods to be developed. One new option is genetically modified canola and lupin varieties that are glyphosate tolerant (GT).

From season 2010 onwards in WA, GT canola is commercially available whilst GT narrow-leafed lupin is in development. Use of glyphosate in-crop with GT canola and also with GT lupin, when eventually available, will facilitate weed control in situations where resistance has rendered selective herbicides ineffective. These GT varieties have lower herbicide costs, simplified weed management and offer the potential to prolong the life of selective herbicides currently used (Llewellyn and Powles 2001). GT canola and GT lupin also may facilitate timelier crop sowing as the need for a pre-sowing knockdown is erased through post-emergence spraying. This may make growing lupin and canola more attractive to farmers, where early sowing of these species is desired to accommodate the sowing of other crops and ensure yield potentials are reached.

The majority of canola currently grown in WA is triazine tolerant (TT), which yields 10-20% lower (and 2-3% lower oil content) than equivalent varieties lacking the TT gene (Moore and Carmody 1997). Weed control in TT canola is reliant on group C herbicides such as atrazine. These herbicides are residual and risk carryover and damage to subsequent cereal crops under low-rainfall conditions, as well as potentially contaminating groundwater. Similarly, the group C herbicides simazine and to a lesser extent metribuzin and atrazine are also widely used for weed control in lupin (White et al. 2008). Hence, GT lupin and GT canola offer rotational and environmental benefits over their traditional counterparts.

However, the ongoing use of glyphosate in GT crops will place selection pressure on weeds which exhibit glyphosate resistance. Hence, accompanying any introduction of these GT crops will be the need for an integrated portfolio of weed management practices such as outlined in Table 1 to reduce the prospects for the occurrence of GT weeds.

The prospective value of introducing both GT canola and GT lupin into a WA farming system is yet to be assessed. Hence, the aim of this study is to determine these economic benefits and investigate which portfolios of weed management techniques are effective to prolong the effective use of glyphosate.

Methods

RIM

RIM (Ryegrass Integrated Management) is a dynamic simulation model of paddock-level management of ryegrass, a principal weed in rotational farming as practised in the grainbelt of WA (Pannell et al. 2004). RIM integrates economic, biological and agronomic aspects of weed management and is designed to guide weed management of annual ryegrass, WA's most economically important crop weed (Pannell et al. 2004). It allows users to specify the enterprise sequence and any feasible combination of 35 different weed management treatments over either 10 or 20 years. Some examples of the 35 options are listed in Table 1.

Table 1. Examples of weed control methods used in RIM for controlling annual ryegrass.

Type	Herbicide group	Weed control Method	Enterprise
non-selective	M	Glyphosate knockdown and pasture-topping	W, B, C, L, S, Z
	L	Paraquat-Diquat knockdown & lupins/pasture - topping	W, B, C, L, S, Z
	M & L	Double knock (glyphosate followed by paraquat-diquat)	W, B, C, L, S, Z
selective	D	Trifluralin (pre emergence)	W, B, C, L
	C	Atrazine (pre and post-emergence)	C
	C	Simazine (pre and post emergent)	C, L
	B	Chorsulfuron (Glean?)(pre and post-emergent)	W, B (post-em only)

A	Fusilade? (post-emergent)	C, L, V, S, Z
A	Select? (Clethodim)(post-emergent)	C, L, V, S, Z
Non-herbicide	High crop seeding rate	W, B, C, L
	seed with full-cut cultivation (default is no-till)	W, B, C, L, S, Z
	delay seeding 10 days	W, B, C, L, S, Z
	high intensity grazing	S, Z, V
	green manure	W, B, C, L, V, S, Z
	Cut for hay, then glyphosate (Group M)	W, B, C, L, V, S, Z
	Swathe	B, C, L
	Seed catch - burn dumps	W, B, C, L

W=wheat, B=barley, C=canola, L=lupin, S=sub-clover, Z=serradella cv. Cadiz, V=volunteer pasture

A detailed representation of the biology of annual ryegrass, crops and pastures, as well as the economics of farm management and production decisions are included in the model. The model allows the consequences of weed management decisions and enterprise sequences to be seen on crop yields, weed populations, resistance status and profitability.

Pluske et al. (2004) have provided a more detailed explanation of the equations and parameters in RIM. RIM is not a resistance model as it excludes the genetics of resistance. Rather, it examines the effects of resistance on weed control and profitability. The resistance status of the annual ryegrass population is specified by the user by entering the number of herbicide applications from each group available before resistance occurs. This imitates field observations, as herbicide resistant weeds usually become widespread quite suddenly.

Including GT canola and GT lupin in RIM required the following modifications:

- Addition of two glyphosate applications, one at 2 weeks and one at 4 weeks following crop emergence, as options in both GT lupin and GT canola
- A rate of 1 L/Ha is assumed for each application with Roundup? priced at $12/L. A kill rate of 95% is assumed with the first application and 99% with the second application.
- GT canola has a 10% yield advantage over the standard triazine tolerant canola used in RIM. GT lupins have no yield advantage over conventional lupin.
- Group C herbicides are no longer an option for weed control in GT canola
- A standard technology fee of 2.57% of the farm-gate price is assumed for both GT lupin and GT canola. This charge is based on the fees charged in Australia for growing GT canola in 2008.

- The default cost of broadleaf weed control of $10.15/ha and $20.10/ha is removed and the additional saving in a cost of application is included. In other words, glyphosate is assumed to control all broadleaf weeds and therefore the application cost of $2.50 is no longer required.

The net present values (NPV) of the gross margins of 4 different rotations were calculated. The rotations were canola-wheat-lupin-wheat (cwlw); canola-wheat-lupin-wheat-barley (cwlwb); canola-wheat-wheat-lupin-wheat-wheat (cwwlww); canola-wheat-lupin-wheat-barley-3 year French serradella cv. Cadiz (cwlwbzzz). These rotations represented the most commonly observed rotations used by farmers in the WA grainbelt on sandy/loam soils where annual rainfall exceeds 400 mm. For each rotation, the crop combinations were to include GT lupin only, or GT canola only or both GT canola and GT lupin or no use of any GT crop. The different combinations of GT crops grown within each rotation allowed the relative profitability of each rotation (and crop sequence) to be assessed. In addition, each rotation was also compared by altering the weed's herbicide resistance at year zero. One scenario was to exclude the use of group A fop herbicides and group B herbicides from year zero. Another scenario was where all herbicide options were effective and available from year zero. Weed management strategies were based around those combinations of practices that reduced the risk of developing glyphosate resistance.

Results

There are significant profit advantages from including both GT canola and GT lupin in farm rotations (Tables 2 and 3) when herbicide resistance is present or absent. The differences in annual average profit are largest in the cwlw rotation, where GT canola and GT lupin are grown every second year.

Table 2. Average annual profit ($/ha/year) equivalent of the NPV over 20 years for rotations with no herbicide resistance at year 0.

	cwlw	cwlwb	cwwlww
GT canola and GT lupin	127	107	113
GT canola only	110	93	103
GT lupin only	105	89	96
Non-GT	83	74	82

Table 3. Average annual profit ($/ha/year) equivalent of the NPV over 20 years of rotations with group A (excluding clethodim) and B herbicide resistance at year 0

	cwlw	cwlwb	cwwlww
GT canola and GT lupin	121	103	108
GT canola only	103	87	94
GT lupin only	99	85	91

Non-GT	75	65	75

The efficacy of GT varieties in controlling ryegrass is shown in Figure 1 for the cwlw rotation where group A fop and group B herbicide resistance is evident at year 0. The relatively higher ryegrass densities in the GT canola-only scenario compared to the GT lupin-only scenario is due to the effectiveness of ryegrass control in non-GT lupin being less than in TT canola. This means ryegrass numbers are not reduced as much in the lupin phase of the GT canola-only rotation, leading to overall higher ryegrass densities. The lupin phase still acts as a weed break in this situation, but it is not as effective as GT or TT canola. On the other hand, control of ryegrass in TT canola is relatively effective, causing low numbers throughout the 20-year period. The lower weed densities in the first year of the GT canola-only scenario is due to the use of glyphosate following swathing rather than using Select? and swathing without glyphosate in the GT lupin and GT canola and GT lupin-only scenarios. Select? was not used in the non-GM and GT canola-only rotations as it was more economic to preserve its use for non-GT lupin. The increase in weed numbers at the end of the 20-year period in the non-GM rotation was due to the lack of herbicide options available in this period. All shots of Select? and group C herbicides had been used, meaning weed control in the final lupin and canola phases was compromised allowing ryegrass numbers to increase. This demonstrates one of the major benefits of using GT canola or GT lupin –the life of other selective herbicides is prolonged since they are not used as frequently.

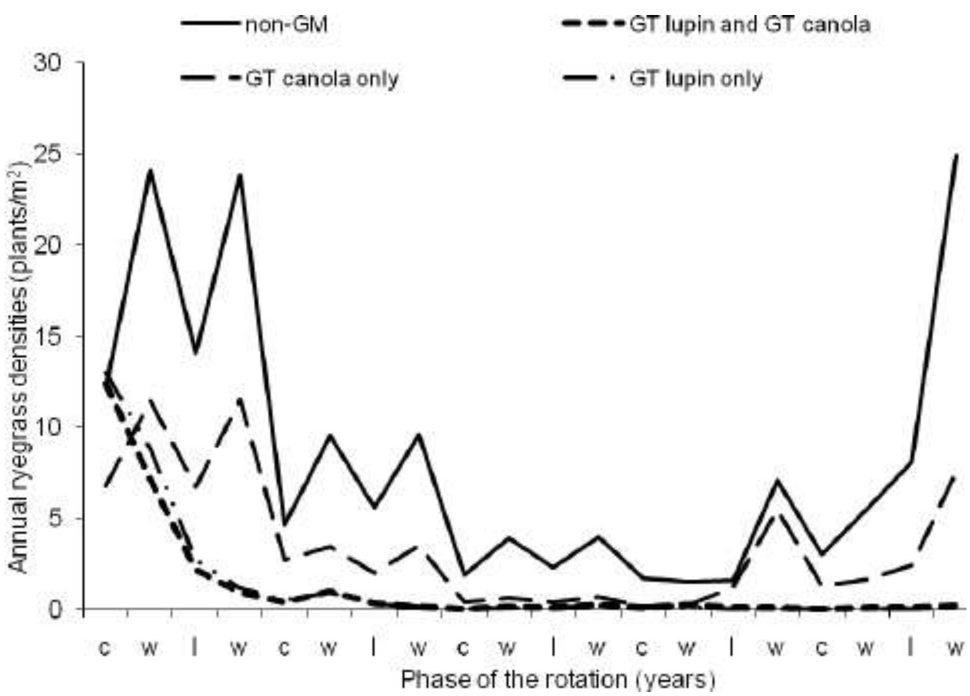

Figure 1. Annual ryegrass densities over 20 years for a canola-wheat-lupin-wheat rotation with initial group A (excluding clethodim) and B herbicide resistance for scenarios including both GT canola and GT canola, GT canola only, GT lupin only and non-GM. (C=canola, l=lupin, w=wheat).

Conclusion

The benefits of including both GT canola and GT lupin in farm rotations could be as high as $A46/ha/year when they are used intensively. Moreover, such a use of GT lupin and GT canola may not necessarily lead to a doubling in the use of glyphosate. This is due to the excellent control of annual ryegrass provided in the GT phase which, if followed by effective ryegrass control in the cereal phase will mean that only one glyphosate application is required in the following GT crop.

Using a GT crop every second year could result in a lower glyphosate resistance risk as glyphosate need only be applied once and on very low weed densities. However, the use of these GT crops requires complementary practices known to delay or prevent the evolution of glyphosate resistance. Farmers should view GT crops as a potentially profitable weed control tool that needs to be accompanied by other weed control practices; not as a single solution to weed problems.

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