# Newly-developed RIM models for integrated management of brome and barley grass

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**Summary** Managing the weeds brome grass (*Bromus rigidus* Roth) and barley grass (*Hordeum* spp.) in the cropping systems of southern Australia is becoming increasingly problematic due to evolving weed populations including the emerging risk of herbicide resistance. We use the new Brome RIM and Barley Grass RIM bio-economic models to demonstrate how an integrated weed management approach can be evaluated. As an example, we show the effect of increased crop competition on reducing reliance on selective herbicides, lowering weed seedbanks and increasing profitability over time.

**Keywords** Brome RIM, Barley Grass RIM, bio-economic modelling, IWM, crop competition.

## INTRODUCTION

Brome grass (*Bromus rigidus* Roth) and barley grass (*Hordeum* spp.) are important weeds in the no-till farming systems of southern Australia (Llewellyn *et al*. 2015). Managing these grass weeds is an increasingly challenging task requiring integration of several practices, often in low-rainfall, low-cost cropping environments, with relatively limited herbicide options within cereal crops, and emerging herbicide-resistance risk (Kleeman and Gill 2009, Boutsalis *et al.* 2014, Owen *et al*. 2015).

The evolution of herbicide resistant populations of annual ryegrass (*Lolium rigidum* Gaudin) led Australian weed researchers to promote an integrated weed management (IWM) approach that combines chemical, physical and biological practices with the aim to kill existing weeds, prevent seed set and deplete the seed bank (e.g. Powles *et al*. 1997). Brome and barley grass populations with delayed germination are now demanding a more strategic IWM approach be applied (Kleeman and Gill 2009).

Decision support tools can help analyse the long-term biological and economic effects of combinations of alternative strategies over a cropping sequence. The aim of this study is to provide an overview of the newly developed Brome RIM and Barley Grass RIM tools, and present a simple example of model results demonstrating the value of increasing crop competition for more sustainable management of brome and barley grasses in a low rainfall region. We discuss the long-term benefit of technologies that could improve crop establishment on sandy soils, and hence increase crop competition against weeds that are rapidly becoming resistant to selective herbicides.

## MATERIALS AND METHODS

**The RIM models** The new bio-economic models were adapted from the original RIM (Ryegrass Integrated Management) model that was developed in the early 2000s (Pannell *et al.* 2004) and later improved (Lacoste and Powles 2014, 2015) as a decision support tool for testing the biological and economic performance of IWM practices to control herbicide-resistant annual ryegrass in the grain belt of Western Australia. Since then, RIM has been adapted to several weed species and cropping systems worldwide (Monjardino *et al*. 2003, Torra *et al*. 2010, Beltran *et al.* 2012, Bagavathiannan *et al*. 2015, Spammer 2018).

The Brome RIM and Barley Grass RIM models represent the population dynamics of brome grass and barley grass over a period of up to 10 years. There a range of enterprise choices, including cereals, oilseed and grain legume crops, as well as pastures/fodder for livestock production. Weed control includes sowing-related options, selective and non-selective herbicides, grazing, spring and harvest options, as well as user-defined practices.

The model includes a detailed representation of the biology of weeds, crops and pasture, as well as the financial costs and returns of agricultural production and management in the context of the typical dryland mixed system of southeastern Australia. The user specifies the crop/pasture and management sequences for up to 10 years and the model calculates the consequences with respect to crop yields, weed population dynamics and profitability. Crop yield may be improved by good agronomy such as suitable crop rotations and effective weed control, but significantly reduced by weed competition, delayed sowing, disease build up or through phytotoxic damage by herbicides applied in-crop.

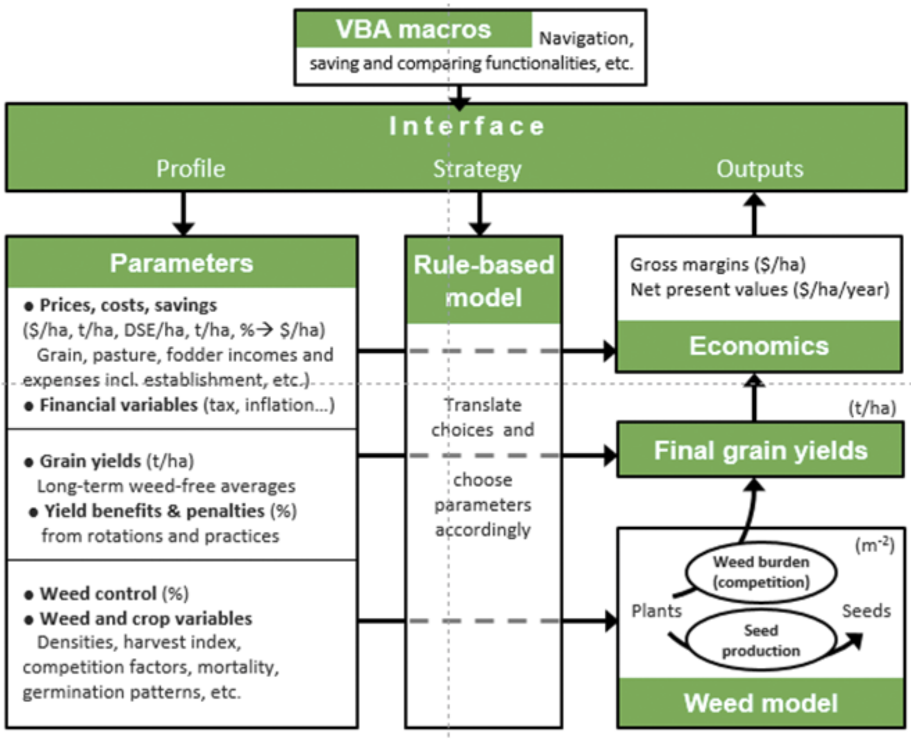


**Figure 1.** Key relationships between the main components of the RIM model (Lacoste and Powles 2015).

**Weed management scenarios** The Brome RIM and Barley Grass RIM models were used to assess the value of improved crop establishment and competition as means of non-chemical control of these weed species.

Two scenarios were simulated with each RIM model for a default common crop sequence of Wheat–Barley–Wheat–Grain Legume in the South Australian-Victorian Mallee cropping region (Moodie 2017). A key assumption was a starting low weed density of one (1) brome and barley grass plant $m^{-2}$ in the spring prior to the first year of the analysis. The two scenarios compared were:

1. ***standard crop competition*** **(baseline)**
   Sowing: delayed in cereals; dry in legumes; standard seeding rate; no-till system.
   Knockdown: glyphosate in all cereal phases, except double-knock in first wheat.
   Pre-emergent: trifluralin in cereals, trifluralin + metribuzin in barley, simazine in legumes.
   Post-emergent: clethodim in legume crops;
   Spring: crop–topping in legume crops.
2. ***high cereal crop competition***
   Baseline + high competition of cereal crops.

**Parameterisation** The underlying parameters of Brome RIM and Barley Grass RIM can be adjusted by the user to reflect local conditions. Key biological factors that drive the pattern of weed population change over time include weed and seedbank population dynamics (i.e. germination rates during the growing season, and natural mortality rates of seedlings, dormant seeds during season and of seeds over summer), as well as weed–crop competition effects for each crop type.

In the analysis we used model default values, including some key ones that describe the main setting (Table 1). While not shown here, brome grass is a more aggressive germinator than barley grass (Kleeman and Gill, 2009), although the latter has a shorter growing season which allows it to set seed even in the driest of seasons (e.g. Mudge 2016).

Brome grass is more competitive than barley grass against all crops, especially cereals. High crop competition is assumed in both Brome RIM and Barley Grass RIM to be equivalent to the High Seeding Rate option at the lower cost of the Standard Seeding Rate option available in the models (Table 1).

The herbicide efficacy values used in this analysis are based on a range of regional trials (e.g. Kleeman

and Gill 2008, Boutsalis *et al*. 2014, Mudge 2016, Fleet *et al*. 2017).

## RESULTS

For both weeds, the high crop competition scenario returned a higher long-term average gross margin (annuity) than that simulated for the standard baseline scenario, resulting in an average annual net benefit of increasing crop competition of \$24 ha$^{-1}$ and \$16 ha$^{-1}$ to control brome grass and barley grass, respectively (Table 2).

An average net profit gain of 12% and 9% for more effective crop competition against brome (Figure 2a) and barley grass (Figure 2b), respectively, resulted from better crop yields due to a significant reduction in the number of mature weed plants setting seed (less 94% and 187% for brome and barley grass, respectively), as well as less weed seeds in the soil (less 114% and 239% for brome and barley grass, respectively) (Table 2, Figures 3a and 3b), without the extra cost of weed control.

## DISCUSSION

The new Brome RIM and Barley Grass RIM models were used to illustrate the potential for improving crop establishment and thus competition against weeds that are becoming increasingly difficult to manage in the southeastern dryland cropping regions of Australia.

The results indicate the potential for greater crop competition to reduce weed seedbanks and improve profit, at least for the default rotation and management strategy used in the models. This is particularly relevant in the case of brome grass which is often found on sandy soils where achieving strong crop establishment can be difficult (McBeath *et al*. 2017).

**Table 1.** Key enterprise-related model parameters used in the analysis.

| Parameter | Wheat | Barley | Legume |
|---|---|---|---|
| Brome grass competition factor | 0.80 | 0.73 | 0.58 |
| Barley grass competition factor | 0.50 | 0.45 | 0.36 |
| Std seed rate (kg ha$^{-1}$) | 60 | 60 | 90 |
| High seed rate (kg ha$^{-1}$) | 90 | 90 | 120 |
| Std seed costs (\$ ha$^{-1}$) | 21 | 21 | 34 |
| Weed-free yield (t ha$^{-1}$) | 1.5 | 1.7 | 1.0 |
| Farm grain price (\$ t$^{-1}$) | 240 | 198 | 365 |
| **% of Brome / Barley grass plants controlled** | | | |
| Trifluralin | 30/60 | 30/60 | |
| Trifl + Metribuzin | 45/65 | 45/65 | |
| Simazine | | | 60 |
| Clethodim | | | 98 |
| Spray-topping | | | 60 |

**Table 2.** Average 10-year annual gross margins (annuity), mature plants setting seed and seeds in soil in autumn results (year 10) generated for the standard and high crop competition scenarios for both brome grass and barley grass.

| | Brome grass | | Barley grass | |
|---|---|---|---|---|
| Model output | Standard | High | Standard | High |
| Annuity (\$ ha$^{-1}$ year$^{-1}$) | 177 | 201 | 173 | 189 |
| Mature plants m$^{-2}$ | 93 | 33 | 78 | 14 |
| Seeds in soil m$^{-2}$ | 870 | 292 | 1,109 | 178 |

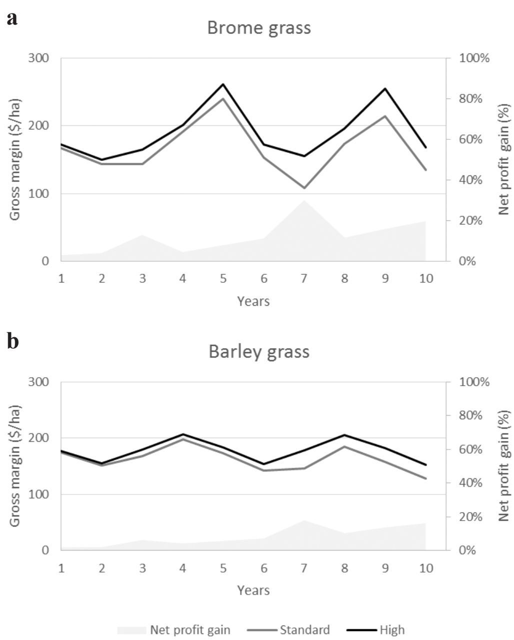


**Figure 2.** Annual gross margin over a 10-year WBWL crop sequence simulated with a) Brome RIM and b) Barley Grass RIM for the standard and high crop competition scenarios.

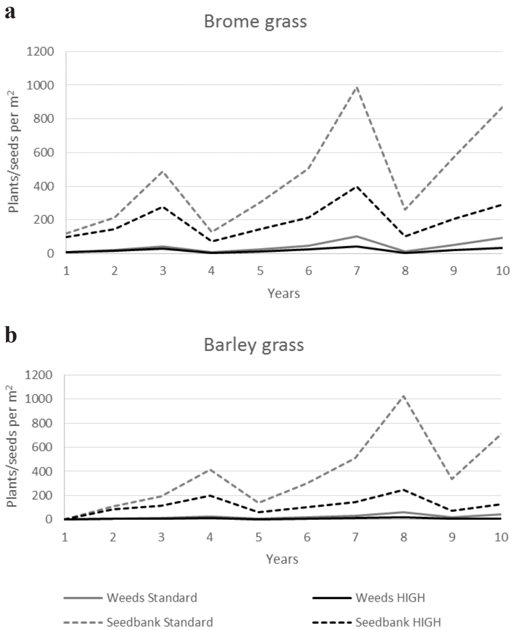


**Figure 3.** Weed and seedbank dynamics over a 10-year WBWL crop sequence simulated with a) Brome RIM and b) Barley Grass RIM for the standard and high crop competition scenarios.

This brief analysis highlights the long-term biological and economic benefits of potential innovations that could improve crop competition, demonstrating potential for analyses around specific technologies, such as high vigour cultivars (e.g. Mudge 2016), soil wetter agents and on-row sowing in non-wetting soils (McBeath *et al*. 2017) that may increase the relative advantage of the crop against weeds.

Overall, the new RIM models provide a practical platform to effectively test a range of weed management options for weeds that are increasingly demanding a strategic integrated management approach.

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