Fodder rotations with cropping to manage weeds

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Take home messages

- An aggressive fodder species with good herbicide options is effective at controlling weeds.
- Grazing in summer or winter has no significant effect on weeds. Instead, controlling the late-in-crop weeds that survive grazing and preventing them setting seed is what's important.
- The timing of seed removal operations is critical. Hay can be just as effective at reducing weeds as silage if it is timed correctly to prevent seed set.
- Modelling has shown that the longer the pasture phase, the greater the weed control. Early work indicates that this may be the case but future trials will need to confirm this.

Background

Although widespread cropping is relatively new in the high rainfall zone (HRZ) of south-eastern Australia, the challenge from weeds is significant. Possible reasons for the high level of weeds include:
- A long growing season with extended springs allowing for late germination and seeding;
- Sub optimal spraying conditions compounded by poor paddock trafficability due to waterlogging;
- Raised bed cropping systems with unsown furrows and headlands; and
- A lack of non-cereal crops in the rotation other than canola;
- Increasing herbicide resistance, with the incidence of annual ryegrass (ARG) herbicide resistance is commonly above those seen in more traditional cropping zones (Table 1).

Table 1. Incidence of herbicide resistant annual ryegrass populations (% of total) in the south-eastern Australian HRZ (South east SA and southern Vic) and LRZ (SA Mallee and northern Vic). (Boutsalis et al 2012).

Region	Year	Trifluralin	Hoegrass	Glean	Axial	Select	Intervix
SA- Mallee	2012	43	20	61	12	3	36
Vic – Northern	2011	0	55	87	31	8	29
SA – South East	2012	78	90	74	80	43	60
Vic – Southern	2009	0	79	88	68	23	39

Herbicide resistance is expected to escalate in coming years with other key weeds such as wild radish and brome grass also exhibiting widespread resistance (White 2014).
Common non-herbicide options are often difficult to implement in the HRZ of south-eastern Australia because of particular environmental and management issues. For instance:
- Narrow windrow burning can be ineffective because ARG seed heads are often below harvest height, windrows can become moist and fail to reach critical seed sterilisation temperatures when burnt and grazing animals disturbing harvest residue.
- Inversion ploughing is unsuited to the shallow duplex soils with subsoil limitations in the region.

However, the south-eastern HRZ does have opportunities via the incorporation of livestock and competitive forage species.

By increased adoption of pasture and fodder-based practices, key weed species that are threatening the long term viability of cropping dominant systems in the southern high rainfall zone can be controlled.

Integrated Weed Management refresher

The principle tactic groups (TG) for weed control within the weed seed cycle are outline in the 2006 IWM manual for farm advisors, IWM in Australian cropping systems. These are:
- TG1 – deplete seed reserves in the seedbank (e.g. autumn tickle, inversion ploughing)
- TG2 – kill weeds (e.g. herbicides)
- TG3 – stop seed set (e.g. hay and silage, grazing, manuring, spray topping)
- TG4 – prevent seeds entering the seed bank (e.g. seed destructor, windrow burning)
- TG5 – quarantine to prevent seeds entering from other sources

The trial work reported on here is experimenting with a range of pasture and fodder-type options based on TG1, 2 and 3 and aims to gain an understanding of how they work in the south-eastern HRZ.
To appreciate the impact fodder rotations could have on weed populations, the Ryegrass Integrated Management

(RIM) model was used to test some of these fodder strategies, by comparing three different 10-year scenarios:

1. 'Typical' canola/wheat/barley rotation using a variety of herbicides with varying levels of efficacy and resistance
2. Two years of persian clover employing autumn tickle, summer grazing, hay and manuring and then into a typical canola/wheat/barley rotation as per scenario 1
3. Four years of lucerne employing silage, summer grazing and winter cleaning then into a typical canola/wheat/barley rotation as per scenario 1

While assumptions were made about the efficacy of different control methods and the level of resistance to different herbicides, the results demonstrate the theoretical value of fodder rotations of varying lengths in controlling ARG in a cropping system (Table 2).

Table 2. Results of RIM modelling showing predicted annual ryegrass numbers at the beginning and end of three different weed management scenarios

Scenario	Ryegrass density per m²			
	Year 0		Year 10	
	seeds	plants	seeds	plants
1. Continuous crop, W, B, C.	10,000	500	16000	530
2. 2 yrs Persian clover fb crop	20,000	1,000	8,400	420
3. 4 yrs lucerne fb crop	20,000	1,000	140	7

The RIM modelling clearly shows that time, preventing seed set and weed seed bank exhaustion are essential elements in effective weed control. Our key experimental findings to date are summarised below as the three key tactic groups being examined: (1) deplete seed reserves, (2) kill weeds and (3) stop seed set.

A warning when interpreting results

Weed populations are dynamic and can fluctuate markedly from year to year. This is the result of dormancy strength conferred at seeding, fluctuations in temperature and moisture over summer, timing of the autumn break, predation, depth of burial and if it is grazed (Grundy 2003). In order to conclude that a treatment has altered a population, the results need to be compared to a control treatment.

Weed populations are often uneven across a site which means there can be large variability even within replicates of the same treatment. This means statistical significance is often not measured, even if the differences appear large. Therefore readers are encouraged to proceed with caution when interpreting results.

TG1: Deplete seed reserves in the seedbank

Shallow cultivation (autumn tickle)

Shallow cultivation is suggested as a useful tactic to encourage more even germination of annual ryegrass and to a lesser extent wild radish (McGillon and Storrie 2006). A one year trial at Lake Bolac (ARG) and Inverleigh (wild radish, WR) showed no significant difference in post-sowing plant populations where an autumn tickle had been used, although numbers were lower than the treatment that had not been cultivated (Table 3).

Table 3. Weed populations at Lake Bolac (ARG) and Inverleigh (WR) with or without a shallow autumn cultivation

Treatment	ARG winter 2012 - Lake Bolac (pl/m²)	WR winter 2012 - Inverleigh (pl/m²)
No autumn tickle	172	7.8
Autumn tickle	157	3.9
LSD $_{P=0.05}$	**ns**	**ns**
Std dev	**61**	**5.7**

Grazing and changes in weed populations

Grazing can be used to reduce weed populations by affecting plant survival and tillering and/or by suppressing seed set. This tactic is mainly used in a pasture phase, often in combination with herbicides and fodder conservation, but to be successful it requires intense grazing pressure (McGillon and Storrie 2006).

An underlying concern exists with many advisors and growers that grazing in the crop phase, either in the stubble or in winter will increase weed populations. They believe grazing will push seeds into the soil, thereby staggering the time of germination and resulting in a greater population of weeds to control after initial knockdown herbicides have been applied.

There is limited data to support this concern in the southern HRZ. Trials conducted over several years at Lake Bolac, Werneth and Inverleigh showed no significant increase in ARG population in 2013 when grazed in summer and winter compared to no grazing (Figure 1). While results from 2011 and 2012 would suggest ARG populations were increasing with grazing, there was a greater decline of the population in 2013 in the grazed treatments than the ungrazed treatment. Further examination of the results showed no evidence that either the summer or winter grazing had a significant influence over the changes in ARG populations.

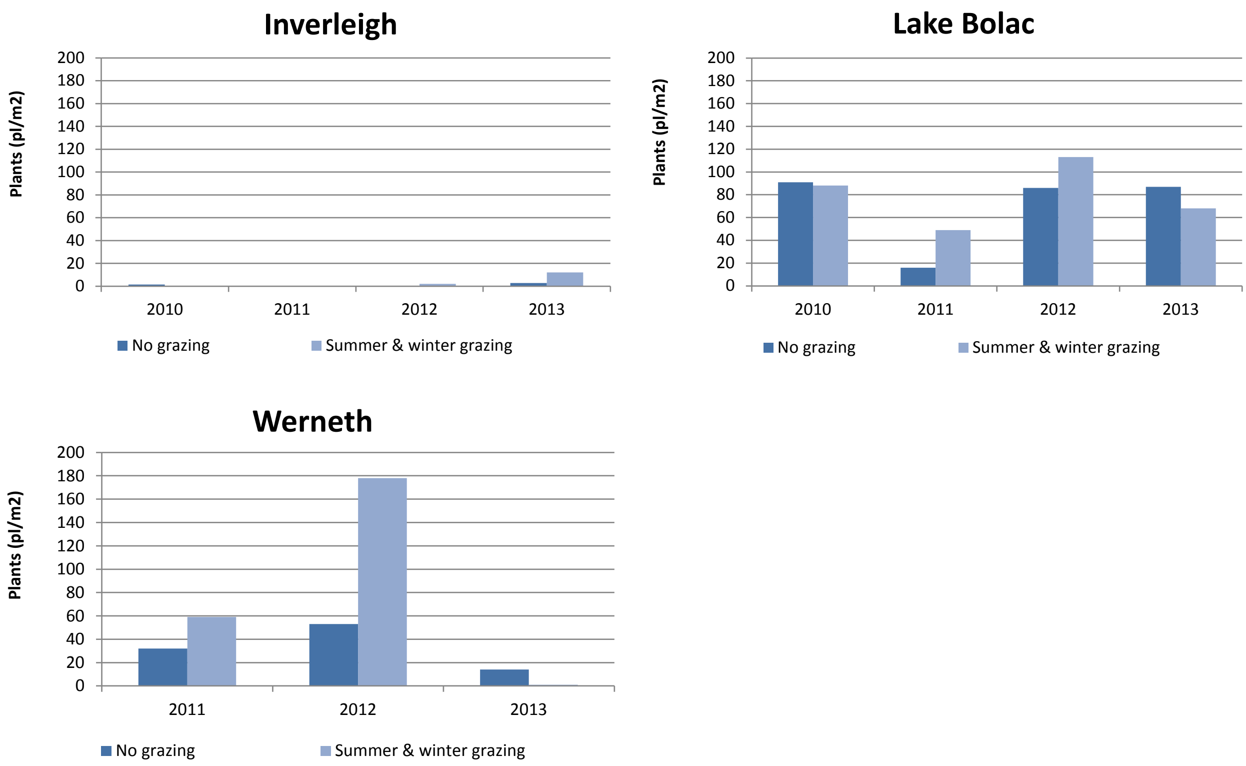

Figure 1. Population of annual ryegrass measured in late winter over consecutive years at Inverleigh, Lake Bolac and Werneth. Annual ryegrass numbers are not significant at p=0.05.

Table 4. Annual ryegrass populations at Lake Bolac over two seasons with or without summer grazing

Treatment	ARG winter 2012 (pl/m^2)	ARG winter 2013 (pl/m^2)
No grazing	419	44
Summer grazing	331	51
LSD (p=0.05)	**ns**	**ns**

An additional study at Lake Bolac, where summer grazing was applied over two seasons, also showed no significant difference in ARG populations (Table 4).

The apparent contradiction in the trial results to observations made by growers and advisors may be explained by the natural annual variability in weed populations that we warned about earlier. If observations were only made in 2011 and 2012 it would be understandable to conclude grazing makes weeds worse, but the reverse would then be case in 2013 (grazing improves weed control) and have no effect in 2010.

We believe of greater importance is the amount of ARG that is likely to survive late in the cropping phase, irrespective of whether grazing has occurred or not. There remains alarming populations of ARG late in crop, regardless of grazing, that are likely to set viable seed. Observations of viable ARG tillers at Lake Bolac in late November 2013 recorded 81 tillers/m^2 in the ungrazed treatment and 83 tillers/m^2 in the grazed treatment.

TG2: Kill or compete against weeds

Fodder species for competition with weeds

Competition from an aggressive fodder species is an effective method of weed control. The key to reducing weed populations is to choose a fodder species that is strongly competitive and offers different, effective herbicide options for controlling the target weed. By 'strongly competitive' we mean a species that has vigorous early growth, rapid canopy closure and high biomass such as a clover, forage oats or peas. Species such as sub clover or lucerne which may be less competitive early on can be an aggressive option in the second or third year when they have fully established and set significant amounts of seed.

Different fodder species, when managed the same way, achieved a significantly similar level of weed control in the following season but had obvious differences in dry matter production and nitrogen legacy (Table 5).

Table 5. Comparison between dry matter production, nitrogen legacy and weed control efficacy of species sown for the same fodder end use. Weed numbers are not significant at p=0.05.

End Use/Species	Dry Matter 2012 (kg/ha)	Total N 0-60cm October 2012 (kg/ha)	ARG 2013 (pl/m2)	% Reduction in ARG from 2012-13
Grazing				
Sub clover	2349	92	19	88
Lucerne	1692	88	19	90
Control[1]	*3242*	*80*	*41*	*79*
Silage				
Arrowleaf clover	7241	109	15	91
Persian clover	5953	87	27	86
Forage oats	8664	90	56	82
Ryegrass	7727	73	19	90
Brown manuring				
Balansa clover	5176	97	19	89
Peas	6135	114	23	89
Serradella	4752	82	5	68

[1]Control plots were weeds only with no sown fodder species. Control plots were grazed as per other fodder species.

These results suggest that an aggressive fodder species will only achieve slightly better weed control when compared to a Control treatment with no fodder species sown, but there will be considerable differences in nitrogen legacy and dry matter production. It is important that this additional weed control by using a fodder is not undervalued; a little extra control may result in huge differences in long term weed numbers. These long-term effects are yet to be determined.

Competition arising from sowing rate

Although crop competition arising from species differences is having an observable effect on weed populations, crop competition arising from sowing rate is not. Trials with a variety of pasture species sown at the recommended rate and then double and triple this rate have shown no significant differences in weed control or herbage production between sowing rates. This is illustrated in Table 6 below, which shows that even at triple the recommended sowing rate, there is no difference in competition (in terms of dry matter production) or weed control.

Table 6. Change in annual ryegrass population under three different species sown at common, double and triple sowing rate. Weed numbers are not significant at p=0.05

Species	Sowing rate (kg/ha)	Establishment (pl/m2)	Dry matter (kg/ha)	ARG 2013 (pl/m2)	% Reduction in ARG
Balansa clover					
Common	6	113	5176	19	89
Double	12	202	5812	34	78
Triple	18	248	4031	19	90
Peas					
Common	100	43	5637	23	89
Double	200	74	6393	25	82
Triple	300	81	4785	26	81
Forage oats					
Common	100	187	8802	56	82
Double	200	279	7824	23	91
Triple	300	447	9681	33	89

These results support other pasture research (Burge and Nie 2012) that shows that the only advantage to higher sowing rates is achieving ground coverage faster. A higher sowing rate does not necessarily translate to more dry matter production, or as shown here, a greater reduction in weed populations.

Killing weeds using herbicides

The final option being tested to kill weeds was herbicides. Different fodder species allow different options for chemical weed control in-crop (Table 7) and so a pasture species can be chosen not just on the basis of its competitiveness, biomass production or potential for N fixation, but also on the chemistry it offers. Rotating herbicide groups and modes of action is a critical part of any IWM strategy.

Table 7. Herbicide groups that can be used in different fodder species during the growing season. Refer to individual product labels for specific application instructions.

Clovers	Serradella	Oats, ryegrass	Lucerne	Peas,
A, I, F, G	A, B, G,	I, F	A,B, C,L	A, B, G

TG3: Stop seed set

Seed set control relies on intercepting the seed production of weeds that have survived earlier attempts at control (McGillon and Storrie 2006). Therefore the timing of a seed removal operation is more critical than the method of seed removal, and the use of multiple seed removal tactics will ensure better control. Tactics being trialled to control seed set include hay and silage, grazing and manuring.

Hay and silage

Fodder conservation is a practical option for growers in the high rainfall zone of southern Australia. The area still has a vibrant livestock industry and Victoria's largest dairy region is close by. The market for fodder (both hay and silage) exists and is likely to grow.

A two year trial at Lake Bolac using five different species and a control showed no significant difference (p=0.05) in ARG populations the following year (when all species were combined). Although some species had higher ryegrass numbers after hay when compared to silage, there was no consistent or statistically significant trend.

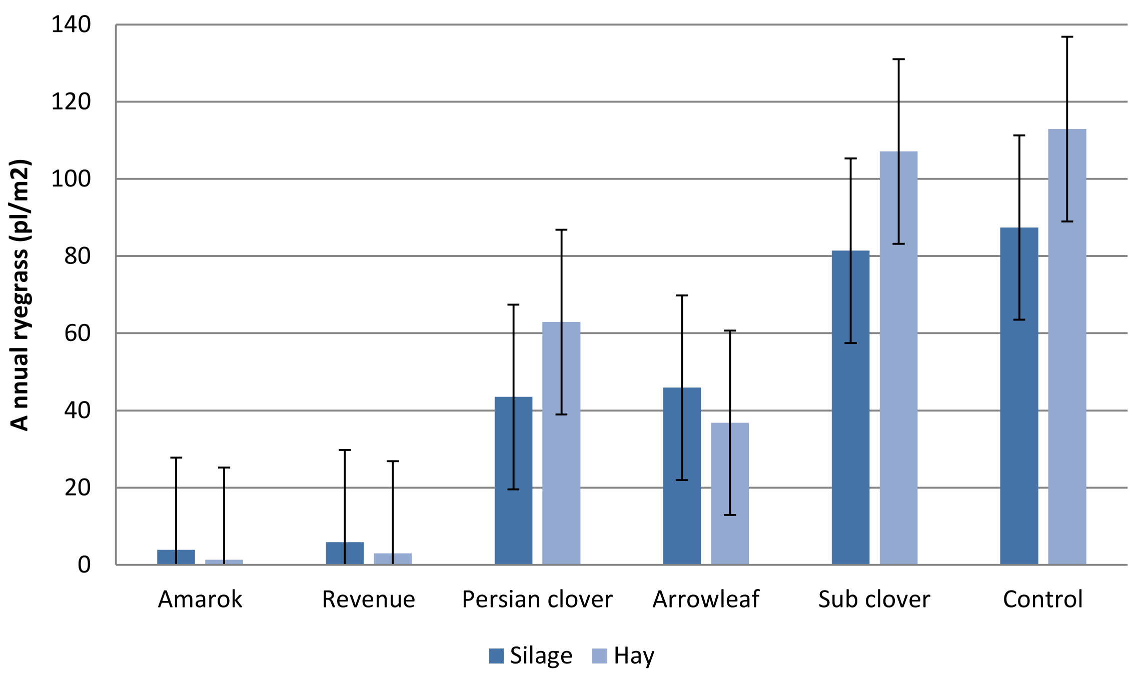

Figure 2. Annual ryegrass numbers under silage and hay in six different treatments. Error bars represent LSD at p=0.05.

Combinations of IWM tactics

The main principle of IWM is to use a combination of tactics to achieve weed control. Several trials are exploring the effectiveness of different combinations of cultivation, species, sowing rates, herbicides, duration of treatment and prevention of seed set (silage, hay and manuring).

In summary the trials show:

- The once off use of a fodder species (arrowleaf clover, balansa clover or peas) in combination with appropriate herbicides, hay or green manuring achieved similar ARG and WR control the next year as a 'fallow' treatment using multiple applications of herbicide. Large quantities of fodder were grown (up to 6t/ha) and significant additions to soil nitrogen were measured.
- The addition of summer fodders (forage rape, forage sorghum or millet) following a winter fodder (persian clover, balansa clover or peas) achieved similar ARG and WR control the next year compared to not growing a summer fodder. However at Inverleigh, the absence of a summer fodder led to a significant increase in other summer weeds (mainly hairy panic and black nightshade). Total dry matter produced from the winter and summer combination was no more than winter only, as a prolonged dry period led to poor performance from the summer fodders (< 0.5 t/ha).

Ongoing trial work

Over the next few years more data will be collected that will allow us to build a picture of which methods work in combination to control weeds. Trials are currently underway that are testing a wider range of non-herbicide control options such as spraytopping and spraygrazing, green and brown manuring and novel legume species. Future work will also answer the question of how long a pasture phase to control weeds should be.

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