

Depleting weed seed banks within non-crop phases for the benefit of subsequent crops

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Summary In 2003 a rotation trial was established at Avondale research station Western Australia to evaluate the effectiveness of introducing various one and three year non-crop phases into the rotation to deplete the seed bank of herbicide-resistant, annual ryegrass (*Lolium rigidum* Gaudin) populations. Treatments included grazed, three year pasture phases of subclover (*Trifolium subterraneum* L.) cv. Dalkeith, biserrula (*Biserrula pelecinus* L.) cv. Casbah, and lucerne (*Medicago sativa* L.); and ungrazed, one year phases of green manured field peas (*Pisum sativum* L.) or canola (*Brassica napus* L.), and brown manured French serradella (*Ornithopus sativus* Brot.) cv. Cadiz. Key measurements included seed bank size and weed density in the non-crop phase and subsequent crops.

Initially (2003) the site had over 1000 ryegrass plants m^{-2} and approximately 350 dormant ryegrass seeds in mid winter. As expected, weed seed-set control was highly effective in green and brown manured treatments; these interventions contained the ryegrass seed bank initially, but one year of seed-set control was inadequate to return to sequential cropping, for the ryegrass seed bank increased rapidly to more than 10,000 dormant seeds m^{-2} within two years. By contrast, grazed, three year pasture phases combined with non-selective seed-set control significantly depleted the annual ryegrass seed bank. Overall grazed subclover was the most effective treatment with the annual ryegrass seed bank falling below 40 seeds m^{-2} and legume content rising from below 20%, in the establishment year, to greater than 90% in the third year of the non-crop phase.

Collectively the results suggest that introducing a non-crop phase can provide an opportunity to decimate weed seed banks and minimise the detrimental impact of weeds on subsequent crops.

Keywords Ryegrass, IWM, brown manuring, herbicide resistance, seed bank management.

INTRODUCTION

The development of herbicide-resistant weeds is driving change in weed management systems and new strategies which do not rely on the use of selective herbicide are needed to deplete ryegrass seed banks

(Walsh and Powles 2007). Scrupulously preventing annual ryegrass seed production (e.g. brown manuring) can rapidly deplete annual ryegrass seed banks over time but may come at the cost of a year of expense without income (Roy 2005). The challenge is to develop systems which are profitable and which can be used in grazing and non-grazing enterprises.

Introducing a non-crop phase into the rotation provides a wider array of weed control options, many of which do not rely on the use of herbicides. Some options may also provide a direct economic return (e.g. grazing, silage) and/or flow on benefits to subsequent crops, such as biologically fixed nitrogen (Revell and Thomas 2004).

This paper compares the response of a large annual ryegrass seed bank to various weed management strategies based on a grazed, three year break or ungrazed, one year break between cropping phases.

MATERIALS AND METHODS

A rotation trial was established (2003) at Avondale research station, Western Australia (32°07'S, 116°52'E) on a red clay loam. The site had a large annual ryegrass population and had been cut for hay in 2002. Ten seed bank management treatments were implemented within a non-crop phase (Table 1). Strategies were based on either a three year pasture phase (grazed subclover, biserrula, lucerne or ryegrass) or a single year break with chemical seed-set control but without grazing (green manured canola or field peas; and brown manured French serradella).

Plots were sown (2003) with a cone seeder (knife-points) after a knockdown herbicide. Subclover (Dalkeith), biserrula (Casbah) and annual ryegrass (Safeguard) were sown at 10 kg ha^{-1} , French serradella (Cadiz) and lucerne (L69) at 40 (pod) and 5 kg ha^{-1} , and canola and field peas at 7 and 100 kg ha^{-1} respectively. Biserrula and lucerne were also re-sown in 2004. There were three replicates for each treatment; plots were 30 × 7 m (un-grazed) and 30 × 11 m (grazed) in size; and sheep grazed plots during winter and spring to achieve a moderate grazing pressure. Subclover and lucerne plots were grazed in common, and biserrula and ryegrass plots in common

Table 1. Weed control treatments evaluated during non-crop phases.

Treatments	Key management inputs ^A			
	2003	2004	2005	2006
One year break				
1 Canola-GM	K, Canola, GM	K, wheat	K, wheat	B, K, wheat, M
2 Field peas-GM	K, Peas, GM	K, wheat	K, wheat	B, K, wheat, M
3 Serradella-BM	K, Cadiz, BM	K, wheat	K, wheat	B, K, wheat, M
4 Serradella-BM-graze	K, Cadiz, BM, G	K, wheat	K, wheat	B, K, wheat, M
5 Subcover-nil	K, Dalkeith	B, K, wheat	K, wheat	–
Three year break				
6 Biserrula-graze	K, Casbah, G	Casbah, G, ST	G, BM	K, wheat
7 Lucerne-graze	K, L69, G	G, K, L69(spring)	G, BM	K, wheat
8 Subclover-graze	K, Dalkeith, G	G, ST	G, BM	K, wheat
9 Subclover-ST-graze	K, Dalkeith, ST	G, ST	G, BM	K, wheat
10 Ryegrass-graze	K, Safeguard	G, ST	G, BM	K, wheat

^A Pasture and crop species/varieties were sown in the years mentioned; inputs are given in chronological order (see codes below):

B – stubble burnt, BM – brown manured, G – grazed, GM – green manured, K – knockdown herbicide, M – mown, ST – late spraytop with paraquat.

with adjacent laneways sown to subclover and biserrula respectively. Both areas were 0.78 ha overall and received the same number of sheep.

Just prior to ryegrass seed-set (September), glyphosate (900g a.i. ha⁻¹) was sprayed across all brown and green manured treatments (2003) followed by biomass incorporation with off-set discs (depth ~6 cm) in the latter. Grazed pasture options were spraytopped (paraquat 125 g a.i. ha⁻¹) in 2004 and brown manured (glyphosate 900g a.i. ha⁻¹) in 2005, the year before crop.

Wheat was sown (70–80 kg ha⁻¹) in 2004–6 (knife-points) after a knockdown herbicide, and a broadleaf selective (but *not* a grass selective herbicide) was applied in-crop. Grazed pasture treatments were topdressed with superphosphate (9% P) in 2005 at 120 kg ha⁻¹.

Assessment of seed bank size over time was based on a neighbourhood sampling method. In 2003, soil cores were collected in mid winter from 12 positions distributed in a grid pattern (3 m apart) across plots; in subsequent years cores were collected within 15 cm of the initial sampling position. One core (84 mm in diameter, depth ~8 cm) was sampled per position in 2003, 2004 and 2006, except for grazed three year break options where two cores per position were sampled in 2006. Cores were bulked by plot halves and seed extracted using dry and wet sieving techniques (i.e. flotation and panning) followed by air aspiration and hand cleaning. Only ‘firm’ seeds were counted as these proved to be viable (Steadman *et al.* 2006).

Analysis of variance (Genstat®2007) was used to compare the effectiveness of the 10 weed management treatments in depleting the ryegrass seedbank; analyses were based on Log₁₀(x + 10) transformed data.

RESULTS AND DISCUSSION

In 2003, when the site was established, about 350 annual ryegrass seeds m⁻² lay dormant in the soil seed bank (mid winter). Over time significant differences (P < 0.001) became evident between treatments (2004 and 2006), particularly one and three year break strategies (Table 2). Not surprisingly the green and brown manured treatments were very effective in containing the size of the annual ryegrass seed bank, at least initially. When these treatments were cropped (2004), the number of dormant ryegrass seeds in the soil was similar or lower than the previous year. By comparison, the penalty for not targeting seed-set control, for just one season, was a nine fold increase in the size of the annual ryegrass problem (treatment 5; subcover-nil).

However, one year of total seed-set control was inadequate to sufficiently deplete the ryegrass seed bank for a return to a multiple cropping sequence. Roy (2005) also found that the benefit of brown manuring did not generally extend beyond two years, as ryegrass density increased rapidly even when wheat seeding rates were raised and stubble burnt to help manage the ryegrass population.

By contrast, a three year non-crop strategy based on a grazed subclover phase with chemical seed-set

Table 2. Average number of dormant, ryegrass seeds in the seed bank after various non-crop treatments^A.

Treatments	2003		2004		2006	
	Log		Log		Log	
1 Canola-GM	2.51	(313)	2.33	(204)	4.16	(14297)
2 Field peas-GM	2.55	(347)	2.28	(181)	4.01	(10308)
3 Serradella-BM	2.53	(327)	2.15	(130)	4.04	(10887)
4 Serradella-BM-graze	2.41	(248)	2.40	(238)	4.05	(11231)
5 Subcover-nil	2.33	(204)	3.25	(1770)	–	–
6 Biserrula-graze	2.35	(216)	2.82	(648)	2.34	(211)
7 Lucerne-graze	2.77	(572)	2.82	(657)	1.93	(75)
8 Subclover-graze	2.59	(376)	2.55	(345)	1.67	(37)
9 Subclover-ST-graze	2.55	(343)	3.13	(1333)	2.29	(186)
10 Ryegrass-graze	2.76	(563)	3.45	(2793)	2.80	(620)
LSD (P = 0.05)	ns		0.40		0.63	

^A Values are $\text{Log}_{10}(x + 10)$ transformations of the number of dormant ryegrass seeds m^{-2} in the seed bank mid winter; back transformed means are in parentheses. See Table 1 for full treatment descriptions.

control (treatment 8) depleted the ryegrass seed bank to levels likely to support a return to a multiple cropping sequence (Table 2); the in-crop ryegrass density in the subsequent wheat (2006) and lupin (2007) crops being less than 5 and 50 plants m^{-2} respectively (data not shown).

Overall, introducing a pasture legume into a large ryegrass population was difficult: lucerne did not persist and the compromise between adequate annual legume seed production for regeneration and ryegrass seed-set control in the establishment year at best contained the size of the ryegrass seed bank but generally resulted in some replenishment. In situations where a large ryegrass population (>1000 plants m^{-2}) makes pasture legume establishment difficult, a better strategy may be to manage the first year of the non-crop phase as a volunteer ryegrass pasture with total seed-set control in spring (e.g. brown manuring) and in the second year establish a pasture legume species.

It is clear that different strategies may achieve similar change in the size of annual ryegrass seed banks (Table 2). The particular strategy adopted will ultimately depend on farmer preference, enterprise mix, the initial size of the weed problem and overall economics. Roy (2005) found that the most economic option to get on top of a large ryegrass problem was a 2–3 year pasture phase; ‘the smaller the weed seed bank size when corrective action is taken the less time out required before returning to a more profitable cropping phase’.

Including a pasture legume in non-crop phases has the potential to contribute additional rotational benefits such as fixed nitrogen and a return from grazing

enterprises (Revell and Thomas 2004). The performance of subsequent crops and overall economics of each treatment in this experiment will be considered in future publications.

ACKNOWLEDGMENTS

This research was funded by the Cropping Program of the CRC for Australian Weed Management. I would like to thank Janey Arkle for processing soil cores and Mario D’Antuono for statistical analyses.

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