Wild oats seed bank dynamics: a long-term study in southern New South Wales

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Summary Wild oats (*Avena* spp.) are one of the most important winter weeds in Australia and in the world. They are prevalent across the northern and southern cropping regions of New South Wales. Wild oats can cause significant yield reductions to crops due to its competitiveness and allelopathic effects. Wild oat populations persist well under current farming practices because of the replenishment of wild oat seeds from the later germinators. A four-year field study was established to investigate the impacts of non-chemical and chemical options with rotational crops on wild oat seed bank dynamics. Results showed that PRE only treatments were not effective in reducing the soil seed bank. Significant seed bank reduction can be achieved by the combination of PRE + POST or PRE + POST + Seed Catching. This study also showed that seed catching did not contribute much to further reduce the wild oat seed bank as wild oat seeds often shed prior to harvest. It will require at least three years of dedicated efforts to successfully manage wild oats populations.

Keywords Wild oats, seed bank, population dynamics.

INTRODUCTION

Wild oats (*Avena* spp.) are one of the most important winter weeds in Australia. They are prevalent across the northern and southern cropping regions of New South Wales (Lemerle *et al.* 1996, Martin *et al*. 1987, Walker *et al*. 2002). Wild oats can cause significant yield reduction to wheat (Martin *et al.* 1987). If left uncontrolled, wild oats could cause up to 80% yield loss in wheat (Storrie 2006). The annual cost of wild oats to the Australian wheat industry alone has been estimated at $A80 million in 1999, with $60 million in control measures and $20 million in lost production (Storrie 2006), which almost doubled the estimates in 1987 (Medd and Pandey 1990). Wild oats are highly competitive for light, moisture and nutrients (Cudney *et al*. 1989, Weaver *et al*. 1994). Moreover, wild oats can also exude some phytotoxic compounds such as scopoletin, coumarin, *p*-hydroxybenzoic and vanillic acid to affect wheat growth and yields (Schumacher *et al.* 1983, Perez and Ormeno-Nunez 1991).

The persistence and success of wild oats are associated with the prolific seed production, dormancy, seed shedding prior to crop harvest and staggered germination (Jones and Medd 1997).

A number of pre-emergent and post-emergent herbicides have been used to control the earlier germinating seedlings, however, there are late germinators that survive or avoid early season herbicide applications (Jones and Medd 1997). These survivors replenish the seed bank, allowing the population of wild oats to persist. The wild oat seed bank under continuous wheat cropping can build-up rapidly even with the use of selective herbicides (Martin and Felton 1993), as the level of control achieved (70–90%) is not adequate to deplete the soil seed bank (Martin *et al.* 1987).

It has been proposed that management strategies for wild oats should be directed to miminise the replenishment of weed seed to the soil (Jones and Medd 1997) as the seed in the soil is relatively short-lived (Martin and Felton 1993, Peltzer and Matson 2002). Long-term field monitoring of a natural wild oats seed bank showed that it declined by 80% in the first year and by 50% in the second year if seed set was stopped (Peltzer and Matson 2002). The input of new seed, rather than the carryover of seeds, is the main contributor to wild oat persistence (Medd 1990).

The aim of this long-term study was to investigate the impacts of nine combinations of non-chemical and chemical options with rotational crops on wild oat seed bank dynamics.

MATERIALS AND METHODS

A four year experiment was established at Rand in southern NSW between 2009 and 2012. In 2009, the site was fallowed because of a dense wild oat population. Volunteer barley, together with wild oat plants were cut for hay on 30 September 2009. Any regrowth and later germinators of wild oats were sprayed with glyphosate to achieve complete seed set control in Year 1.

In Year 2 (2010), the site was sprayed with 900 g a.i. ha^{-1} glyphosate (as Roundup®) + 1000 g a.i. ha^{-1} atrazine pre-sowing on 24 April and sown with TT canola (cv. Thunder) on 30 April. There were three management options imposed in 2010. Management 1 (M1) received only the pre-emergent (PRE) application of 900 g a.i. ha^{-1} of glyphosate + 1000 g a.i. ha^{-1} atrazine; M2 (PRE + POST) was PRE (900 g a.i. ha^{-1} of glyphosate + 1000 g a.i. ha^{-1} atrazine) followed by post emergent (POST) applications of (1000 g a.i. ha^{-1} atrazine on 27 May + 60 g a.i. ha^{-1} clethodim on 5 July); and M3 [(PRE + POST + seed catching (SC)] was PRE (900 g a.i. ha^{-1} of glyphosate + 1000 g a.i. ha^{-1} atrazine) + POST (1000 g a.i. ha^{-1} atrazine on 27 May + 60 g a.i. ha^{-1} clethodim on 5 July) + SC at harvest. Each management option was applied to a large plot (20 × 45 m). SC and canola harvest were not conducted due to the flooding from the Billabong Creek for four days in October 2010.

In Year 3 (2011), each large plot of the M1, M2 and M3 in 2010 was divided into three subplots (20 × 15 m) for further treatments in 2011 (Table 1). M1 (PRE) had PRE (540 g a.i. ha^{-1} glyphosate + 2.5 L ha^{-1} S-metolachlor plus prosulfocarb (as Boxer Gold®) applied to the entire trial area on 3 May. M2 (PRE + POST) had PRE (540 g a.i. ha^{-1} glyphosate + 2.5 L ha^{-1} Boxer Gold) on 3 May followed by a POST (15 g a.i. ha^{-1} pyroxsulam + 1% paraffinic oil) on 20 July. M3 (PRE + POST + SC) was PRE (540 g a.i. ha^{-1} glyphosate + 2.5 L ha^{-1} Boxer Gold®) on 3 May followed by a POST (15 g a.i. ha^{-1} pyroxsulam + 1% paraffinic oil) on 20 July + SC on 14 December at harvest. A system of tarpaulins tied behind the harvester was used to collect all material before it reached the ground. Wheat (cv. Gregory) was sown at 70 kg ha^{-1} combined with 70 kg ha^{-1} of MAP fertiliser on 5 May. An additional 80 kg ha^{-1} Urea was applied on 24 August.

In Year 4 (2012), 900 g a.i. ha^{-1} of glyphosate plus 3 g a.i. ha^{-1} metsulfuron-methyl was applied in February to control summer weeds and 2.0 L ha^{-1} paraquat plus diquat (as Spray.Seed®) was applied before sowing. Wheat (cv. Gregory) was sown at 60 kg ha^{-1}, together with 70 kg ha^{-1} of MAP on 5 May. Urea at 90 kg ha^{-1} was applied on 29 July. No further control options were targeted on wild oats in 2012 to evaluate the carryover impact of previous management options in 2010 and 2011 on wild oats seed bank in 2012.

Herbicide applications and measurements Treatments were applied with a tractor-mounted compressed-air-pressurised sprayer calibrated to deliver 100 L ha^{-1} at 2 bars.

Seed bank of wild oats was estimated by taking soil cores prior to sowing on 26 March 2010, 19 April 2011 and 26 April 2012. Twenty soil cores were collected from each plot. Soil cores from each plot were bulked and spread over germination trays. Trays were placed outdoors and irrigated when necessary. Wild oat emergence was counted monthly. The total emergence was used for seed bank estimation.

Field emergence was conducted on 5 July, 18 August and 12 November 2010; 14 July, 31 August and 26 September 2011; and 6 September 2012. Wild oat plants were counted in three random quadrats (50 cm × 50 cm) each plot. In 2012, visual rating (% control) was also conducted prior to wheat harvest. Wheat was harvested with a plot harvester on 11 December 2011 and 10 December 2012.

Design and statistical analysis The experiments were designed as a randomised complete block with three replications. ANOVA was conducted using Genstat.

Table 1. Management practice structure for 2010 and 2011.

Treatment	2010 TT Canola	2011 Wheat
T1	M1	M1
T2	M1	M2
T3	M1	M3
T4	M2	M1
T5	M2	M2
T6	M2	M3
T7	M3[a]	M1
T8	M3[a]	M2
T9	M3[a]	M3

[a] Seed catching (SC) was not imposed due to the flooding in October 2010.

RESULTS

The baseline data from the soil cores and from the field emergence were collected in 2010 (Table 2), showing the uneven distribution of wild oats in the experimental site although complete seed set control was achieved in 2009 over the entire area. The carryover impacts of 2010 management options were reflected in the 2011 data and the impacts of 2011 management options reflected in the 2012 data. The management option M1 in 2010 had limited impact on the 2011 wild oat emergence (104.5 plants m^{-2}) in the field, while the M2 and M3 reduced wild oats emergence to 7–10 plants m^{-2}. Across 2010 and 2011, there were nine combinations of management options. Treatment T1, M1 in 2010 followed by M1 in 2011, was the worst treatment, resulting in the highest seed bank and second highest wild oats population emerging in 2012.

However, wild oats numbers from both soil cores and emergence were significantly lower in treatments (T5, T6, T8 and T9) receiving either M2 or M3 in 2010 and 2011, when compared to treatment T1. These results suggest that reliance on pre-emergent herbicide (M1) would not be effective in reducing the soil seed bank. Significant seed bank reductions were achieved by the combination of PRE + POST or PRE + POST + (SC).

Compared to treatments (T5, T6, T8 and T9), the two treatments (T4 and T7) receiving M1 (PRE) only in 2011 had significantly higher wild oats numbers from the soil cores and from field emergence in 2012, despite M2 or M3 being imposed in 2010. Treatment T7 (M2 in 2010 + M1 in 2011) resulted in the highest wild oats emergence (109 plants m^{-2}) among the nine treatments in 2012 and had the same 0% visual rating as T1 (Table 2). These results demonstrated that one year of complete seed set control in 2009 followed by another year of PRE + POST treatments in 2010 was not enough to reduce the seed bank. It would require another year of effective control in order to maintain a low soil seed bank.

No significant differences occurred between T5 and T6 and between T8 and T9 for their carryover effects on soil seed bank (soil cores) and wild oat emergence in the field in 2012, indicating that seed catching in 2011 did not contribute to further reduction in the seed bank. Nietschke *et al.* (1996) also reported that wild oat seed tends to shed before harvest and it is ineffective to use non-chemical options to reduce the seed rain at harvest.

Wild oats caused significant wheat yield losses (Table 3). Among the three management options (M1, M2 and M3) in 2010, M1 (PRE only) resulted in the lowest wheat yield in 2011. The 2012 data also showed that treatments (T1, T4 and T7), which had M1 imposed in 2011, had significant higher wild oats densities as compared to the other treatments (Table 2). The higher wild oats densities in these plots resulted in 33%, 23% and 45% yield loss (Table 3), compared to the highest yielding treatment T5 (4203 kg ha^{-1}).

Conservation farming systems rely heavily on herbicides to control weeds. Even so, herbicides are unlikely to produce a useful decline in wild oat populations, particularly in the northern grain region (Martin and Felton 1993, Wilson 1979). However, this study showed that a combination of PRE + POST for multiple years can reduce wild populations

Table 3. Effects of weed management options on wheat yield in 2011 and 2012.

	Yield (kg ha^{-1})	
Treatment	2011	2012
T1		2827
T2	4165	3907
T3		4159
T4		3219
T5	4574	4203
T6		3932
T7		2311
T8	4886	3691
T9		4158
LSD (P=0.05)	348	287

Table 2. Wild oat population dynamics over three years.

	Soil seed bank (seeds m^{-2})			Emergence (plants m^{-2})			Visual rating (% control)
Treatment	2010	2011	2012	2010	2011	2012	2012
T1			76.4			34.4	0
T2	119.0	34.0	8.5	160.8	104.5	6.0	63
T3			0			1.0	90
T4			42.5			18.5	30
T5	157.0	46.0	0	200.0	9.6	1.4	90
T6			0			1.4	93
T7			8.5			109.1	0
T8	63	5.7	0	25.6	7.2	3.8	80
T9			1.5			0.8	90
LSD (P=0.05)	25.4	18.3	6.4	78.9	20.3	7.9	26

in southern NSW. It has also been suggested that competitive crops, grazing, hay making, or nonselective herbicides can be used to prevent the build-up of wild oat numbers (Martin and Felton 1993). High wheat densities can out-compete wild oats (Martin *et al.* 1987, Radford *et al.* 1980). Walker *et al.* (2002) reported that a combination of high wheat density and herbicide application at reduced rates can significantly reduce seed set of wild oats.

The trend toward wide row spacing in order to cope with climatic variability could potentially provide an ecological niche for wild oats to flourish. Wheat and wild oats are equal competitors and the relative competitive effects of wild oats are influenced by the densities of both weeds and crops (Cudney *et al*. 1989, Martin *et al*. 1987).

The use of PRE + POST herbicides, together with non-chemical options and rotational crops to control survivors and seed set, is the key to the success of wild oat management. At least three years of dedicated effort is required to successfully manage wild oats populations.

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