Weed seed removal by ants in the crop growing areas of Western Australia

David M. Minkey[1] and Helen Spafford[2]
[1] School of Plant Biology (M086), WAHRI, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia.
[2] CRC for Australian Weed Management and School of Animal Biology (M085), University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia.
Email: helen.spafford@uwa.edu.au

Summary Granivory in Western Australian agroecosystems contributes to the decline in weed seed banks over the summer months. The findings of this four year study identified key ant species that removed the seed of two significant weed species, annual ryegrass (*Lolium rigidum* Gaudin) and wild radish (*Raphanus raphanistrum* L.). The majority of the seeds deposited in ant nests were effectively removed from the seed bank and although seed removal was high it was also variable. Seed removal was lower for wild radish than annual ryegrass. Rates of removal were also influenced by tillage and crop residue.

Keywords Seed bank, ants, predation, IWM.

INTRODUCTION

In agroecosystems there is interest world wide in encouraging biodiversity to improve soil health and attract naturally occurring predators as biological control agents of pests, including weeds (Swanton and Murphy 1996). For the crop growing areas of Western Australia, the development of herbicide resistance has created a need for non-chemical weed control options. Seed removal by animals is recognised as a mechanism for depleting the weed seed bank. Identifying the presence of granivores, and estimating the significance and variability of weed seed removal in this environment are essential first steps in assessing the potential of granivory as a weed management tool.

This paper summarises the results of a four year study that sought to:

1. Determine the significance of weed seed removal in an agricultural landscape;
2. Identify the species that predate on weed seeds and further the understanding of their biology;
3. Investigate the agricultural management practices that affect the variability of weed seed removal.

SIGNIFICANCE OF WEED SEED REMOVAL

While seed removal is known to occur in the Western Australian cropping environment (Twigg *et al.* 1981, Spafford Jacob *et al.* 2006), the extent, on a field scale, was previously unknown. Based on three years of field investigation throughout the crop growing areas of Western Australia, an average of 80% of annual ryegrass (*Lolium rigidum* Gaudin) and 40% of wild radish (*Raphanus raphanistrum* L.) seed was found to be removed from the soil surface. Seed removal occurred from the period of seed drop after harvest in December to just prior to the following growing season in April.

Alternative approaches for measuring weed seed removal were examined in this study. It was demonstrated that the most commonly used methodology that measures seed loss (seed placed in caches) can lead to an overestimation of weed seed removal. While this methodology is useful to determine trends in seed removal rates, it was shown to be inadequate when assessing the total seed loss from an agroecosystem. For example, Spafford Jacob *et al.* (2006) placed weed seeds in exclusion cages on top of a mesh that had been evenly covered with loose soil (seed placed in caches). At the same time and in the same field we also scattered weed seeds on the soil surface over four square meters to mimic natural seed drop. The resultant seed loss between the two methods was fairly similar, with approximately 80% for annual ryegrass and 40% for wild radish pod segments being recorded. However, this was achieved in just 14 days from the caches of seed (Spafford Jacob *et al*. 2006) compared to three months when seed was scattered on the soil. The likely reason for this outcome is that seed is placed in a perfect line of sight and availability for predators in the caches, leading to rapid seed removal. Seeds scattered on the soil surface are more likely to be hidden under debris or covered by soil that had been shifted by wind and rain, and thus more difficult for predators to find.

In evaluating this further, we found that method of seed placement influenced the foraging efficiency of the ant species *Melophorus turneri* Forel. Ants formed highly organised columns from the cached seed to the nest and removed the seed at a very fast rate. Whereas when seed was scattered on the soil surface, ants foraged individually and took longer to find and return seeds to the nest.

Despite the high rate of removal, there are several limitations in seed removal that may partially explain why these weed species persist in this environment.

Seed density influenced the rate of removal. When initial seed densities were low, wild radish seed removal was found to vary enormously, from 0–80%, but at higher initial seed densities there was a steady rate of loss remaining at approximately 50%. However, removal of annual ryegrass seed increased from 40–90% as initial seed density increased. Despite the increase in percentage of seed removed, a threshold in annual ryegrass seed removal was found. Once the initial seed bank reached between 1500–2000 seeds m^{-2} no more seeds were removed below the threshold (Figure 1a). A seed bank of this size reflects a large weed burden for the following growing season. While the seed bank was reduced substantially, seed removal is not enough by itself to control this weed. There was no threshold for wild radish. A steady rate of seed loss was found, which means as initial seed density increases more seeds are left behind in the seed bank (Figure 1b). By observation the residual seeds tended to be contained in the larger pod fragments.

The success of a weed management tool is dependent on how consistent and reliably it performs. Contrary to other studies (Diaz 1994, Spafford Jacob *et al.* 2006) seed removal was not found to be affected by proximity to fence lines. Removal rates of annual ryegrass seed were generally consistent across the field while wild radish seed pods were removed at a higher rate in the centre of the field and in a zone 50 m from the fence line. However, for both annual ryegrass and wild radish seed removal, there were patches within the field of low or no seed removal. These patches represent lower seed losses within the field that could result in higher weed burdens, yield losses and allow more plants to emerge to contribute to future seed banks.

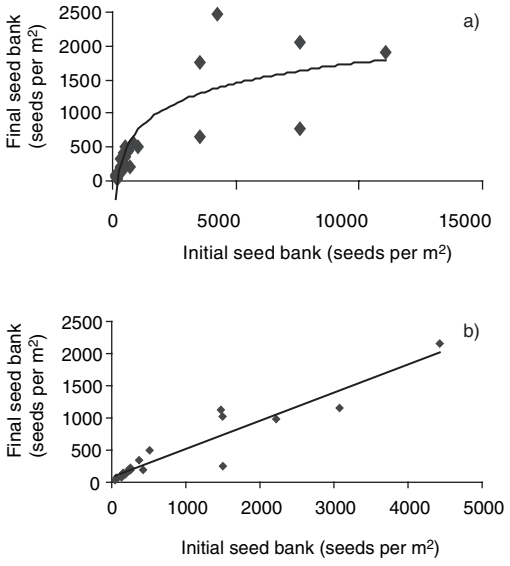

Figure 1. Relationship between initial seed bank (immediately post-harvest) and the final seed bank (after three months) in a natural population of (a) annual ryegrass (Final = 1736+ (−1815*0.999494^{*Initial}), R^2 = 0.71) and (b) wild radish (Final = 50.4 + 0.6435*Initial, R^2 = 0.85) in a cropping field at Avondale research station.

WHO IS REMOVING THE WEED SEEDS?

The predominant predators of weed seeds in the Western Australian crop growing areas were found to be ants, particularly in the centre of fields. While up to thirty species of ant were identified in the field, the ant species *Melophorus turneri* Forel., *Monomorium rothsteini* Forel., *Pheidole hartmeyeri* Forel and, to a lesser degree, *Rhytidoponera metallica* Smith were identified as potential biological control agents for annual ryegrass. *Pheidole hartmeyeri* was identified as a biological control agent for wild radish. *Iridomyrmex greensladei* Shattuck also removed wild radish pod segments from the soil surface but its dislike for disturbance makes it an unlikely granivore of any significance within cropping areas.

The vast majority of seed that was removed by these ant species were found to be taken into their nest and stored in egg chambers. This storage effectively removed the seed from the seed bank by either subsequent granivory or due to deep burial. The exceptions to this were where seeds were stored near the soil surface, as was the case for *Monomorium rothsteini*, or where a small percentage of seed was stored around the nest entrance of *Melophorus turneri.*

CROP MANAGEMENT AND SEED REMOVAL

Manipulation of weed seed removal levels is possible with residue management and tillage practices. Less seed was removed in the presence of stubble compared to bare soil (Table 1). The reasons for this are not understood. High crop residue may inhibit the foraging ability of granivores and more research will be needed to determine if retaining stubble residue, a practice that

Table 1. Average percent (+SEM) of annual ryegrass seeds removed from December to April in plots with either high or low stubble load and with ants permitted or excluded.

	Exclusion treatment	
Stubble load	Ant permitted	Ant exclusion
High stubble	36.4 (6.89)	9.6 (1.86)
Low stubble	61.0 (7.83)	12.0 (4.38)

is becoming more popular, results in long term shift in ant species and other granivores.

Under a canola and wheat residue there was a shift towards the ant species *I. greensladei* and *M. rothsteini* and away from *P. hartmeyeri* and *R. metallica.* This change was associated with a reduction in wild radish pod removal under these residue types but not of annual ryegrass seed removal. The reason for this species shift is not known but it was hypothesised that it could be due to the chemicals that are exuded by wheat and canola (Wu *et al.* 2001, 2002, Gurha and Srivastava 2002, Bertin *et al.* 2003).

Single tillage events before sowing were found to have a negative impact on seed removal rates of annual ryegrass and seed pod removal rates of wild radish, however the effects tended to be short lived and were only found after a severe tillage event such as a disc plough or mouldboard plough. Ant abundance and type were again found to be loosely related to seed loss and could possibly be due to a delay in nest building after a mouldboard or disc plough event. No-till is widespread in the Western Australian cropping fields so these results are encouraging. However, a study investigating the influence that long term tillage practices has on weed seed removal is critical for a complete examination of this issue.

CONCLUSIONS

In this study we have demonstrated that weed seeds are removed by granivores in the cropping environment and that five key ant species are the principle seed predators in Western Australia. The limitations in seed removal associated with seed density and the variation of seed removal across the field indicates that weed seed removal by itself is not enough to control the populations of annual ryegrass and wild radish. Nevertheless, seed removal is a significant contributor to seed bank decline.

Crop type, tillage systems and residue management are critical issues for grain growers and are clearly linked to weed seed removal. More definitive experiments are needed to investigate weeds seed loss and predator population shifts under different management techniques over the long term before absolute recommendations can be made. Understanding the response of granivores to management practices is a critical issue for the success of granivory as an IWM tool, particularly for wild radish.

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