The crucial role of weed ecology and biology in managing awnless barnyard grass and feathertop Rhodes grass

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Key words

phenology, seed bank, seed biology, temperature, tillage

GRDC codes

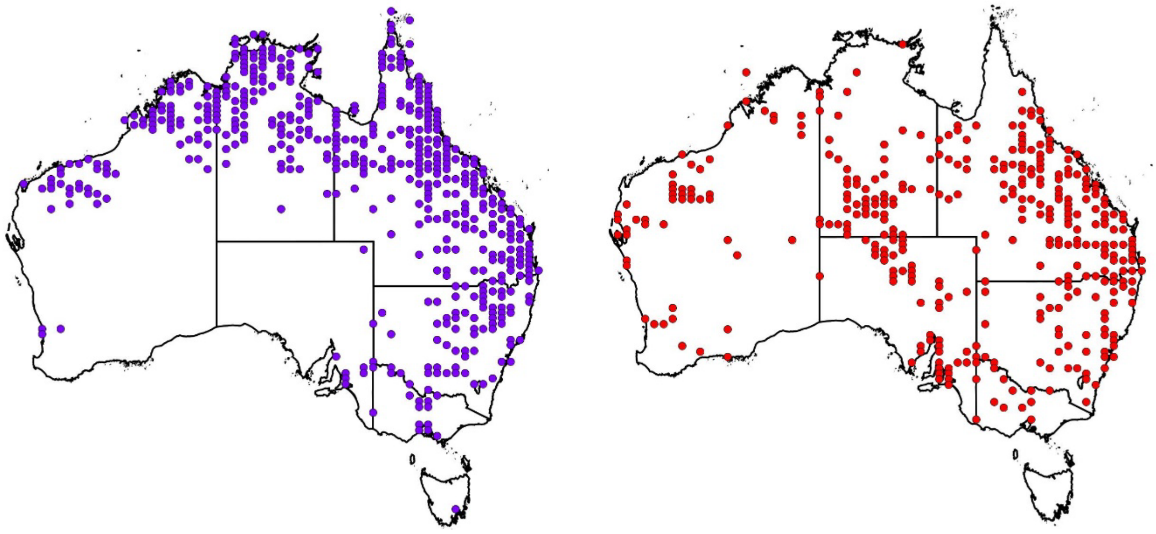
UA00156, US00084

Take home messages

- The surface seeds of awnless barnyard grass (ABYG) and feathertop Rhodes grass (FTR) exhibit the highest germination rates, indicating an increased likelihood of infestation in conservation agriculture systems.
- An effective control strategy for managing ABYG and FTR seed banks involves burying the seeds below their maximum depth (6 to 8 cm) of emergence.
- Burial extends the life of the seed bank compared to surface seeds; therefore, tillage operations should be avoided after seed burial.
- ABYG and FTR are unlikely to develop persistent seed banks and can be depleted rapidly if new seed inputs are prevented for 2-3 years.
- Small rainfall events will trigger germination of some FTR seeds, suggesting the need for implementing control measures.
- Although ABYG and FTR are primarily spring and summer-emerging weeds, their seasonality is expanding in Queensland.
- Close monitoring of emergence is necessary throughout the year to prevent the spread of seeds and replenishment of the soil seed bank.

Background

Weeds pose a significant biological constraint to crop production on a global scale. In Australia, they inflict an annual cost exceeding $3.3 billion for grain growers (Llewellyn *et al.*, 2016). Among the grass weed species in the northern grain region of Australia, awnless barnyard grass (ABYG, *Echinochloa colona*) and feathertop Rhodes grass (FTR, *Chloris virgata*) are the most problematic in summer crops and fallows. These two species alone contribute to annual revenue losses surpassing $22 million in this region. In addition to the northern grain region, these weed species occur in other states also (Figure 1). Recent studies have demonstrated that infestations of approximately 40 plants/m^2 of ABYG and 25 plants/m^2 of FTR can result in a 50% reduction in grain yield for mungbean when compared to weed-free plots (Mahajan and Chauhan, 2022; Manalil *et al.*, 2020).



Awnless barnyard grass　　　　　Feathertop Rhodes grass

Figure 1. Distribution of awnless barnyard grass and feathertop Rhodes grass in Australia (Australasian Virtual Herbarium 2023; http://avh.ala.org.au).

Aside from their highly competitive nature, ABYG and FTR exhibit prolific seed production capabilities. Under fallow and well-irrigated conditions, ABYG can produce up to 150,000 seeds/plant, while FTR can produce as many as 143,000 seeds/plant (Chauhan, 2022; Squires *et al*., 2021).

Chemical management remains the predominant approach for weed control in the northern grain region. However, due to the consistent use of herbicides with the same mode of action, multiple ABYG and FTR populations have evolved resistance to commonly used herbicides, including glyphosate (Chauhan and Mahajan, 2023; Ndirangu Wangari *et al*., 2022). Furthermore, the availability of herbicides with new modes of action is limited. Concerns regarding environmental pollution further compound the issue. These observations highlight the urgent need to reduce dependence on herbicides and develop effective and sustainable weed management strategies. To achieve this, a comprehensive understanding of the ecology and biology of ABYG and FTR is imperative.

Ecology and biology of ABYG and FTR

Biology and ecology are vast subjects, and not all-encompassing information regarding ABYG and FTR is readily available. Hence, this article will focus specifically on seed ecology and phenology. Weed biology also encompasses research on how weeds respond to crop competition. Since there is a separate paper on this topic in this proceeding, the results and their implications will not be presented here.

Seed ecology

Several factors, including light, temperature, rainfall and seed burial depth, influence seed germination.

Light

Both species, ABYG and FTR, exhibit light-dependent germination (Fernando *et al.*, 2016; Mutti *et al*., 2019). This suggests that their emergence in conservation agriculture systems, such as no-till practices, may be stimulated since most seeds remain on or near the soil surface after shedding. Although germination in dark conditions is lower compared to light conditions, it is evident that some seeds of ABYG and FTR can still germinate under a crop canopy and crop residue.

Temperature

Temperature is another crucial factor that impacts weed seed germination. Different weed species have specific temperature requirements for optimal germination. Understanding the temperature conditions that favour weed seed germination enables managers to predict and time control measures effectively. For instance, if a weed species exhibits higher germination rates at specific temperatures, growers/agronomists can plan herbicide applications or cultural practices to coincide with those conditions, thereby maximizing weed control efficacy. Additionally, a better understanding of ABYG and FTR's response to different temperatures can aid in predicting their potential invasiveness beyond their current boundaries.

Controlled experiments have shown that ABYG seeds can germinate within a temperature range of 20/10 to 35/25°C (alternating day/night temperatures), indicating that ABYG can emerge during spring, summer, and autumn in the northern region (Mutti *et al*., 2019). While the previous study (Mutti *et al*., 2019) did not observe germination at 15/5°C, a recent field study conducted in Gatton reported ABYG emergence in the months of May and July, suggesting its ability to emerge even in the colder temperatures of late autumn and winter (Chauhan, 2022). Similarly, seed germination of FTR was observed within a temperature range of 15/5 to 35/25°C (Figure 2; Desai and Chauhan, 2022). The data for both species suggests that ABYG and FTR can germinate throughout the year in the northern region, potentially expanding their invasion in winter crops and fallows.

It is important to note that germination and growth are distinct parameters. Seed germination under low temperatures does not guarantee successful growth and seed production during winter. To address this, it is necessary to understand the effects of low temperatures on growth and seed production through phenology studies.

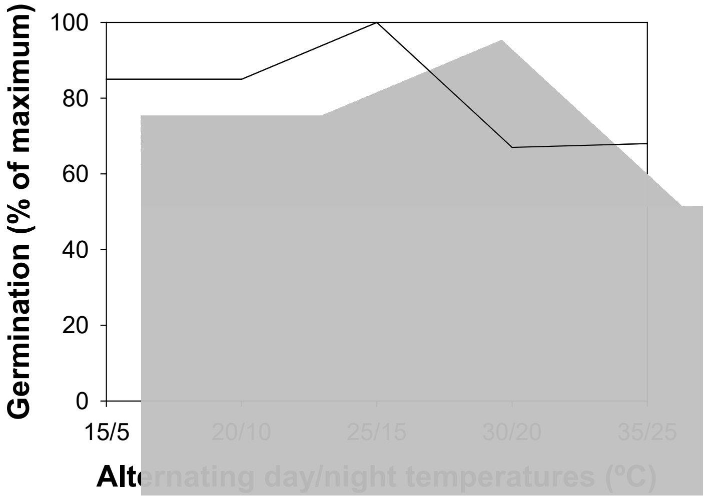


Figure 2. Effect of alternating day/night temperatures (12 h/12 h) on seed germination (% of maximum germination) of feathertop Rhodes grass (Desai and Chauhan 2022).

Rainfall

Rainfall events and amounts play a crucial role in weed seed germination. When the rainfall meets or exceeds the moisture threshold required by a specific weed species, it can trigger the germination process. Moreover, the timing and frequency of rainfall events during the optimal germination window significantly affects the success of weed seed germination. For instance, in a controlled experiment, it was observed that ABYG seeds did not germinate with a rainfall event of 5 mm, while some FTR seeds did germinate at this level of rainfall (Werth *et al.*, 2017). These findings suggest that a small proportion of FTR emergence, such as 1 or 2 plants per 10 m^2, may occur after minor rainfall events. In such cases, growers might overlook controlling them and wait for further emergence during subsequent rainfall events. However, by that time, the FTR plants have already grown large and become difficult to manage with knockdown treatments. These plants can contribute to replenishing the soil seed bank. Understanding these factors enables growers to plan and implement more effective weed control measures to mitigate the growth and spread of problematic weeds like ABYG and FTR.

Seed burial depth

Seed burial depth can significantly influence the germination and emergence of weed species by altering the environmental conditions surrounding the seeds. Understanding how weed seeds respond to different burial depths helps predict seedling emergence patterns. Some weed species have specific depth requirements for optimal germination and emergence, while others exhibit a wider range of depths within which they can successfully emerge. By knowing the preferred or optimal burial depth for a particular weed species, growers can anticipate when and where seedlings are likely to emerge, enabling timely implementation of control measures.

In the case of ABYG and FTR, the highest germination occurs for surface seeds, and emergence drastically decreases with increasing burial depths (Mutti *et al.*, 2019; Ngo *et al*., 2017). To completely inhibit their emergence, ABYG seeds require a burial depth of 8 cm (Figure 3), while FTR seeds need to be buried at a depth of 6 cm. Due to their small seed size, ABYG and FTR may lack sufficient energy reserves to push the coleoptile through deep burial. The observation of highest emergence from surface seeds, coupled with their response to light, suggests that conservation farming systems (e.g., no-till) could enhance the emergence of ABYG and FTR. If their seed banks are concentrated on the soil surface, these weeds could be managed by burying their seeds below their maximum depth of emergence (i.e., 8 cm or deeper). However, in the northern region, most cultivation systems do not bury all of the weed seeds. When multiple passes are made, it further mixes the seeds within the cultivated soil. Therefore, when deep burial is implemented as a management strategy, it becomes crucial to employ additional tactics to effectively handle any seeds that may still remain in the germination zone.

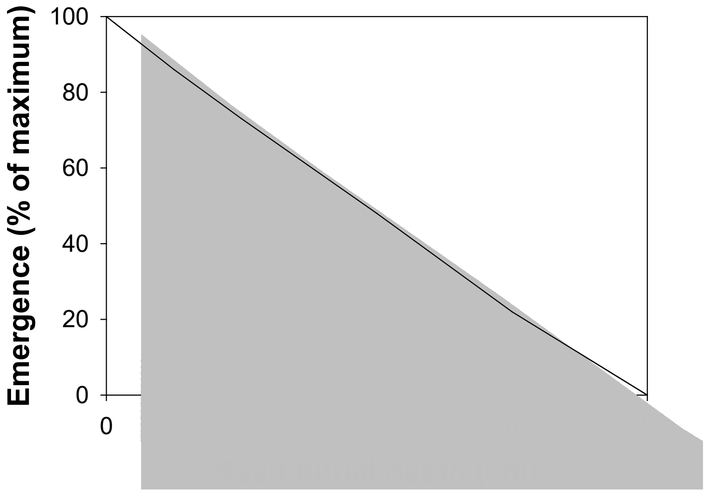


Figure 3. Effect of seed burial depths on seedling emergence (% of the maximum) of awnless barnyard grass (Mutti *et al*. 2019).

Seed bank

Knowledge of weed seed persistence is invaluable for planning long-term control strategies, targeting weed seeds during germination windows, timing cultural practices, assessing control success, preventing seed bank replenishment, and developing site-specific weed management strategies for ABYG and FTR. By incorporating this knowledge into weed management plans, the effectiveness and efficiency of weed control efforts can be significantly enhanced. This, in turn, leads to reduced weed populations and minimized impact on crop yields and ecosystem health.

In a recent study conducted in St. George, it was found that ABYG took approximately 2.5 years to deplete all seeds at depths ranging from 1 to 15 cm (Mahajan and Chauhan, unpublished data). In another study conducted in Gatton, FTR seeds on the soil surface depleted faster (1 year vs 1.5 years) compared to buried seeds (Chauhan and Manalil, 2022). While the rate of depletion varies across burial depth (0 to 10 cm), all seeds of FTR depleted within 1.5 years after placement in the Gatton study.

Leaving seeds on the soil surface facilitates more rapid depletion of the seed bank, as burial enhances seed bank longevity. Based on seed persistence data of ABYG and FTR, it can be inferred that these weeds are unlikely to develop persistent seed banks and could be depleted relatively quickly if no new seed inputs are allowed for 2-3 years (Chauhan and Manalil, 2022). These observations also suggest that once ABYG and FTR seeds are buried below their maximum depth of emergence, subsequent tillage operations should be avoided for at least the next 2.5 years to prevent viable seeds from resurfacing.

Phenology

Phenology is another crucial aspect to consider in weed management. Knowledge of weed phenology provides critical insights into weed growth stages, timing, and behaviour. This information enables better implementation of control measures, including cultural practices, prevention of seed production, early detection in different cropping situations, understanding the life cycle, and optimizing herbicide application by aligning it with the most susceptible growth stage. Although ABYG and FTR are primarily spring and summer-emerging weed species, recent studies suggest that their seasonality is expanding (Chauhan, 2022; Chauhan, unpublished data).

A study was recently conducted at UQ, Gatton, to assess the effect of emergence dates (every second month from September 2020 to July 2021) on the phenology, growth, and seed production of ABYG (Chauhan, 2022). It was observed that ABYG produced the highest number of seeds when emerged in January under fallow conditions, but a considerable number of seeds were also produced for other planting months (Figure 4). Most plants of ABYG from the May planting died due to cold temperatures, but some plants survived and produced seeds (4,750 seeds/plant). Similar results are being observed in an ongoing study conducted in Gatton (Queensland) on FTR, where some plants that emerged in May and July (winter) survived and produced seeds (Chauhan, unpublished data). In Wagga Wagga (New South Wales), however, FTR plants sown in early March (autumn) did not produce seeds (Asaduzzaman *et al.*, 2022). This differential response could be due to cooler temperatures occurring in Wagga Wagga compared to Gatton. These responses also suggest the need for multi-location trials in the northern grain regions.

The results align with recent observations by growers and agronomists in Queensland. These studies suggest that while greater emphasis should be placed on controlling spring and summer-emerging ABYG and FTR plants, close monitoring of their emergence is necessary throughout the year. Any surviving plant can contribute to the soil seed bank, and therefore, all efforts should be made to prevent the introduction and spread of ABYG and FTR seeds to non-infested fields (Spaunhorst *et al.*, 2018). Most herbicides for ABYG and FTR are recommended for summer crops and fallows, highlighting the need to develop management options that integrate both chemical and non-chemical tools for winter crops and fallows.

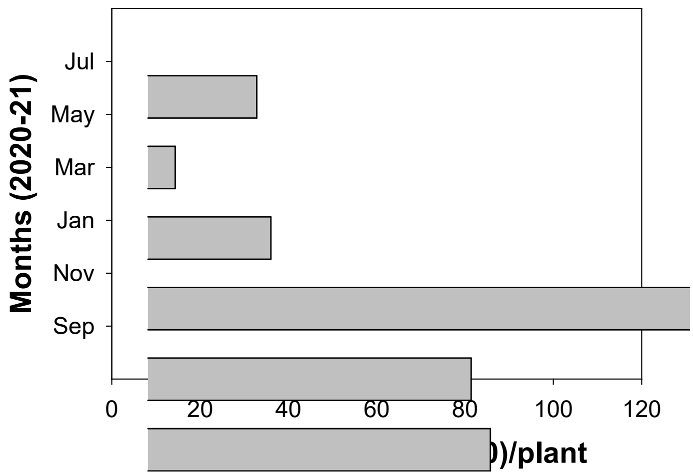


Figure 4. Seed production of awnless barnyard grass as affected by planting dates (2020-21) at the University of Queensland, Gatton (Chauhan 2022).

Conclusions

Understanding the seed ecology, phenology, and biology of ABYG and FTR is essential for developing and implementing effective weed management strategies. Factors, such as light, temperature, rainfall, and seed burial depth, play significant roles in their germination and emergence patterns. Both ABYG and FTR exhibit light-dependent germination, suggesting that their emergence can be stimulated in conservation agriculture systems where seeds remain on or near the soil surface. Temperature requirements for germination vary, but studies indicate that ABYG and FTR can germinate and emerge throughout the year, potentially expanding their invasion in winter crops and fallows. Germination of some FTR seeds can occur after small rainfall events, highlighting the necessity for implementing control measures. Seed burial depth also influences their emergence, with surface seeds exhibiting the highest germination rates. This knowledge highlights the importance of burying seeds below their maximum depth of emergence to manage these weeds effectively. In situations where complete seed burial by tillage is not achieved, it becomes essential to employ additional tactics to effectively address the seeds in the germination zone.

Additionally, understanding the phenology of ABYG and FTR is crucial for timing control measures. While they are primarily spring and summer-emerging species, recent studies suggest their seasonality is expanding. Continuous monitoring and preventive measures are crucial to prevent the introduction and spread of ABYG and FTR seeds to non-infested fields, ensuring long-term weed control success. Integration of chemical and non-chemical tools in weed management is essential, especially for winter crops and fallows where herbicide options are limited.

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. The author would also like to thank the University of Queensland for partial funding this research through students' projects.

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Date published

July 2023