Germinable Soil Seed Bank of *Bothriochloa macra* Dominated Pasture in South-Eastern Australia

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The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.
Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress
Published by the Kenya Agricultural and Livestock Research Organization

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Key words: grazing management; botanical composition; perennial; native grass; pasture

Abstract

In native pastures, soil seed banks play an important role in conserving the genetic material in a plant population, influencing community structure and providing protection against adverse climatic conditions. One important native grass is *Bothrichloa macra* (Steud.) S.T.Blake (Red grass, Red-leg grass). This grass is a C_4 indigenous perennial grass that is commonly found in native pastures in the high rainfall zone of south-eastern Australia.

At Tarrawingee, NE Victoria, (36°25′S, 146°31′E) and Wymah, southern NSW, (35°58′S, 147°11′E), Australia, two sites that had *Bothriochloa macra* as the dominant native grass were sampled. Three hundred cores (50 mm diameter and 50 mm depth) were collected from each site and bulked in May 2005. The soil samples were spread evenly over seed raising flats and maintained in a glasshouse, under natural light and modified day/night temperatures. The samples were kept moist for periods of between 35 and 70 d. During each census, germinants were identified to the following functional groups (*B. macra*, broadleaf, grass and legume) and removed. At the end of each cycle remaining seedlings were counted and water withheld. The dry soil samples were then thoroughly mixed and re-watered to initiate another cohort of germination. This cycle was repeated five times over a nine-month period.

These counts showed that *B. macra* only represented a very low proportion of the soil seed bank (1.1 to 3.4% of total germinants), with the soil seed bank dominated by annual species. Fifty-eight different species germinated from the soil seed bank, with 83% of all seeds germinating in the first two cycles. The soil seed bank of these *B. macra* pastures possessed characteristics typical of most soil seed banks, including poor correlation with the standing vegetation, domination by one or two species and low representation of perennial species.

Introduction

Grazed pastures dominated by native grasses occupy around 22% of agricultural land in the high rainfall zone of south-eastern Australia (Hill et al. 1999). *Bothrichloa macra* (Steud.) S.T.Blake (Red grass, Red-leg grass, hereafter *Bothriochloa*) is an indigenous species that is commonly found in these pastures (Garden et al. 2001) and is a low growing C_4 perennial (Simon 1990). In many hilly parts of the landscape native grass pastures offer the only sustainable options for grazing, maintaining perennial ground cover and reducing rates of land degradation (Simpson and Langford 1996). The relative abundance of native grasses within these pastures is critical for landscape function with respect to natural resource management reducing deep drainage and maintaining ground cover (Virgona et al. 2003).

Soil seed banks play an important role in plant population dynamics and community structure (Fenner 1985; Teo-Sherrell et al. 1996). They serve as pools of genetic material that act as a population buffer against adverse climatic conditions. Soil seed banks can be composed of seed that is produced in that area, or seed that has come from elsewhere via wind, water or animals (Harper 1977). Seed in the soil seed bank is continually added to by seed rain and thus represents past and present vegetation of the area and surrounding areas (Harper 1977). Seed can be lost from the soil seed bank by predation, old age – loss of viability, soil pathogens, fungal attack, decay or germination.

Soil seed banks are one component in the population biology of a species. Germination, emergence and survival of a species are key life-history stages that ensure persistence of plant populations (Clarke and Davison 2004). There is a paucity of published information on either the size or composition of germinable soil seed banks in native pasture communities in the high rainfall zone (annual average rainfall > 550 mm) of southern Australia. Quantifying the regeneration potential of the soil seed bank is an important aspect in developing management strategies for sustainable land use (McIvor and Gardener 1994). The aim of this experiment was to improve our understanding of the quantities of germinable *Bothriochloa* seed that are present in the soil.

Methods and Study Site

The experiment was conducted on two native pasture sites. The Tarrawingee site in NE Victoria (36°25´S, 146°31´E) had an annual average rainfall of 643 mm, soil pH ($CaCl_2$) of 6.4 and *Bothriochloa* 24% of above ground biomass. The Wymah site in southern NSW (35°58´S, 147°11´E) had an annual average rainfall of 751 mm, soil pH ($CaCl_2$) of 4.9 and *Bothriochloa* 40% of above ground biomass.

Samples were collected at Tarrawingee on 23 May 2005 and at Wymah on 18 May 2005. From each site, three hundred cores (50 mm diameter and 50 mm depth) were collected and bulked. Bulked soil samples were dried at 40°C for 48 h and sieved to remove gravel and remaining plant material. The samples were then sieved through a coarse (4 mm) and fine (2.5 mm) sieve (Ter Heerdt et al. 1996). Each sample was divided into four and placed on germination trays, which were randomly allocated to four replicated blocks in a randomised complete block design to account for variation in temperature and light within the glasshouse.

Soil samples were spread evenly over seed-raising flats containing sand and peat mix (2:1) with a layer of vermiculite. The soil samples were maintained in a glasshouse at the Agriculture Victoria, Rutherglen, under natural light and modified day and night temperatures, 14 to 42°C in summer and 9 to 31°C in winter. To ensure that the soil was kept moist, black plastic was topped with a layer of capillary mat (geotextile fabric), and then permeable weed mat and the trays were placed on a layer of vermiculite. Plastic tubes with holes were placed down three sides of the table to keep the weed mat moist. An automatic tap timer was used to apply water for 10 minutes every 24 h.

The samples were kept moist for periods of between 35 and 70 days from August 2005 to June 2006. Germinated seedlings were removed, identified and classified into the following functional groups: native grass, broadleaf species, grasses (both annual and perennial) and legumes. At the end of each germination cycle, remaining seedlings were counted, and water withheld. The dry soil samples were thoroughly mixed and re-watered to initiate another cohort of germination. There were five cycles of germination.

Soil seed bank seedling counts were analysed using ANOVA within Genstat (Payne et al. 2014). Least significant differences (l.s.d.) are shown at the P = 0.05 level.

Results

Summer rainfall (December 2004, January 2005, February 2005) was above average for both sites, Tarrawingee site 226 mm (LTA 126) and Wymah site 223 mm (LTA 144). Whereas autumn rainfall (March, April, May 2005) was well below average at both sites, Tarrawingee site 18 mm (LTA 147 mm) and Wymah site 34 mm (LTA 171 mm).

The total seed density for Tarrawingee was 737,291 seeds/m^2 and Wymah was 1,096,646 seeds/m^2. Fifty-eight different species germinated from the seed bank. Within the first two cycles, 83% of the total seed germinated (Table 1). The germinable soil seed bank was dominated by species in the 'Other species' category, with this grouping *Juncus* L. spp. accounted for 51% of the total soil seed bank.

The majority (87%) of the *Bothriochloa* germinated in the first cycle at both sites (Table 1). *Bothriochloa* only represented 2% of the total soil seed bank, with more *Bothriochloa* germinated from the soil seed bank collected at the Tarrawingee site. Overall, native grasses only represented 3% of the total germinable soil seed bank (Table 2). The soil seed bank at both sites were dominated by introduced species which represented 94% of the individuals to germinate and 79% of total species that germinated.

Table 1. Mean number of seeds germinating (m^2) in the soil seed bank for each of the five germination cycles for five species groups for Tarrawingee and Wymah field sites.

Cycle number	1	2	3	4	5	l.s.d. (*P* = 0.05)
			Tarrawingee			
Bothriochloa	1,078	151	2	5	0	194
Other native grasses	316	75	42	22	10	176
Annual broadleaf	2,436	727	126	39	706	907
Annual grass	720	51	15	37	3	646
Legumes	289	37	36	66	41	310
Other species	19,696	4,125	659	674	4,680	4,686
			Wymah			
Bothriochloa	526	73	0	2	0	194

Other native grasses	616	183	8	3	34	176
Annual broadleaf	10,792	979	487	151	567	907
Annual grass	6,395	255	747	90	59	646
Legumes	7,470	146	185	755	657	310
Other species	16,058	3,180	222	256	3,837	4,686

Table 2. General characteristics of soil seed bank of *Bothriochloa* dominated pastures in southern Australia

Group	Individual/seeds		Species	
	Number	%	Number	%
Annual	47,860	90	38	66
Perennial	5,487	10	20	34
Introduced	49,991	94	46	79
Native	3,356	6	12	21
Monocotyledon	35,369	66	34	59
Dicotyledon	17,978	34	24	41
Total	53,347		58	

Discussion

The soil seed bank of these *Bothriochloa* pastures in southern Australia possessed characteristics typical of most soil seed banks, including high spatial variation, poor correlation with the standing vegetation, domination by one or two species and low representation of perennial native grasses. The outstanding feature of the results from this experiment was the small number of *Bothriochloa* seeds in the germinable soil seed bank. Annual grasses, annual broadleaf species and sedges dominated the soil seed bank of these pastures. These low levels of germinable *Bothriochloa* seed in the soil seed bank suggest it is likely that there are limited opportunities for seedling recruitment. *Bothriochloa* seedlings that could germinate would face immense competition from the germination of other species in the soil seed bank.

For the Tarrawingee site, *Bothriochloa* germinated in four of the five cycles, whereas at Wymah it germinated in only three cycles. A small proportion (less than 10%) of *Bothriochloa* seed may have long-term viability or dormancy. Low levels of *Bothriochloa* seed dormancy and high germination percentages (> 80%) have been previously found (Johnston et al. 1998; Clarke and French 2005; Clarke et al. 2007).

Seasonal conditions clearly influenced the number of *Bothriochloa* seedlings in the soil seed bank. These samples were collected after a wet summer, where the *Bothrichloa* produced large quantities of seed. Species not found cannot automatically be presumed to be absent from the soil seed bank, since sampling procedure, such as time of year, and germination procedures may not have been appropriate for all species (Lunt 1997). The sampling intensity used in this experiment was considered sufficient to indicate the general characteristics of the soil seed bank, particularly in terms of life form and origin.

The composition of the soil seed bank did not reflect the above-ground species composition. The general reason for this is that it contained seeds from both the past and present vegetation and species have different seeding capacities and seed viability over time (Harper 1977). This difference between species composition above ground and in the soil seed bank has been found in a range of environments and pasture types in Australia and overseas (Harper 1977; McIvor and Gardener 1994; Briske 1996; Batson 1999; Lodge 2001). The high number of annual grass and sedge seeds present in the soil seed bank suggests that any disturbance that creates bare ground, such as overgrazing, could result in a dramatic shift in botanical composition of the pasture. Hence, in this case, careful management of *Bothriochloa* within pastures would be important for maintaining composition.

Soil seed bank studies remain essential to complete our understanding of the whole regeneration pathway of species, from germination to adult reproduction, and for understanding and predicting community dynamics (Venn and Morgan 2010). Germination and recruitment events among perennial grass species may be episodic in nature (Briske 1996; King et al. 2006) only occurring when season conditions are ideal.

Acknowledgements

We thank the landholders on whose properties these experiments were conducted, Jim and Rosie Corrigan, David and Alison Hawthorn. This work was funded by Agriculture Victoria Research (and its predecessors) and the Dryland Salinity Collaborative Research Centre.

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