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Effect of growing site, moisture stress and seed size on viability and dormancy of *Sporobolus pyramidalis* (giant rats tail grass) seed

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Abstract. *Sporobolus pyramidalis* P. Beauv (giant rats tail grass) is a serious agricultural and environmental weed in tropical and subtropical areas of Australia. Infestations of this unpalatable plant reduce the productivity of pastures and the profitability of industries dependent on grazing animals. This paper reports a series of studies undertaken to assist in the development of control strategies for this species. In particular, these studies measured the viability and dormancy status of fresh seed of *S. pyramidalis* and the decline of dormancy with time. Variability in these characteristics was determined in seeds collected from several sites within south-east Queensland. The effect of moisture availability during the inflorescence and seed production phases on seed viability and dormancy was also determined. The dormancy of freshly collected seed from several sites ranged from 15 to 95%, but decreased to negligible levels after 4–6 months. Seeds that matured under conditions of high moisture availability were initially more dormant than seeds matured where moisture was less readily available. The proportion of viable seeds was significantly lower in smaller than larger seeds even though viability for all seed sizes exceeded 90%. This study has shown that seed of *S. pyramidalis* generally has high viability with a large proportion of the seed germinable soon after maturity.

Introduction

The tropical, perennial grass *Sporobolus pyramidalis* (giant rats tail grass) is a serious agricultural and environmental weed in eastern and northern Australia (Simon and Jacobs 1999; Vogler and Bahnisch 2002). It is native to Africa, where it is distributed throughout tropical areas, extending to South Africa, Madagascar, Mauritius and Yemen (Clayton 1965). This distribution generally follows average annual rainfalls above 500 mm. *S. pyramidalis* is considered a weed of native and sown pastures in its native environment (Innes 1977; Rodel and Boultwood 1981; Sharma 1984; Tainton 1981).

In Australia, current infestations of *S. pyramidalis* are generally located in areas receiving more than 600 mm average annual rainfall (Vogler and Bahnisch 2002), although it will probably grow successfully in areas receiving as little as 500 mm as it does in Africa (Georgiadis and McNaughton 1990). This places most of Queensland's grazing lands and other extensive areas of northern Australia under threat.

Sporobolus pyramidalis is considered a major problem because it replaces palatable species, thereby reducing the productivity of pastures and the profitability of grazing enterprises. In addition to its low palatability, it is difficult for stock to graze due to the fibrous nature of its leaves (Sharma 1984; Tainton 1981; Vogler and Bahnisch 2002). Over time, if plants are not controlled, they increase in number until almost pure stands remain.

Sporobolus pyramidalis can produce inflorescences throughout the year if temperatures are suitable and soil moisture is available, although most inflorescences are produced during the warm/wet season in south-east Queensland. Once seeds are mature, they drop from the inflorescence, which dies and is replaced by a new inflorescence. Individual inflorescences are capable of producing 400–1000 seeds (W. D. Vogler, unpublished data) and seed production within dense (>1 plants/m^2) infestations has been estimated at up to 85 000 seeds/m^2 (Vogler and Bahnisch 2002).

The conditions under which seeds germinate have not been fully determined, with studies to date being restricted to identification of temperature requirements. The optimal temperature regime for germination is 15/35°C with a 12-h thermoperiod, although germination can occur with constant temperatures ranging from 15 to 45°C (Andrews 1995). Andrews (1995) also noted the presence of seed dormancy, but did not quantify its rate of decline.

This paper reports a series of studies undertaken to gain further information on the germinability of *S. pyramidalis.* Variability in viability and dormancy status was determined

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through testing fresh seed lots collected from several sites within south-east Queensland. The effect of soil moisture and seed size on dormancy and viability of fresh seed and the decline in dormancy with time was also studied.

Materials and methods

Seed collections

Seeds were collected at Gympie (152°49′E, 26°0′S) on 15 November 1996 (G1), 17 February 1997 (G2) and 6 April 1997 (G3); Foxtail Flats near Bundaberg (151°50′E, 24°15′S) on 15 November 1996 (F1), 17 February 1997 (F2) and 6 April 1997 (F3); Kilcoy (152°34′E, 26°48′S) on 15 January 1997 (K1) and 6 April 1997 (K2); and Brian Pastures Research Station near Gayndah (151°45′E, 25°40′S) on 6 April 1997 (B1). A minimum of 50 entire inflorescences that contained mostly mature light brown to dark brown seeds were harvested on each occasion.

Seed cleaning, storage, germination and viability testing procedure

Mature seed was obtained by rubbing inflorescence gently between the thumb and forefinger several times, which left immature seed attached to the inflorescence stalk. The seed and inflorescence parts resulting from this process were sieved several times and then manually separated by gently blowing the trash away from the seed. All seed was stored under laboratory conditions in paper envelopes placed in a drawer until required. The laboratory was cooled with a refrigerated air-conditioner during the day with temperatures generally kept between 20 and 30°C. Humidity levels were relatively low (<50%) given the air-conditioned environment.

For each seed lot, 5 samples each comprising 50 randomly selected seeds were chosen for testing at each period. Germination testing was undertaken by placing individual seed samples in covered 90-mm Petri dishes containing a germination pad moistened with deionised water. The Petri dishes were then placed in a germination cabinet set at 15/35°C with a 12 h thermoperiod (Andrews 1995). The germination cabinet was lit with two 30 W cool white fluorescent tubes during the high temperature phase.

Germination counts were conducted daily until no germination was recorded for 4 consecutive days. Deionised water was added when necessary to keep the germination pads moist and the location of the Petri dishes was re-randomised daily. Seeds were considered to have germinated when the coleoptile was at least as long as the seed (Andrews 1995).

After germination had ceased, coats of the remaining seeds were pricked to release the seeds from dormancy (Andrews 1995). It is not known how pricking releases the seed from dormancy but it indicates that the seed coat acts, at least to some extent, as a factor in the seed dormancy of *S. pyramidalis* seed. The seed coat of *S. pyramidalis* is permeable to water, as both dormant and active seeds imbibe, but may be impermeable to oxygen like *Hordeum* and *Triticum* spp. or contain inhibitory chemicals like the tannins in *Triticum* spp. (Bewley and Black 1994).

Following pricking, seeds were then returned to the germination cabinets for a further 14 days under the conditions outlined above, with seeds removed as they germinated. Seeds that germinated after pricking were classified as dormant. The sum of the germinated and dormant seeds was considered to be the seed lot viability, and seeds that did not germinate after being pricked were classified as dead (Andrews 1995).

Viability and dormancy of seeds

Germination, viability and dormancy testing of all seed lots was conducted within 1 week of collection using the procedure described, and thereafter at 2-monthly intervals for a further 10 months during storage in the laboratory. An additional 30 samples (5 replicates × 6 retrieval times) of 50 seeds from both the G1 and K1 collections were placed individually into 300-micron nylon mesh bags and buried 1 cm deep in a sandy loam soil at The University of Queensland, Gatton Campus. This was done to compare dormancy release of seed buried in soil to that of seed stored in the laboratory. These samples were also retrieved at 2-monthly intervals, but testing ceased after 8 months because of accidental uncovering of the remaining buried seed.

Effects of moisture stress on dormancy

Glasshouse

During the autumn and winter of 1997 a glasshouse study was conducted to determine the effect that moisture stress during the flowering and seed production phase has on the level of innate seed dormancy. A completely randomised experiment with 4 replicates was conducted in a glasshouse at The University of Queensland, Gatton Campus. There were 4 treatments comprising different levels of moisture stress.

Initially, a soil moisture characteristic curve was established using the method outlined by Fawcett and Collis-George (1967). This was used to calculate the amount of water required to obtain gravimetric soil moisture contents of 5.2, 10.3 (wilting point), 15.5 and 20.6% (field capacity). The corresponding combined soil and water masses for each soil moisture treatment were 10.2, 10.7, 11.2 and 11.7 kg, respectively.

Fifty 25-cm diameter pots were lined with plastic bags, filled with 9.7 kg of air dry clay loam soil, and watered to field capacity. A pinch of *S. pyramidalis* seed was sprinkled on the soil surface and covered with 2 mm of the same soil. Seedlings were thinned to obtain 3 established seedlings in each pot. All pots were watered to field capacity as necessary until the emergence of first inflorescences, which occurred after 15 weeks.

At this point, 16 of the most uniform pots were selected from among those that had inflorescences present, arranged randomly in 4 rows of 4 pots each and watered to field capacity a final time. Each pot was allowed to dry down from field capacity to the moisture content of its respective treatment, which was randomly allocated. Once each pot had reached its required soil moisture content by mass, it was maintained at that mass by watering every second day until the end of the experiment.

Seed was collected as it matured by placing individual seed heads in paper bags and gently shaking them. This was done every second day until all seed was collected, with seed from plants in each pot collected separately. As soon as all seed had been collected it was tested for viability and dormancy using the procedure described previously. Testing was repeated after 2, 4 and 6 months of laboratory storage to determine the decline in seed dormancy. Dormancy was expressed as a percentage of viable seed.

Field

During the 1997–98 summer, two 4 by 4 m plots of *S. pyramidalis* were selected at Brian Pastures Research Station. These areas of *S. pyramidalis* comprised the only stands available so it was not possible to replicate the treatments. One plot was watered at a rate of 200 mm of irrigation applied every 2 weeks irrespective of rainfall from December 1997 until seed was collected. The second plot was subject to rainfall only.

These treatments produced seed that matured under either little if any water stress or intermittent stress conditions, the level of which was dependent on the timing and amount of rainfall.

Within 1 week of collection, seed was tested for viability and dormancy using the procedure described. This test was repeated after 2, 4 and 6 months of laboratory storage to determine the decline in the level of seed dormancy in both seed lots. Dormancy was expressed as a percentage of viable seed.

Seed size and dormancy

Five lots of 10 whole mature inflorescences were collected from the Gympie and Foxtail Flats sites on 2 December 1996. Seed was extracted from each lot of inflorescences within 1 week after collection and stored

Table 1. Mean daily maximum and minimum ambient temperature for 4 weeks immediately before seed collection at each site

Collection date	Ambient temperature (°C) (max/min)			
	Gympie	Foxtail Flats	Kilcoy	Brian Pastures
15 November1996	27.7/13.6	27.1/16.7	—	—
15 January 1997	—	—	27.5/17.8	—
17 February 1997	29.4/19.0	30.1/21.5	—	—
6 April 1997	27.9/16.1	28.0/18.9	28.2/16.6	29.9/17.2

separately under laboratory conditions. Each seed lot was then sieved into 0.3–0.4 mm, 0.4–0.5 mm and >0.5 mm sizes for the Gympie samples and 0.4–0.5 mm, 0.5–0.6 mm and >0.6 mm sizes for the Foxtail Flats samples. The difference in the seed size classes is due to the inherent differences in seed size between seed samples collected at these sites.

One month after harvest (January 1997), seed from each size class was tested for viability and dormancy using the procedure described. This procedure was repeated at 2-monthly intervals until it was apparent that seed dormancy was negligible. Seed dormancy was expressed as a percentage of viable seed for each seed lot. Seed viability for each seed lot was expressed as a percentage of total seed number.

Data analysis

Seed lot mean and standard error were calculated for the viability and dormancy of field collected seed including seed used to determine the effect of moisture availability on dormancy (field). All other data were arcsine transformed before analysis. Analysis of variance and Fisher's l.s.d. test were used to determine significant differences between treatments for the effect of moisture stress (glasshouse) and the effect of seed size on dormancy.

Results

Viability and dormancy of field-collected seed

Mean daily maximum and minimum temperatures for 4 weeks before each seed collection at each site ranged from 27.1 to 30.1 and 13.6 to 21.5, respectively (Table 1). Rainfall for the same periods at each site ranged from 10 mm at Foxtail Flats to 121 mm at Kilcoy (Table 2).

Table 2. Rainfall for 4 weeks immediately before seed collection at each site

Collection date	Rainfall (mm)			
	Gympie	Foxtail Flats	Kilcoy	Brian Pastures
15 November1996	110	10	—	—
15 January 1997	—	—	36	—
17 February 1997	72	59	—	—
6 April 1997	81	62	121	39

Table 3. Viability of *S. pyramidalis* seed lots collected at Gympie, Foxtail Flats, Kilcoy and Brian Pastures

Collection date	Viability (% ± s.e.)			
	Gympie	Foxtail Flats	Kilcoy	Brian Pastures
15 November1996	95.2 ± 1.4	96.1 ± 0.7	—	—
15 January 1997	—	—	90.2 ± 1.2	—
17 February 1997	87.0 ± 0.7	91.7 ± 1.0	—	—
6 April 1997	91.2 ± 0.5	92.1 ± 1.8	88.1 ± 1.8	91.9 ± 1.1

There were small differences ($P<0.05$) in the viability of fresh seed of *S. pyramidalis* collected at different locations and times. Nevertheless, viability of *S. pyramidalis* seed was consistently high, ranging from 87 to 96% for all seed lots (Table 3).

There were large differences ($P<0.05$) in the level of innate dormancy of seed lots of *S. pyramidalis*. The proportion of freshly collected seeds that were germinable ranged from 5 to 85%, with seeds from Gympie and Kilcoy being significantly more dormant than those from Foxtail flats and Brian Pastures (Fig. 1). There were also large differences in the rate of dormancy release between sites and between collections at the same site even though seed was stored under the same conditions. This is evident with collections G1 and K1 compared with collections G3 and K2 that reached near maximum germinability 4 and 6 months after collection, respectively (Fig. 1).

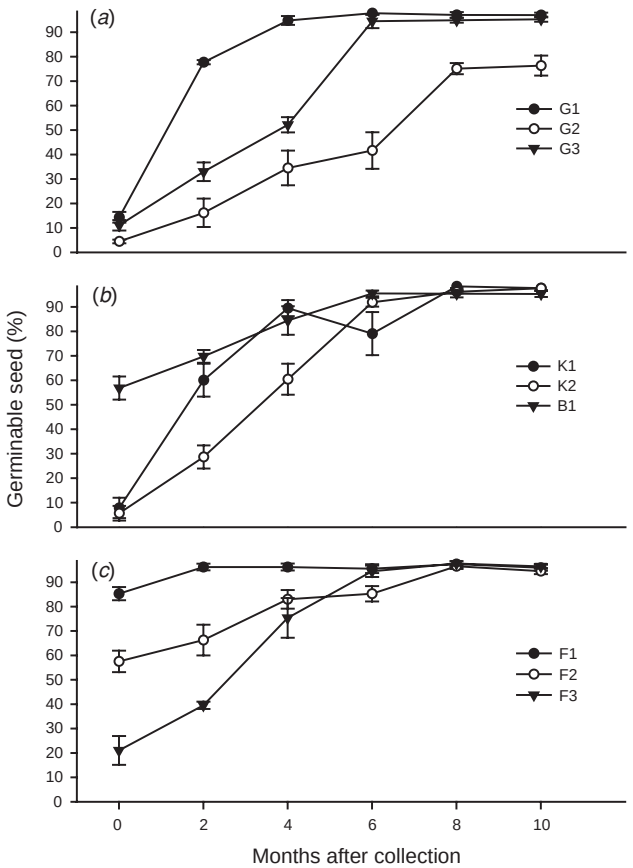

Fig. 1. Germinability of laboratory-stored *S. pyramidalis* seed collected at Gympie and Foxtail Flats in November 1996 (G1, F1), February 1997 (G2, F2) and April 1997 (G3, F3); Kilcoy in January 1997 (K1) and April 1997 (K2); and Brian Pastures in April 1997 (B1), when tested immediately after collection and at 2-monthly intervals until 10 months after collection. Vertical bars represent 1 standard deviation from the mean.

There was no difference in the rate of dormancy release of the soil-stored G1 and K1 collections with little dormancy remaining after 6 months (Fig. 2). Laboratory-stored G1 seed lost dormancy faster than field-stored G1 seed with about 80 and 65% being germinable 2 months after collection, respectively (Figs 1 and 2). Nevertheless, after 4–6 months the effect of dormancy on seed lot germinability was negligible, with germinable seed levels of more than 90% being recorded in the majority of seed lots including those which were buried in soil (Fig. 2). G2 was an exception, with the germinable seed level remaining below 80% even after 10 months (Fig. 1).

Effects of moisture stress on dormancy

Glasshouse treatments

Moisture stress during flowering and seed production affected the level of dormancy of fresh seeds. Initially, there was a positive linear relationship (r^2 = 0.69) between moisture supply and the proportion of dormant seeds (Fig. 3). For example, 8–12% more of the fresh seeds produced under field capacity conditions were dormant compared with those obtained from plants grown close to wilting point (Fig. 3). Although dormancy declined over time in all treatments, the effect of moisture supply was greatest at 2 and 4 months. By 6 months, only a small effect (P<0.05) remained, with 12% of the seeds produced at field capacity still dormant compared with 5% of those produced at lower available moistures. The proportions of non-viable seed did not differ (P>0.05) between moisture treatments, averaging less than 10% when tested at 0, 2, 4 and 6 months after collection.

Field treatments

Inflorescences emerged in mid- to late December 1997 in the rainfall treatment and were collected on the 20 January 1998. No significant rainfall had fallen for 4 weeks before inflorescence collection (Fig. 4). This, along with the relatively high ambient temperatures during this period, caused the plants in this treatment to become severely wilted. The plants in the irrigated plot tended to produce more foliage before inflorescence emergence. This delayed seed maturity resulting in inflorescences being collected on 9 March 1998. Ambient mean daily maximum and minimum temperatures for 4 weeks before the January and March collection dates were 33.1/21.0 and 32.1/20.9°C, respectively.

For the first 4 months after collection, seeds that matured under conditions of high soil moisture availability were more dormant than seeds that matured under lower moisture

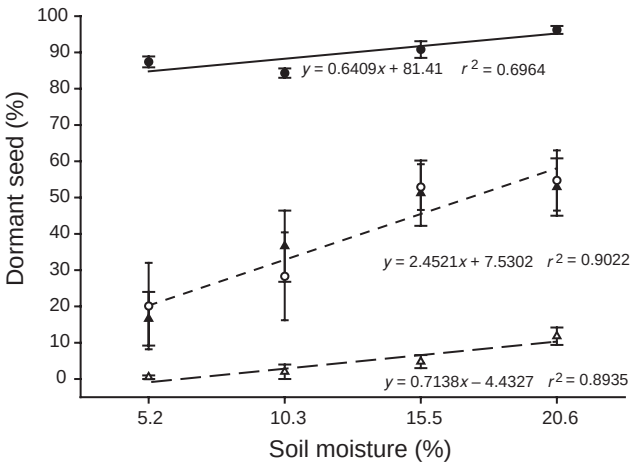

Fig. 3. Mean dormancy (%) of *S. pyramidalis* seed at collection (●) and 2 (○), 4 (▲) and 6 (△) months after collection when subjected to different gravimetric soil moisture conditions during seed maturation. The regressions at collection (solid line), 2 and 4 months (short-dashed line) (combined because not significantly different) and 6 months (long-dashed line) after collection are shown. Vertical bars represent 1 standard deviation from the mean.

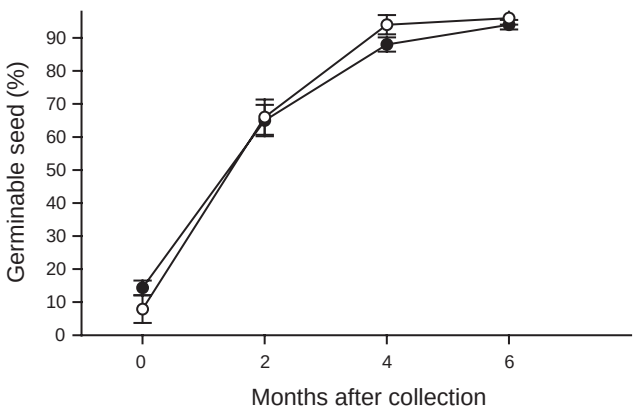

Fig. 2. Germinability of soil-stored *S. pyramidalis* seed collected at Gympie in November 1996 (● G1) and Kilcoy in January 1997 (○ K1) when tested immediately after collection and at 2-monthly intervals until 6 months after collection. Vertical bars represent 1 standard deviation from the mean.

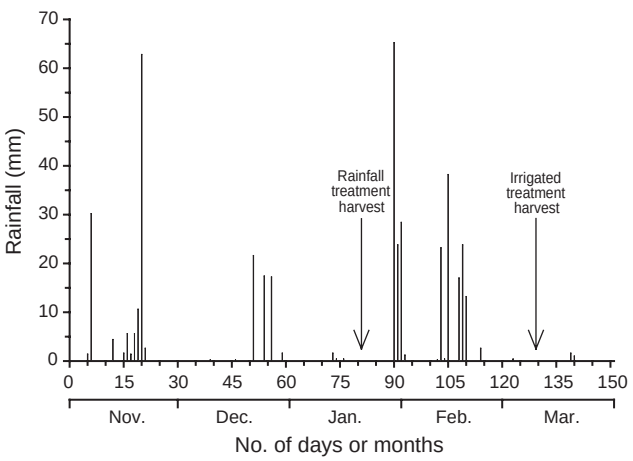

Fig. 4. Daily rainfall at Brian Pastures Research Station from November 1997 to March 1998.

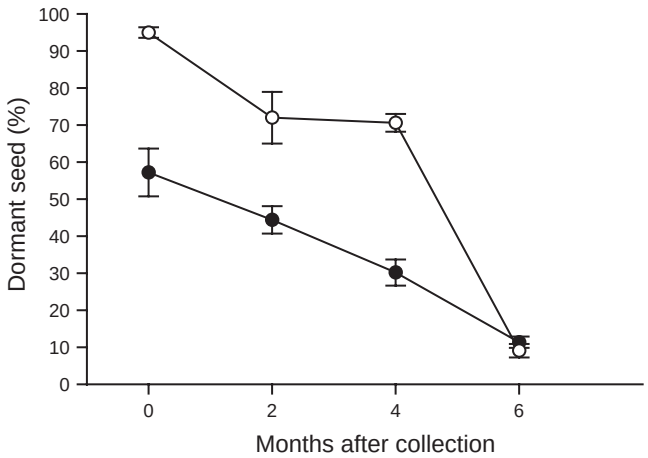

Fig. 5. Mean innate dormancy (%) over time of *S. pyramidalis* seed subjected to high (○) and low (●) field soil moisture conditions during maturation. Vertical bars represent 1 standard deviation from the mean.

availability. After 6 months storage the proportion of dormant seeds averaged 10% irrespective of moisture conditions during seed maturation (Fig. 5).

Seed size and dormancy

The smallest seed from each site had lower levels of viability (P<0.05) than larger seed from each site at every duration after collection. Viability of each seed size did not change throughout the experiment; therefore, mean seed viability is presented for each seed size from each site (Table 4). Viability for all seed sizes from both sites was above 90%.

There was no difference in dormancy (P>0.05) between the seed sizes from Gympie, except at 1 month after collection when dormancy levels for the smallest seed were lower than those of the other seed sizes (Table 5). At Foxtail Flats dormancy levels were only different at 1 month after collection, where the smallest seed was significantly more dormant (P<0.05) than the other seed sizes (Table 5).

Discussion

Moisture stress

The dormancy of seed is influenced by the microclimate imposed by the parent (within the seed producing structure)

Table 4. Seed viability (%) of different seed size classes for seed collected from Gympie and Foxtail Flats in Queensland

Means within columns for each site followed by the same letter are not significantly different (P>0.05); —, no seed present in these size categories

Seed size (mm)	Gympie	Foxtail Flats
0.3–0.4	91.0a	—
0.4–0.5	96.0b	90.5a
0.5–0.6	96.9b	97.1b
>0.6	—	96.7b

Table 5. Seed dormancy (%) of different seed size classes for seed collected from Gympie and Foxtail Flats in Queensland

Means within columns followed by the same letter are not significantly different (P>0.05); —, no seed present in these size categories; MAC, months after collection

Seed size	Gympie			Foxtail Flats		
(μm)	1 MAC	3 MAC	5 MAC	1 MAC	3 MAC	5 MAC
0.3–0.4	39.4b	15.4a	6.2a	—	—	—
0.4–0.5	52.6a	30.8a	4.0a	17.4a	2.8a	2.8a
0.5–0.6	58.2a	20.0a	5.2a	2.8b	0.8a	0.4a
>0.6	—	—	—	2.8b	0.0a	0.4a

and also the wider environment (Fenner 1991; Groves *et al*. 1982). Control of seed germinability by parental environment assumes significance and plays an important role in the spread and persistence of plant species, because it allows seeds to germinate and establish under a range of conditions (Kigel *et al*. 1977). When grown in a glasshouse where temperature was the same for all treatments, *S. pyramidalis* plants subjected to moisture stress produced seeds with lower dormancy compared with seed produced from unstressed plants (Fig. 3). This effect also occurred in field treatments where, despite treatments being harvested in January and March, both mean maximum and minimum ambient temperatures during 4 weeks before harvest were no more than 1°C different. This suggests that where temperatures are relatively similar available moisture significantly influences seed dormancy in *S. pyramidalis* at least during the first few months after maturity. However, these differences were of no ecological consequence after 6 months in both glasshouse and field treatments (Figs 3 and 5) because dormancy release was completed within this time.

The effect of drought (water stress) on the subsequent germinability of seed depends on the dormancy mechanism present. Where dormancy is regulated by seed coat thickness, water stress increases the thickness of the coat, thereby reducing germinability (Fenner 1991). Where the dormancy mechanism is biochemical, water stress reduces dormancy possibly by reducing the production of a germination inhibitor, which is the mechanism present in *Avena fatua* (wild oats) (Fenner 1991; Peters 1982). The lower seed dormancy of water stressed seeds reported here is similar to that reported for *A. fatua* and suggests that seed dormancy of *S. pyramidalis* may be controlled biochemically.

Seed dormancy

For all sites except Gympie, dormancy of fresh field collected *S. pyramidalis* seed was generally higher and lasted longer as rainfall during the 4 weeks before collection increased (Table 2). This occurred irrespective of the small differences in ambient temperatures during the maturation of seed in collections from Kilcoy, Foxtail Flats and Brian

Pastures (Table 1), which agree with the findings of the glasshouse experiment (Fig. 3), although temperatures in the glasshouse were the same for all treatments. At Gympie this pattern was reversed, with seed from collection G1 having less dormancy despite more rainfall during seed maturation compared with other collections at Gympie (Fig. 1). This occurred even though ambient temperatures were the lowest during the maturation of seed in collection G1 (Table 1), which, if anything, should have increased seed dormancy levels (Fenner 1991). The reason for this anomaly is unclear; however, it may be due to the accumulative effects of previous rainfall on seed from collections G2 and G3 thereby providing sufficient soil moisture to produce seeds with higher dormancy levels, interactions with available soil nutrients (which were not measured) or an interaction of these factors. Further, the effect of genetics on the inter-site variation of dormancy cannot be discounted given the well documented genetic variation within this genus, which produces a continuous morphological intergradation between species (Simon and Jacobs 1999).

Nevertheless, when the seeds were stored in a warm, dry laboratory or in soil, seed dormancy and differences in dormancy between sites were generally negligible after 4–6 months with germinability averaging more than 90% in all seed lots (Fig. 1). The ability of *S. pyramidalis* to produce a proportion of seeds with innate dormancy is consistent with findings for other *Sporobolus* spp. (Andrews 1995; Lodge and Whalley 1981; Persad 1980; Toole 1941). Seed dormancy is common in grasses, with at least half of the grass genera possessing dormancy mechanisms; 92% of these exhibit weedy traits (Simpson 1990).

Seed dormancy is considered one of the most important factors influencing germination. It ensures that germination is distributed over time to ensure species survival, by increasing the probability that at least some seed will germinate when conditions are favourable for seedling establishment (Bewley and Black 1994; Silvertown and Doust 1993; Simpson 1990). Dormancy also has an important impact on seed longevity by allowing seeds to remain ungerminated over long periods (Silvertown and Doust 1993).

The level of dormancy for *S. pyramidalis* reported in this study is similar to that inferred by Andrews (1995), where, at a temperature fluctuation of 15/35°C, few seed did not germinate 6 months after seed maturity. This is in contrast to many Australian grasses, including *Sporobolus elongatus*, *Themeda triandra* and *Heteropogon contortus*, which exhibit seasonal dormancy, enabling germination to occur mainly during the wet season and giving the best chance of seedling survival and establishment (Campbell 1995; Groves *et al*. 1982; Lodge and Whalley 1981).

The occurrence of dormancy in all seed lots immediately after collection (Fig. 1) indicates that seed produced in any season could enter the seed bank and remain ungerminated if temperature, moisture and light conditions are not suitable for germination. However, the short duration of dormancy (Fig. 1) suggests that some *S. pyramidalis* seed is able to germinate when conditions are suitable throughout the year, regardless of season. It is also probable that seed produced in the early part of a warm/wet season will contribute to seedling emergence and recruitment in a later part of the same season, as happens with *Aristida ramosa* (Campbell 1995).

Seed size

This study showed that small seed of *S. pyramidalis* was 5–9% less viable than larger seed (Table 4). However, it is doubtful these differences would have any ecological consequence due to the small size of the differences. Although there were differences in dormancy at 1 month after collection, dormancy was unaffected by seed size when tested at least 3 months after collection (Table 5). The short duration of these differences suggest they are of little ecological significance.

Implications

A large proportion of the seed produced has high viability and can germinate soon after maturity, and this occurs independently of seed size and moisture conditions during seed maturation. This suggests that viable seed of *S. pyramidalis* only remains in the soil seed bank for extended periods due to unfavourable conditions rather than any inherent dormancy mechanisms. Therefore, large-scale germination and emergence of *S. pyramidalis* is likely as soon as environmental conditions are favourable. This may help explain that while annual seed production in dense infestations (>10 000 plants/ha) has been measured at 85 000 seeds/m^2 (Vogler and Bahnisch 2002), the viable soil seed bank generally remained below 6000 seeds/m^2 (W. D. Vogler, unpublished data).

The limited innate dormancy duration of *S. pyramidalis* seed is a potential weakness that may be exploited by land managers. Where existing plants are destroyed, seed input eliminated and favourable environmental conditions occur; the viable seed bank may be depleted relatively quickly to low levels. However, if *S. pyramidalis* seed has entered the soil seed bank and is located where germination is prevented, such as buried where light, temperature or moisture conditions are not suitable for germination it will be difficult for land managers to eliminate them. Therefore, minimal soil disturbance, along with maintaining a competitive pasture and some basic quarantine practices, should enable a diligent landholder to minimise the potential impact of this portion of the soil seed bank of *S. pyramidalis*.

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