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Hardseededness Development of Lotononis bainesii and Its Breakdown

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Abstract

Hardseededness development and its breakdown of *Lotononis bainesii* grown with *Digitaria decumbens*, at Mt. Cotton, southeast Queensland in Australia, were investigated. Strong hierarchical development of hardseededness took place within the next 6 days following the apparent cessation of embryo development, where germination and hardseededness of collected seeds were negatively correlated with each other with time. The further hardseededness development in standing plants was observed and this inherent attribute of hardseededness development was considered as one of the constraints for the plant replacement through the seedling recruitment, since the natural release of germination was found not reliable even with a high density of soil seed bank. The controlled fire contributed hardseededness breakdown but also killed the associated grass and a considerable proportion of soil seed reserves, depending on the intensity of the fire and the soil seed distribution, which affect replacement of plants.

Discipline: Grassland
Additional key words: controlled fire, hardseed softening, seedling recruitment, seed viability, soil seed reserves

Introduction

Lotononis (*Lotononis bainesii* cv. Miles) is a short-lived subtropical pasture legume when associated with pangola grass (*Digitaria decumbens*) at Mt. Cotton, southeast Queensland[3,11]. Persistence in plant yield was achieved by the variable grazing pressure in season to enhance the cycle of plant replacement by seedlings[5].

In the previous study[4], the burning and the cut-remove treatments, and the short duration heavy grazing contributed to plant regeneration by seedlings. The success of pasture renovation by the creation of the "gap" and subsequent seedling recruitment were considered to require a favourable combination of soil seed reserve increment and favourable conditions for seedling recruitment.

The high level of hardseededness and its slow breakdown may exert a primary control of population dynamics. Poor seedling regeneration often occurs where high soil seed reserves of lotononis are present. This is partly due to the high hardseededness and its slow breakdown[8], and also to an unfavourable environment for seedling emergence as well as to seedling susceptibility to competition, especially for light[6].

A series of field and laboratory studies were carried out during 1985 to 1987 to investigate hardseededness development in lotononis grown at Mt. Cotton, long-term hardseed softening of soil seeds, and their rapid breakdown by a controlled fire.

Hardseededness development

To investigate hardseededness development in the seed maturing process on plants under the natural diurnal environments, seeds of lotononis were collected from the pasture at sequential stages of seed development as first flower appearance classes (here-

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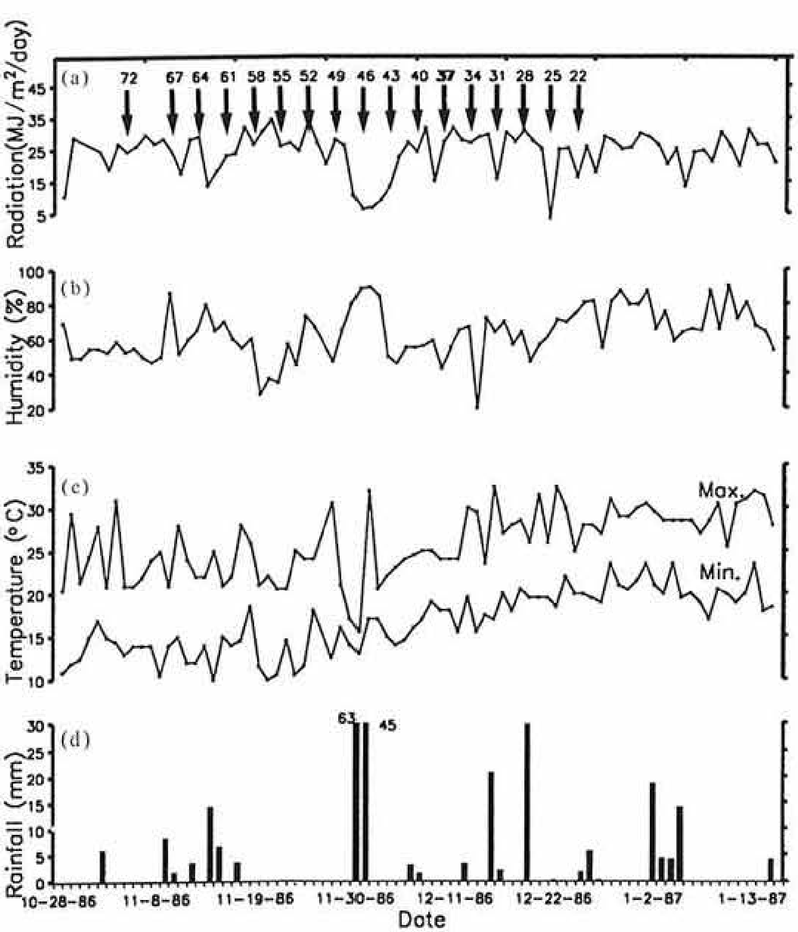


Fig. 1 Mean daily solar radiation at Redland Bay Research Station (a), mean daily relative humidity (b), mean daily maximum and minimum temperature (c) and daily rainfall (d) at Mt. Cotton Research Station during the experiment in 1986/1987
Arrow symbols and values indicate the FFA classes.

after FFA classes); the experiment was established by tagging inflorescences on 17 occasions in the period from 28 October to 24 December 1986. Those tagged inflorescences were harvested on 15 January 1987, and seeds of known FFA classes were submitted to a seed viability test. The surface texture development of lotononis seeds was also observed by a scanning electron microscope on a separate series of seeds harvested.

(1) Weather in 1986/87

Large fluctuations especially in daily maximum/minimum temperatures were evident (Fig. 1). Rainfall was well distributed during the experiment and the plant growth was normal after the prolonged drought in the early months in 1986. The duration of flowering (duration of anthesis of the first flowering floret to the last one) was constant throughout the measurements; it was ca. 6 days except in rainy weather where it tended to be longer.

(2) Germination and hardseededness development

It is evident that germination and hardseededness are inversely correlated with each other with time; the partial correlation coefficient was -0.71 (Fig. 2). There were similar FFA class effects on abnormal germination, fresh-ungerminated seeds and dead seed proportion as those on germination (results not

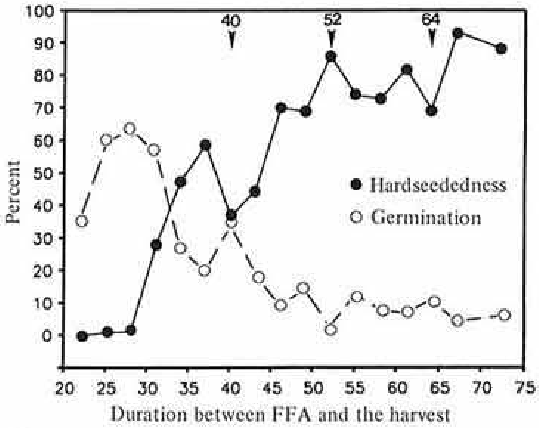


Fig. 2 Effects of duration from the first flower appearance until the harvest (15 Jan. 1987) on hardseededness and germination of lotononis seeds

shown); in general these decreased as FFA class increased.

(3) Electron microscope observations

Scanning electron microscopic observations on the surface structure of lotononis seeds from near the hilum and near the strophiole revealed the progressive development of textural patterns. The conspicuous reticulate texture and the depth of enclosed area evident at 18 and 24 days FFA (Plate 1, (d), (e)) decreased as the seed matured (Plate 1, (f)). The matted (Plate 1, (a)) and the open-matted texture (Plate 1, (b)) which resembled closely woven hyphae changed to an alveolate texture (Plate 1, (c)) as hardseededness developed.

Hardseededness breakdown

To investigate long-term hardseed softening of lotononis, seeds which were recovered from each 2 cm layer (0–10 cm; 5 layers) in the grazing experiment site using the soil seed recovery technique described by Jones and Bunch[7], were submitted to a seed viability test incubated at temperature of 30/20°C. A fire experiment was conducted to investigate effects of fire on soil seed reserves, seed viability as well as seedling regeneration and nodal regrowth of lotononis at Mt. Cotton.

(1) Long-term hardseed softening

Seeds recovered from each 2 cm layer up to 10 cm in October 1985 illustrated the relatively even distribution of seeds to 8 cm soil depth (Table 1). Seeds in the 2–4 cm layer exhibited significantly higher softening than other seed classes throughout the incubated storage period and seeds recovered from top 2 cm had the least soft seed proportion (Fig. 3).

Table 1. Distribution of the soil seed reserves in October 1985

Soil depth (cm)	Seeds recovered	Distribution (%)
0 – 2	360	31
2 – 4	281	25
4 – 6	213	19
6 – 8	205	18
8 – 10	78	7

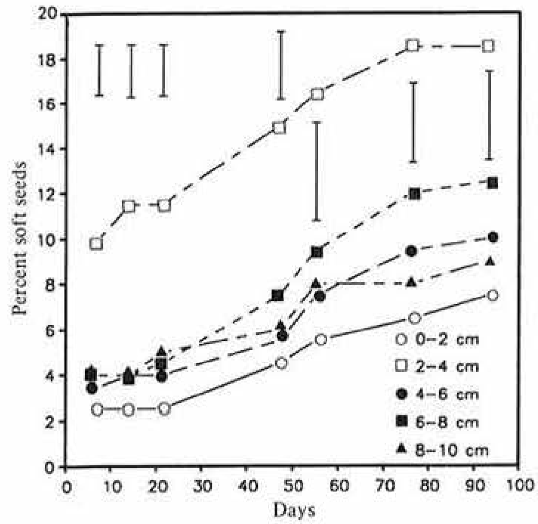
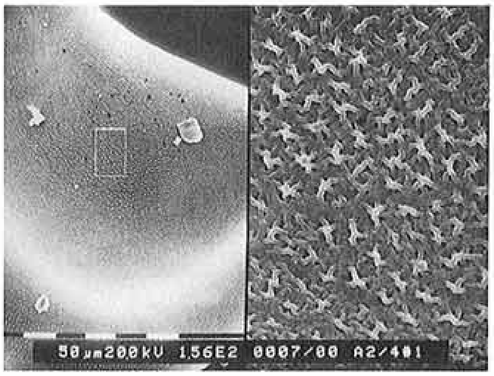


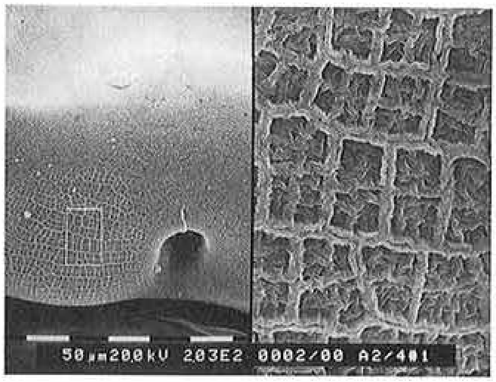
Fig. 3. Effects of seed position on hardseed softening of lotononis at 30/20°C
Vertical bars are the standard deviation of the means.

(2) Hardseededness breakdown by fire

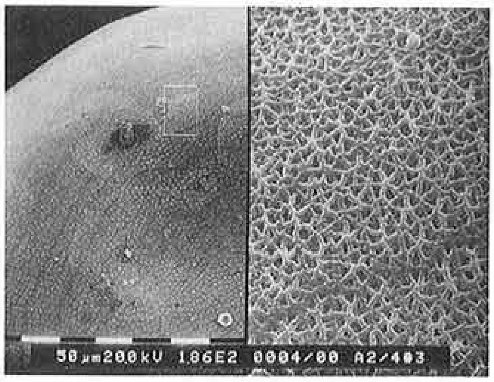
The fire experiment was conducted in February 1986, comprising two fuel loads of 2,500 and 5,000 kg hay/ha and a non fire (control) treatment. The fire of 2,500 kg/ha fuel load apparently but not significantly increased seedling density of lotononis compared with other treatments. The 5,000 kg/ha fuel load apparently but not significantly increased nodal root density of lotononis 57 days after the treatment (Table 2). Dead shoot density of the associated grass increased significantly ($P < 0.01$) as fuel load increased.



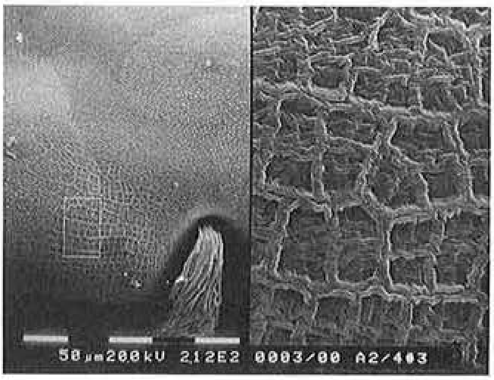
(a) 18 days after FFA



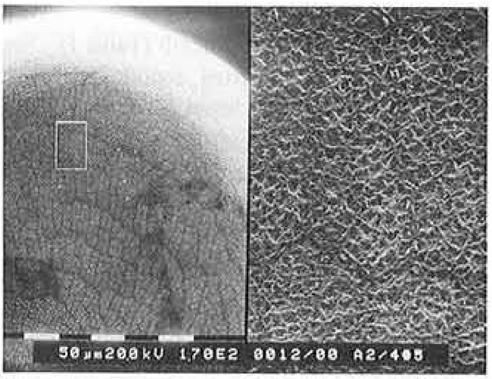
(d) 18 days after FFA



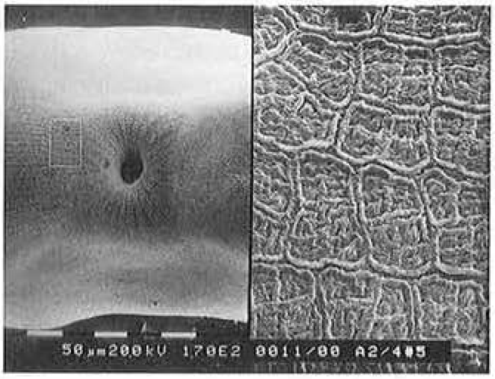
(b) 24 days after FFA



(e) 24 days after FFA



(c) 30 days after FFA



(f) 30 days after FFA

Plate 1. Scanning electron microscope photographs of lotononis seeds at 18, 24 and 30 days after FFA

Table 2. Effects of the fire on seedling emergence and nodal root regrowth of lotononis and live and dead shoot density of pangola grass at Mt. Cotton

Treatment	Lotononis		Pangola grass	
	Seedling density (/m²)	Nodal root density (/m²)	Live shoot density (/m²)	Dead shoot density (/m²)
Fuel load of 2500 kg/ha	1.3	0.2	113.8	148.6
Fuel load of 5000 kg/ha	0.5	0.9	49.5	191.7
Control (non fire)	0.3	0.2	205.6	0.0
LSD (P=0.05)	n.s.	n.s.	35.9	37.8

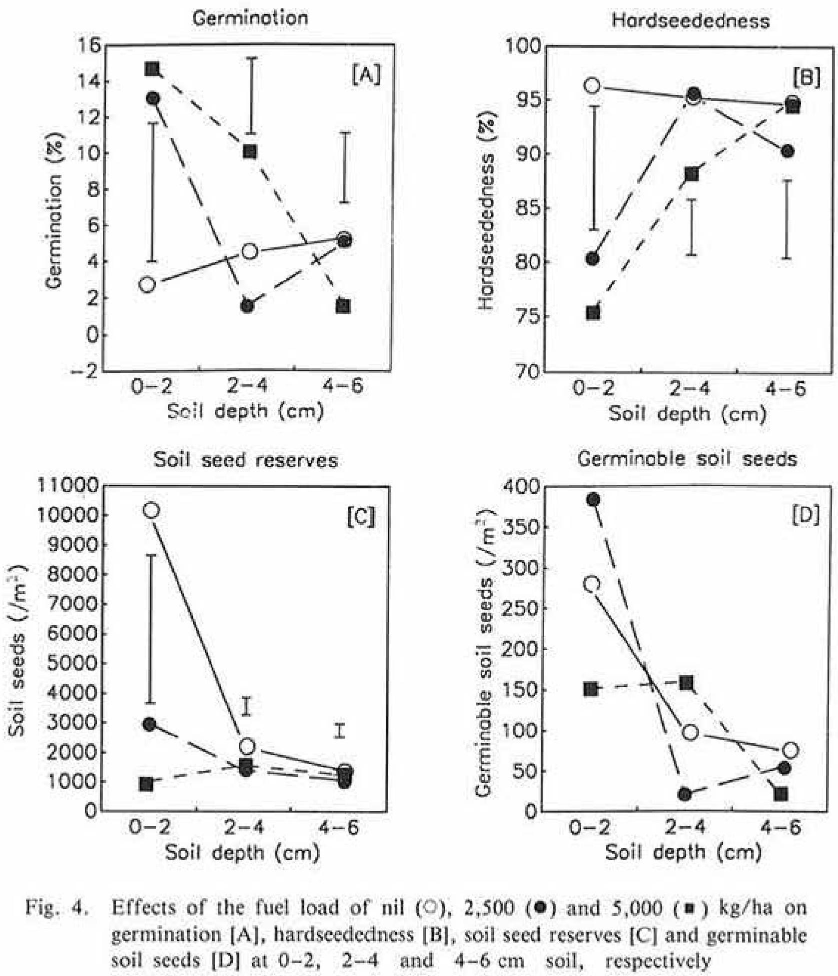


Fig. 4. Effects of the fuel load of nil (○), 2,500 (●) and 5,000 (■) kg/ha on germination [A], hardseededness [B], soil seed reserves [C] and germinable soil seeds [D] at 0-2, 2-4 and 4-6 cm soil, respectively
Vertical bars indicate LSD at P=0.05.

The fire affected soil seed reserves in the top 2 cm of soil dramatically (Fig. 4, [C]); these reserves were reduced to 30 and 10% by the fire of 2,500 and 5,000 kg/ha fuel load, respectively. The seed viability test revealed a significant ($P<0.01$) hardseededness breakdown and a significant increase of

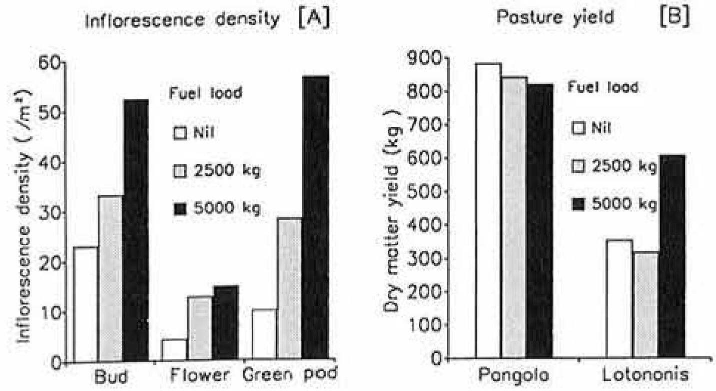


Fig. 5 Effects of the fuel load of fire on inflorescence density of lotononis [A] and pasture yield [B] at Mt. Cotton in December 1986

germination in the 0–2 cm layer by both fuel loads, and significant ($P<0.05$) decrease of hardseededness and a significant ($P<0.01$) increase of germination at 2–4 cm by the higher fuel load (Fig. 4, [A], [B]). In the following flowering season, the fuel load had positive and proportional effects on inflorescence density in the plots (Fig. 5, [A]) and the fuel load of 5,000 kg/ha apparently increased dry matter yield of lotononis, although not reaching significance (Fig. 5, [B]).

Discussion

1) Hardseededness development with time

Verano stylo developed hardseededness in positive relationship to the temperature during the stages from the first floret blooming to the browning of the upper articulation, when grown in the open field at St. Lucia, southeast Queensland[1]. In subsequent experiments in controlled environment cabinets at different temperature regimes, hardseededness development was enhanced by higher temperature and high hardseededness was positively linked with lower moisture content in seeds at harvest. Furthermore, 120-day storage at 77% relative humidity increased seed moisture content from ca. 10 to ca. 13% and decreased hardseededness from ca. 64 to 33% (as averages of temperature provenance treatments), while storage in lower relative humidity decreased seed moisture content and increased hardseededness[2].

Lotononis exhibited further hardseededness development with time and this was negatively correlated with germination (Fig. 2). Significant decline in hardseededness development in 40 and 64 days FFA classes may be associated with significantly lower maximum temperature during an earlier period. Similarly, the greater hardseededness increase in 52 days FFA class may be associated with the higher maximum temperature during the phase described previously (Fig. 1).

Browning of lotononis seed pods in the pasture was observed ca. 28 days after the first flower appearance. Embryo development apparently ceased with the rapid decline of dead seeds in 28 days after FFA in the 1986/87 series and in 27 days after FFA in the next flowering season (results not shown), and lotononis exhibited inherently high hardseededness levels within the next 6 days (Fig. 2).

The sequential structural change in lotononis seed coats displayed by the electron microscopic observations (Plate 1) in 18, 24 and 33 days after FFA appears to reflect hardseededness development, where the highest germination took place in 24 days after FFA and the rapid hardseededness development also occurred in the period from 27 to 33 days after FFA; this evidence is not definitive. The under-developed reticulate texture and its development from 18 to 24 days after FFA in lotononis (Plate 1, (d), (e)) may correspond to the developing surface of the soft Verano stylo seed, and the developed alveolate texture in 33 days after FFA may correspond to the hardseed surface of Verano stylo[2].

2) Hardseededness breakdown

Fire may break down hardseededness but also kill a considerable proportion of soil seed reserves, depending on the intensity of the fire and the soil seed distribution, which affect replacement of plants.

Seven managed fires were created on native grass and Stylosanthes species pastures during early or late dry, or early wet seasons at Katherine, Northern Territory in Australia[10]. All fires killed a considerable proportion of soil seeds, varying from 40 to 100% original population in 10 cm soil, and both early and late dry season fires significantly increased the proportion of soft seeds. However, this significant increase in soft seeds did not lead to successful legume seedling recruitment because of the large loss of soil seed. Two separate accidental fires on a buffel grass and Siratro pasture at Narayen, southeast Queensland, induced higher soft and dead seed proportions, but resulted in higher seedling recruitment in burnt sites[9].

The field fires induced a great loss of soil seed reserves (Fig. 4, [C]) in the top 2 cm soil with a significant increase in germinability [A] and a significant decrease in hardseededness [B], which was reflected in germinable soil seeds [D] and also partially reflected in seedling recruitment in April 1986 (Table 2).

Conclusion

Strong hierarchical development of hardseededness took place within the next 6 days following the apparent cessation of embryo development when germination exhibited the highest value, and newly matured lotononis seeds (FFA classes 22–28 days) exhibited further hardseededness development either in standing plants or in low humidity storage conditions for 200 days[3]. Due to this inherent attribute, soil seeds were found to be almost completely impermeable and the natural release of germination is not reliable even with a high density of soil seed bank (Table 1 and Fig. 3). Lenient stocking rate of 5 sheep/ha during the main flowering and seed setting phase led to subsequent seedling emergence[6] and the spelling for 1 year increased soil seed reserves by a factor of 6 as reported in the previous paper[4]. The fire contributed to hardseededness breakdown but also destroyed a considerable proportion of soil seeds in the top soil. Hence, these management strategies might be conveniently applied in a grazing system to replenish recently set seeds into soil seed banks for seedling recruitment of this short-lived legume, especially under the circumstance where soil seed reserves are less than 6,000/m^2 which usually indicates poor lotononis presentation yield.

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