Germination of soft brome (*Bromus hordeaceus*)

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Summary

Soft brome (*Bromus hordeaceus*) seed germinated completely and rapidly in dark conditions over an isothermal temperature range of 10 to 30°C. Germination was slow at 7°C; slow and reduced at 35°C and inhibited at 38°C.

Chilled seed germinated more completely in light than non-chilled seed, but chilling did not enhance germination in dark conditions.

Periods of prior wetting of between 4 and 40 h had a stimulatory effect on germination during the first 4 days of incubation. From 40 to 60 h of prior wetting there was a gradual decline in germination to 47% assessed after 15 days of incubation.

At 38°C, soft brome exhibited a high-temperature enforced dormancy. Furthermore, imbibed seed exposed to this temperature showed increasing mortality from 14% after 10 days to 42% after 20 days.

These germination and seed survival characteristics are discussed in relation to the success of the species in southern Australia.

Introduction

Many of the agriculturally important annual weeds in southern Australia provide excellent examples of invasion and colonization over widespread areas by exotic plant species. Such species require, among other things, the production of a large number of propagules, seed dormancy and the ability of seeds to germinate over a range of temperatures that prevail during autumn and early winter in this region.

Soft brome (*Bromus hordeaceus* ssp. *molliformis*) (often referred to as *Bromus mollis*) is a conspicuous example of a weed of European and west Asian origin which has become naturalized in all States of Australia (Willis 1970).

Winter annuals germinate most rapidly between 15 and 20°C but are capable of germinating over a range from just above 0°C to greater than 30°C (Rossiter 1966). Soft brome germinated uniformly well in tests conducted at day/night temperatures of 30/17°C and 23/10°C and it was concluded that it could germinate during all seasons of the year in southern California (Ashby and Hellmers 1955).

A number of experiments were conducted to gain more specific information on the germination behaviour of *B. hordeaceus* that may better explain its present and increasingly widespread distribution in southern Australia.

Materials and methods

Seed source and germination procedures

The seed in all experiments was obtained from seed cleanings of a commercial crop of perennial ryegrass harvested from a single paddock at Mansfield in north-eastern Victoria. The experiments were carried out 6 months after collection to ensure that the seed was non-dormant. Germination tests were on seeds placed on two layers of moistened blotting paper overlying moistened towelling in shallow metal trays. Light was excluded by using a tight fitting metal lid. Normal daylight from windows adjacent to glass-topped tanks (with the germination trays supported above a layer of water) provided light for tests in experiment 3. In the same experiment seeds were chilled by keeping them in a refrigerated cabinet in an imbibed state at 7°C for 7 days.

All germination tests were of five replicates each of 50 seeds except in experiment 4 where 100 seeds were used per replicate. Germination, recorded daily (at approximately the same time), was taken as plumule emergence. All results are expressed as percentages.

Experimental

Details of the five experiments are summarized in Table 1.

Statistical treatment of germination results

The results from all experiments were transformed to arcsine values before analysis of variance was carried out (experiments 1–3, split plot design; experiments 4 and 5, randomized block design).

Significant differences between treatments were calculated from arcsine least significant differences and are shown on Figures 1 to 5.

In experiments 1, 2 and 3, the time to 50% of final germination (G_{50}) as influenced by different temperatures and treatments was calculated by a procedure of parallel curve analysis involving a logistic function which is a special case of the Richards function (Richards 1959).

Table 1 Details of temperature regimes and test conditions for the five germination experiments

Experiment	Germination temperature regime or pre-treatment	Test conditions and comments
1	Isothermal temperatures of 7, 10, 15, 20, 25, 30, 35 and 38°C	Dark conditions
2	Alternating temperatures 10–25°C and 15–25°C	Dark conditions Lower temperature imposed overnight for 16 h
3	Alternating temperatures of 20–30°C	Pre-chilling / No pre-chilling × Dark conditions / Light conditions
	and	
	20–35°C	Pre-chilling / No pre-chilling × Light conditions Lower temperature imposed overnight for 16 h
4	Seed pre-soaked for periods from 2 to 60 h at 15°C	After drying at 30°C for 24 h, seeds were germinated at 15°C Dark conditions
5	Seed imbibed at 38°C for periods of 1 to 10 days and 20 days	After high temperature treatment seeds were immediately transferred to a germinating temperature of 15°C Dark conditions

Results

Experiment 1

Germination response to seven isothermal temperatures is shown in Figure 1. Germination was rapid and complete at temperatures from 10 to 30°C with the time to G_{50} decreasing as the temperature increased from 10 to 30°C. At 7°C no germination occurred until after day 11, but G_{50} was reached after 13.1 days (Figure 1). At 35°C germination was slow and reached only 30% after 15 days, although G_{50} occurred after 4.9 days. A temperature of 38°C inhibited germination in *B. hordeaceus*.

Experiment 2

Germination at the two alternating temperature regimes of 10–25° and 15–25°C was relatively fast and complete with G_{50} taking 4.5 and 4.0 days respectively (Figure 2). Chilling did not significantly alter the germination response and hence values for that treatment are not reported.

Experiment 3

Pre-chilled seed at 20–30°C in light and dark conditions had high germination, with G_{50} being reached after 1.6 and 1.5 days respectively. Without pre-chilling in dark conditions, germination was significantly slower, with G_{50} taking 3.4 days (Figure 3). Germination was depressed in light without pre-chilling. Maximum germination was only 63% with G_{50} being 4.3 days. A subsequent chilling treatment resulted in a further germination of *c.* 30% (Table 2).

Germination at 20–25°C in light proceeded significantly faster with pre-chilled seed (G_{50} = 1.7 days) than with no pre-chilling (G_{50} = 6.5 days) and the final germination was *c.* 35% higher in the former compared with the latter treatment (Figure 4). A subsequent chilling treatment resulted in a further germination of *c.* 42% in the originally unchilled seed (Table 2).

Experiment 4

Periods of wetting between 4 and 40 h followed by drying, had a stimulatory effect (with peaks at 18 and 32 h) during the first 4 days of germination (Figure 4). Germination potential after 10 days was virtually unimpaired for seeds treated to periods of 2 to 32 h of prior wetting compared with the non-wetted control treatment. Germination decreased with 36 h and increased with 40 h prior wetting and thereafter, a decline to a level of 47% germination after 60 h prior wetting (Figure 4). Germination of seed from prior wetting treatments of 32 to 60 h was associated with a lag interval between plumule and radicle emergence. For example, after 6 days of the germination test, 45 of 60 seeds from the 44 h prior wetting treatment which had an emerged plumule, did not have an emerged radicle. The treatment of 30 h or less had no lag interval between plumule and radicle emergence (data not presented).

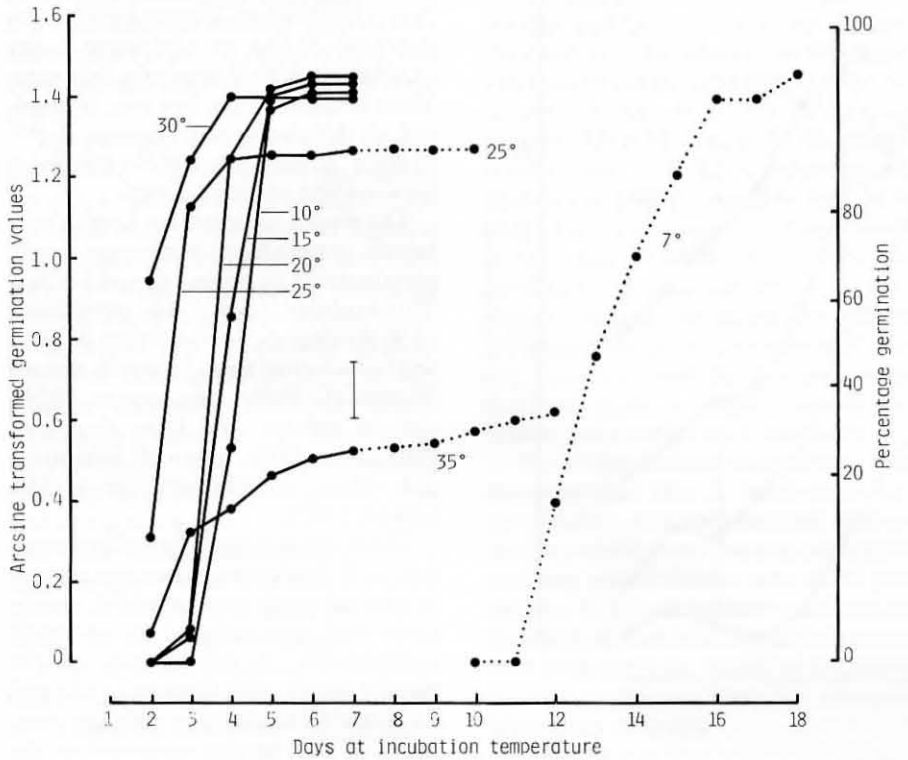

Figure 1 The germination (shown as arcsine values) of seeds of *B. hordeaceus* incubated at temperatures of 7, 10, 15, 20, 25, 30 and 35°C. The bar represents arcsine least significant difference between any germination temperature and the time after the start of incubation ($P < 0.01$) and apply only to the solid lines of the graph.

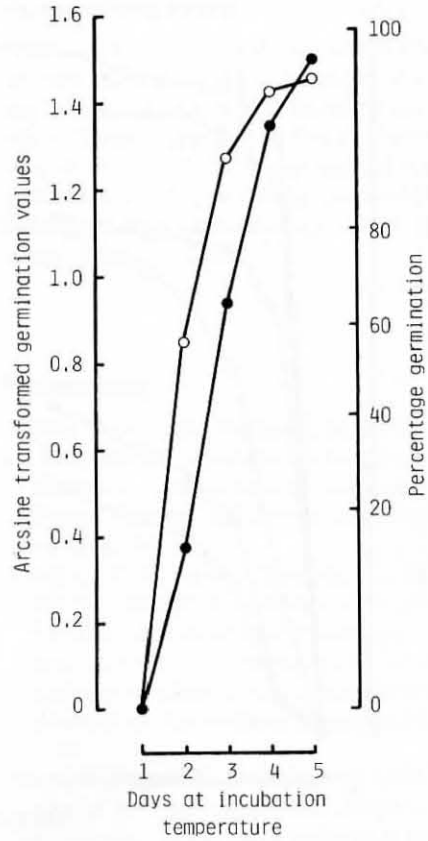

Figure 2 The germination (shown as arcsine values) of seeds of *B. hordeaceus* following chilling and dark incubation at alternating temperatures of 10–15°C (•) and 15–25°C (o). Additional footnote as for Figure 1.

Experiment 5

The exposure of imbibed seed to a temperature of 38°C resulted in seed mortality increasing as the duration of the high temperature treatment increased from 1 day (1% mortality compared to the control) to 10 days (14%) and 20 days (42%) (Figure 5).

Table 2 Maximum germination of unchilled seed incubated at the alternating temperature of 20–30°C and 20–35°C, and final germination after the imposition of a chilling treatment

Temp. regime (°C)	Max. germ. (%)	Final germ. after chilling treatment[A] (%)
20–30	63.0	92.0
20–35	51.5	94.0

[A] After an initial incubation period of 15 days, a chilling treatment was imposed for 2 days and final germination was recorded after a further 6 days of incubation.

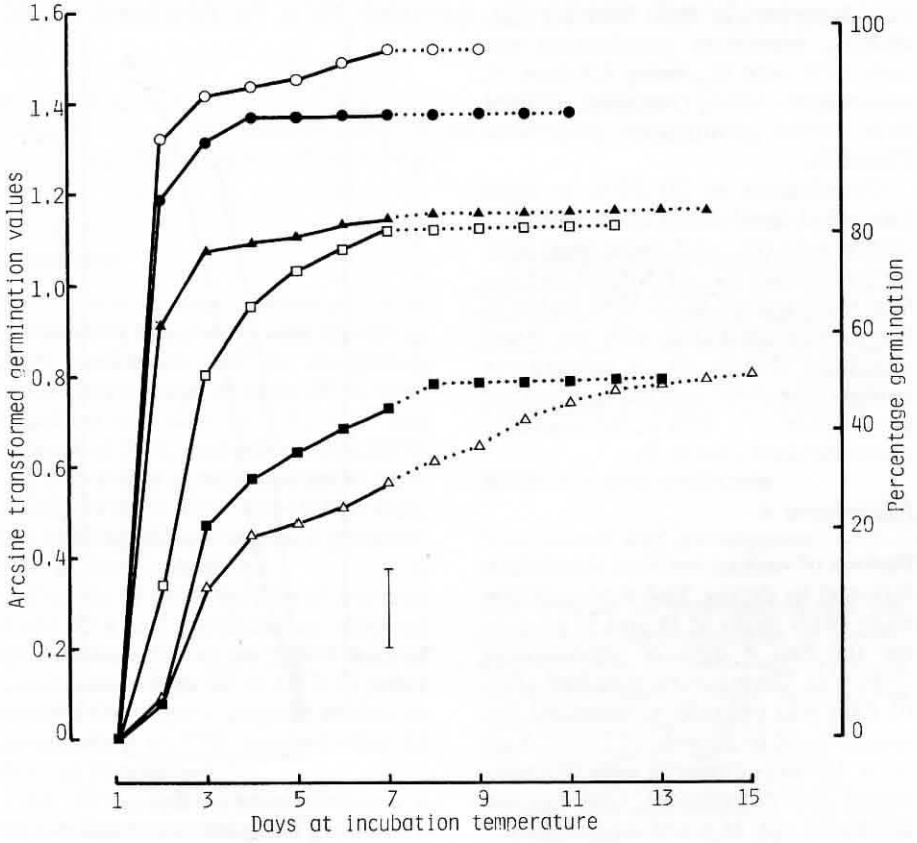

Figure 3 The germination (shown as arcsine values) of seeds of *B. hordeaceus* following chilling and incubation at 20–30°C in the light (•) and dark (o); no chilling and incubation at 20–35°C in the light (■) and dark (□) and incubation at 20–35°C in the light following chilling (▲) and no chilling (Δ). Additional footnotes as for Figure 1.

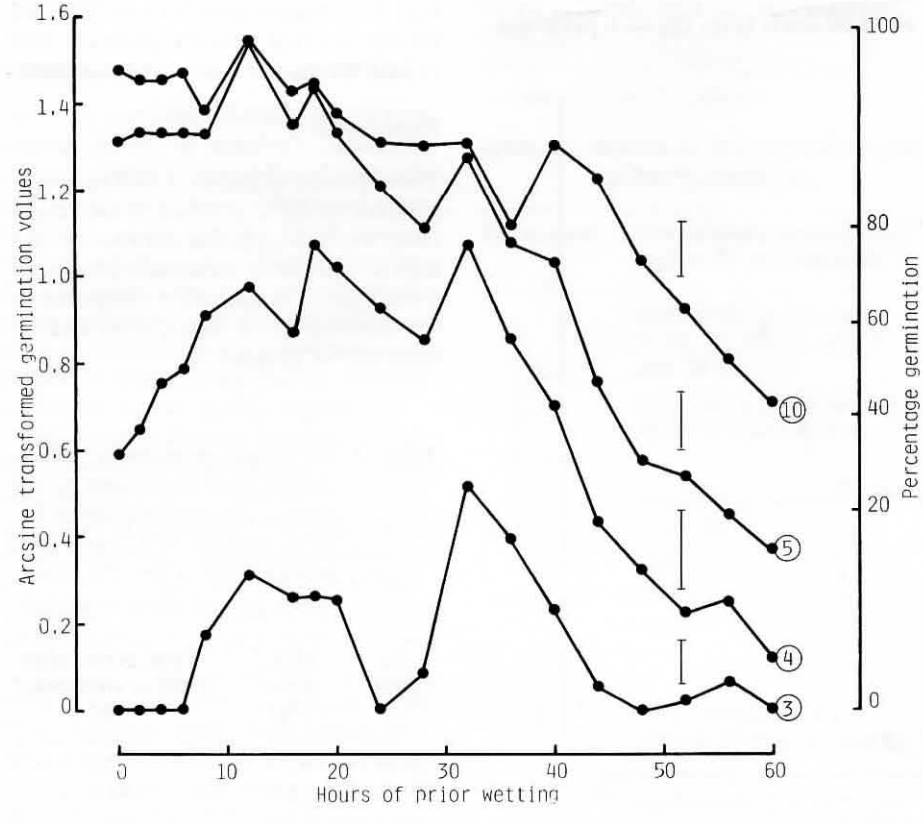

Figure 4 The germination (shown as arcsine values) of seed of *B. hordeaceus* after various periods of prior wetting at 15°C, followed by drying at 30°C and then incubation at 15°C. The number of days after the start of the final incubation at 15°C is shown within the circle on each curve. Bars represent arcsine least significant differences between wetting treatments for each day ($P < 0.01$).

Discussion

Seed of *B. hordeaceus* germinated satisfactorily in dark conditions over a range of isothermal temperatures from 7 to 30°C and in alternating regimes within that range. Such a response allows it to germinate during much of the year except in the dry summer months and in early autumn before seed dormancy (McGowan 1970) is relieved. In a pasture situation at Rutherglen, however, McGowan (1970) reported that seed of *B. hordeaceus* was observed to germinate only between mid-February and mid-July in 1966 and between the end of March and early September in 1967.

Light appeared to slow the rate and reduce the total germination of non-chilled seed at alternating temperatures. It has been previously reported that light inhibits the germination of freshly shed seed of several *Bromus* species (Hulbert 1955) but Froud-Williams (1981) demonstrated that the inhibition appeared not to be prolonged in *B. sterilis* and was not apparent for either *B. hordeaceus* or *B. erectus*. The present observations, however, indicate that a mechanism may operate to prevent the germination of seeds lying on the soil surface until a period of cool temperatures has intervened. This would occur with the onset of cooler autumn conditions, marking the start of more favourable conditions for germination and seedling establishment. The observation that chilling of previously non-chilled seed for only 2 days stimulated maximum germination potential during an additional 6-day incubation period supports this view. More detailed study, however, is required to determine the apparent light-chilling interaction which influences germination in this species.

The results indicate that seed of soft brome, given adequate moisture, would germinate on or below the soil surface. This explains, in part, the persistence of *B. hordeaceus* in the perennial grass seed producing areas in north-eastern Victoria (L. Parks, pers. comm., 1978), and in pasture and crop situations (McGowan 1970), although cultivation did reduce seedling emergence (McGowan 1967).

There was a stimulation of germination in *B. hordeaceus* when wetting and drying of seeds had preceded conditions that were suitable for complete germination. A comparison of the present results with those of Cocks and Donald (1973) indicates that seed mortality of the species increased in the order: *Lolium rigidum*, *B. hordeaceus* and *Hordeum leporinum* after similar periods of pre-wetting. *B. hordeaceus*,

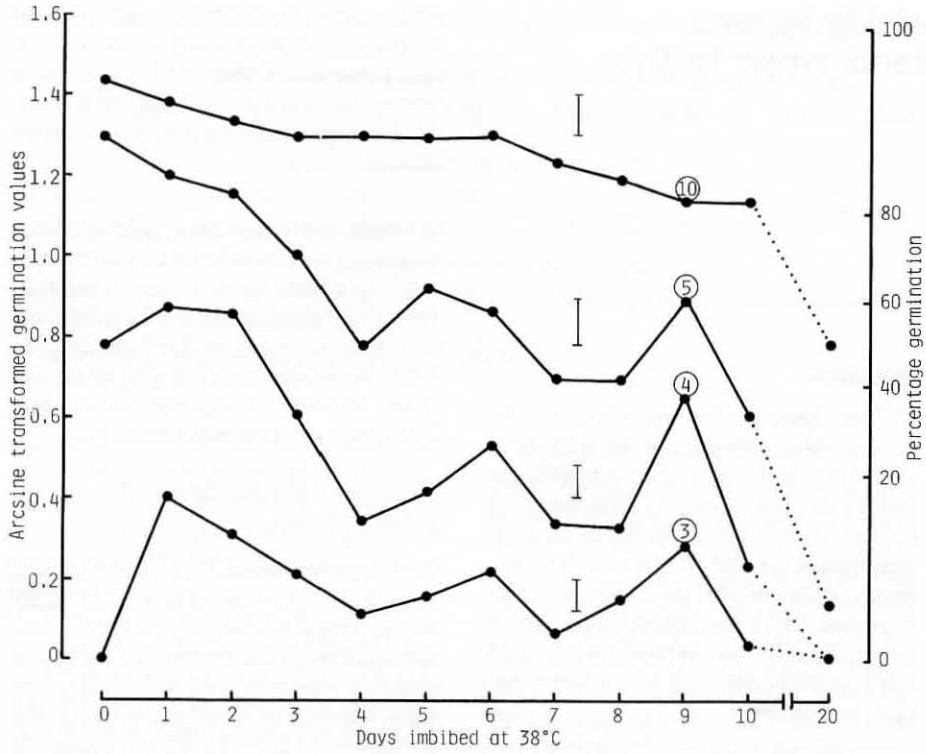

Figure 5 The germination (shown as arcsine values) of seeds of *B. hordeaceus* which were imbibed at 38°C for 1 to 10 and 20 days and then incubated at 15°C. The number of days after the start of incubation at 15°C is shown within the circle on each curve. Bars represent arcsine least significant differences between treatments for each day ($P < 0.01$).

however, required a longer period of pre-wetting (*c.* 32 h) compared with *L. rigidum* (18 h) and *H. leporinum* (10 h) before a gradual decline in seed viability was apparent. The ecological significance of the wetting and drying of seed in a Mediterranean environment (i.e. stimulation of germination in autumn after seeds have been exposed to cycles of wetting and drying from intermittent summer rains) has been discussed by Cocks and Donald (1973).

The decline in the rate of germination that accompanied increasing periods of prior wetting would reduce the ability of some seed to become established. With seeds that had started to germinate during the period of wetting, the subsequent drying treatment killed the protruding radicle. Many of these seeds germinated but plumule emergence preceded radicle emergence (Flood, unpublished data) with primary roots being produced from the base of the dead radicle. This also occurred with *L. rigidum* and *H. leporinum* and was considered to be a valuable survival mechanism for these species (Cocks and Donald 1973) as it would be for *B. hordeaceus*.

B. hordeaceus exhibited a temperature enforced dormancy (Harper 1959) when imbibed seeds were incubated at 38°C and mortality was 14% after 10 days and 42% after 20 days. This mechanism would prevent germination of non-dormant seeds during periods of summer rainfall where climatic conditions would not favour satisfactory seedling establishment. *H. leporinum* and *L. rigidum* also have a high-temperature dormancy mechanism (Cocks and Donald 1973) but *B. hordeaceus* has the ability to withstand exposure to an elevated temperature for longer periods than the other two species. After 10 days at 38°C, germination was still 82%, whereas *H. leporinum* and *L. rigidum* had 35% and zero seed survival respectively (Cocks and Donald 1973). However, although temperature enforced dormancy can play an important rôle in preventing the germination of seed during summer, prolonged exposure of imbibed seeds to high temperatures causes substantial seed mortality.

The results of these experiments have demonstrated that *B. hordeaceus* has germination and seed survival characteristics which contribute to successful seedling establishment and to its persistence as a troublesome weed species in southern Australia. Some field measurements, however, would be necessary to confirm the applicability of these laboratory findings.

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