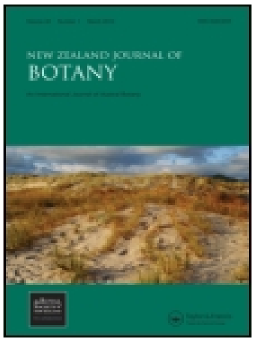

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New Zealand Journal of Botany

ISSN: 0028-825X (Print) 1175-8643 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzb20

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To cite this article: Peter A. Williams , David A. Norton & Jane M. Nicholas (1996) Germination and seedling growth of an endangered native broom, Chordospartium muritai A.W.Purdie (Fabaceae), found in Marlborough, South Island, New Zealand, New Zealand Journal of Botany, 34:2, 199-204, DOI: 10.1080/0028825X.1996.10410684

To link to this article: http://dx.doi.org/10.1080/0028825X.1996.10410684

Published online: 31 Jan 2012.

New Zealand Journal of Botany, 1996, Vol. 34: 199–204
0028–825X/96/3402–0199 $2.50/0 © The Royal Society of New Zealand 1996

Germination and seedling growth of an endangered native broom, *Chordospartium muritai* A.W.Purdie (Fabaceae), found in Marlborough, South Island, New Zealand

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Abstract In the wild, adult *Chordospartium muritai* shrubs and trees up to 6 m tall are confined to a single population in the northern South Island. There are few juveniles and seedlings have only recently been recorded. Seed viability, germination requirements, fate of seeds in the soil seed bank, and seedling growth were investigated. Seeds required scarification, after which a high proportion germinated over a wide range of temperatures, but particularly between 20°C and 24°C. The few seeds that survived a year's burial were still viable, suggesting the effects of soil scarification. Seedling growth was very slow and 65% of seedlings that survived the first 2 years reached a height of only 12 cm. Site factors including past grazing, competition from herbs, and lack of suitable substrates, are considered largely responsible for the failure of *C. muritai* regeneration. The management implications of the results are discussed.

Keywords *Chordospartium muritai*; threatened plants; germination; seed banks; seedling growth; conservation

B95021
Received 5 May 1995; accepted 7 December 1995

INTRODUCTION

An apparent failure of regeneration through reproductive failure, lack of seedling establishment, competition with weeds, and predation of young plants, appears to be prevalent among many species of threatened woody plants in New Zealand, for example, *Muehlenbeckia astonii* * (de Lange & Silbery 1993) and *Pittosporum obcordatum* (Clarkson & Clarkson 1994). For the long-term survival of such taxa, it is suggest that conservation management should focus on the causes of the regeneration failure.

The tree broom genera *Chordospartium* and *Notospartium* (Fabaceae), containing two species each, are confined to the north-eastern South Island, especially Marlborough. All four species are uncommon, and *Chordospartium muritai* particularly so, with only about 30 naturally growing shrubs and trees confined to a single coastal cliff site (Purdie 1985). *C. muritai* has been categorised as 'Endangered' according to the IUCN classification (Cameron et al. 1993). The population has been well augmented with nursery-grown plants, but wild juveniles and seedlings are very uncommon. Rabbit (*Oryctolagus cuniculus*) browsing and competition from herbaceous vegetation (Purdie 1985), especially introduced grasses, appear to be the main factors preventing natural regeneration. The site was fenced several years ago, which prevented sheep from grazing, and the resulting long grass has possibly created an unsuitable habitat for rabbits. Apart from the observations of Purdie (1985) the ecology of *C. muritai* is not known, and information on related species is also limited (Conner & Conner 1988).

As a contribution towards understanding the ecology of *C. muritai*, and for its successful conservation, we investigated the viability of seeds, their germination requirements, and their fate in the soil seed bank, to determine whether these aspects of the

*Nomenclature follows Allan (1961) and Webb et al. (1988).

life cycle were limiting factors in the perpetuation of *C. muritai* at its natural site. During the early stage of this investigation small wild seedlings were recorded for the first time at the site. Their survival and growth over the ensuing two years is reported here.

METHODS

Seed germination

C. muritai seeds are produced irregularly (Purdie 1985). Seeds pods were collected from several trees in March 1992 following a heavy flowering in January. The pods were shelled and the seeds stored in a paper bag at room temperature. The viability of fresh seed was determined using a 1% aqueous solution of tetrazolium bromide. Three replicates of 25 seeds each were used. Seeds were soaked in water for 24 hours and then soaked in the tetrazolium bromide solution for 48 hours. Seeds that had not started to germinate after 48 hours were pricked with a sharp needle and soaked for a further 48 hours.

The effects of temperature on germination were investigated in June. Five hundred and twenty-five seeds were pricked and soaked overnight in water and divided into 21 lots of 25 seeds. Each lot was placed in a petri dish lined with moistened filter paper and placed in groups of four replicates on a temperature gradient bench at 10, 15, 20, 24, and 28°C under a 40 watt fluorescent tube (giving a cool white light). One dish containing seeds was kept as a control plate at room temperature. Dishes were examined over 13 days, when germinated seeds were removed and the dishes rotated within the groups on the plate.

Buried seeds

To determine the length of time seeds would remain viable in the soil, 15 subsamples of 25 seeds were sealed in nylon mesh bags with a gauze size of 1 mm. These were buried in late April 1992 on a north-facing slope under 1 cm of soil in the sparse grassland surrounding the adult trees. The ground surface above the bags was exposed to the high light levels typical of open grassland at the site. Each bag was covered with a small wire cage. Three bags were lifted five times (September 1992, November 1992, April 1993, October 1993, March 1994) over the ensuing two years. Whole seeds that remained in the bags after lifting were washed and placed in petri dishes lined with filter paper. They were not scarified. The number of seeds in each dish varied depending on how many remained in the bags; only three or four seeds were available from each of the last three dates. Dishes were placed in natural light at room temperature, moistened with tap water, and examined at intervals. After 81 weeks the five seeds remaining from the first bags lifted were tested for viability using tetrazolium bromide solution.

Analysis of variance was used on archsine transformed data to compare the means of the final germination percentages of seeds buried for 20 weeks and 30 weeks.

Seedling survival and growth

Seedlings ($n = 20$) were originally tagged in August 1992, and their extended length was recorded at intervals until March 1994. Live plants were substituted for dead plants to maintain sample size, and further seedlings were added to the sample as they were detected during continued searching in the area. The sample size reached a maximum of 33 in spring 1993. The majority of seedlings were covered with small wire cages and their continued survival monitored over time. There is probably a total of between 50 and 80 seedlings at the site.

RESULTS

Germination

After 48 hours soaking in tetrazolium bromide solution, $12 \pm 4\%$ of unpricked fresh seeds had begun to swell. After being pricked, and soaked for a further 48 hours, $98 \pm 3\%$ of fresh seeds had swollen, and the embryos were stained bright red. Germination of pricked seed was rapid at 20°C and 24°C, and about 90% of seeds germinated in 4 days. Germination was slower at 10°C: 40% of the seeds germinated in 7 days, and 90% after 13 days (Fig. 1). At 15°C and 28°C, and in the control dish, germination varied between 88% and 92 % after 6–8 days.

Twenty-five percent of buried seeds had either germinated or disappeared from the bags between autumn and the first spring (20 weeks), and over 90% had disappeared over the first winter (55 weeks) (Fig. 2). About 5% (one per bag) of the seed remained in the bags after two years. Seeds from the first collection (20 weeks) and the second collection (30 weeks) germinated rapidly in the laboratory for several weeks after being collected, but then the germination rate slowed (Fig. 3). Mean germination percentages at the end of the experiment were significantly different for these two collections ($P < 0.001$; F 97.7). Fifteen percent of seeds ($n = 9$) from the first collection (20 weeks) remained ungerminated after

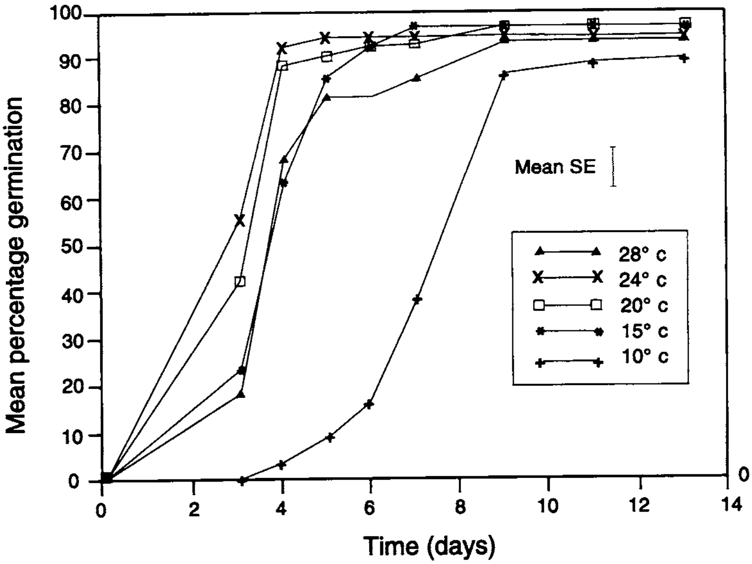

Fig. 1 Cumulative germination of *Chordospartium muritai* seeds at five controlled temperatures.

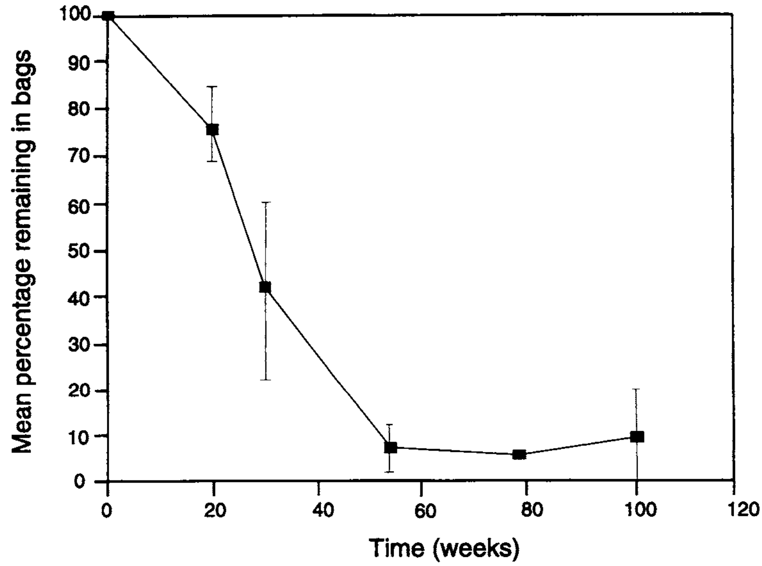

Fig. 2 Percentage of *Chordospartium muritai* seeds remaining in buried bags over time.

81 weeks, and all were viable (based on tetrazolium stain). All seeds from the second collection (30 weeks) had either germinated or decayed within 40 weeks of being collected. The several seeds retrieved from bags that had been buried for more than 30 weeks all germinated within a few days in the laboratory.

Seedling growth

Germination of seeds largely occurred in the autumn of 1992. Few additional seeds were produced in the summer of 1993/94 or 1994/95, and consequently no further burst of seedlings has yet appeared. The results of the 1994 moderate flowering have not been observed.

Seedlings produced following the 1992 flowering season were only about 2 cm tall when measurements commenced in spring 1992, and of the general form described by Purdie (1985). About 88% of seedlings survived the first summer and almost doubled their height to 4.0 cm by the end of 4 months (Fig. 4). Most seedlings also developed a second or third shoot over this period. Sixty-eight percent of the original seedlings survived by the end of two

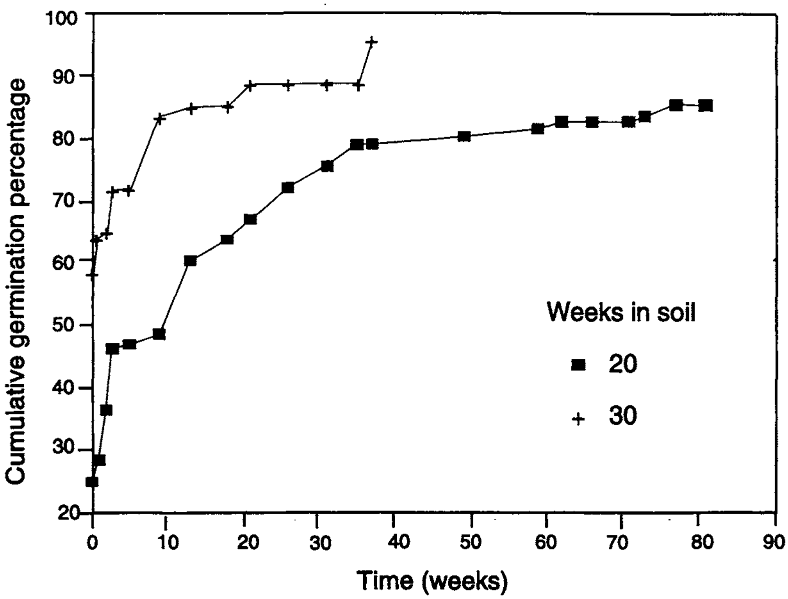

Fig. 3 Germination of *Chordospartium muritai* seeds in the laboratory at room temperature after 20 weeks and 30 weeks burial.

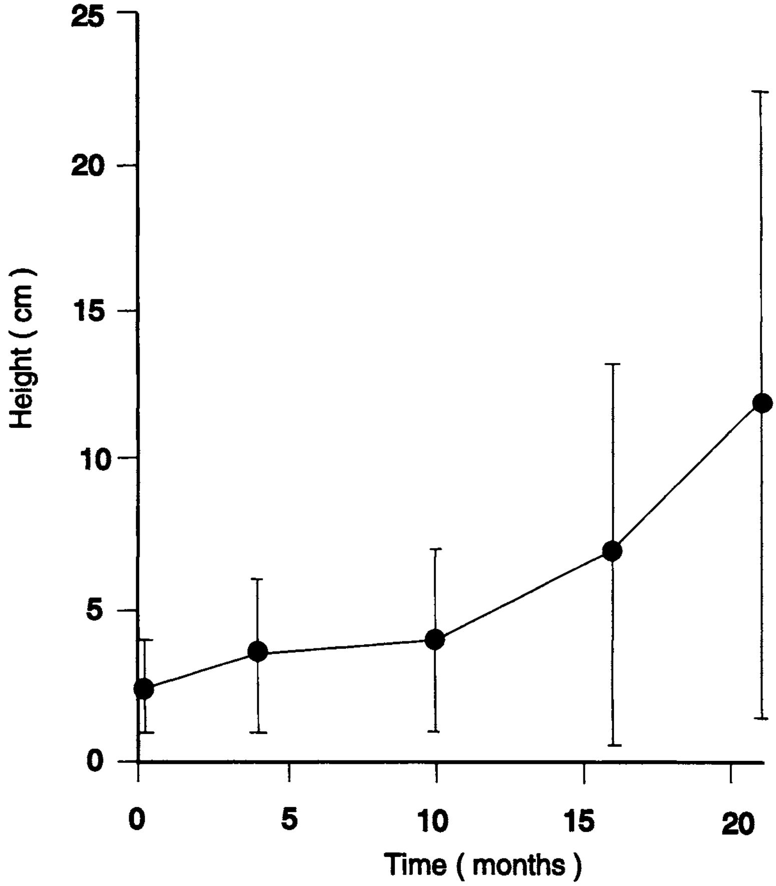

Fig. 4 Cumulative shoot length of *Chordospartium muritai* seedlings in the wild (mean ± SD).

summers, and the average seedling height increased to 12 cm at about 21 months of age. Death or disappearance of seedlings was associated with the most extremely stony dry ridges in full sun, with instability of the substrate exposing their roots, and with smothering by long grass or other herbs. No browsing of the seedlings by rabbits was observed.

DISCUSSION

The poor germination of unpricked fresh *C. muritai* seeds suggests that a high proportion experience delayed germination because of a physical constraint imposed by the seed coat (see Burrows 1989). A similar response was found in another species of the genus, *Chordospartium stevensonii* (Conner & Conner 1988). Dormancy induced by a water-impermeable testa appears to be common among native Fabaceae (Fountain & Outred 1991).

Scarification is usually required to germinate seeds of native Fabaceae (Fountain & Outred 1991), and once the seed coat had been broken in *C. muritai* there was little impediment to germination, which was rapid at 20–24°C and delayed down to 10°C. This is comparable with *C. stevensonii*, for which the optimum temperature for germination is 20–25°C (Conner & Conner 1988). Soil temperatures recorded at 10 cm depth for Blenheim (25 km west of the *C. muritai* site) are above 10°C between October and April and above 15°C for the three warmest months (New Zealand Meteorological Service undated). Soil temperatures at shallower depths would be warmer, providing near-optimum temperature conditions for *C. muritai* germination for more than half the year. However, soil moisture conditions are likely to be limiting during the warmest months because mean annual rainfall at Blenheim is approx. 624 mm (New Zealand Meteorological Service undated). Many seeds germinate the year they fall, but an unknown percentage enters the soil seed bank. Most of these germinate or otherwise disappear within the first year, but about 5% may remain viable in the soil for up to two years.

The New Zealand flora is characterised by species with relatively short-lived seed banks (Burrows 1994), and both *C. muritai* and the related *C. stevensonii* (Conner & Conner 1988) fit this pattern. However, the survival of a small percentage of seeds in the soil for up to two years accounts for the occasional new seedling appearing amongst the tagged seedlings over the course of this study. The effect of soil scarification, whatever the mechanism, is illustrated by the more rapid germination of seed lifted after 30 weeks as against either fresh seed or seeds lifted after only 20 weeks. The production of viable seed, albeit on an irregular basis (Purdie 1985; pers. obs.), does not appear to be a limiting factor in the survival of *C. muritai* in the wild.

Seed survival in the soil beyond a few months is much lower for *C. muritai* and other native brooms (Conner & Conner 1988; P.A.Williams unpubl. data) than for the adventive broom (*Cytisus scoparius*), which survives transport in river gravels (Williams 1981) and deep burial in the soil for long periods (Partridge 1989). The lack of a long-term seed bank probably contributes to the rarity of *C. muritai* in comparison with the abundance of *C. scoparius* in the Marlborough landscape.

The growth of *C. muritai* seedlings during their first year averaged less than 2 cm, which can be considered extremely slow. During this period seedlings would be vulnerable to competition from grasses and other plants, and to grazing in earlier years before the area was fenced (Purdie 1985). With the end of sheep grazing and the decline of the rabbit population, conditions have become more favourable for seedling survival, but only in localised areas. Rank grass covers most ground receiving full sunlight in the vicinity of the adult trees, and it is only where grass growth is inhibited – in a narrow zone between here and the areas of deeper shade created by the crowns of *C. muritai* and *Olearia paniculata*, or on the stony outcrops too dry for grass – that *C. muritai* seedlings survive. Most of these sites are highly erosion-prone, and their long-term stability is unlikely.

It appears that a failure in seed production or germination is not the major constraint to regeneration in *C. muritai*, but that factors associated with the site are responsible, including grazing, competition (especially with grasses) (Purdie 1985), and limited availability of suitable establishment sites. Areas suitable for the long-term natural regeneration of *C. muritai* within the present reserve are uncommon, and no great resurgence of *C. muritai* can be expected. This problem is not unique to *C. muritai*, but appears to apply to a number of other threatened New Zealand plant species (e.g., Morgan & Norton 1992; de Lange & Silbery 1993; Clarkson & Clarkson 1994) probably owing to the spread of adventive plant species and mammalian herbivores (Norton 1991), and habitat loss primarily as a result of agricultural development.

Active conservation management is essential to ensure the long-term survival of *C. muritai*. Options include modification of conditions at the present site to reduce competition from introduced grasses, and location of further potential sites in the Marlborough area for establishing new populations. The second option appears essential, both to reduce the likelihood of a stochastic disturbance (e.g., geological instability or fire) killing the remaining wild plants and to locate sites where recruitment may be more successful. The rarity and recent discovery of *C. muritai* (Purdie 1985) means that the evaluation of potential new sites must be based on limited knowledge of its one remaining site coupled with knowledge of related species (e.g., *C. stevensonii*).

ACKNOWLEDGMENTS

Terry and Gwen Costello for their hospitality and for assistance in searching for seedlings on precipitous cliff faces, Ivan Morgan for drafting, and two anonymous referees for helpful comments. Funding was provided by the Foundation for Research, Science and Technology Contract no. CO9405.

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