

Seed dormancy and germination of a panel of New Zealand plants suitable for re-vegetation

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Abstract Seeds of *Carex trifida*, *Coprosma robusta*, *Cyperus ustulatus*, *Hebe stricta*, *Leptospermum scoparium*, *Muehlenbeckia australis*, *Myrsine australis*, *Phormium tenax*, *P. tenax* ‘Yellow Wave’, and *Sophora prostrata* were assessed for germination and dormancy. Seeds of *Carex trifida*, *Cyperus ustulatus*, and *Myrsine australis* showed no germination in light or dark at 20°C, but a high percentage of seed of *Carex* and *Cyperus* germinated after 12 weeks of low stratification. Despite high viability, germination of *Myrsine australis* seeds was low and occurred only after 12 weeks of low temperature stratification. Germination was low for *Muehlenbeckia australis* in the light, at 20°C, but increased after 4 weeks of low temperature stratification. After 12 months, 50% of *Coprosma robusta* seeds germinated but germination was greater after 4 weeks or more of stratification. No seeds of *Coprosma robusta* or *Muehlenbeckia australis* germinated in the dark. Rapid germination of *Hebe stricta* seeds was obtained, with 100% of the seed germinating in the light but 7% in the dark. *Leptospermum scoparium* had rapid germination, with 100% germinating in the light but 3% in the

dark. A low percentage of *Phormium tenax* seeds germinated in both the light and dark in the first month with no further germination, but after 8 weeks or more of low temperature stratification there was almost complete germination. There was rapid germination of *Sophora prostrata* seeds with 100% of the seed germinating in the light and dark.

Keywords *Carex trifida*; *Coprosma robusta*; *Cyperus ustulatus*; *Hebe stricta*; *Muehlenbeckia australis*; *Myrsine australis*; *Phormium tenax*; *Phormium tenax* ‘Yellow Wave’; *Sophora prostrata*; seed; germination; dormancy; stratification

INTRODUCTION

In New Zealand there is an increasing awareness of the importance of using native vegetation on roadside reserves including roadside cuttings. Native vegetation can play an effective role in the stabilisation and restoration of eroded land, reduce or halt soil erosion on roadside reserves and cuttings, and enhance local biodiversity.

An understanding of the germination requirements of native seeds is also vital to develop successful land restoration procedures. Germination requirements of a number of New Zealand species have been described in an ecological context (e.g., Burrows 1995, 1996a,b,c), but there is a general paucity of dormancy and germination data for the New Zealand flora (Fountain & Outred 1991; Bannister & Jameson 1994).

Seeds of certain New Zealand species germinate poorly. This may be due to poor viability but frequently it is due to seed dormancy. This can include embryo dormancy due to immature embryos (e.g., *Arthropodium cirratum*, Conner & Conner 1988a), seed coat impermeability to water (e.g., *Chordospartium stevensonii*, Conner & Conner 1988b), inhibitors in the fruit (e.g., *Solanum laciniatum*, Burrows 1996a; *Melicytus ramiflorus*, Partridge & Wilson 1990), or requirements for

specific factors such as light (e.g., *Leptospermum scoparium*, Herron et al. 2000) or chilling (e.g., *Hoheria glabrata*, Haase 1987). Seeds of many temperate species require a period of chilling (stratification). *Phormium tenax*, *Coprosma repens*, and *Myrsine australis* belong to this group (Anon. (undated) in Fountain & Outred 1991). Metcalf (1995) recommended that *Carex* spp., *Coprosma*, *Muehlenbeckia australis*, *Myrsine australis*, and *Phormium tenax* be subjected to a period of stratification before sowing. Some seed may have a double dormancy, e.g., seed of matagouri (*Discaria toumatou*) was shown to have testal (impermeability to water) and embryo dormancy (requiring chilling) (Keogh & Bannister 1994). Seeds of many other species (e.g., *Hebe* spp.) are not dormant and germinate readily.

The species investigated

Carex trifida are clumping sedges, which spread rapidly and can be deep rooted and persistent (Metcalf 1998);

Coprosma robusta suits poor soils, is deep rooted, and can spread readily by seed (Cave & Paddison 1999). It is a pioneering shrub (Langer et al. 1999) and is suitable for establishment of new plantings (Porteous 1993);

Cyperus ustulatus is easily grown in a variety of soils and situations (Metcalf 1998) especially in coastal areas, particularly where there is damp or wet ground;

Hebe stricta is a widespread early colonising species that has a fibrous root system and suits moist exposed sites (Porteous 1993);

Table 1 The nine plant species, their collection site locations, the map grid reference (NZMS 260), and seed collection dates.

Species	Location	Map grid reference	Seed collection date
<i>Carex trifida</i> Cav.	Massey University, Turitea Campus, Palmerston North	T24/323878 40°23'20"S 175°37'25"E	17 May 2001
<i>Coprosma robusta</i> Raoul	Ballance Road, northern Wairarapa	T24/494922 40°20'50"S 175°49'25"E	15 Apr 2001
<i>Cyperus ustulatus</i> A.Rich.	Okau, southern Wairarapa Coast	U26/680750 40°50'S 176°14'E	29 Apr 2001
<i>Hebe stricta</i> (Benth.) L.B.Moore	Centre Road, northern Wairarapa	T24/492924 40°20'45"S 175°49'20"E	12 Aug 2001
<i>Leptospermum Scoparium</i> J.R. et G.Forst.	Massey University, Turitea Campus, Palmerston North	T24/323878 40°23'20"S 175°37'25"E	28 Jun 2001
<i>Myrsine australis</i> (A.Rich.) Allan	Massey University, Turitea Campus, Palmerston North	T24/323878 40°23'20"S 175°37'25"E	16 Apr 2001
<i>Muehlenbeckia australis</i> (Forst.f.) Meissn.	Pohangina Road, Manawatu	T23/453031 40°15'00"S 175°45'55"E	19 Apr 2001
<i>Phormium tenax</i> J.R. et G.Forst.	Makino Road, Feilding	S23/283076 40°13'20"S 175°34'10"E	1 Apr 2001
<i>Phormium tenax</i> 'Yellow Wave'	Massey University, Turitea Campus, Palmerston North	T24/323878 40°23'20"S 175°37'25"E	20 Apr 2001
<i>Sophora prostrata</i> Buchan.	Massey University, Turitea Campus, Palmerston North	T24/323878 40°23'20"S 175°37'25"E	9 Apr 2001

Leptospermum scoparium is a pioneer shrub (Porteous 1993; Langer et al. 1999), and mature *L. scoparium* stands provide reinforcement to the soil and inhibit the development of shallow landslides (Watson & O'Loughlin 1985);

Muehlenbeckia australis can act as a ground cover (Cave & Paddison 1999);

Myrsine australis is a suckering shrub with good rooting and persistence and is tolerant of shade (Williams & Buxton 1989). In re-vegetation, it encourages birds (Porteous 1993);

Phormium tenax is a nurse plant (Porteous 1993; Reay & Norton 1999) with high water-absorbing, deep rooting qualities suited to exposed sites;

Sophora prostrata is a low-growing kowhai with nitrogen fixing ability and is deep-rooted (Salmon 1980).

This paper reports the germination responses of seeds from this group of indigenous New Zealand plants selected for potential re-vegetation use.

MATERIALS AND METHODS

Mature fresh fruits were collected from several plants of each species (Table 1).

Fruits were individually harvested by hand and placed in paper bags, except for *Coprosma robusta* and *Myrsine australis* which were placed in sealed plastic containers. Once harvested, the seeds were subjected to various and appropriate cleaning techniques developed by the authors (Appendix 1).

Seed storage

After cleaning, all seeds were placed into sealed, dried storage (water impermeable 12/20/50 μm laminated polyester/aluminium foil/polythene packets) at 5°C until required for germination and other experiments. As required, seeds were subsampled from each packet and the packet resealed. Storage time was variable.

General experimental procedures

In all experimental work the following protocols were used to determine seed moisture content (SMC), seed viability, and germination.

Seed moisture content (SMC)

SMC was determined using the constant air oven method for samples normally of 25 or 30 seeds (ISTA 1999). Seeds were dried at $103 \pm 2^\circ\text{C}$ for 17

± 1 h, then placed into a desiccator for approximately $\frac{1}{2}$ hour to cool. Seed moisture loss was calculated on a fresh weight basis. SMC was determined immediately after harvest (to give some indication of the moisture content of the seeds when shed from the parent plant), and after the final cleaning process before seeds were placed into storage. As the seed were stored in sealed foil packets, the latter SMC was assumed to be the moisture content for all experiments.

Seed viability

Seed viability was determined using the topographical tetrazolium test (ISTA 1999). Seed was taken from storage after 2–3 months, preceding the stratification experiment. Four replicates of 25 seeds (pooled) were preconditioned by rolling them in moistened seed germination paper (Anchor Paper Company, St. Paul, Minnesota, USA). The roll was placed in a jar with approximately 2 cm of water in the bottom. The jar and roll were placed in a plastic bag at $20 \pm 2^\circ\text{C}$ for 24 h, after which a scalpel was used to make an incision in each seed. Seeds were placed in 1% phosphate-buffered 2,3,5-triphenyl tetrazolium chloride solution at $20 \pm 2^\circ\text{C}$ for a further 24 h in the dark (light-excluding photographic film bag). Seed was classified as viable if both the radicle and cotyledon(s) showed uniform red staining.

Germination experiment

Seed germination was determined for four replicates of 50 seeds for each species. There were four treatments. Seeds were either dusted with thiram fungicide (using the ratio of 1 seed volume for every 50 seeds) or left undusted, and these treatments were placed either in the light or the dark (for *Sophora prostrata*, seeds were scarified by chipping with a sharp scalpel). Each replicate treatment was placed on two moist seed germination blotters (Anchor Paper Company) which were placed into a sealable plastic box. Boxes were kept either in the light with a continual 24 h, cool white 58 W fluorescence light source (PAR received was between 0.07 and $3.15 \mu\text{mol m}^{-2} \text{s}^{-1}$, depending on where the box was placed in the 20°C room) or in photographic film bags at $20 \pm 2^\circ\text{C}$. Each replicate was treated as a block and treatments were randomised within that block.

Seed germination was monitored weekly, except for *Leptospermum scoparium* and *Hebe stricta* (monitored every two days) and *Sophora prostrata* (every four days). Dark treatments were counted

Table 2 Seed moisture content at harvest and storage, and seed viability preceding the stratification experiment. Tz, tetrazolium test; n.d., not determined. Seed viability plus dead seed does not always equal 100% due to presence of empty seed.

Species	Seed moisture content		Seed viability (Tz) (%)	Dead seed (Tz) (%)
	At harvest (%)	At storage (%)		
<i>Carex trifida</i>	13	8	90	6
<i>Coprosma robusta</i>	31	12	80	17
<i>Cyperus ustulatus</i>	13	9.5	73	16
<i>Hebe stricta</i>	n.d.	n.d.	n.d.	n.d.
<i>Leptospermum scoparium</i>	11	8	n.d.	n.d.
<i>Muehlenbeckia australis</i>	33	12	43	39
<i>Myrsine australis</i>	30	17	92	4
<i>Phormium tenax</i>	13	10	96	4
<i>Phormium tenax</i> 'Yellow wave'	11	9	96	4
<i>Sophora prostrata</i>	12	10	n.d.	n.d.

Table 3 Seed germination data for light and dark (thiram and non-thiram) treatments. †, dormancy within the population precluded complete germination by one year (end of experiment was 25 May 2002); n.d., not determined.

Species	Starting Date	Percentage of seeds germinated					
		Light		Light		Dark	
		Days to 1st germination	Days to complete germination	Thiram	Non-Thiram	Thiram	Non-Thiram
<i>Carex trifida</i>	15 Aug 2001	0	†	0	0	0	0
<i>Coprosma robusta</i>	25 May 2001	19	†	48	52	0	0
<i>Cyperus ustulatus</i>	25 May 2001	0	†	0	0	0	0
<i>Hebe stricta</i>	24 Aug 2001	4	10	100	n.d.	7	n.d.
<i>Leptospermum scoparium</i>	30 Oct 2001	4	23	100	n.d.	3	n.d.
<i>Muehlenbeckia australis</i>	25 May 2001	26	†	2	2	0	0
<i>Myrsine australis</i>	25 May 2001	0	†	0	0	0	0
<i>Phormium tenax</i>	15 Aug 2001	12	†	11	16	1	1
<i>Phormium tenax</i> 'Yellow wave'	25 May 2001	12	†	12	13	7	7
<i>Sophora prostrata</i>	20 Aug 2001	7	15	100	100	100	100

Table 4 Final percentage germination of seeds of *Carex trifida*, *C. robusta*, *C. ustulatus*, *Muehlenbeckia australis*, *Myrsine australis*, *P. tenax*, and *P. tenax* 'Yellow Wave' after stratification at 5°C for 0 (set up after the stratification period), 4, 8, or 12 weeks and subsequent incubation at 20°C. Means in the same row sharing the same letter are not significantly different ($P > 0.05$). The percentage of seeds germinating during stratification (i.e., at 5°C) is given in parentheses.

Species	Stratification period (weeks)			
	0	4	8	12
<i>Carex trifida</i>	0a	26b	69c	90d
<i>Coprosma robusta</i>	4a	23b	65c	85d (22)
<i>Cyperus ustulatus</i>	0a	34b	26b	64c
<i>Muehlenbeckia australis</i> (10)	11a	28a	25a	31a
<i>Myrsine australis</i>	0a	0a	0a	4a
<i>Phormium tenax</i>	7a	34b	82c	94d (48)
<i>Phormium tenax</i> 'Yellow wave'	8a	57b	81c (3)	95d (76)

under a weak green safe light (PAR up to $0.17 \mu\text{mol m}^{-2} \text{s}^{-1}$). A seed was considered to have germinated when the radicle measured approximately 1 mm, for all species. Germination was scored when cotyledons were visible (*Coprosma robusta*, *Hebe stricta*, and *Myrsine australis*), the first true leaves were apparent (*Sophora prostrata*), the coleoptile was visible (*Cyperus ustulatus*), or the coleoptile and first true leaf were visible (*Phormium tenax*).

Stratification experiment

Seeds were dusted with thiram and placed on moist germination blotters as described in the initial germination method. Seeds were stratified by placing four replicate boxes of each species in a 5°C controlled germination room with a 24 h continual 58 W cool light source for periods of 4, 8, and 12 weeks before transfer to the standard conditions of the germination room ($20 \pm 2^\circ\text{C}$, 24 h continual light source). Four replicate boxes of each species, which were set up at the end of the stratification period, served as unstratified controls. Replicated boxes of unstratified seeds, set up to accompany the experiment as real-time controls, gave similar results (results not shown).

Data were analysed by analysis of variance (ANOVA) using SAS for Windows (Release 8.2 (TS 2mo), SAS Institute, Cary, NC, USA). Prior to analysis, data were checked for normality and homogeneity of variance using the proc univariate procedure in SAS.

RESULTS

Seed moisture and viability

At harvest, *Carex trifida*, *Cyperus ustulatus*, *Leptospermum scoparium*, *Phormium tenax*, *P. tenax* 'Yellow Wave', and *Sophora prostrata* had seed moisture contents of 11–13% and when placed into storage their moisture contents (8–12%) did not alter greatly. After 18 weeks of storage, viability was high for all of these species (Table 2). *Coprosma robusta* had a moisture content of 31% at harvest but was successfully dried to a moisture content of 12% without loss of viability (Table 2). *Muehlenbeckia australis*, which had a moisture content of 33% at harvest, dried down to a moisture level of 12% but viability was low (43%). *Myrsine australis* also had high moisture content at harvest (30%), which was reduced to 17% before storage, with 92% viability (Table 2).

Germination

Very low germination percentages were recorded in the light and dark treatments for *Muehlenbeckia australis* and *Phormium tenax*, but 100% germination was achieved in the light treatment for *Hebe stricta*, *Leptospermum scoparium*, and *Sophora prostrata* (Table 3). *Sophora prostrata* also reached 100% germination in the dark treatments. Fifty percent of *Coprosma robusta* germinated but the germination was spread throughout the year. There was no germination in any of the germination treatments for *Carex trifida*, *Cyperus ustulatus*, and *Myrsine australis*.

Carex trifida

Seed viability was 94% (Table 2) but no untreated seed germinated. In contrast, stratification for 12 weeks gave 90% germination (Table 4).

Coprosma robusta

Seed germinated in the light in both non-thiram and thiram treatments (48% and 52%, respectively). No germination occurred in the dark treatment. No abnormal germination was observed in any treatments. Stratification increased germination to 60% (8 weeks) and 85% (12 weeks). After 12 weeks stratification 22% of the seeds germinated at 5°C before being subjected to 20°C (Table 4).

Cyperus ustulatus

No germination was seen in any of the germination treatments (Table 3), but a high percentage (73%) of the seed was viable (Table 2). Stratification for 4 or 8 weeks enabled around 30% of the population to germinate, but 12 weeks stratification was needed before the majority (64%) of the population germinated (Table 4).

Hebe stricta

In the light, germination of *Hebe stricta* began 4 to 5 days after the seed was set to germinate, and 100% germination was reached after 10 days. In the dark treatment only 7% of the population germinated. After 26 days seeds from the dark treatment were transferred to the light and a further 85% of them germinated. No abnormal germination was seen.

Leptospermum scoparium

In the light treatment, germination began 4 days after the seed was set to germinate and 100% germination of full seeds was reached after 23 days. Embryo-less seeds were ignored in calculation of percentage germination. In the dark treatment, germination did

not begin until after 7 days and only 3% of the population germinated. After 30 days, no further germination was observed. When transferred to the light, a further 93% of the seed germinated within 7 days. No abnormal germination was observed.

Muehlenbeckia australis

In the light treatment 2% of the seeds germinated in both the thiram and non-thiram treatments. There was no germination in the dark. The viability test indicated that at least 43% of *Muehlenbeckia australis* seed was viable (Table 2). The remaining seed either did not contain an embryo or had been attacked by insects before harvest. There was substantial fungal growth on the seeds, irrespective of fungicide treatment, and seeds that germinated tended to rot. Stratification did not improve germination (Table 4).

Myrsine australis

Only one unstratified seed germinated (from 200) within a year of incubation. After 12 weeks stratification 4% of seeds germinated but there was no further increase to one year of incubation. Viability was high (92%) (Table 2).

Phormium tenax

An initial flush of seeds germinated in the light with 16% (non-thiram treatment) and 11% (thiram treatment). In the dark, 1% (non-thiram and thiram treatments) germinated. Stratification for 4 and 8 weeks significantly improved germination, but 12 weeks stratification was required before the majority (94–95%) of the population germinated (Table 4). After 12 weeks stratification 48% of the seeds germinated at 5°C. Results for 'Yellow wave' were similar (Table 4).

Sophora prostrata

After 15 days there was 100% germination in all treatments.

DISCUSSION

Seed moisture

After developing seeds reach physiological maturity, they either desiccate (for orthodox seed to a moisture content of 5–15%) or bypass complete desiccation (recalcitrant seeds) (Hartmann et al. 1997). A recalcitrant seed loses viability after drying, while orthodox seeds tolerate drying (Bewley & Black

1994). *Carex trifida*, *Cyperus ustulatus*, *Coprosma robusta*, *Leptospermum scoparium*, *Myrsine australis*, *Phormium tenax*, and *Sophora prostrata* are orthodox seeds, as they remained viable when desiccated to moisture content of <20%. For *Muehlenbeckia australis* the situation was more complex with seeds at 12% SMC exhibiting 43% viability. The possibility of recalcitrance in remaining seed was ruled out by observations of immature embryos and seed predation. It is also unlikely that *Muehlenbeckia australis* is recalcitrant, as Metcalf (1995) observed that it stores well. Establishing whether seeds are orthodox or recalcitrant can give guidance for seed storage and indicate whether they will remain persistent in a seed bank. This has implications for sustainable revegetation applications.

Germination

Carex trifida required stratification before germination occurred. This concurs with Schutz (2000) who found that in almost all species of *Carex* evaluated, dormancy was broken by stratification at low temperatures. Not all *Carex* spp. require stratification to break dormancy, and Ralph (1994) reported that some Australian *Carex* spp. germinate readily. For some New Zealand plants, Metcalf (1995) recommended a period of stratification to increase germination percentages. Schutz & Rave (1999) reported that there was almost no germination in darkness prior to stratification, and germination in the light (after stratification) was considerably higher in all but two species compared with that in darkness for 28 species of *Carex*; thus, light and stratification are required for germination of these species. Schutz & Rave (1999) concluded that the *Carex* species studied had broadly similar germination response patterns and the fact that they were released from high levels of primary dormancy by low-temperature stratification suggests that they are spring germinators. Our results indicate that in *Carex trifida* the levels of dormancy are variable within the seed population with stratification period determining the germination percentage.

Coprosma robusta did not germinate in the dark. Although there was germination in the light it was spread over the year. Miller & Henzell (2000) found that *Coprosma repens* germinated better in the light, but their results were inconclusive due to low germination. In contrast, Burrows (1995) recorded germination of *Coprosma robusta* in both light and dark treatments (90% and 60%, respectively). Burrows (1995) indicated that seed extracted from

the fruit had rapid germination onset and was completed (90% germinated, 10% dead) within 10 weeks, but for seed still in the fruit there was less germination (72%), suggesting that the fruit may inhibit germination. Burrows (1995) harvested seed in February while our seed was harvested in mid April. Although a different location and growing season make comparisons difficult, it may be that the delayed harvest of our seed allowed the development of embryo-based dormancy, but without detailed information on the developmental sequence in *Coprosma robusta* seed this is speculative. Stratification was able to alleviate dormancy in this species, and again there was a population response with length of stratification determining germination percentage. Clearly *Coprosma robusta* has a chilling requirement. However, this work demonstrated that a proportion of the population is also responsive to light. It may be that in this portion of the population light is able to bypass the chilling requirement.

The germination behaviour of *Cyperus ustulatus* is similar to that of *Carex trifida* and *Coprosma robusta* in that after 12 weeks stratification a reasonably high level of germination was obtained (Table 4). Again, germination response was a function of stratification period. Chozin & Yasuda (1991) examined the progeny of *Cyperus iria* and *Cyperus microiria* and found that dormancy was broken by stratification for a period of 1 month. The species studied here is thus similar in its cold requirement to *C. iria* and *C. microiria*. Metcalf (1995) also suggested that *Cyperus ustulatus* required a period of cool-moist stratification in order to break dormancy.

The germination of *Hebe stricta* is clearly light dependent. In complete darkness, germination was 7% after 10 days, while 100% of seeds kept in the light germinated. Widyatmoko & Norton (1997) reported that *Hebe cupressoides* is light requiring with germination percentage and germination rate increasing with increasing irradiance; germination percentage in the dark was 12% and in “full light” was 84%. Fountain & Outred (1991) noted that seed of some species of *Hebe*, e.g., *H. speciosa* and *H. salicifolia*, require light for germination and Simpson (1976) reported that many species of *Hebe* germinated readily at 25°C in light.

The germination of *Leptospermum scoparium* seed is, like *Hebe stricta*, light dependent. Other authors (Grant 1966; Mohan et al. 1984; Herron et al. 2000) have similarly found little or no germination in *Leptospermum scoparium* seed incubated in darkness. We therefore confirm their

earlier reports with experiments performed under the standard conditions reported here.

Muehlenbeckia australis did not show a stratification requirement. Although the actual germination percentage (31%) was low, under light conditions the percentage of viable seed germinating was high (58–72%). These data are in conflict with germination results reported by Burrows (1996b) who found that *Muehlenbeckia australis* reached 75% germination in the dark and 97% germination in light, which is substantially more than the germination achieved in this study in either the light or dark. Clearly the dormancy status of the seedlots studied must have differed. Possible reasons for this are ecotype variation, location, and collection time.

While the viability of *Myrsine australis* was high (92%), only minimal germination occurred after 12 weeks stratification. It is not clear if this is a stratification response or simply an indication that dormancy in at least a portion of the population is being alleviated over time, or a combination of the two. It is possible that much longer stratification is required. In all treatments there was swelling in the area where the embryo emerges through the endocarp and seed coat suggesting that this species requires an after-ripening period in order for the embryo in the seed to mature. Burrows (1996c) reported that *Myrsine australis* was slow to germinate and suggested that the embryo may still be developing after seed fall. Metcalf (1995) also reported that *Myrsine* seed, even after being subjected to stratification, could take 2 to 18 months to germinate. It is possible that *Myrsine australis* has both after-ripening and chilling requirements; this is the subject of further experimentation. Burrows (1996c) indicated that *Myrsine australis* required winter low temperature to overcome a biochemical block to germination. Fountain & Outred (1991) suspected that *Myrsine australis* is quiescent, meaning that no specific priming treatments are needed to initiate embryo growth and that seeds germinate after seed fall. Data from this work do not support that observation. It is likely that seedlings growing under parent plants observed by Fountain & Outred (1991) were, in fact, from seeds from previous growing seasons. Burrows (1996c) concluded that the dormancy of *Myrsine australis* seed could permit seed to persist either at the soil surface or beneath the soil for up to 2 years.

A small percentage of the *Phormium tenax* population was not dormant, as there was some germination in all treatments. *Phormium tenax* seed requires a period of chilling to overcome dormancy

in the majority of the population. Our data are in agreement with Metcalf (1995) who reported that *Phormium tenax* could be cool-moist stored for several months and that seed stored for 5 months germinated within 12 days. A high percentage (48%) of *Phormium tenax* seed in our studies germinated at 5°C in the 12-week stratification period, so if seed was to be stored we recommend that it be stored with low seed moisture content at 5°C. Eight to 10 weeks stratification is required as a pre-treatment to break dormancy.

Species of *Sophora* have a coat-imposed dormancy and require scarification in order to allow water uptake (Stilinovic & Grbic 1988; Fountain & Outred 1991; Wang 1991; Metcalf 1995). Our data on *Sophora prostrata* support these observations, and also indicate that there is no light requirement for germination in addition to the seed-coat-imposed dormancy. Everitt (1983) obtained similar results for *Sophora secundiflora* and reported that light was not required for germination and no other dormancy mechanisms were observed other than the hard seed coat.

CONCLUSION

The results of the present study show that, of the species tested, *Carex trifida* and *Cyperus ustulatus* require a period of low temperature stratification in order to break dormancy. The majority of *Phormium tenax* require a period of chilling to break dormancy, and *Coprosma robusta* and *Muehlenbeckia australis* require a period of chilling to increase germination rate. This information is critical to the use of these species in re-vegetation studies or applications. *Hebe stricta* and *Leptospermum scoparium* seeds require light in order to germinate. Scarification of *Sophora prostrata* seed is required in order to break dormancy. *Myrsine australis* requires further research in order to determine the mechanism by which dormancy is imposed.

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Appendix 1 Cleaning descriptions and the equipment that was used for each species studied.

Species	Cleaning description
<i>Carex trifida</i>	Seed heads were air-dried at ambient room temperature for 1 month, then threshed through a Westrup (LA-H) Dehuller with a screen size of 2 mm × 2 mm. The seeds were then processed through an air-screen cleaner (Burrows Office Clipper Tester and Cleaner) using a round-shaped screen with an aperture of 1.59 mm (top) and an oblong-shaped screen with an aperture of 5.99 mm × 0.73 mm (bottom). Seeds were then processed through a Westrup (LA-H) Indented Cylinder Separator with a 2.75 mm indent to remove chaff and remaining husks. Lastly, a South Dakota seed blower with constant airflow of 1.07 m s ⁻¹ removed any remaining seed husks and light seed.

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Appendix 1 *continued*

Taxon	Cleaning description
<i>Coprosma robusta</i>	Immediately after harvesting, mature fruits were placed in a plastic container containing distilled water and placed in the $20 \pm 2^\circ\text{C}$ constant temperature room to ferment, for a period of 4 days. Water was decanted off and the flesh and skins surrounding the seeds were rubbed off by hand and the cleaned seeds were left overnight at room temperature spread out on dry, 38 lb regular weight seed germination paper (Anchor Company), in order to dry off excess water. Seeds were rubbed between rubber mats to dislodge any dry debris attached to the seeds, and then the debris was removed in a South Dakota seed blower (airflow 4.00 m s^{-1}).
<i>Cyperus ustulatus</i>	Seed heads were air-dried at ambient room temperature for 3 weeks then threshed through a Westrup (LA-H) Dehuller-screen size $2 \text{ mm} \times 2 \text{ mm}$. Seeds were then processed through the air-screen cleaner with oblong shaped screen sizes $4.22 \text{ mm} \times 0.82 \text{ mm}$ (top) and $0.54 \text{ mm} \times 0.54 \text{ mm}$ (bottom) and then processed through the Westrup (LA-H) Indented Cylinder Separator with a 2.75 mm indent followed by a 1.25 mm indent, which takes out grains of sand and round, inert particles. Lastly, seeds were processed through the South Dakota seed blower with a constant airflow of 4 m s^{-1} to remove husks and light seed.
<i>Hebe stricta</i>	Seed heads were placed in a paper bag and kept at ambient room temperature for 1 week. This enabled capsules to open, thus releasing seeds. Seed and debris were sieved (aperture 1 mm^2) which separated seeds from the debris. The sieving procedure was repeated several times.
<i>Leptospermum scoparium</i>	Branches with capsules attached were collected. Seed from several seasons were collected (probably from the 1998–99, 1999–00, and 2000–01 seasons) as all remained on the bushes. The branches with attached capsules were placed in a paper bag and dried at ambient room temperature for 1 month. The capsules opened, thus releasing seeds, which collected at the bottom of the bag. The seed was separated by, firstly, sieving (sieve aperture 1 mm^2) and then placed in a seed cleaning device (Contab LC m Microblower type 35, 220 V). Seeds were blown for 3 minutes with a constant airflow (9 setting) to remove further debris and empty seed. Seeds were then re-blown at the same setting (debris was subjected to a germination test to discover if any of the seed blown off was “full” but there were none).
<i>Muehlenbeckia australis</i>	Seed heads were air-dried at ambient room temperature for 1 month, threshed through Westrup (LA-H) Dehuller-screen size $2 \text{ mm} \times 2 \text{ mm}$ and processed through the air-screen cleaner using round-shaped screen sizes of 2.98 mm (top) and 1.59 mm (bottom). Then they were processed through the Westrup (LA-H) Indented Cylinder Separator with a 2.75 mm indent followed by a 1.25 mm indent, which removes grains of sand and round, inert particles. Lastly, seeds were processed through the South Dakota seed blower with a constant airflow of 4 m s^{-1} , which takes out husks and light seed.
<i>Myrsine australis</i>	Mature, fresh fruit were placed on dry 38 lb regular weight seed germination paper and left for three days to air-dry at ambient room temperature. To remove fruit skins, fruits were rubbed between two rubber mats. Loose skins were removed with a South Dakota seed blower with airflow of 4 m s^{-1} .
<i>Phormium tenax</i>	Capsules were spread out on a bench, where they were air-dried for a period of 2 weeks. Capsules split open and seed fell out or was shaken out by hand. Seeds were separated from the debris by hand.
<i>Sophora prostrata</i>	Pods, containing seed, were individually harvested by hand. Once harvested, pods were placed in a cardboard box and left at ambient room temperature for a period of 1 month. Pods were threshed through a Westrup (LA-H) Dehuller with a screen size of $10 \text{ mm} \times 10 \text{ mm}$. The seed were then cleaned through an air-screen cleaner using round shaped screens with holes 5.16 mm (top) and 3.77 mm (bottom).

A preliminary experiment was performed prior to *Leptospermum scoparium* seed being processed through the microblower in order to compare the germination percentage before and after processing. It has been stated in past papers (Grant 1966; Mohan et al. 1984) that the overall germination percentage for *L. scoparium* seed is low. Four replicates of 100 seed were placed on Anchor Steel Blue seed germination blotter. The blotters were placed in clear plastic boxes, placed in $20 \pm 2^\circ\text{C}$ germination room. Germination obtained was $2.95 \pm 0.62\%$ per 100 seeds. The remaining seeds were without embryos. All “full” seed germinated.