Light and the seed germination of the New Zealand species *Metrosideros excelsa*

Helen Herron, Dennis Greer[1] and John Clemens[2]

Institute of Natural Resources, Massey University, Palmerston North, New Zealand
[1] The Horticulture and Food Research Institute of New Zealand, Palmerston North, New Zealand
[2] Institute of Molecular BioSciences, Massey University, Private Bag 11222, Palmerston North, New Zealand

Abstract

Recent literature on the effects of light on seed germination in New Zealand native plants is reviewed, with emphasis given to selected members of the family Myrtaceae (*Leptospermum* and *Metrosideros*). Recent reports address the effects of irradiance, duration of light exposure, and photoperiod, although effects of spectral composition on seed germination have not been reported. Red and far-red light emitting diodes were used in factorial combination with irradiance (0, 5.5 and 480 μmol/m^2/sec) to study germination responses to light in *Metrosideros excelsa* (pohutukawa). This species germinated poorly in the dark, but required only low irradiance to stimulate >90 % germination. There was no evidence of a high irradiance suppression of germination. Effects of red and far-red light on germination indicated a phytochrome-mediated response. Dark-incubated seeds germinated as well as light controls when the dark treatment was supplemented with red light. Far-red light inhibited germination when seeds were incubated at low irradiance (1 % ambient), although not appreciably at ambient irradiance. There was also some stimulation of germination by far-red light in otherwise dark-incubated seeds. The results suggest a mechanism whereby *Metrosideros* seed may be inhibited from germinating beneath a leafy canopy where ambient light would be enriched in far-red wavelengths, despite the permissive effect of low irradiance on germination.

Additional key words: *irradiance, light quality*

Introduction

Seed germination physiology, dormancy and the requirements for seed germination in New Zealand plants were reviewed earlier this decade by Fountain and Outred (1991) and Bannister and Jameson (1994). These authors noted that there were few reports of the effects of light on seed germination of New Zealand native species, although responses to contrasting light and dark treatments tended to indicate a positive effect of light on seed germination. Seed germination of some species, e.g., *Gaultheria depressa* and *Pernettya macrostigma* (Bannister, 1990) and *Metrosideros umbellata* (southern rata) (Wardle, 1971), is completely inhibited in the dark. In other species germination may take place in the dark, although higher germination percentages occur in the light. For example, Conner (1987) found that seed germination in five subalpine *Acaena* was in the range 7-26 % and 43-61 % in the dark and light (180-190 μmol/m^2/sec), respectively. Scott (1975) conducted a number of trials on the germination requirements for *Celmisia* (mountain daisy), comparing germination in the dark with that in sunlight. Most species showed a much higher germination percentage in the light. There was a positive response to the duration of light exposure on seed germination in *C. coriacea* (9 %, 36 %, 66 % and 81 % germination in the dark, and after 1 h, 7 days and 28 days exposure, respectively). Seeds of yet other species germinate equally well in the light and the dark, e.g., *Discaria toumatou* (matagouri) (Keogh, 1990). Burrows has published a series of germination experiments on a range of native trees, shrubs and vines (e.g., Burrows, 1995), in which germination was similar in the dark and the light.

The effects of irradiance on seed germination have been reported for *Hebe*, *Sophora* and members of the

Ericaceae. The endangered shrub *Hebe cupressoides* is an example of a species in which germination percentage and germination rate increase with increasing irradiance. In the dark, 75 % irradiance, and "full light" (no details given), germination percentage was 12 %, 30 %, and 84 %, respectively (Widyatmoko and Norton, 1997). Moore (1996) studied the response to irradiance (0, 20, 50 or 250 $\mu mol/m^2/sec$) of seeds of native and naturalised members of the family Ericaceae. Seed of all species that had been treated with fluctuating temperature (12/22 °C) for four weeks displayed a light requirement for germination. However, some species responded more favourably to higher irradiance than others, and the pretreatment interacted with irradiance in some species.

Seed germination of some native plants can also be inhibited by high and/or prolonged irradiance. Scarified seed of *Sophora microphylla* and *S. prostrata* (kowhai) germinated better at very low irradiance (0.09 $\mu mol/m^2/sec$) than in less shaded conditions (90-96 % compared to 50-80 %). Germination of the former species was reduced to 20 % when light was applied for extended periods (18 h) (Webb, 1993). Such behaviour had been noted earlier by Conner and Conner (1988) for *Arthropodium cirratum* (rock lily) for which seed germinated more successfully in the absence of light or in light of low irradiance (48 $\mu mol/m^2/sec$) than in light of high irradiance (295 $\mu mol/m^2/sec$) (56-85 % and 5-9 %, respectively).

Mohan *et al.* (1984) showed that there was also no difference between the effects of irradiance at 2 $\mu mol/m^2/sec$ and at 25 $\mu mol/m^2/sec$ on germination of *Leptospermum scoparium*. Seed germination in this species did occur in the dark, although this was half that of seeds germinated in the light (5 % and 11 %, respectively). When dark-incubated seeds were subsequently transferred to the light, germination percentage increased to 11 % after a further 8 days. Silvester (1962) found that while *Leptospermum scoparium* did not germinate in darkness, only very low irradiance (0.25-0.5 % full sunlight) was needed to stimulate germination. Both Bieleski (1959) and Silvester (1962) believed low light levels under canopies of established vegetation would limit the natural regeneration of this species. As a pasture weed, establishment of *L. scoparium* has been shown to be disfavoured by competitive pasture stands in which light levels were very low at the soil surface (Grant, 1966).

Little information on the effects of spectral quality of light on seed germination has been published for New Zealand species (Fountain and Outred, 1991; Bannister and Jameson, 1994). The only mention of an effect of spectral composition on seed germination was a suggestion that far-red light inhibited the germination of *Leptospermum scoparium* seed (Mohan *et al.*, 1984). However, the authors did not present results relating to this effect.

In this paper we report our results for the effects of irradiance and light quality on the seed germination of *Metrosideros excelsa* (pohutukawa), like *Leptospermum scoparium*, an early successional species, and a member of the family Myrtaceae. Because of the response of *Leptospermum* and other *Metrosideros* to light (Wardle, 1971; Drake, 1993), we anticipated that seed of *M. excelsa* would have a light requirement for germination. However, we wanted to test if germination was inhibited at low irradiance, as suggested for *Leptospermum scoparium* by some authors (Bieleski, 1959; Silvester, 1962); and at high irradiance, as for *Arthropodium* (Conner and Conner, 1988) and *Sophora* (Webb, 1993). As *M. excelsa* occurs naturally on coastal rock outcrops such a response could be interpreted as tending to prevent germination in well lit sites where moisture would be most limiting. In addition, if there was a light requirement for germination of *M. excelsa*, was there evidence for a phytochrome-mediated response? Novel use was made of light emitting diodes to deliver red and far-red light in factorial combination with irradiance treatments. More recent work on the effects of these factors on seed germination of *Leptospermum scoparium* and of the secondary colonising species *Melicytus ramiflorus* (mahoe) will be reported elsewhere.

Materials and Methods

The experiment was carried out in a controlled environment room in the National Climate Laboratory, Palmerston North, which was maintained at 18 ± 0.5°C. The mean photosynthetic photon flux density in the room was 672 $\mu mol/m^2/sec$ delivered during a 12h photoperiod, with a red:far-red ratio of 1.2. Seeds of *Metrosideros excelsa* were incubated in closed containers either in ambient light, at 1 % ambient irradiance (provided by neutral density shade cloth) or in the dark. These corresponded to 480, 5.5 and 0 $\mu mol/m^2/sec$ experienced by the seed. Irradiance was studied in factorial combination with three light quality treatments. There was either no supplementation, or red or far-red light supplementation (50 $\mu mol/m^2/sec$). The latter treatments were applied using red and far-red light emitting diodes (LEDs; Quantum Devices, Wisconsin) inserted through the lids of the germination vials. Light supplementation was synchronised with the daily photoperiod. There were four blocks, with the red/far-red LED treatments applied as split-plots within the irradiance main plots. Seedlots containing approximately 50 viable seeds were used. Germinated seeds were recorded 20 days after sowing, as were viable seeds that had not germinated.

Results and Discussion

As reported for the New Zealand species *Metrosideros umbellata* (southern rata) (Wardle, 1971), and for the Hawaiian *M. polymorpha* (Drake, 1993), almost no *Metrosideros excelsa* seed germinated in the dark. However, germination was 97 % and >90 % at 5.5 and 480 μmol/m^2/sec, respectively (Fig. 1). This result is similar to those obtained by Silvester (1962) and Mohan *et al.* (1984) who found only very low irradiance was necessary to stimulate germination in the closely-related *Leptospermum scoparium*. The lack of appreciable decline in germination at high irradiance indicates that this species does not exhibit the classic high irradiance inhibitory response found in *Sophora* (Webb, 1993) and *Arthropodium* (Conner and Conner, 1988).

Supplementation with red light resulted in 99 % germination in otherwise dark-incubated seeds, a response similar to that at 5.5 and 480 μmol/m^2/sec without supplementation. Under high light conditions, 87 % of *Metrosideros* seed germinated when supplemented with far-red light. However under low light conditions, *Metrosideros* seed germination was considerably inhibited (44 %) by far-red light supplementation. By contrast, there was some stimulation of germination when dark-incubated seed was exposed to far-red light (Fig. 1). A stimulation by far-red light also occurred in *M. polymorpha* (Drake, 1993).

Stimulation of germination in dark-incubated seeds by red light, and its inhibition by far-red light (at least under low irradiance) indicates a phytochrome-mediated response in *M. excelsa*. Similar results were found for *M. polymorpha* (Drake, 1993). Our results further suggest a mechanism whereby seed of this species may be inhibited from germinating beneath a leafy canopy where ambient light might be expected to be enriched in far-red wavelengths, despite the permissive effect of low irradiance on germination. A similar mechanism may operate in *Leptospermum scoparium* to prevent the regeneration of this species beneath its own canopy (or those of other species) (Bieleski, 1959; Silvester, 1962).

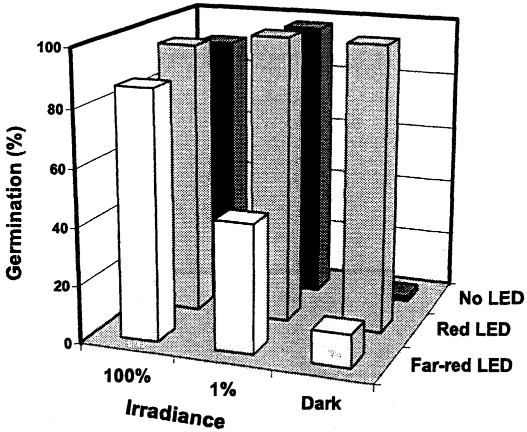

Figure 1. The effect of red and far-red light supplementation provided by light emitting diodes (LEDs) on the final germination percentage of *Metrosideros excelsa* seed incubated at three levels of irradiance, expressed as a percentage of 480 μmol/m^2/sec.

Acknowledgments

This work was supported by the Massey University Research Fund. The use of light emitting diode equipment of Dr Mike Hay (AgResearch, Palmerston North), and the assistance of Tina Fulton (HortResearch, Palmerston North), and of Karen Hill and Ruth Morrison (Seed Technology Centre, Massey University, Palmerston North) is greatly appreciated.

References

Bannister, P. 1990. Seed germination in *Gaultheria antipoda*, *G. depressa* and *Pernettya macrostigma*. *New Zealand Journal of Botany* **25**, 5-10.

Bannister, P. and Jameson, P.E. 1994. Germination physiology of seeds from New Zealand native plants. *In* Seed Symposium: Seed Development and Germination. Special Publication No. 9 (eds. P. Coolbear, C.A. Cornford and K.M. Pollock), pp 9-15. Agronomy Society of New Zealand.

Bieleski, R.L. 1959. Factors affecting growth and distribution of kauri. *Australian Journal of Botany* ***7***, 252-294.

Burrows, C.J. 1995. Germination behaviour of the seeds of the New Zealand species *Fuchsia excorticata*, *Griselinia littoralis*, *Macropiper excelsum* and *Melicytus ramiflorus*. *New Zealand Journal of Botany* ***33***, 131-140.

Conner, L.N. 1987. Seed germination in five subalpine *Acaena* species. *New Zealand Journal of Botany* ***25***, 1-4.

Conner, L.N. and Conner, A.J. 1988. Seed biology of *Chordospartium stevensonii*. *New Zealand Journal of Botany* ***26***, 473-475.

Drake, D.R. 1993. Germination requirements of *Metrosideros polymorpha*, the dominant tree of Hawaiian lava flows and rain forests. *Biotropica* ***25***, 461-467.

Fountain, D.W. and Outred, H.A. 1991. Germination requirements of New Zealand native plants: A review. *New Zealand Journal of Botany* ***29***, 311-316.

Grant, D.A. 1966. Factors affecting the establishment of *Leptospermum scoparium* J.R. ex G. Forst (manuka). MAgrSc Thesis, Massey University.

Keogh, J.A. 1990. The ecology and seed biology of wild Irishman, *Discaria toumatou* Raoul, an endemic woody weed. PhD Thesis, University of Otago.

Mohan, E., Mitchell, N. and Lovell, P. 1984. Environmental factors controlling seed germination of *Leptospermum scoparium* (manuka). *New Zealand Journal of Botany* ***23***, 95-101.

Moore, S.H. 1996. Germination characteristics of some native and naturalised species of Ericacae in New Zealand. MSc thesis, University of Otago.

Scott, D. 1975. Some germination requirements of *Celmisia* species. *New Zealand Journal of Botany* ***13***, 653-664.

Silvester, W.B. 1962. Regeneration in the Hunua Ranges. MSc Thesis, University of Auckland.

Wardle, J. 1971. Biological flora of New Zealand. 6. *Metrosideros umbellata* Cav. (Myrtaceae) southern rata. *New Zealand Journal of Botany* ***9***, 645-671.

Webb, J.A. 1993. A study of the seed ecology of two species of kowhai, *Sophora microphylla* and *Sophora prostrata* in Canterbury, New Zealand. MSc Thesis, University of Auckland.

Widyatmoko, D. and Norton, D.A. 1997. Conservation of the threatened shrub *Hebe cupressoides* in New Zealand. *Biological Conservation* ***82***, 193-201.