WINTER FROST AND ITS EFFECT ON KAURI (*Agathis australis*) SEEDLINGS

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ABSTRACT

Winter frost tolerance of kauri (Agathis australis) *seedlings from seven sites was determined by subjecting dormant cotyledonary and 18-month-seedlings to a series of simulated frosts ranging in intensity from –1 to –6°C.*

Cotyledonary seedlings survived frosts down to –4°C, usually with some damage. A few badly damaged seedlings survived frosts of –6°C. Seedling origin does not appear to influence a seedling's ability to withstand frost damage.

INTRODUCTION

The genus *Agathis* contains some thirteen species, distributed throughout the tropics and subtropics of south-east Asia and the south-west Pacific (Whitmore, 1977). Kauri is endemic to New Zealand, extending further south than any other *Agathis* and, prior to exploitation, was abundant to latitude 37° 30′ south.

Factors determining kauri's distribution, especially its present southern limit, are unknown but are possibly related to the incidence of killing frosts. Little is known of kauri's resistance to frosts except that dormant twigs, leaves and buds of a young tree survived a temperature of –7°C. (Sakai and Wardle, 1978). Material from other trees normally found north of latitude 38°S were also tested by Sakai and Wardle. Pohutukawa (*Metrosideros excelsa*) and mangrove (*Avicennia resinifera*) tolerated less than –3°C. Taraire (*Beilschmiedia taraire*) withstood –4 to –5°C. The leaves of tawapou (*Planchonella novo-zelandica*) were killed by –4°C frosts, although the buds, cortex and xylem withstood –8°C. These results suggest that kauri has similar frost tolerance to those other species which are mainly confined to sites north of latitude 38° south.

How frost affects kauri seedlings, and therefore the ability of kauri to establish itself on colder sites, is unknown although field observation suggests that their frost tolerance is quite low.

This paper examines the effect of freezing temperatures on dormant kauri seedlings and seeks to ascertain whether seedling origin influences resistance to frost damage.

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MATERIALS AND METHODS

Plant Material

Seedlings from seven sites, covering the natural range of kauri, were used in the experiment (Table 1).

TABLE 1: ORIGIN OF SEEDLING MATERIAL

Site	*Latitude*	*Longitude*	*Altitude (m)*
Te Paki	34° 28′ 30″	172° 46′	100
Russell	35° 24′	174° 16′	30-190
Waipoua	35° 40′	173° 33′	150
Pukekaroro	36° 08′	174° 27′ 30″	130
Moehau	36° 32′	175° 23′	760
Hunua	37° 07′	175° 12′	180
Katikati	37° 36′	175° 55′	250

The tests were carried out using five cotyledonary and five 18-month-old seedlings from five sites lack of plant material dictating the small sample size. In addition, a few cotyledonary seedlings from a tree at Waipoua and some 18-month-old seedlings from Moehau were included in some of the frost regimes.

Seedlings were grown in propagating tubes at Hunua, in a mixture of one part coarse sand and one part peat with slow release fertilisers added to provide the necessary nutrients. In mid-July they were taken to the Climate Laboratory in Palmerston North and placed in a controlled environment holding room (Fig. 1).

Frost Regimes

The frost regimes decreased in 1°C steps from −1 to −6°C. No cotyledonary seedlings were exposed to −6°C and no 18-month seedlings to −1°C. As plants from Russell as well as Moehau and Waipoua were in short supply, some temperature steps were omitted or only two seedlings used.

For the duration of each frost the seedlings were placed in trays with pumice packed around the propagating tubes. The tray and its contents were held at 4°C during each frost period so that only stems and leaves were subjected to below-zero temperatures.

Data on the microclimate within a regenerating kauri stand were obtained from the southern edge of the Hunua Ranges for the period 1973-1978. (A.R.A. records). Although full data on

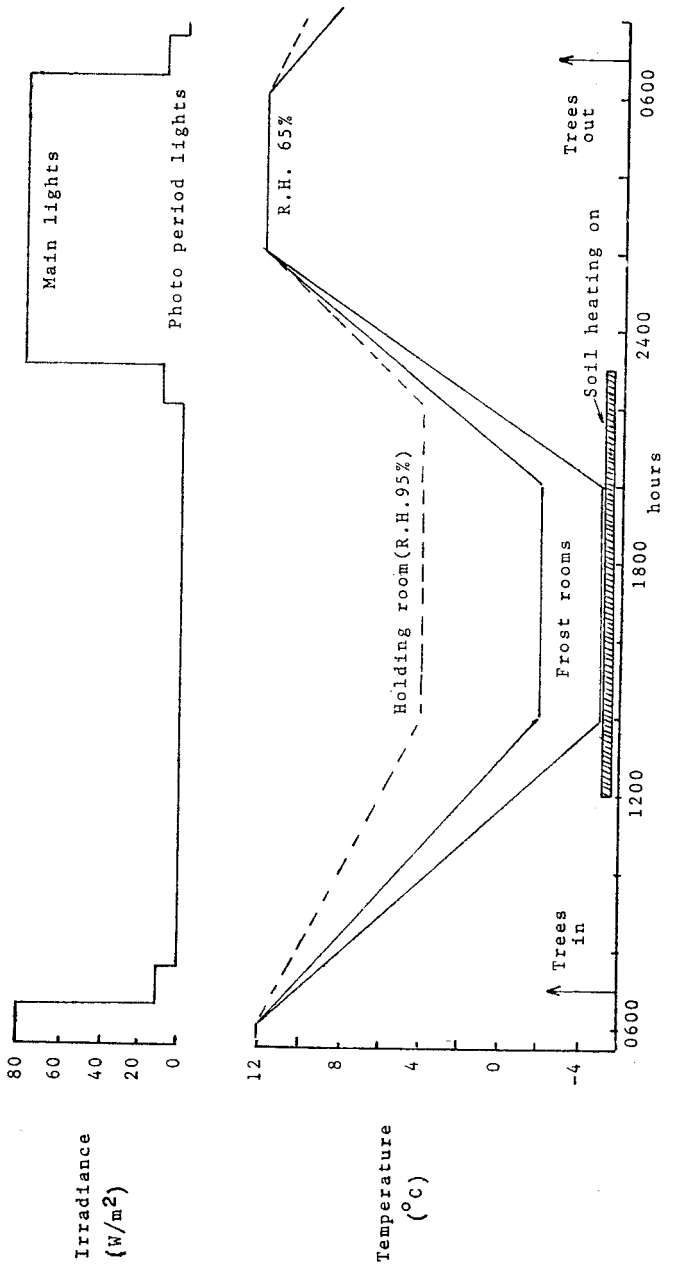

FIG. 1: *Climate rooms. Data for 1×24 hr cycle.*

frost duration and intensity were not recorded, it was possible to predict the length and maximum intensity of frost that might be expected. The experiment was designed to fit the data collected from this stand. The period of time seedlings spent at the minimum temperature was 6 hours and, depending upon frost intensity, actual frost length ranged from 7.5 to 10.0 hours. It took eight hours to reduce from the holding room temperature of 12°C to the required frost level and six hours to rise back to 12°C.

One problem which arose was that frosts in northern New Zealand are almost always of the radiation type while those produced in the climate chamber are advective frosts. With radiation frosts there is usually a variation in temperature from top to bottom of the plant, coldest temperatures being at the top. Temperatures during advective frosts are the same for all parts of the plant (Warrington and Rook, 1980). This difference would not apply to tiny cotyledonary seedlings, and have little effect on the open foliage of the 18-month-old plants.

To facilitate the experiment, the night/day regimes of the frost and holding rooms were reversed so that "night" and the frosting process took place during the day. Plants were acclimatised to this regime for between 48 and 120 hours before being subjected to sub-zero temperatures.

Details of temperature. light and humidity regimes for the frost and holding rooms are contained in Fig. 1. Details of climate room operation can be found in Robotham *et al.* (1978).

Damage Assessment by Visual Scoring

Before being placed in the frost room all plants were assessed for size, appearance and stage of development. After each frost

TABLE 2: VISUAL SCORING ASSESSMENT FOR FROST-DAMAGED KAURI SEEDLINGS

0	Plant dead.
1	New wood dead. Plants subsequently recover with new terminal bud developing on old wood.
2	Terminal bud damaged (oozing sap) or dead. Leaves damaged or dead. Plants subsequently recover with new terminal bud developing on new wood just below old terminal bud.
3	Apart from slight darkening of leaves, or dark spots developing on leaves, plants are undamaged.

TABLE 3: FROST DAMAGE ASSESSMENT FROM VISUAL SCORING

Seedling age and Origin	*−1°*		*−2°*		*−3°*		*−4°*		*−5°*		*−6°*	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Cotyledonary seedlings:												
Te Paki	3		2	0–3	0.4	0–2	0				0	
Russell	3		1.6	0–2	0.4	0–2	–		–			
Waipoua	3		2.2	2–3	0		–		–			
Pukekaroro	3		2.6	2–3	0		0		0			
Hunua	3		2	all 2	0.4	0–1	0		0			
Katikati	3		2	0–3	0		0		0			
18-month-old seedlings:												
Te Paki			3		2.6	2–3	1.4	1–3	0		0	
Russell			3		2.8	2–3	1.2	1–2	0		0	
Pukekaroro			3		3		1.2	0–2	0		0	
Hunua			3		2.8	2–3	2.2	1–3	0.6	0–1	0.6	0–1
Katikati			3		3		1.2	0–2	0.2	0–1	0	
Moehau			–		3		–		0.8	0–1	–	

– No plants from this site used at this temperature.

plants were scored for damage immediately following the thaw and subsequently at one, five, ten and twenty days. A scale of 0 to 3 was used (Table 2). The final assessment was made at the end of August, between 36 and 40 days after the frost treatment.

RESULTS

Cotyledonary seedlings were able to withstand a frost of –1°C but were damaged by –2°C frosts. At –3°C a few plants survived although severely damaged. No plants survived the –4°C frost (Table 3).

Eighteen-month-old seedlings from three sites were slightly damaged at –3°C and all plants were damaged by the –4° frost. A few plants were able to survive –5° and –6°C frosts, although damage was severe (Table 3).

Ability to resist frost damage was apparently not influenced by seedling origin. The largest difference in response was between 18-month-old Hunua and Russell seedlings but even here there was a 35% probability that the seedlings belonged to the same population. All other differences were similar with at least an 80% probability that the seedlings belonged to the same population.

Frost hardiness temperature (FHT), the lowest temperature to which a plant can be exposed without damage; and mean lethal temperature (LT_{50}), the temperature at which 50% of the population is killed, are useful methods for comparing plant responses to frost (Warrington and Rook, 1980). For the cotyledonary seedlings in this experiment the FHT was –1°C and the LT_{50} –2°C. Eighteen-month-old seedlings had an FHT of between –2 and –3°C and an LT_{50} of –4°C (Fig. 2).

Leaves and terminal buds of cotyledonary seedlings were equally susceptible to freezing. Once the bud was killed the plant was dead, for new buds were not produced on the stem below the terminal bud. The stems and branches of 18-month-old plants were less susceptible to freezing than the terminal buds and leaves, which were killed by temperatures between –4 and –5°C. Plants damaged in this way, but not killed, produced new terminal buds from undamaged stem during the following spring.

Prior to frosting, plants were assessed for leaf colour and plant size. Neither leaf colour, which ranged from bright green to red/brown, nor plant size appeared to influence survival ability but sample sizes were too small for statistical testing.

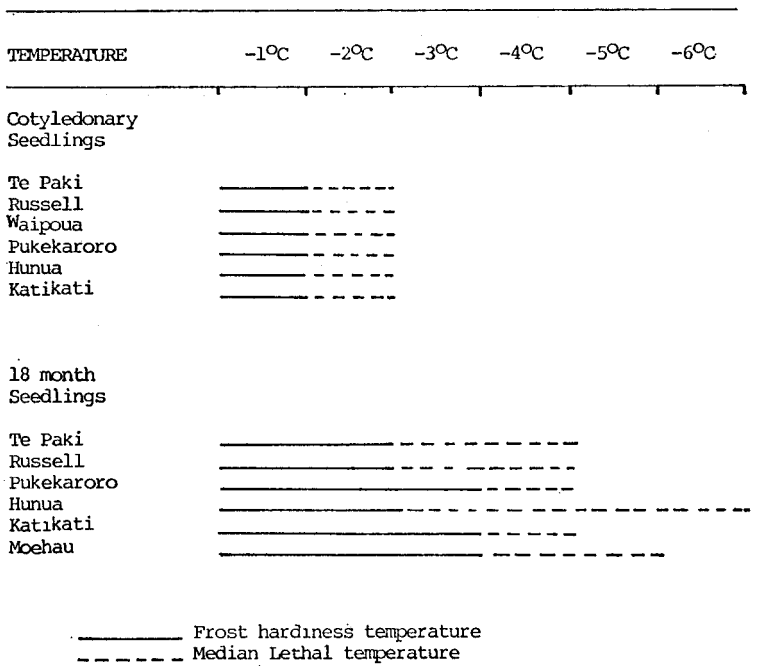

FIG. 2: *Frost hardiness temperature and median lethal temperature for kauri seedlings.*

CONCLUSION

There is apparently no variation in the frost tolerance of kauri seedlings from different areas but, because only small numbers of plants were used in this experiment, thorough statistical analysis was not possible. Further work, using a large number of plants at several stages of development from several sites, would possibly indicate some variation in ability to withstand frost. However, because all of the plants in this experiment behaved in a similar manner, such differences are not expected to be large.

For practical purposes it can be accepted that, during winter, most cotyledonary seedlings will survive temperatures down to –2°C and older seedlings down to –4°C.

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