SEASONAL FROST-TOLERANCE OF EUCALYPTUS SALIGNA, E. REGNANS, AND E. FASTIGATA

M. I. MENZIES, D. G. HOLDEN, D. A. ROOK,

Forest Research Institute, New Zealand Forest Service,
Private Bag, Rotorua, New Zealand

and A. K. HARDACRE

Plant Physiology Division, DSIR, Private Bag,
Palmerston North, New Zealand

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ABSTRACT

Seasonal frost-tolerance of **Eucalyptus saligna** Sm., **Eucalyptus regnans** F. Muell., and **Eucalyptus fastigata** Deane et Maiden was determined by frosting seedlings monthly during 1976 in a controlled environment. Frost tolerance of **E. saligna** ranged from **c.** -3°C in summer to -7°C in winter, of **E. regnans** from **c.** -3.5°C in summer to -9°C in winter, and of **E. fastigata** from **c.** -4°C in summer to -10°C in winter. Seedlings started hardening in April; **E. saligna** reached maximum tolerance in late June, whereas **E. fastigata** reached maximum frost-tolerance in late July, the coldest part of winter. The seed source for **E. regnans** was changed in July, and so it is unknown if it continued hardening during July. **Eucalyptus saligna** started to deharden during July, whereas **E. fastigata** started to deharden a month later, and all three species continued to deharden throughout October. Some variation in the absolute frost-tolerances can be expected depending on the growing climate (nursery location and seasonal variation).

The frost tolerance of the three eucalypt species is less than that of **Pinus radiata** D. Don for all times of the year, and so their establishment should be restricted to sites with good air drainage to minimise the risk of frost damage.

INTRODUCTION

Eucalypts are increasing in importance as an exotic plantation species in New Zealand, but frost has been a problem during their establishment. A tentative selection of species for New Zealand conditions includes *E. saligna* for low elevation sites, and the ash eucalypts *E. regnans* and *E. fastigata* on higher elevation sites. The natural distributions of the three species in eastern Australia, from the south-east of Queensland to Tasmania, have been described by Hall *et al.* (1975) and are shown here in Fig. 1.

Field experience has indicated that the peak winter frost-tolerance of *E. saligna* is *c.* –7°C and that of *E. regnans* and *E. fastigata c.* –7°C to –9.5°C (Bunn 1971). Recent evaluation of frost tolerance of *E. regnans* and *E. fastigata* in controlled environments has agreed with these results and indicated that there is a wide variation in tolerance among provenances. Most of the frost-tolerant provenances originated from the higher elevation, inland, seed sources (Rook *et al.* 1980; Wilcox, Rook & Holden 1980). The best provenances of *E. regnans* and *E. fastigata* tolerated winter frosts of –7° and –9°C respectively.

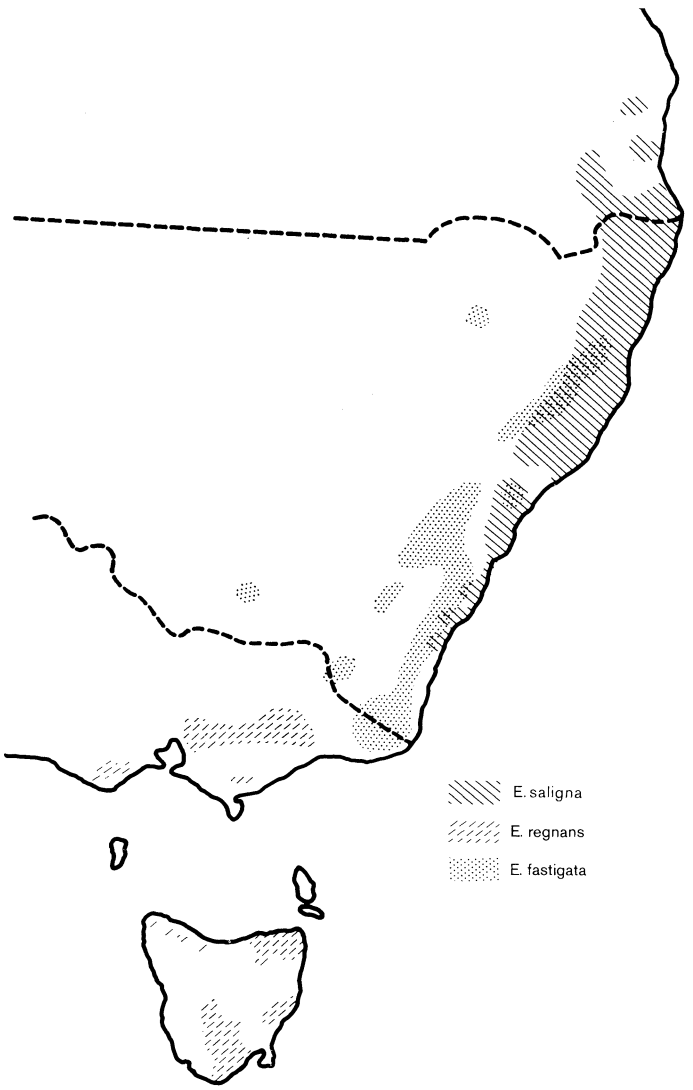

FIG. 1—Natural distribution of **E. saligna**, **E. regnans**, and **E. fastigata** in Australia (adapted from Hall **et al.** 1975).

However, it is often the unseasonable frosts of the late spring, summer, and early autumn which cause damage, as well as the more severe winter frosts, and so a knowledge of the seasonal variation in frost tolerance is needed if meteorological data are to be used effectively as an aid to species siting.

METHODS

Seedlings of *E. saligna, E. regnans,* and *E. fastigata* were sown in 1976 in 60 × 60 × 50 mm peat pots and transplanted into 4-*l* capacity plastic pots, using a 40 : 40 : 20 by volume soil : peat : pumice mixture, including 4 kg/m^3 of Magamp*, a slow-release nitrogen fertiliser also supplying phosphorus, potassium, and magnesium. The seedlings were kept outdoors at the FRI nursery, Rotorua, with the pots buried in the nursery bed to maintain temperatures equivalent to the surrounding soil.

Seed sources used were:

Eucalyptus saligna 1/0/75/016, collected from Cpt 16 Athenree Forest in the northern Bay of Plenty, New Zealand.

Eucalyptus regnans initially 7/0/73/1160, collected from Waitati in Otago, New Zealand. Most of these seedlings were severely damaged by a natural frost in early July in the FRI nursery, and so had to be replaced with other *E. regnans* stock. The replacement stock was barerooted 1/0 seedlings of seed source 8/0/68/614 from Moogara, Tasmania, which were similarly potted up into 4-*l* capacity plastic pots.

Eucalyptus fastigata 8/0/68/616 from Oberon in New South Wales.

The seedlings were allowed to condition naturally in the Rotorua climate, then taken to the DSIR Climate Laboratory, Palmerston North, just before they were due for frosting each month from late March to late October, using the frost rooms described by Robotham *et al.* (1978). The frost programmes were based on data from field frosts (Menzies & Holden 1981), and involved a day temperature of +10°C reducing to the selected night temperature (minimum frost temperature). For frosts of –5°C or less, the rooms were programmed to cool for 4 hours from a temperature of +10°C to the selected frost temperature, maintain that temperature for 4 hours, and then return to +10°C over 2 hours (coded 4-4-2). Frosts of –6° to –8°C were run on a 6-6-4 programme and frosts colder than –8°C were run on an 8-8-4 programme. Soil temperature was maintained above 5°C at 10 cm depth by heating wires located below the pots. The controlled-environment room was programmed on a 24-hour cycle, with a 12-hour photoperiod (irradiance approx. 175 W/m^2 photosynthetically active radiation). The lights were switched on during the last hour at the frost temperature and remained on during thawing. The vapour pressure deficit was maintained near 0 mb while the room was below 0°C.

One or two test frosts with 10 seedlings per species were run a week prior to the main runs to determine frost levels. Ideally the frost levels selected should allow the actual frost-tolerance of the stock at that time of year to be determined, i.e., one frost which would provide medium frost damage with a rating of 2 to 3, and one frost more severe and one less severe to determine the spread of frost damage between individual plants. Three frost temperatures were run each month, using 20 seedlings/

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species/frost. The seedlings were randomly arranged on four trolleys for each frost. After frosting, the seedlings were kept outdoors for 4 weeks after which time frost damage was assessed visually on a scale of 0 to 5 as follows:

0 = no foliage damage;
1 = some leaves slightly damaged;
2 = 10–30% of the foliage killed;
3 = 40–60% of the foliage killed;
4 = 70–90% of the foliage killed;
5 = shoot dead.

Field experience with *P. radiata* and other conifers (Menzies & Chavasse in press) has shown that trees with a frost damage category of 2 or less will recover but those assessed as 3 or greater will be severely weakened and may succumb in subsequent frosts or to weed competition. Later field experience with eucalypts has confirmed this, and although new shoots often sprout vigorously from the stem base, the trees are usually malformed, with multiple stems and large basal branches (Wilcox, Faulds, Vincent & Poole 1980). A damage rating of 2 or less was considered therefore as indicative of a non-critical level of frost damage, i.e., "frost tolerant".

RESULTS

The seasonal changes in frost tolerance of *E. saligna* are indicated in Fig. 2. The seedlings tolerated −3 °C in March (test frost only) and October, but lower temperatures resulted in severe damage. Hardening started in April, and by late May seedlings tolerated −5 °C. Peak winter frost-tolerance occurred in late June when seedlings

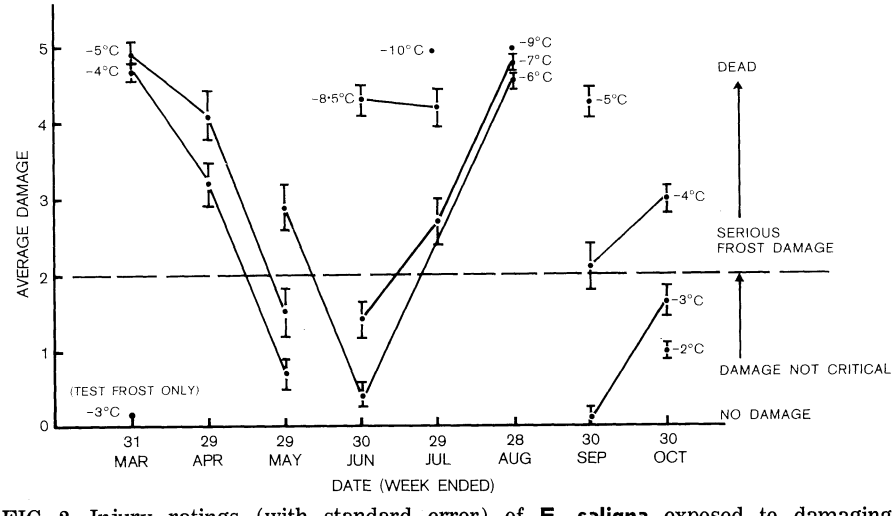

FIG. 2—Injury ratings (with standard error) of **E. saligna** exposed to damaging frosts at different times of the year.

tolerated a –7°C frost. Loss of frost tolerance commenced in July. The –6° to –9°C frosts in August were too severe for *E. saligna*; by late September tolerance levels decreased to –4°C, and in late October to –3°C.

The seasonal changes in frost tolerance of *E. regnans* are shown in Fig. 3. As described previously, the seed source was changed in July because of frost damage to the seedlings in the nursery. Summer tolerance for both seed sources was between –3° and –4°C. Hardening began in April, and continued through autumn so that the seedlings withstood between –6° and –7°C by late June. Peak frost-tolerance occurred in July, when seedlings of the Moogara seed source withstood a frost of –8.5°C. Seedlings started losing frost tolerance in August and by the end of that month frost levels of –7°C resulted in mortality. The frost tolerance was between –4° and –5°C at the end of September, and between –3° and –4°C at the end of October.

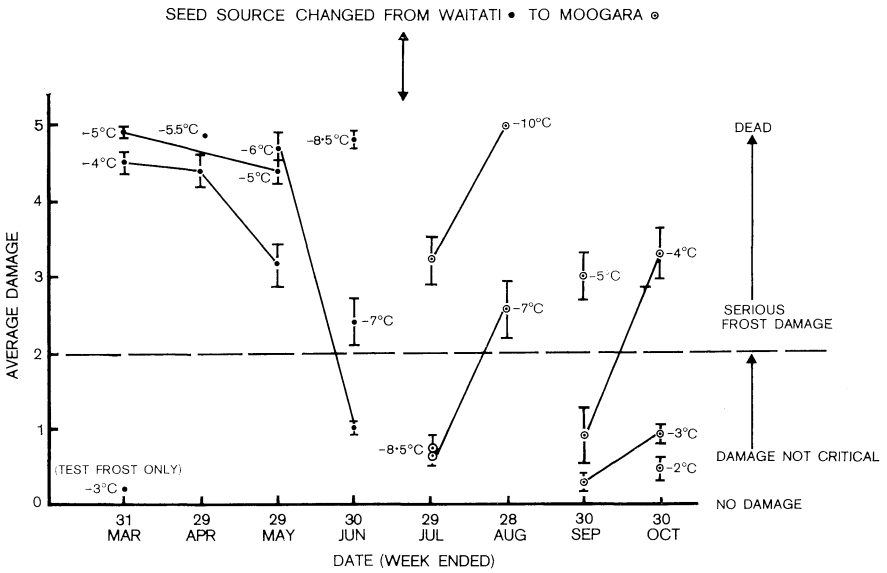

FIG. 3—Injury ratings (with standard error) of **E. regnans** exposed to damaging frosts at different times of the year.

The seasonal changes in frost tolerance of *E. fastigata* are graphed in Fig. 4. Summer tolerance was nearly –4°C. Seedlings began to harden in April, and by late May tolerated a frost of –6°C. Hardening continued with a late June frost-tolerance of –8.5°C, and the peak winter tolerance in late July was –10°C. The seedlings rapidly lost frost tolerance in August and the –9°C frost in late August resulted in mortality. By late September the seedlings were able to tolerate frosts of –5°C without severe damage, and this frost tolerance decreased to –4°C by late October.

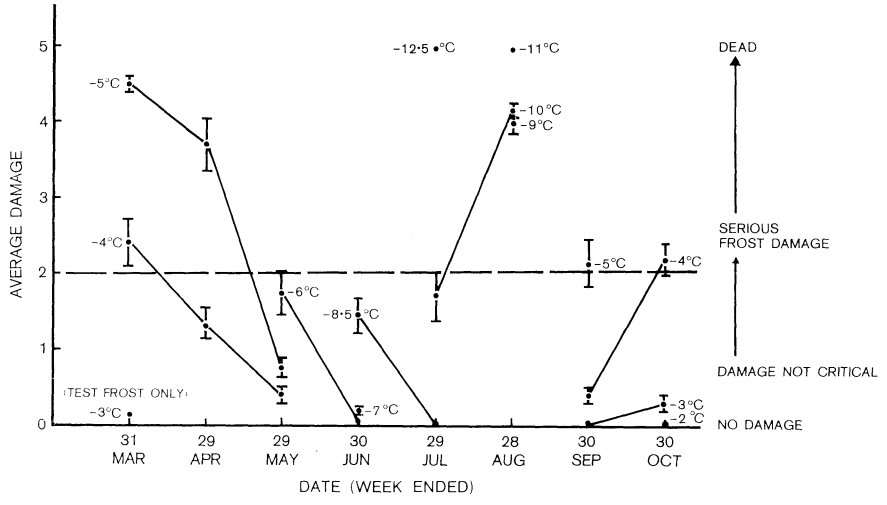

FIG. 4—Injury ratings (with standard error) of **E. fastigata** exposed to damaging frosts at different times of the year.

DISCUSSION

The frost tolerance of the three species appears to parallel the temperature climate found in their natural distribution (Fig. 1). *Eucalyptus saligna* is predominantly a coastal species, and occurs from the south-east corner of Queensland to Bateman's Bay in southern New South Wales, always within 160 km of the coast, where the climate is frost-free at sea level, but with mild winter frosts at higher altitudes. *Eucalyptus regnans* occurs in Victoria and Tasmania, from an altitude of 150 m to 910 m in Victoria, and from near sea level to 610 m in Tasmania. Frosts and light snowfalls are liable to occur throughout most of the year, with 80 or more frosts per year at higher elevations. *Eucalyptus fastigata* occurs mainly in the southern highlands of New South Wales, with some extensions into Victoria. At the southern extent of its range it occurs down to altitudes of 150 m but some of the best stands occur between 1070 m and 1220 m in New South Wales. Frosts are frequent and usually severe, with 50–100 per year.

There was little difference in summer (late March, late October) frost-tolerance among species, ranging from –3° to –4°C, and all three began hardening during April. However, *E. saligna* reached a maximum winter tolerance of –7°C at the end of June coinciding with the shortest day, while *E. fastigata* continued hardening until the end of July (the coldest period of winter), withstanding a frost of –10°C. Both species held this peak frost-tolerance for less than a month, as opposed to 2 to 3 months for conifers (Menzies & Holden 1981).

A subsequent study comparing the frost tolerance of different provenances of *E. regnans* (Rook *et al.* 1980) showed that the Waitati seed source was the least frost-tolerant and the Moogara seed source was the most frost-tolerant of the 38 provenances tested. Because of this provenance difference it is unknown when *E. regnans* reaches a

peak winter frost-tolerance. Rook *et al.* (1980) found a winter difference between provenances of about 2.5°C, and on this basis the late June and July frost tolerances in this study would be similar. However, this would need to be confirmed.

Based on the data of frost damage for the different levels of frost in Figs 2–4, it is possible to estimate seasonal variations in frost tolerance of the three species (Fig. 5). These estimates are based on an average damage rating of 2 or less being an acceptable or non-critical level of damage. Where the frosts were either too severe or non-damaging, the data have been extrapolated from the frost damage in the months before and after. These curves include the hardier provenances of *E. regnans* and *E. fastigata.* The autumn frost-tolerance of the Moogara seed source of *E. regnans* from Rook *et al.* (1980) is used, rather than that from the Waitati seed source. The differences in frost tolerance between provenances of *E. saligna* have not been studied, and so it is not known if the Athenree seed source is one of the hardier ones.

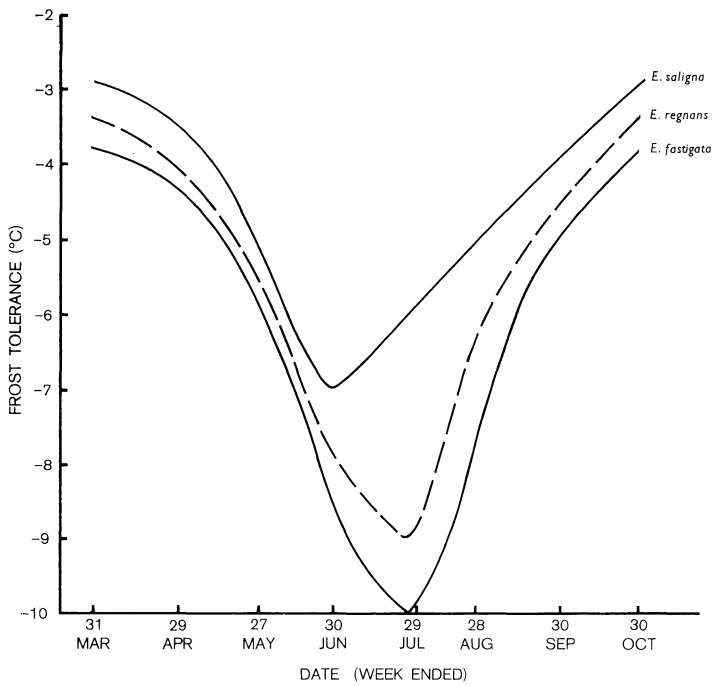

FIG. 5—Changes in seasonal frost-tolerance of **E. saligna**, **E. regnans**, and **E. fastigata** during 1976 (based on damage rating $\leqq 2$).

The maximum winter frost-tolerance of –9°C for *E. regnans* and –10°C. for *E. fastigata* in this study are similar to the results of Rook *et al.* (1980) who reported a maximum winter frost-tolerance for the Moogara seed source of *E. regnans* of –7°C, and Wilcox, Rook & Holden (1980) who reported a maximum winter frost-tolerance of –9°C for the Oberon seed source of *E. fastigata.* The slightly better frost-tolerance in this study could reflect differences in the climate. The seedlings in this study were

grown in Rotorua whereas those in the other two studies were grown in a milder climate at Palmerston North. Nursery location can influence the resulting frost tolerance of radiata pine seedlings (Menzies *et al.* 1981) and there can also be a seasonal effect changing the frost tolerance from year to year (Green & Warrington 1978; Menzies & Holden 1981).

CONCLUSIONS

The peak winter frost-tolerances found in this study agree closely with those suggested from field experience in New Zealand (Bunn 1971), and indicate that *E. saligna* should be restricted to coastal areas with good air-drainage where frosts are not a problem. *Eucalyptus regnans* and *E. fastigata,* with their greater winter frost-tolerance, can be more widely planted in New Zealand, but their frost tolerance is not as good as that of *P. radiata* which can tolerate about –6°C in summer and –12°C in winter (Menzies & Holden 1981). Both *E. regnans* and *E. fastigata* will be susceptible to spring and autumn frosts in New Zealand, and should be planted on sites with good air drainage to minimise the risk of frost damage.

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