FRI BULLETIN NO. 124

# INTRODUCED FOREST TREES IN NEW ZEALAND

## Recognition, Role, and Seed Source

# 18. ASH EUCALYPTS

***Eucalyptus fastigata, E. regnans, E. obliqua, E. delegatensis, E. fraxinoides, E. sieberi, E. oreades, E. pauciflora, E. dendromorpha and E. paliformis.***

J.T. MILLER, A.E. HAY, AND C.E. ECROYD

This bulletin series was compiled for people with an interest in the introduced trees of New Zealand, such as foresters, farm foresters, nurserymen, and students. It includes:

1 *Pinus nigra* Arn.—European black pine
2 *Pinus contorta* Loudon—contorta pine
3 The larches—*Larix decidua* Miller, *Larix kaempferi* (Lambert) Carr., *Larix* x *eurolepis* A. Henry
4 *Pinus mugo* Turra—dwarf mountian pine; *Pinus uncinata* Mirbel—mountain pine
5 *Pinus attenuata* Lemmon—knobcone pine
6 The spruces—*Picea stichensis* (Bong.) Carrière, *Picea abies* (L.) Karsten, ornamental spruces
7 The silver firs—*Abies* spp.
8 *Pinus pinaster* Alton—maritime pine
9 The cypresses—*Cupressus* spp.; *Chamaecyparis* spp.
10 Ponderosa and Jeffrey Pines—*Pinus ponderosa* P. Lawson et Lawson, *Pinus jeffreyi* Grev. et Balf.
11 *Eucalyptus nitens*—(Deane et Maiden) Maiden
12 Radiata pine—*Pinus radiata* D. Don
13 The Redwoods—*Sequoia sempervirens* (D. Don) Endl.—coast redwood; *Sequoiadendron giganteum* (Lindley) J. Buchholz—giant sequoia and the related ornamental genera *Taxodium* and *Metasequoia*
14 Douglas-fir—*Pseudotsuga menziesii* (Mirbel) Franco
15 The willows—*Salix* spp.
16 *Cryptomeria*, *Thuja* and *Tsuga*
17 The Poplars—*Populus* spp.

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COVER PHOTO: Stand of Eucalyptus fastigata aged 66 years in Compartment 122 Kaingaroa Forest (volume 1230 $m^3$/ha, centre tree DBH 110.5 cm, height 64.9 m).

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Thanks to the forest companies who provided data on their eucalypt estates, and the Management of Eucalypts and Eucalypt Breeding Cooperatives who allowed some of their data to be included in the bulletin.

The maps in Appendix 3 were prepared by John Smith. Steve Burgess prepared the maps in Fig. 1 and the drawings (Fig. 6–9). The photographs were taken by: C.E. Ecroyd—Fig. 4, 11, 12, 15, 17, 18 (*E. delegatensis, E. sieberi, E. dendromorpha*), 19 (lower trunk), 20 (lower trunk), 22 (lower trunk), and 23 (lower trunk); H.G. Hiemcke-Hemming—Fig. 2, 10, 18 (*E. regnans*), 20 (leaves), Table 2 (*E. regnans* and *E. delegatensis* capsules); D. Blake—Fig. 18 (*E. oreades*), 22 (leaves), 28, Table 2 (*E. oreades* capsules); M.D. Wilcox—Fig. 21 (lower trunk); and J.H. Barran (all remaining photographs).

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# CONTENTS

# SUMMARY

This bulletin, the eighteenth in the Bulletin No. 124 series, provides an account of the ash eucalypts in New Zealand, with emphasis on *Eucalyptus fastigata, E. regnans, E. obliqua* and *E. delegatensis.* It covers their natural distribution, introduction and history in New Zealand, their role as introduced species, their growth and yield, and their utilisation as sawn timber and pulpwood. Tables are provided to assist their recognition in the field, and information is included about the significant pests and diseases to which they are vulnerable. The bulletin includes information on current improvement programmes, a list of local seed sources, and an appraisal of the possible future status of the ash eucalypts in New Zealand forestry. Currently, *E. fastigata* is the main ash eucalypt being planted for commercial forestry in New Zealand.

**KEYWORDS**: *Eucalyptus delegatensis, E. dendromorpha, E. fastigata, E. fraxinoides, E. obliqua, E. oreades, E. paliformis, E. pauciflora, E. regnans, E. sieberi*, ash eucalypts, recognition, silviculture, utilisation, role, provenance trials, breeding programmes, New Zealand.

# INTRODUCTION AND HISTORY

The genus *Eucalyptus*, which belongs to the family *Myrtaceae*, includes over 800 species, mainly of Australian origin. The ashes form a natural group within the sub-genus *Eucalyptus**. They are distinguished from other eucalypts by several common features of leaves and flowers (see pp. 13–25). They take their popular name from their mainly pale-coloured timbers, traditionally reminiscent of European ash (*Fraxinus excelsior*).

The 37 species of ash eucalypts are mainly native to New South Wales, Victoria, and Tasmania, but a few are also found in South Australia and Queensland (see Appendix 1). In Australia the ash eucalypts are amongst the most important commercial eucalypts harvested for timber and pulpwood. Twenty-four ash eucalypt species are known to be growing in New Zealand. The more common species in New Zealand are, in order of importance, *Eucalyptus fastigata* (brown barrel)†, *E. regnans* (mountain ash), *E. obliqua* (messmate), and *E. delegatensis* (alpine ash). Species of lesser importance include *E. fraxinoides* (white mountain ash), *E. sieberi* (silvertop ash), and *E. oreades* (Blue Mountains ash). Two other ash species, *E. dendromorpha* (Budawang ash) and *E. paliformis* (Wadbilliga ash), have been planted in New Zealand on an experimental scale only. *Eucalyptus pauciflora* (snow gum) has been planted in trials and is used as an amenity tree.

## Natural Distribution and Ecology

### *Eucalyptus fastigata*

The natural stands of *E. fastigata* are found mainly in the southern highlands, northern tablelands, and coastal escarpments of New South Wales (Fig. 1). They also extend into Victoria (around Bendoc) to overlap with the natural range of *E. regnans*. *Eucalyptus fastigata* occurs within the latitudinal range 30°30'S–37°30'S, mainly at altitudes between 650 and 1400 m. Occasionally the species may be present as low as 300 m in moist gullies. Over its natural range the climate is mild; summers are warm (mean maximum temperatures for the hottest month are 23–28°C) and winters are cold (mean minimum temperatures for the coldest month are -4 to 3°C), with frequent, severe frosts, and light to moderate snowfalls. The mean annual rainfall varies from 750 to 2000 mm, mostly evenly distributed but tending to a summer maximum on the northern tablelands. Loamy soils with a moist but well-drained subsoil provide the best growth. In the warmer parts of its range *E. fastigata* favours shaded southern and eastern aspects. Elsewhere it occurs in the valleys, on the slopes of the mountains, and on the edges of the tablelands. Over limited areas, and under very favourable conditions, it occurs in pure stands. However, it is more commonly found in association with *E. delegatensis, E. dalrympleana, E. viminalis, E. nitens, E. obliqua, E. fraxinoides*, and some peppermint eucalypts.

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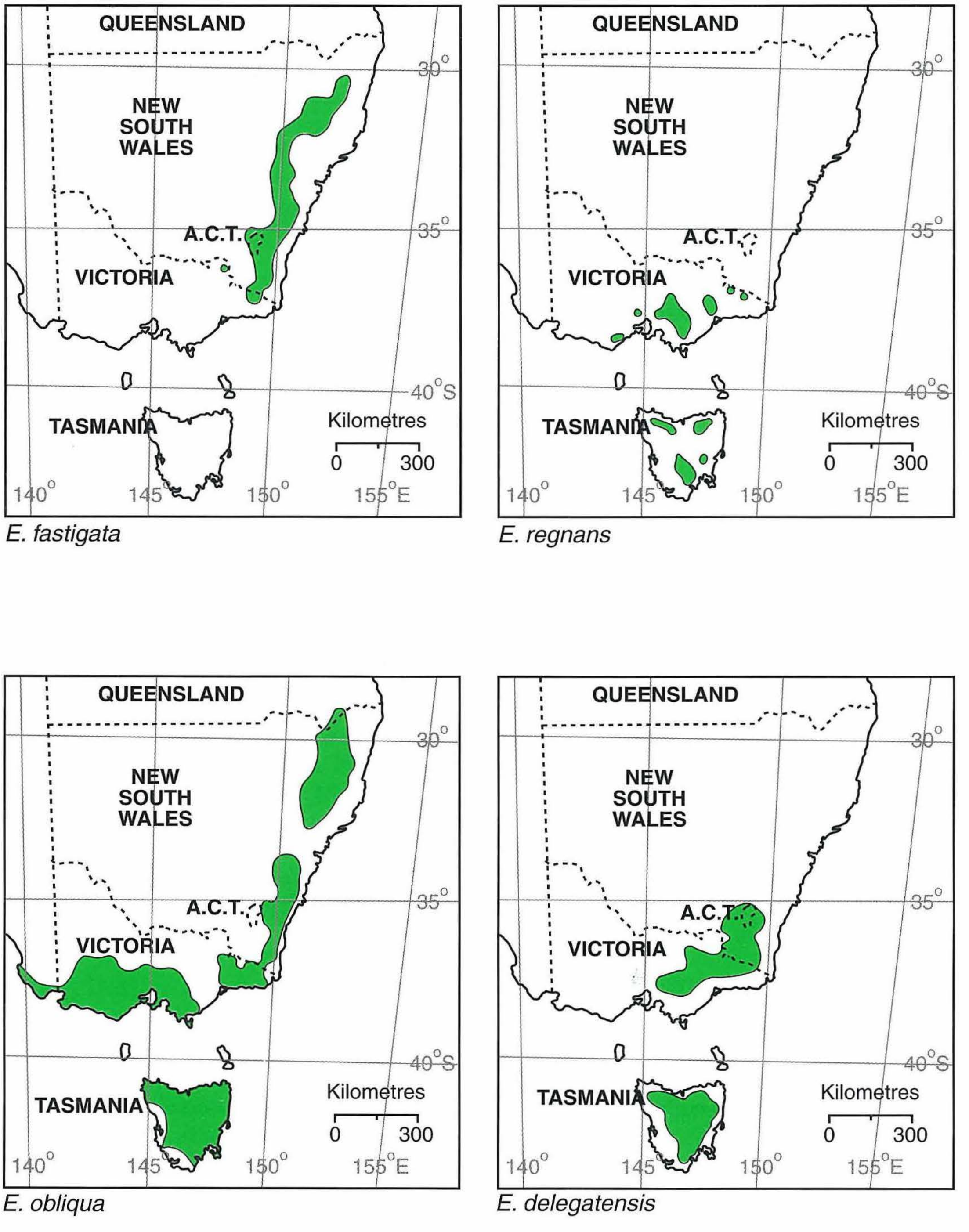
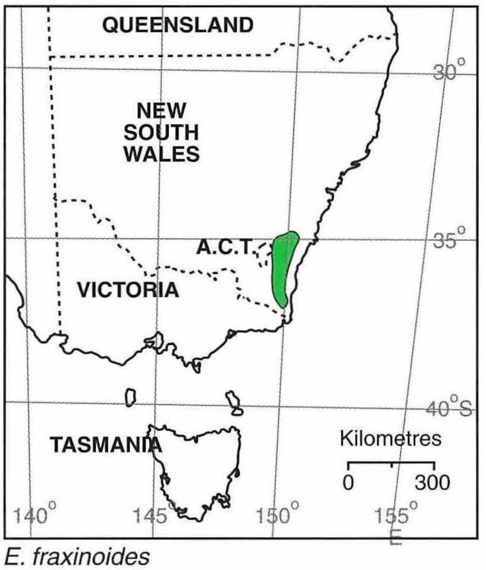
* See Brooker 2000 for a recent classification of the genus *Eucalyptus*.

† In New Zealand eucalypts are commonly referred to by botanical names rather than by their common names and this practice is adhered to in this bulletin.

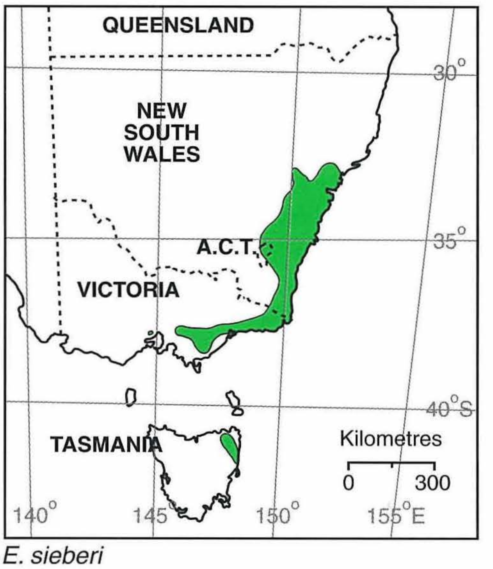
**FIG. 1—Natural distribution of ash eucalypts (based on Boland *et al.* 1984 and Brooker and Kleinig 1999)**



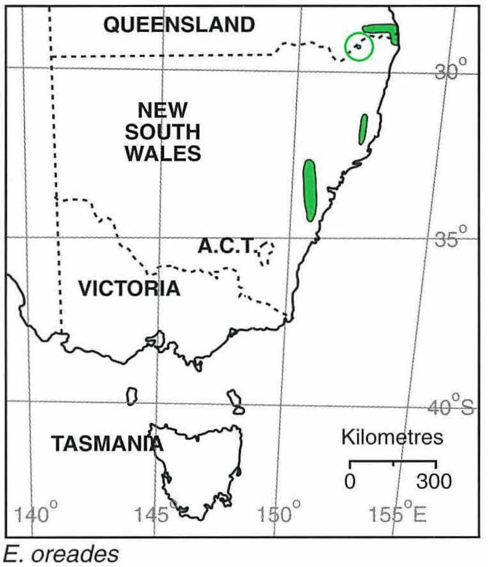

*E. fastigata* — *E. regnans* — *E. obliqua* — *E. delegatensis*



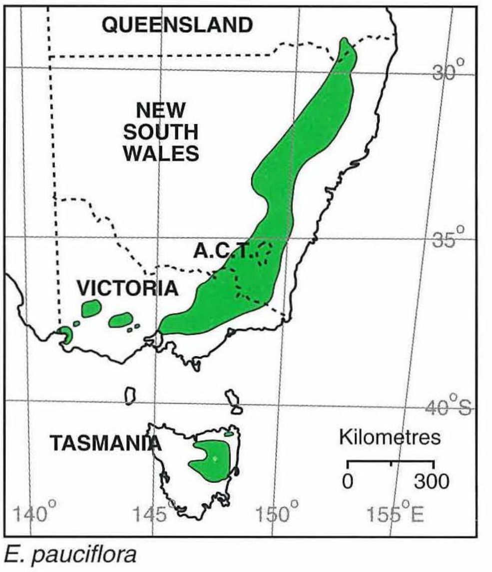
*E. fraxinoides*



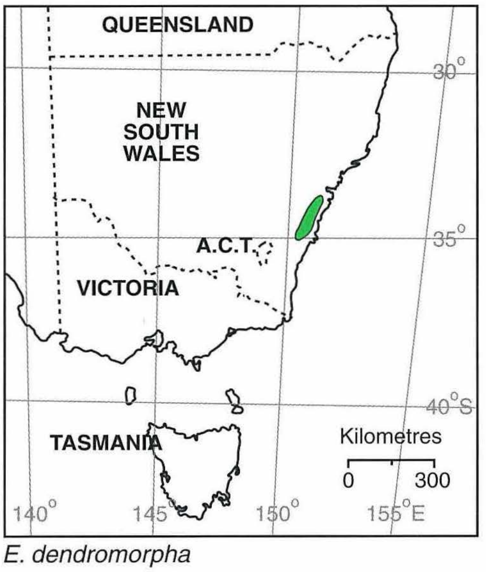
*E. sieberi*



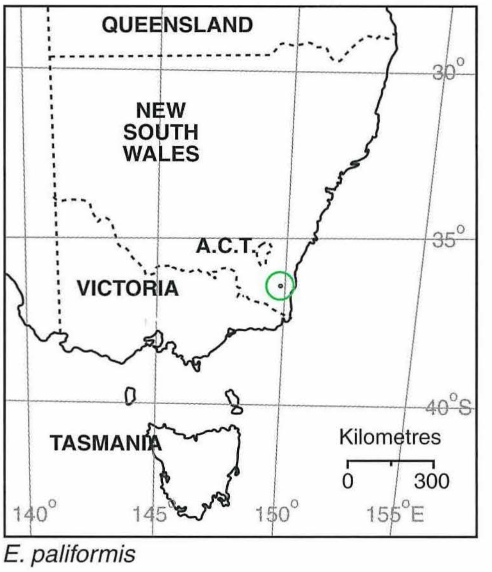
*E. oreades*



*E. pauciflora*



*E. dendromorpha*



*E. paliformis*

***Eucalyptus regnans***

*Eucalyptus regnans* grows naturally between latitudes 37°15'S and 43°15'S in Victoria and Tasmania (Fig. 1). In Victoria it is mainly restricted to the mountains of the eastern half of the State, south of the Great Dividing Range, with small occurrences south-west of Melbourne at Mt Macedon and in the Otway Ranges. In Tasmania the main areas of distribution are in the north-east, the south-east, and the valleys of the Huon and Derwent Rivers. The altitudinal range for *E. regnans* is from sea level to 600 m in Tasmania, and from around 150 to 1100 m in Victoria. Mean annual rainfall within the natural range varies from 750 to 1700 mm with a winter maximum, but without a severe dry period. At higher elevations light to moderate snowfalls may occur throughout the year, and frosts are frequent (over 80 per annum). However, the climate is much milder at low elevations, and frosts rare. Sheltered mountain sites, with deep friable clay loams and rainfall exceeding 1100 mm provide the best growth. *Eucalyptus regnans* usually grows in pure stands as a tall open-forest formation, and often as regeneration following wild fires. However, where soils are poor and rainfall low, it may be confined to valleys. Associated species may include *E. viminalis, E. nitens, Nothofagus cunninghamii,* and *Acacia dealbata.*

***Eucalyptus obliqua***

*Eucalyptus obliqua* is widely distributed in the cooler, southern parts of eastern Australia, principally in New South Wales, central and southern Victoria, and Tasmania. It also occurs in South Australia, in mountain ranges near Adelaide and in the south-east of the State (Fig. 1). In New South Wales it is distributed over the whole length of the State on the eastern side of the tablelands, and just extends into adjacent areas of Queensland. *Eucalyptus obliqua* is an important species in Tasmania and is found throughout the State, but is scattered on the west coast and parts of the central-eastern region. The latitudinal range is from 28°S to 43°30'S. The altitudinal range is from sea level to 750 m in Tasmania, from near sea level to 1000 m in Victoria, and up to 1200 m on the northern tablelands of New South Wales. Mean annual rainfall within the natural range varies from 500 to 2400 mm, with a winter maximum in the south grading to a summer maximum in northern New South Wales, but with no severe dry period in any locality. In the cooler parts of its range, e.g., Tasmania, the species experiences frequent and severe frosts and some snowfalls. *Eucalyptus obliqua* occurs on hilly and mountainous country on a wide range of soils, with best development on good quality loams. The better stands of *E. obliqua* are found in cool mountain areas in tall, open-forest formation where associated species include *E. fastigata, E. nitens, E. cypellocarpa, E. viminalis,* and *E. delegatensis.*

***Eucalyptus delegatensis***

*Eucalyptus delegatensis* is the main commercial species in the cooler, high-altitude regions of south-eastern Australia (Fig. 1). It is found in the southern ranges of New South Wales, in the Australian Capital Territory, in central Victoria, and is widely distributed in Tasmania, where it forms a distinctive subspecies, *E. delegatensis* subsp. *tasmaniensis.* While the latitudinal range is from 35°S to 43°S, its altitudinal range is 900–1500 m on the mainland, and 160–1200 m in Tasmania. Rainfall tends to be concentrated in the winter months and ranges from 700 to around 2500 mm per annum. Frosts may be as frequent as 100 per annum and most populations will receive several months of snow each year. Well-drained, deep soils on steep slopes are characteristic of preferred sites. Commonly associated species on the mainland are *E. radiata, E. dalrympleana,* and *E. pauciflora,* and in Tasmania *E. coccifera, E. urnigera,* and *E. gunnii.* On cooler, moister Tasmanian sites southern beech (*Nothofagus* spp.) may also occur in association with *E. delegatensis.* Many stands of *E. delegatensis* on both the mainland and in Tasmania are pure and even-aged, having regenerated, presumably, after past wild fires.

***Other ash eucalypts***

*Eucalyptus fraxinoides* is confined to the higher eastern slopes of the southern tablelands and the upper slopes of the coastal escarpment of New South Wales. It is also found in the eastern corner (Howe Range) of Victoria (Fig. 1). Its latitudinal range is from 35°S to 37°30'S. The altitudinal range for well-formed trees is 150–850 m, but it will grow in stunted form at altitudes of 1000 m or more.

*Eucalyptus sieberi* occurs naturally between latitudes 33°S and 43°S in eastern Victoria, on the south coast of New South Wales and in north-eastern Tasmania (Fig. 1). It is found at altitudes from sea level to 450 m in Tasmania and up to 1000 m on the mainland, where it experiences fewer frosts and less snow.

*Eucalyptus oreades* is attuned to milder climates. It is found in disjunct populations at altitudes of 750–1150 m in New South Wales and on the Queensland border from latitudes 28°S to 34°30'S (Fig. 1). The best-known stand occurs in the Blue Mountains of New South Wales.

*Eucalyptus pauciflora* is widely distributed from sea level through to 1500 m in Tasmania, Victoria, and New South Wales, where it can reach to the tree line on mountain tops and covers the latitudinal range from 28°S to 42°45'S (Fig. 1).

*Eucalyptus dendromorpha* has a restricted distribution in the central and southern tablelands of New South Wales, while *E. paliformis* is a species of even more restricted distribution, growing only on top of Wadbilliga Mountain in southern New South Wales (Fig. 1).

## History in New Zealand

Since the latter part of the nineteenth century over 180 of the 800 or so species of eucalypts have been introduced to and established in New Zealand*.

In the early years of settlement eucalypts were planted on farms because they grew rapidly and provided shelter for homes, crops, and stock. Some species were identified as being healthy, fast growing, tolerant of a variety of sites, and frost resistant, with good tree form and crown characteristics. Sawing and seasoning experience was gained as well as an assessment of their wood properties and durability.

As early as 1920 D.E. Hutchins noted in an unpublished report that the most promising eucalypt species were found to originate from cooler locations in the south-eastern and eastern parts of the Australian mainland and from Tasmania.

***Eucalyptus fastigata***

*Eucalyptus fastigata* was first planted in New Zealand during the 1880s and 1890s and has been successful on farm sites in many areas, especially the central North Island. Among the better-known stands were those of the Maxwell family in Taranaki. Through Taranaki Forests Ltd they successfully grew *E. fastigata* in plantations at Oakura, in the Kaitake range near New Plymouth, and over the years sawn timber originating from these stands was used for flooring and other high quality decorative products.

*Eucalyptus fastigata* was planted throughout the Waikato, and good examples of trees were found at Cambridge, Hinuera, and Gordonton, where a large specimen (which in 1977 was 264 cm in diameter and 31 m high) was planted in 1890 on the Woodlands Estate. At Papakura, Auckland, a railway reserve plantation of unknown provenance was planted in 1894. Good stands also existed on pumice soils around Hunterville, Taihape, Tokoroa, and in Kaingaroa Forest (see cover).

The first plantings in State Forests occurred in 1899 at Whakarewarewa where, within a few years, about 48 ha were established. Small plantings followed in Hawke's Bay, Wellington, and parts of the South Island. More substantial plantations were established in the

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* New Zealand place names mentioned in the text are shown in Appendix 3.

Waikato from the late 1970s onwards when Carter Holt Harvey Forests Ltd* considered eucalypts to be a suitable replacement for the native hardwood, *Beilschmiedia tawa* (tawa), as a pulpwood source.

By 1977, it was reported to be widely planted on a small scale in New Zealand in both coastal and inland localities.

### *Eucalyptus regnans*

The planting, in 1856, of the "Greytown Gum" at St Luke's churchyard, Greytown, Wairarapa, is believed to have been the earliest planting of *E. regnans*. This was one of three trees out of a dozen 2-year-old seedlings brought from Australia by Charles Rooking Carter (after whom the town of Carterton was named) which went missing 80 km from Wellington while being transported to Carterton by wheelbarrow!

One of the earliest stands of *E. regnans* recorded in New Zealand is growing at Waitati, near Dunedin, in the grounds of the now disused Orokonui Psychiatric Hospital. A few trees were planted near the railway line in about 1870, and vigorous regeneration occurred after fires in 1906 or 1907. These trees have developed into a notable stand extending over 8 ha.

Two other early plantings of *E. regnans* were at Newstead, east of Hamilton, and at Napier. At Newstead, a dozen trees were planted in 1878 by a Captain Runciman, and over time vigorous regeneration occurred with some very large trees developing. In about 1880, five *E. regnans* were planted just north of Napier on a promontory. They grew into large trees which were marked on admiralty charts, and were used by seafarers to guide their ships into Napier harbour. There have been small plantings in inland Hawke's Bay (Fig. 2).

As with *E. fastigata*, Carter Holt Harvey Forests Ltd also planted large areas of *E. regnans* in the Waikato during the 1970s and 1980s for short-fibre pulp production. By 1990 there were around 8000 ha of eucalypts in plantations, about 60% in *E. regnans*.

### *Eucalyptus obliqua*

The earliest date of planting of *E. obliqua* in New Zealand is uncertain. A tree on the property of F. Powell, Kihikihi, Te Awamutu, is believed to date from 1868. Later plantings are recorded at Homebush, Canterbury, between 1870 and 1885. In 1896 the species was recorded by T. Mason growing at "The Gums", Taita, Wellington, having by then reached a height of 6 m. In about 1910, *E. obliqua* was planted in both the Wellington and Gisborne districts. Plantings over the last 50 years have shown that the species can grow well at a wide variety of North Island locations including Waikato, Taranaki, Hawke's Bay, and Wairarapa. In the South Island it has grown successfully in Marlborough (near Picton and in the Wairau Valley), at Cheviot, North Canterbury, on Banks Peninsula (Fig. 3), and on selected warmer sites in Westland, Otago, and Southland.

### *Eucalyptus delegatensis*

The early history of *E. delegatensis* is also uncertain. Early plantings, in about 1900, were probably made under the name *E. obliqua*. It was included with other eucalypts, and pine species, in over 20 ha of mixed plantings at Kaingaroa Forest between 1901 and 1917. It was also recorded at Tokomaru, on the East Coast, in 1917. At Golden Downs Forest, south of Nelson, the earliest planting was in 1929. After 1930 the species was more widely planted, though generally in small areas, at cooler sites in the central North Island, Wairarapa, Hawke's Bay, and in most parts of the South Island (Fig. 4). During the 1950s and 1960s *E. delegatensis* was used in the rehabilitation of native forest cutover and as a nurse crop for beech forest regeneration, both in Southland (Rowallan Forest) and on the West Coast near Reefton. In the North Island, *E. delegatensis* was used experimentally in Rangataua

* At this time the company was known as NZ Forest Products Ltd.

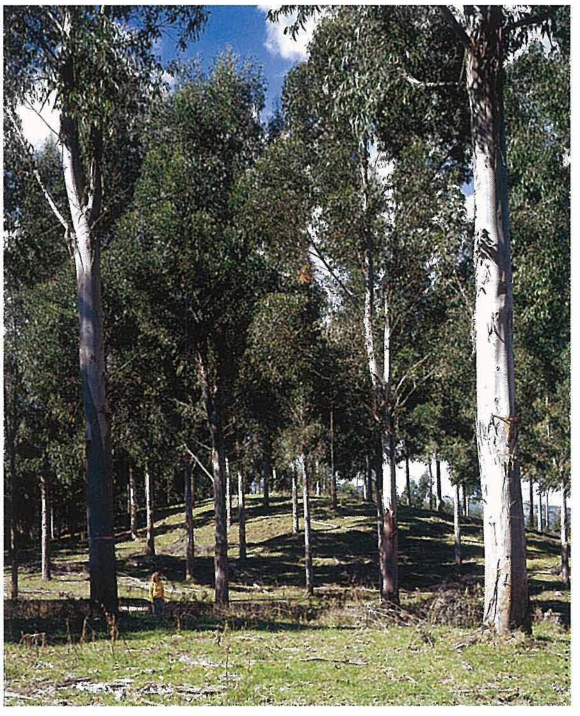

FIG. 2—*Eucalyptus regnans* aged 12 years in Esk Forest. Note that trees of this age are smooth barked almost to the base.

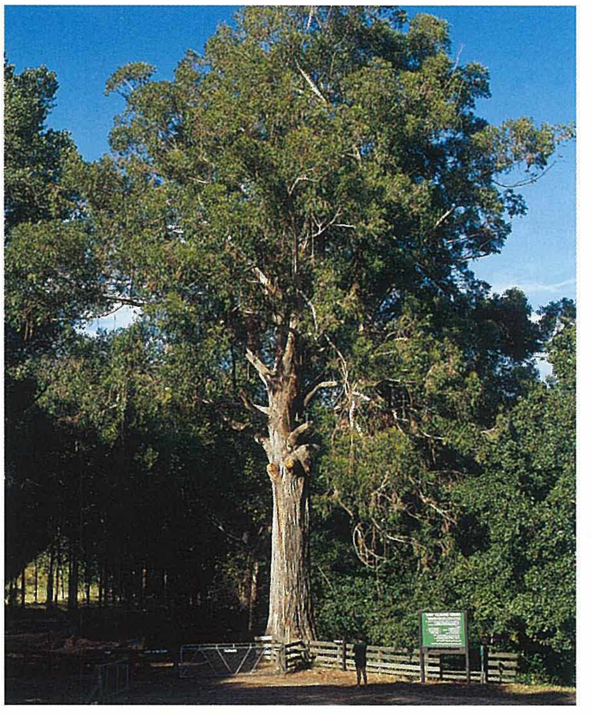

FIG. 3—A mature *E. obliqua* at Orton Bradley Park on Banks Peninsula.

FIG. 4—*Eucalyptus delegatensis* aged 19 years in a provenance trial on Lyndon Hill, Craigieburn Forest Park, altitude 850 m.

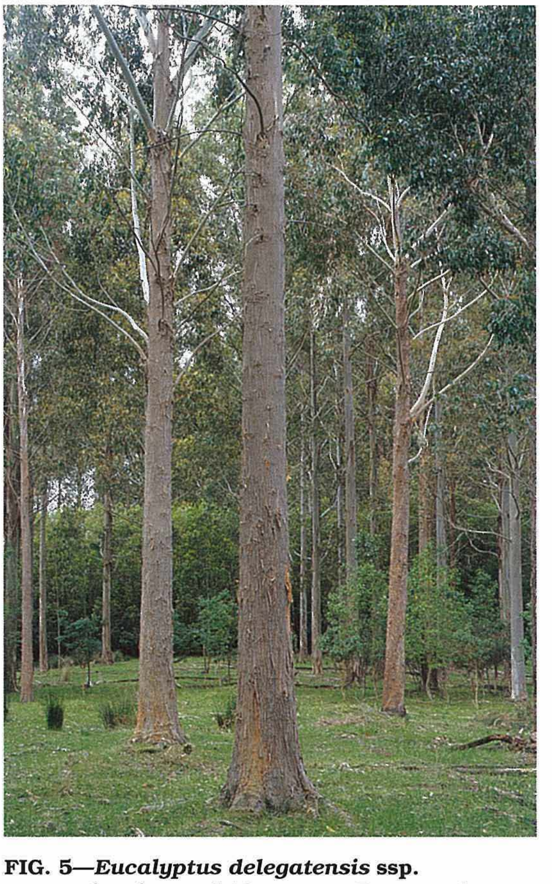

FIG. 5—*Eucalyptus delegatensis* ssp. *tasmaniensis*, aged 19 years at Longwood Forest, Southland. This subspecies has rough bark over the whole trunk.

Forest (on the southern slopes of Mt Ruapehu) as a nurse crop for beech, and further north, around Rotorua, it was used as a rehabilitation species. In Kaingaroa Forest during the mid-1970s large areas of *E. delegatensis* were planted in mixture with radiata pine. The aim was to increase the eucalypt estate, with the pine serving as insurance in case of failure. Most of these areas have now been felled, chipped, and converted to pine. Until recently *E. delegatensis* was the most commonly planted eucalypt in Otago and Southland (Fig. 5), mainly because of its frost tolerance, which is roughly equivalent to that of radiata pine. A shelterbelt planted in 1925 at Crookston, near Tapanui, west Otago, was the seed source of many subsequent plantings of the species in that region.

### *Other ash eucalypts*

Of the minor ash eucalypts growing in New Zealand, *E. fraxinoides* is one of the more significant. It has been planted on a small scale on both islands, including elevated sites in the Wairarapa and, as horticulture shelterbelts, around Auckland. It has performed well in trials on a moderate rainfall site at Longwood Forest in Southland (Fig. 14).

*Eucalyptus sieberi*, although not common in New Zealand, was planted as early as 1890 at Kamo, Northland, but may have been planted earlier in Canterbury, Otago, and Southland. It was first established in State Forests at Whakarewarewa (Fig. 15) and Waiotapu in 1901 with further plantings in Taranaki in 1914 and 1927, and at Tairua Forest in 1932. The most notable remaining stand is in Whakarewarewa Forest where there has been considerable natural regeneration.

*Eucalyptus oreades* is less well known in New Zealand but is occasionally found in farm shelterbelts in the North Island. It has also performed well in species trials, one of the best results being at Rotoehu Forest. There was until recently a vigorous small stand in Kaingaroa Forest. It has also grown well at Longwood Forest (Fig. 16).

*Eucalyptus pauciflora* is of interest mainly because of its possible application in the New Zealand high country; it is occasionally grown as an ornamental tree (Fig. 17). *Eucalyptus dendromorpha* was first introduced to New Zealand in species trials at Kaingaroa Forest in 1981 (Fig. 11). It proved both hardy and healthy and as a result two further experimental plantings of 500 trees were made at Karioi and Kaingaroa Forests in 1984. *Eucalyptus paliformis* was also introduced experimentally in 1981, with the intention of evaluating it as a potential shelterbelt species. Small areas were planted in 1983 in Kaingaroa Forest (Fig. 12 and 13) and near Palmerston North at the Plant Materials Centre of the Ministry of Works and Development. *Eucalyptus paliformis* and *E. dendromorpha* are very rare in New Zealand outside these trials. Four other ash eucalypts, *E. andrewsii, E. triflora, E. stenostoma,* and *E. rossii,* have been planted with varying degrees of success in a number of eucalypt species trials (see p. 33).

## Genetic Variation

The planting and cultivation of eucalypts in New Zealand for some 150 years has resulted in a widely scattered estate of individual trees, shelterbelts, small stands of trees, and latterly some large private plantations. Some of these local stands of eucalypts, although mostly of unknown origin and narrow genetic base, have helped to identify desirable species for formal testing. During the mid- and late-1970s numerous eucalypt trials, including 11 provenance trials, 19 progeny trials and seven species tests, were established by both Forest Research and Carter Holt Harvey Forests Ltd. The ash eucalypts featured in the species tests were *E. andrewsii, E. delegatensis, E. dendromorpha, E. fastigata, E. fraxinoides, E. obliqua, E. regnans, E. sieberi, E. stenostoma* and *E. triflora.* The purpose of these trials was to investigate the genetic variability of species and to identify and provide reliable, well-adapted seed sources for future plantings and for further improvement work. *Eucalyptus fastigata* and *E. regnans* were found to be the best species to plant at middle elevations of 300–500 m in the central North Island. *Eucalyptus delegatensis* performed moderately well on cooler sites.

Provenance and progeny tests of *E. fastigata*, *E. regnans*, and *E. delegatensis* were established in the late 1970s (see Table 1). Open-pollinated family seedlots collected from superior trees selected in New Zealand plantations and family, or provenance, seedlots imported from natural stands in Australia produced breeding populations with a broad base of genetic variability.

**TABLE 1: Provenance and progeny test information for *E. fastigata*, *E. regnans*, and *E. delegatensis***

| | ***E. fastigata*** | ***E. regnans*** | ***E. delegatensis*** | |
|---|---|---|---|---|
| Sites | Kinleith, Kaingaroa | Kinleith, Kaingaroa | Rotoaira | Golden Downs, Kaingaroa, Longwood |
| No. provenances | 25 | 36 | 108 | 36 |
| No. families | 126 | 108 | 36 | |
| Year of establishment | 1979 | 1977 | 1977–79 | 1977–79 |

In general, the tests showed that in these eucalypt species there is significant genetic variation at both the family level and the provenance level. As the best performers came from many different provenances, provenance selection alone could not be relied upon to maximise genetic improvement.

*Eucalyptus fastigata* has a wide and disjointed natural distribution in New South Wales and extends into the northern part of Victoria. The Oberon provenance in New South Wales ranked best overall, followed closely by an exotic landrace from Natal, South Africa. Provenances from Barrington Tops, northern New South Wales, and Oakura, New Zealand, also ranked well.

*Eucalyptus fastigata* has several advantages over the other two main ash eucalypt species. It is one of the healthiest and most adaptable eucalypts planted in New Zealand. It is less susceptible to serious fungal disease and insect damage and tolerates frosts of -10°C. It has performed well and remains healthy at elevations from 80 to 500 m, though it appears to be more suited to North Island sites where the latitude is similar to the natural distribution of the species in Australia. *Eucalyptus fastigata* is a steady performer on the better sites, showing good increments from about age 12 years, although the early growth rates of *E. delegatensis* and *E. regnans* can often exceed it. It has two end-uses and therefore offers greater flexibility to the grower. It is suitable as sawn timber, producing a high quality decorative wood, and it yields a short-fibre pulp suited to the production of fine printing papers. Its worst feature is a tendency for the crown to break up early into rough, heavy branches. This characteristic was emphasised in the plantings of seed sourced from Rossi in the late 1980s. In contrast, a seedlot from South Africa, planted as surround in a breeding trial in Kinleith Forest and as a commercial plantation near Tolaga Bay, has shown relatively faster growth and better form.

In *E. regnans*, frost tolerance, tree form, and disease resistance differed considerably between provenances. The south Gippsland provenance (Strzelecki Ranges, Traralgon) in Victoria was the fastest growing and had good disease resistance. However, it showed poor frost tolerance. The best native provenance for combined traits was from inland south Tasmania, e.g., Moogara, Styx River, where excellent frost tolerance was combined with good growth rate. In contrast, stock raised from the New Zealand stand at Waitati, near Dunedin, notable for its impressive growth and form, was found to be extremely frost tender.

The *E. delegatensis* provenances from southern Victoria appeared, at age 3 years, to be best overall, with Victorian provenances generally superior to those from Tasmania and New South Wales. However, at age 8 years, the Tasmanian provenances were found to have overtaken the initially faster growing Victorian provenances, at least in diameter growth. The New Zealand material ranked relatively low for diameter but ranked well for straightness, similar to the New South Wales seedlots. The general standard of tree form in the trials was acceptable (King *et al.* 1993). Stands of *E. delegatensis* can be found throughout New Zealand and like *E. regnans*, there are examples where growth has been good, although very little has been planted recently. The youngest stands are those planted in Southland in the late 1980s before *E. nitens* became the preferred species. In general *E. delegatensis* is severely affected by *Mycosphaerella* and *Aulographina* fungi. It is not highly regarded as a pulpwood species when evaluated against species such as *E. globulus* or *E. nitens*, and has severe drying defects when sawn.

Two levels of genetic improvement have been applied to these species. Gains have been made by sourcing seed from the top provenances in New Zealand and then establishing seed stands from these. At a more intense level the best individuals from these provenances (in the progeny trials) have been selected and established as seedling and clonal orchards to produce seed for commercial plantings.

Despite this potential for tree improvement, growers were disappointed with poor survival rates, siting difficulties, including frost damage, and attack by leaf-destroying insects, fungi, and browsing animals. Consequently, the level of interest in research dropped sharply and from 1980 to 1989 no new trials were initiated, although importation of seed from the better provenances was encouraged.

In the late 1980s, the industry began to focus on producing eucalypts for short-fibre pulp. Based on the results of the earlier breeding experiments, Forest Research, through the Eucalypt Breeding Cooperative, revived breeding programmes in two ash eucalypts, *E. regnans* and *E. fastigata*.

The Cooperative began work in 1991 to establish advanced breeding populations of these species. Seed of 300 open-pollinated families per species was collected from the best trees in earlier trials, existing New Zealand forest stands, and imported genetic material from native stands in Australia and from improvement programmes in South Africa.

In conjunction with this, seedling and clonal seed orchards were established using selections of the best individuals in the best families in the earlier provenance/progeny trials. These genotypes were selected for improved growth and form, increased frost resistance, and crown health.

Stem straightness, malformation, and diameter growth have been shown to be variable and heritable. The current breeding programme aims to develop a tree with rapid growth, fine branching, good stem straightness, and no malformation. Future research on wood properties (basic density and checking) and pulping characteristics will enable further intensive selection of clones for seed orchards and specific end-uses.

## Pests and Diseases

The growing of ash eucalypts in New Zealand carries the risk of attack by a range of insects and fungi. The chance introduction of eucalypt pests and pathogens, either windborne or brought by people, is increased by New Zealand's relatively close proximity to Australia; such introductions can be problematic or even disastrous.

### *Insects*

The ash eucalypts are host to a number of insect pests, although only a few cause serious problems. Attacks have been mainly localised and seasonal, and their adverse effects have sometimes been reduced by good siting and silviculture.

The New Zealand native pinhole borers (*Platypus apicalis* and *P. gracilis*) can bore into the sapwood of all the ash eucalypts and the risk of attack is greater if eucalypts are planted close to (within 5 km of) native forest areas. Signs of this attack are kino streaks down the bark, the production of kino veins, and sometimes kino pockets within the wood which can reduce the timber grade and quality.

Damage to the wood of the ash eucalypts can also be caused by the larvae of various wood-borers. These include larvae of the longhorn beetles (Cerambycidae), especially the native species *Navomorpha lineata*, which mines within small branches and can cause them to fall off, and of the introduced wood-boring longhorn beetle *Callidiopsis scutellaris*. Larvae of the following species have also been recorded as attacking the wood of ash eucalypts: the puriri moth *Aenetus virescens*, which is confined to the North Island; the scolytid beetle *Amasa truncata*; stag beetles (Lucanidae); weevils (Curculionidae, *Catoptes* spp. and *Phrynixus* spp;) and the relatively unimportant anobiid beetles *Leanobium* sp., *Methemus* sp., and *Deroptilinus* sp.

A large number of other insects attack the ash eucalypts but are of lesser significance. These include the leaf-eating gum tree weevil *Gonipterus scutellatus*, which could be a serious defoliator were it not well controlled by the egg parasitoid wasp *Anaphes nitens*. Caterpillars of the greenheaded leafroller moth *Planotortrix excessana*, the brownheaded leafroller *Ctenopseustis obliquana*, the eucalyptus leafroller *Strepsicrates macropetana*, the common forest looper caterpillar *Pseudocoremia suavis*, and the brilliantly coloured caterpillar of the gum emperor-moth *Opodipthera eucalypti* can all reduce the tree's growth rate or flowering capacity, and result in defoliated branches in the upper crown. Although these effects may only be seasonal, there may be an impact on future tree form and growth.

Damage may also be caused by psyllids *Ctenarytaina* spp.—sapsuckers which distort the leaves, by larvae of the eucalypt leaf-mining sawfly *Phylacteophaga froggatti*—although this is now controlled by an introduced parasite *Bracon phylacteophaga*, and by the gum tree scale *Eriococcus coriaceus*, which in some severe localised attacks has caused branch dieback and even tree death, although it is usually well controlled by its ladybird predators. Ash eucalypts are also attacked by Cerambycid larvae, cicadas (*Amphisalta* sp.), the grey planthopper *Sephena cinerea*, and by thrips (Thysanoptera). There are instances where the eucalyptus tortoise beetle *Paropsis charybdis* has caused defoliation in some stands of ash eucalypts, especially *E. fraxinoides*, although the introduction in 1988 of the parasite *Enoggera nassaui* has reduced the severity of such attacks.

### *Fungi*

Leaf-spot fungi are commonly found on most ash eucalypts. The older leaves at the base of the tree are usually affected, but often not severely enough to cause major defoliation, so the trees may still be largely healthy. These attacks may be localised and occur as a result of seasonal climatic change; for example, warm, humid summers usually encourage fungal infection. However, at certain sites, such as parts of the central North Island and Nemona and Mahinapua Forests in Westland, which experience high rainfall or persistent atmospheric humidity associated with fog, high levels of infection have occurred and defoliation has been severe and widespread.

Prominent leaf-spot fungi that infect ash eucalypts include: *Aulographina eucalypti, Mycosphaerella cryptica, Sonderhenia eucalyptorum, Pseudocercospora eucalyptorum, Elsinoe eucalypti, Colletotrichum* sp., and *Botrytis cinerea*.

A particularly severe attack involving this suite of fungi was observed on *E. regnans* in Kinleith Forest in spring 1989, and later in other North Island locations. It marked the first recognition of the condition known as "Barron Road Syndrome" (BRS). In its most severe form, BRS causes loss of new foliage, with the upper crown of affected trees eventually becoming devoid of leaves. In addition, emerging leaves and the older leaves which are retained show small necrotic spots, and the shoots, stems, and petioles become typically roughened with galling (Kay 1993). While all the fungi associated with BRS have been recorded on *E. fastigata*, their impact on tree health has been relatively slight. In one instance in the North Island a plantation of *E. fastigata*, growing in immediate proximity to severely affected stands of *E. regnans*, showed no signs of attack other than increased leaf-spotting. Elsewhere, particularly in sporadic occurrences in Westland and Southland, *E. delegatensis* has been found hosting most of the characteristic suite of fungi associated with BRS. Since the initial BRS attack, there has been a significant degree of recovery in many of the affected areas. The risk of future serious attacks may be reduced by planting *E. regnans* on less humid sites, and possibly, by selection of more resistant provenances.

When the summer rainfall is high the ash eucalypts, in particular *E. regnans* and *E. delegatensis*, can be severely infected by *Mycosphaerella cryptica.* As a result irregularly shaped spots form on the leaves and cankers appear on the new shoots in the upper crown. The resulting tip dieback and defoliation then cause malformation. Infection may be frequent during the early years of tree growth, and the Tasmanian provenances of both *E. regnans* and *E. delegatensis* are more resistant than the Victorian provenances. *Eucalyptus delegatensis* may be severely defoliated by *Mycosphaerella cryptica*, especially where the trees have been planted on sites which are too warm for the species.

### *Other fungal diseases*

Silverleaf (*Chondrostereum purpureum*) causes stain and decay within the wood of branches and the stem. In eucalypts, silverleaf is usually associated with pruning wounds. As the fungal spores are particularly active during rain or high levels of humidity, pruning should be done during fine, dry weather. Both *E. regnans* and *E. delegatensis* are particularly prone to silverleaf damage, whereas *E. fastigata* is less likely to suffer major decay.

There are a number of other fungi which attack the ash eucalypts, but these are generally not considered to pose major problems. *Eucalyptus regnans,* in common with other ash eucalypts, is occasionally attacked by *Armillaria* spp. Likewise the root-rot fungus, *Phytophthora cinnamomi,* has been recorded as causing deaths sporadically on sites with fluctuating water tables. For example, mortality has occured in *E. fraxinoides* growing in Northland shelterbelts. Similarly, when planted in damp conditions, ash eucalypts have died as a result of infection by *Botrytis* spp.

Keeping stands reasonably open encourages good air movement and helps reduce the effects of fungal attack.

A nursery fungus, *Hainesia lythri*, reputedly causing considerable problems in Australia, has been recorded in New Zealand and may be capable of spreading. Normally, fungal infections in the nursery are readily controlled by good basic hygiene, i.e., avoidance of over-crowding and unnecessary dampness of stock.

The general susceptibility of *E. delegatensis* to disease has contributed to its being discontinued as a plantation species in New Zealand. Similarly, the lack of resistance to fungal infection in recent years has also resulted in the decline of *E. regnans* as a major plantation species. Conversely, *E. fastigata* has come to be regarded as the most healthy of the ash eucalypts grown in New Zealand and is currently the favoured ash eucalypt for solid wood and pulp production in the North Island.

### *Other pests*

In common with other eucalypts, the ashes are susceptible to browsing by rabbits, hares, possums, and deer. On older trees bark rubbing and stripping by deer can be a problem, as well as branch breakage and leaf stripping in tree crowns caused by possums. Grazing of sheep and cattle should be avoided in young stands until the tops of the trees are well above browse height. For sheep this may be after 18–24 months. However, cattle must be kept out longer due to the risk not only of foliage damage, but also of stem breakage and bark stripping.

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# RECOGNITION

Eucalypts can be very difficult to identify because, among over 800 species, there are only subtle differences between many that are closely related. However, correct identification can be vital because, even within a group of closely related species such as the ash eucalypts, different species have different site requirements, growth rates, and tree form, as well as markedly different wood properties and potential end-uses.

Eucalypt identification is a three-step process: first, an adequate sample should be collected; the sample should be classified into one of the eucalypt groups (see Appendix 2); and finally, the particular species or variety can be identified. Information on what material to collect and the best features to use for identification is provided in Box 1. Explanations of the terms used in eucalypt identification are in the Glossary (p. 49).

## Features of the Ash Eucalypts

The ash eucalypts are a well-recognised natural group and the main identification characteristics of this and other common eucalypt groups grown in New Zealand are summarised in Appendix 2. However, a few species have some characteristics which bridge the boundaries between the ashes and some of the more closely related stringybarks and peppermints. Consequently, there are a few species, usually included in these other eucalypt groups, which may fit the general description of ash eucalypts and can only be distinguished using features such as internal flower structure.

### *Habit and bark*

Ash eucalypts are commonly tall trees, although a few of the less common species are small multi-leadered trees (i.e., mallees). The trunks of ash eucalypts can be smooth or rough barked. The rough bark can vary from being stringy, like the stringybarks, to being finely fissured and interlaced, like many of the peppermints. Unlike the true stringybarks, however, ash eucalypts usually have smooth, whitish, small branchlets and they generally have only weak coppicing ability compared to that of peppermints.

## BOX 1—Samples to collect and features to use for eucalypt identification

While the experienced field observer may be able to identify some eucalypts from the habit and appearance of the tree, it is usually necessary to resort to a more detailed examination. Mature seed capsules are usually the most useful single item for reliable identification, but flower buds, flowers, bark, and leaves are also helpful and often necessary. The arrangement on the stems of capsules, buds, flowers, and leaves can be important and it is helpful if the samples collected are still attached to the branchlets.

It is easier to work with fresh material but if this is not available or is impractical to collect, dead material can be useful. There is no best time to collect samples, but a tree needs to be mature enough to produce flowers and seed capsules.

### *Habit and bark*

Note the general shape and size of the tree and whether it has a single, straight trunk or whether it is multi-leadered from ground level. The characteristics of the bark are particularly useful. Is it rough, smooth, flaky, or stringy? How far does the rough bark extend up the trunk and does it continue on to the large or small branches? What colour is it and do ribbons of bark hang down the trunk? This information can be particularly helpful in differentiating between certain closely related species.

### *Leaves*

During a eucalypt tree's development the leaf size, shape, and colour can change quite markedly and different leaf stages can be recognised. After the first few seedling leaves there is often a sudden change to a different type of juvenile leaf form, followed later by intermediate leaves and, finally, the adult leaf form when the plant has become mature. Usually, even closely related species show differences in at least one leaf type. The distinctive leaves on coppice shoots, for example, can be very useful for species identification when used in conjunction with mature leaves. The most typical leaves of each stage, usually those growing midway along a branchlet, should be used to compare with the descriptions. Seedling leaves are not often used to identify mature trees in New Zealand because most of the trees are plantation grown and not many regenerate naturally from seed.

The angle at which the side veins of the leaf join the central vein or midrib (Fig. 6) is useful for distinguishing between the groups of eucalypts (see Appendix 2) and can help separate some of the species in the ash group. The leaf veins will show clearly if illuminated from behind and the vein angle near the middle of the leaf can be measured with a protractor.

### *Flower buds, flowers, seed capsules, and seed*

The peduncle, which is the stalk connecting a cluster of flowers or seed capsules to the stem (see Fig. 7), can be round, flattened, or angular in cross-section, depending on the species. Each flower bud or seed capsule also has an individual stalk or pedicel (see Fig. 7). The number of flower buds formed in a cluster is significant. It is usually an odd number rather than an even one. For example, with a cluster of six buds, it is likely that seven buds were originally formed and, under magnification, a scar from the missing one would be evident at the top of the peduncle.

When the seed capsule is fully ripe, lines of weakness develop in the top surface and form cracks which finally separate into a series of teeth or valves. These valves eventually open to release the seed. Mature capsules (Fig. 8 and 9) in which the valves are clearly visible, are much more useful for identification than immature ones. Fully formed flower buds which are nearly ready to open and mature seed capsules should be used for all measurements and comparisons with the descriptions. Seed colour is a useful means of identification, but care is needed to distinguish the seed from the unfertilised ovules or "chaff" which forms the bulk of the contents of mature capsules of most species.

### *Leaves*

The adult or mature leaves are alternate, stalked, pendulous, lanceolate or falcate (strongly curved) with uneven bases (Fig. 6), usually concolorous (the same colour on both surfaces), with side veins at a relatively narrow angle to the midrib, often 20–30° but ranging from 5 to 40°.

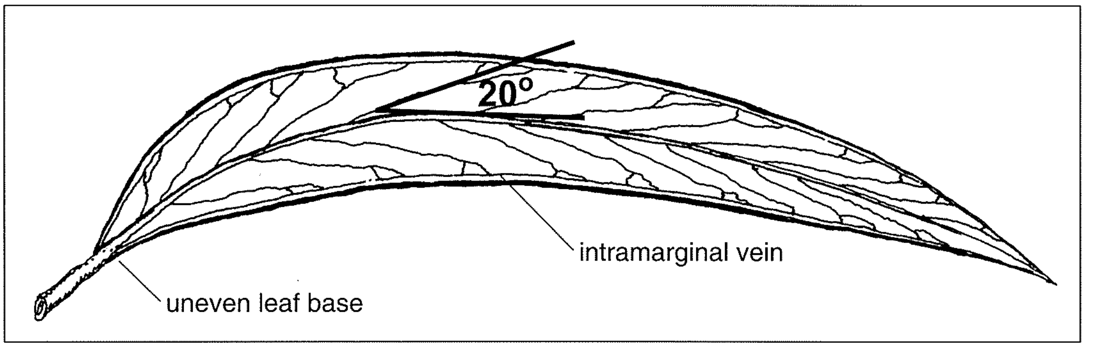


**FIG. 6—A typical ash eucalypt leaf showing the curved (falcate) shape with uneven leaf bases and the secondary veins at an angle of about 20° to the midrib.**

### *Flower buds and flowers*

The flower buds (Fig. 7) occur in the leaf axils in clusters of 5–27 and are usually club-shaped with no operculum scar (in most eucalypts the operculum is formed in two layers and during bud development one layer falls off leaving a ring scar). The stamens are white.

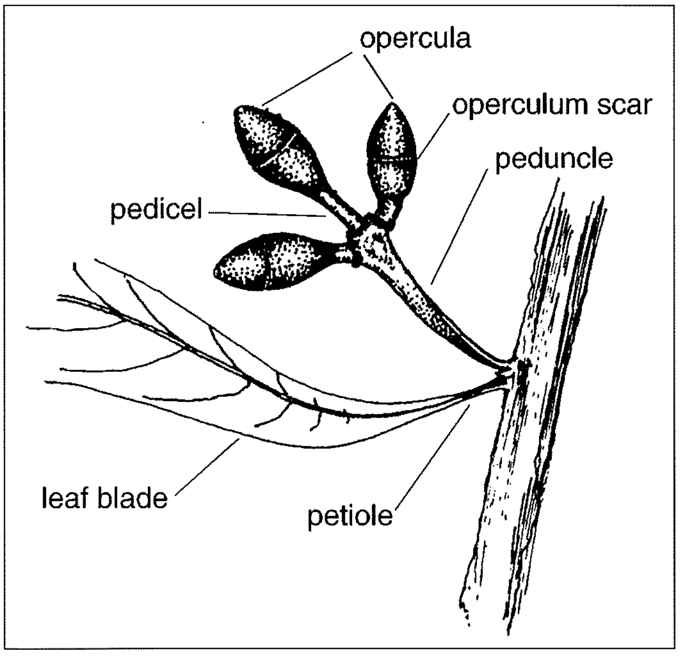


**FIG. 7—A single cluster of eucalypt flower buds showing the peduncle (stalk of a flower cluster), pedicels (individual flower stalks), opercula (bud caps), and opercula scars (absent in ash eucalypts).**

### *Mature seed capsules*

The mature seed capsules are stalked, relatively loosely clustered, longer than wide, usually pear-shaped and flat-topped, with a broad disc which ranges from ascending to descending (Fig. 8 and 9). The mature seed capsules contain a mix of seed and similar-sized unfertilised ovules termed "chaff". The seed is 1.5–3 mm long, usually brown (or occasionally black), with a smooth or minutely pitted surface, and the chaff is reddish brown.

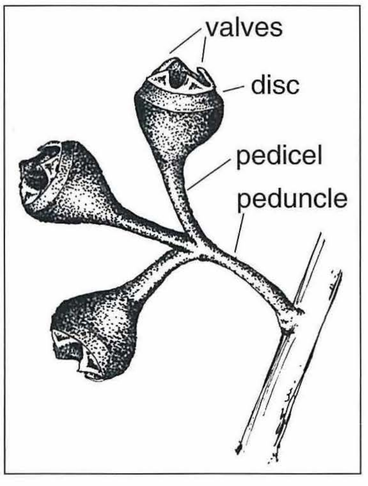


**FIG. 8—Mature seed capsules showing exserted valves, ascending discs, pedicels, and peduncles.**

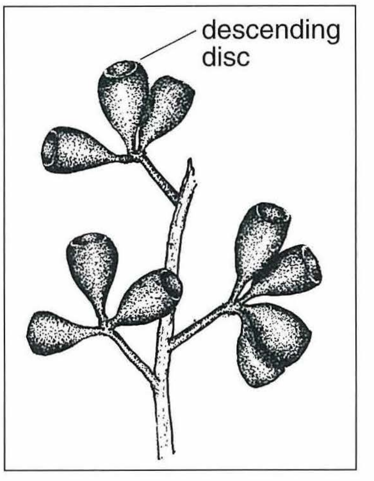


**FIG. 9—Mature seed capsules with descending discs and sunken valves concealed inside.**

### *Seedlings*

In the ash eucalypts the first 2–7 pairs of seedling leaves are held horizontally, but the leaves forming after these pairs hang vertically (Fig. 10). These first few leaves are also attached in opposite pairs and are at right angles to each other; they are stalkless or short stalked; the outer surface is green, and the underside is usually purplish. The next few pairs are arranged alternately and are stalked. This abrupt change distinguishes the seedlings of ashes from those of the stringybarks, blackbutts, white mahoganies, and most of the peppermints which all have many more pairs of opposite leaves. The seedling leaves of ash eucalypts are either hairless or have a few minute hairs, distinguishing them from stringybark seedlings which have conspicuous hairs on the leaves.

**FIG. 10—The leaves on this *E. regnans* seedling change at the fourth pair from opposite and stalkless to alternate and stalked with the blades held vertically instead of horizontally.**

## Recognition of Ash Eucalypts Growing in New Zealand

The botanical characteristics of the 10 ash eucalypts most commonly found in New Zealand are summarised in Table 2 (pp. 18–21). The other 14 species in New Zealand are less common. When attempting to identify these species, more comprehensive Australian texts should be used as a reference point or specimens should be sent to Forest Research for identification.

FIG. 11—Stand of *E. dendromorpha* aged 17 years in Kaingaroa Forest. Note the very erect branches typical of this species.

FIG. 12—A multi-leadered *E. paliformis* tree aged 15 years showing the heavy branching and rounded crown typical of this species.

FIG. 13—A shelterbelt of *E. paliformis* aged 15 years in Kaingaroa Forest.

**TABLE 2: Recognition of ash eucalypts in New Zealand**

| | *E. fastigata* | *E. regnans* | *E. obliqua* | *E. delegatensis* | *E. fraxinoides* |
|---|---|---|---|---|---|
| **Habit** | A medium to tall tree, growing up to 60 m in height and over 1 m in diameter in both Australia and New Zealand. Often has a very broad, moderately open crown. Heavily branched in open situations (cover). | The world's tallest hardwood tree, growing to 100 m in natural stands and up to 70 m in New Zealand. Moderate to open crowned and lightly branched in stands (Fig. 2). | A small to very tall tree with straight trunk and ascending branches. Can grow up to 90 m high in Australia and to over 50 m in New Zealand. Grey, drab appearance from a distance (Fig. 3). | A tall tree, growing up to 90 m high and 2 m in diameter in Australia, and up to 50 m high in New Zealand. In a stand it forms a straight, branchless trunk with a moderately open crown (Fig. 4 and 5). | A medium to tall tree, growing up to 40 m in New Zealand. Often untidy in appearance. Large branches are common in the open, but trees of better form can be found in stands (Fig. 14). |
| **Bark** | Grey-brown, rough, furrowed and stringy on the trunk and large branches (Fig. 19). Upper branches usually smooth, white or cream, with long ribbons of bark hanging down. Young trees may be half barked. | Grey-brown, rough, thin, fibrous over the lower trunk or to c. 15 m on tall trees. Upper trunk and branches smooth, streaked cream, light grey, greenish or orange and usually with long ribbons of shedding bark (Fig. 18). | Grey to grey-brown, rough up to small branchlets, variable, either compact and irregularly fissured or stringy and furrowed but without the long fibres of true stringybarks (Fig. 20). | Grey to brown, rough, thick, short-fibred or slightly stringy on lower half of trunk, deeply furrowed on large trees, smooth above, greyish, shedding, with a few long ribbons hanging in upper branches (Fig. 18). New bark creamy white. Branchlets usually white and waxy, becoming orange-red. | On mature trees dark grey to black, rough and compact for a few metres at the base of the trunk, but smooth, yellowish white with patches of light grey on the upper trunk and branches (Fig. 14). On young trees (< 20 years) smooth to base (Fig. 21). Branchlets sometimes whitish and waxy. |
| **Leaves** | **Seedling:** opposite for 3–4 pairs.<br>**Juvenile:** ovate to broad lanceolate or curved with uneven base, 4.5–17 cm long, 1.8–6 cm wide, glossy, green, discolorous. | **Seedling:** opposite for 2–3 pairs.<br>**Juvenile:** ovate to broad lanceolate with uneven base, 5.5–17 cm long, 2.2–8 cm wide, glossy, green. | **Seedling:** opposite for 2–7 pairs.<br>**Juvenile:** ovate to broad lanceolate or curved with uneven base, 6–21 cm long, 2.3–8.5 cm wide, glossy green. | **Seedling:** opposite for 4–5 pairs.<br>**Juvenile:** ovate to broad lanceolate (in subsp. *tasmaniensis*, orbicular, with uneven base and pointed tip) 7–25 cm long, 6–10 cm wide, usually dull grey-green, but sometimes reddish. | **Seedling:** opposite for 5–6 pairs.<br>**Juvenile:** lanceolate to ovate or curved with uneven base, 6–20 cm long, 1.5–6.5 cm wide, green or blue-green, concolorous. |
| | **Adult:** leaf stalks 1–2.2 cm long; blades 8–21 cm long, 1.2–5 cm wide, glossy, green (Fig. 19); leaf vein angle 10°–20°. | **Adult:** leaf stalks 1–2.5 cm long; blades 9–23 cm long, 2–8 cm wide, glossy, green; leaf vein angle 10°–30°. | **Adult:** leaf stalks 0.7–3.4 cm long; blades 6–22 cm long, 2.5–7 cm wide, glossy, dark green (Fig. 20); leaf vein angle 15°–40°. | **Adult:** leaf stalks 2–4.5 cm long; blades 9–23 cm long, 2–5 cm wide, glossy, grey-green, often turning red with age; leaf vein angle 10°–30°. | **Adult:** leaf stalks 1–1.8 cm long, blades 8–18 cm long, 1–3 cm wide, glossy, green (Fig. 21); leaf vein angle 10°–25°. |
| **Buds and flowers** | In clusters of 11–15. Peduncles slender, rounded to angular, 5–13 mm long. Pedicels 1–4 mm long. Mature buds club shaped, 5–6 mm long, 2–3 mm wide. Cap conical or short beaked. | In clusters of 9–15. Peduncles slender, rounded to angular, 4–14 mm long. Pedicels 2–4 mm long. Mature buds club shaped, 5–7 mm long, 3–4 mm wide. Cap conical or rounded with a small point. | In clusters of 7–11. Peduncles angular to flattened, 5–20 mm long. Pedicels 1–6 mm long. Mature buds club shaped, 6–7 mm long, 3–5 mm wide. Cap rounded and flattened with a small point. | In dense clusters of 7–17. Peduncles rounded to angular, 9–20 mm long. Pedicels 2–7 mm long. Mature buds club shaped, 5–6 mm long, 3–4 mm wide. Cap rounded with a small point. | In clusters of 7–11. Peduncles angular to flattened, 8–19 mm long. Pedicels 1–6 mm long. Mature buds club shaped, 6–7 mm long, 3–4 mm wide. Cap conical. |

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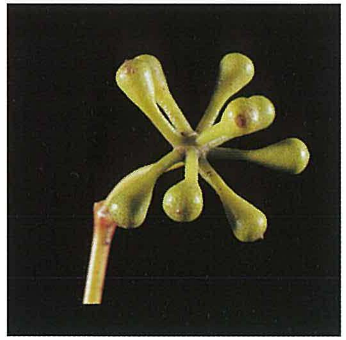
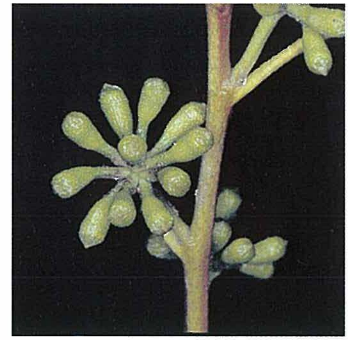
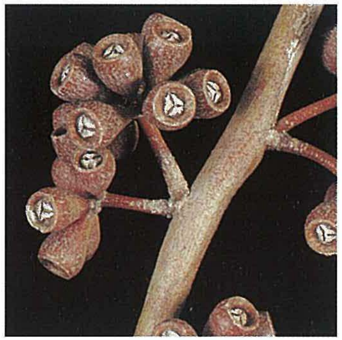
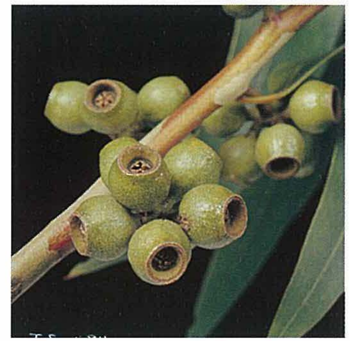
|---|---|---|---|---|---|
| |  |  |  |  |  |
| **Mature seed capsule** | Pear-shaped to conical, 5–8 mm long, 5–7 mm wide. Disc distinct, usually brown, ascending or occasionally level. Valves 3, rarely 4, slightly exserted or near rim level. | Pear-shaped to cup-shaped, 5–9 mm long, 5–8 mm wide. Disc level or slightly descending. Valves 3–4, rarely 5, to rim level or very slightly exserted. | Barrel-shaped to egg-shaped, 7–14 mm long, 5–11 mm wide. Disc descending. Valves 3–5, near rim level or enclosed. | Cup-shaped to pear-shaped, 7–13 mm long, 6–11 mm wide. Disc usually descending, occasionally level. Valves 3–5, usually 4, enclosed. | Barrel-shaped to rounded, 8–13 mm long, 6–11 mm wide, glossy green or reddish when young. Disc descending. Valves 4 or 5, deeply enclosed. |
| |  |  |  |  |  |
| **Comment** | Bark rough and stringy on trunk but smooth and white on upper branches. Usually with some flower clusters in pairs, a distinctive feature shared with *E. regnans*. Similar to *E. regnans* but rough bark extends higher on the trunk and capsules usually domed on top with an ascending disc, whereas *E. regnans* capsules are flat topped. | Flower clusters often in pairs, a characteristic shared with *E. fastigata*. Distinguished from *E. fastigata* by short stocking of rough bark and flat-topped capsules. Adult leaves can be larger than most other ashes, except *E. delegatensis* and *E. obliqua*. | Distinguished from other ashes by the rough, stringy bark throughout, buds rounded with a small point and adult leaves with distinctly uneven bases. Leaves often larger and wider than other ashes except *E. regnans* and *E. delegatensis*. | Distinguished from other ashes by rough bark at least on the lower trunk, grey-green adult leaves, and dense clusters of long, cup- to pear-shaped capsules with descending discs. Differentiated from *E. regnans* by grey-green leaves and slightly larger capsules, in single clusters. Leaves and capsules similar to *E. sieberi* but bark is very different. Subsp. *tasmaniensis* has raised oil glands on seedling stems, giving them a warty appearance, and more orbicular seedling and juvenile leaves. | Trunk with a short stocking of dark, rough bark below and conspicuous smooth whitish bark above. Leaves strongly curved, narrow, glossy. Capsules glossy, barrel-shaped with 4–5 depressed valves. Seed black. Differs from *E. delegatensis* in the shorter stocking of rough bark, capsule shape and narrower leaves. |

**TABLE 2: Recognition of ash eucalypts in New Zealand (continued)**

| | *E. sieberi* | *E. oreades* | *E. pauciflora* | *E. dendromorpha* | *E. paliformis* |
|---|---|---|---|---|---|
| **Habit** | A medium to tall, straight tree growing up to 35 m, with a wide rounded crown (Fig. 15). | A medium-sized, well-formed tree growing up to 40 m (Fig. 16). Large branches common when grown in the open. | A very variable species, often crooked and multi-leadered with heavy branching (Fig. 17) but can also form a straight trunk and grow up to 30 m tall. | Grows to 30 m tall with light to heavy, erect branching (Fig. 11). | A small tree growing to 15 m tall with heavy branching and a rounded crown (Fig. 12 and 13). |
| **Bark** | Rough on lower trunk or to base of large branches. On young trees orange-brown, thin,flaky, becoming thicker with age, hard, compact, furr-owed, dark grey-brown (Fig.18). On upper trunk and crown, smooth and white. Branchlets often shiny red under a thin layer of whitish wax. | Grey, rough, thick, fibrous on lower half of trunk; smooth white or yellowish above (Fig. 18), usually with ribbons of bark hanging in the upper branches. Small branchlets are often whitish and waxy. | The trunks are smooth white or mottled with patches of grey and cream bark (Fig. 22). The branchlets are often white and waxy. | A thin layer of roughish, compacted, grey-brown bark on the lower trunk and smooth light grey and cream bark above (Fig. 18). Ribbons of bark often hang from the upper branches. | Smooth throughout, white to grey or green, with abundant ribbons hanging from the trunk and branches (Fig. 23). |
| **Leaves** | **Seedling:** opposite for 3–5 pairs.<br>**Juvenile:** ovate to lanceolate or curved with uneven base, 6–17 cm long, 1.6–7.5 cm wide, dull blue-green.<br>**Adult:** leaf stalk 1–2 cm long; blades relatively thick, 10–22 cm long, 1.5–4 cm wide, glossy, grey-green; leaf vein angle 10°–20°. | **Seedling:** opposite for 5–6 pairs.<br>**Juvenile:** ovate or curved with uneven base, 8–21 cm long, 3.5–10 cm wide, dull grey-green.<br>**Adult:** leaf stalks 1.2–2.8 cm long; blades 7.5–18 cm long, 1–3.2 cm wide, glossy, green; leaf vein angle 10°–30°. | **Seedling:** opposite for 2–5 pairs.<br>**Juvenile:** ovate, 13–18 cm long, 5–8.5 cm wide, bluish green, concolorous.<br>**Adult:** leaf stalks 0.8–2 cm long, blades <u>thick</u>, 5–22 cm long, 2–4 cm wide, dull blue-green to glossy green (Fig. 22); leaf <u>veins almost parallel to the midrib</u>. | **Seedling:** opposite for 4–7 pairs.<br>**Juvenile:** broad lanceolate, 5–14 cm long, 1.5–5 cm wide, green and discolorous.<br>**Adult:** leaf stalks 0.6–1.5 cm long; blades 7–18 cm long, 1–4 cm wide, glossy, green; leaf vein angle 20°–30°. | **Seedling:** opposite for 3–5 pairs.<br>**Juvenile:** narrow lanceolate, 6.5–11 cm long, 1.5–2 cm wide, glossy, green, concolorous.<br>**Adult:** leaf stalks 0.5–1.2 cm long; blades 7–13 cm long, 1.2–2 cm wide, lanceolate to falcate with entire to very shallowly scalloped margins (Fig. 23), glossy green; leaf vein angle 15°–30°. |
| **Buds and flowers** | In clusters of 7–15. Peduncles angular to flattened, 8–23 mm long. Pedicels 1–4 mm long. Mature buds club-shaped, 5–7 mm long, 3–4 mm wide. Cap rounded or slightly conical. | In clusters of 7–11. Peduncles flattened, 9–25 mm long. Pedicels 0–3 mm long. Mature buds diamond-shaped and slightly curved, 6–8 mm long, 3–4 mm wide. Cap conical or beaked. | In clusters of 7–17. Peduncles rounded to angular, 0.3–1.6 mm long. Pedicels absent or very short. Mature buds smooth or finely warty, club-shaped, angular, 5–9mm long, 3–5 mm wide. Cap rounded or beaked. | Abundant flowers in clusters of 7–9. Peduncles angular to flattened, 6–15 mm long. Pedicels 0–4mm long. Mature buds finely warty, 5–10 mm long, 3–4 mm wide, slightly angular. Cap conical. | In clusters of 7. Peduncles rounded to angular, 4–8 mm long. Pedicels 2–3 mm long. Mature buds finely warty, club-shaped, 5–7 mm long, 1–3 mm wide. Cap conical to rounded. |

| | | | | | |
|---|---|---|---|---|---|
| |  |  |  |  |  |
| **Mature seed capsule** | Pear-shaped, 8–12 mm long, 6–9 mm wide. Disc level to slightly descending. Valves 3, occasionally 4, near rim level or slightly enclosed. | Cup-shaped to barrel-shaped, 6–10 mm long, 6–10 mm wide. Disc descending or level. Valves 4–5, near rim level or enclosed. | Cup-shaped, 7–16 mm long, 6–14 mm wide. Disc level or descending. Valves 3 or 4, near rim level or enclosed. | Cup-shaped to globose or barrel-shaped, 7–13 mm long, 8–11 mm wide. Disc descending. Valves 3–4, enclosed. | Globose, 5–8 mm long, 5–7 mm wide, with a small opening. Disc descending. 3 or 4 very small enclosed valves. |
| |  |  |  |  |  |
| **Comment** | Distinctive orange-brown flaky bark on younger trees but on large trees the bark is hard and furrowed. Branchlets shiny red. Grey-green leaves with side vein angle of 10–20°. Capsules mostly 3-valved, similar in shape to *E. regnans* but usually larger. | Rough bark only at the base of the trunk. Distinguished from *E. regnans* by the diamond-shaped and slightly curved mature buds, usually in single clusters of 7. | Five sub-species are recognised and they show considerable variation in the shape and colour of the flower buds and capsules. Distinguished by the smooth, white trunks and the thick, dull, blue-green leaves with side veins almost parallel to the midrib. | A very rare species in New Zealand. Similar to *E. fraxinoides*, but has slightly wider leaves and more pointed angular buds on shorter pedicels, and black, as opposed to brown, seed. The stocking of rough bark is thinner and the young seed capsules less shiny than *E. fraxinoides*. | Very rare in New Zealand. Distinguished from other ash eucalypts by the smooth bark throughout, narrow leaves with very shallowly scalloped margins, small round seed capsules and the smooth, pale yellow seeds. Sometimes confused with *E. fraxinoides* but has smaller leaves, buds and seed capsules. |

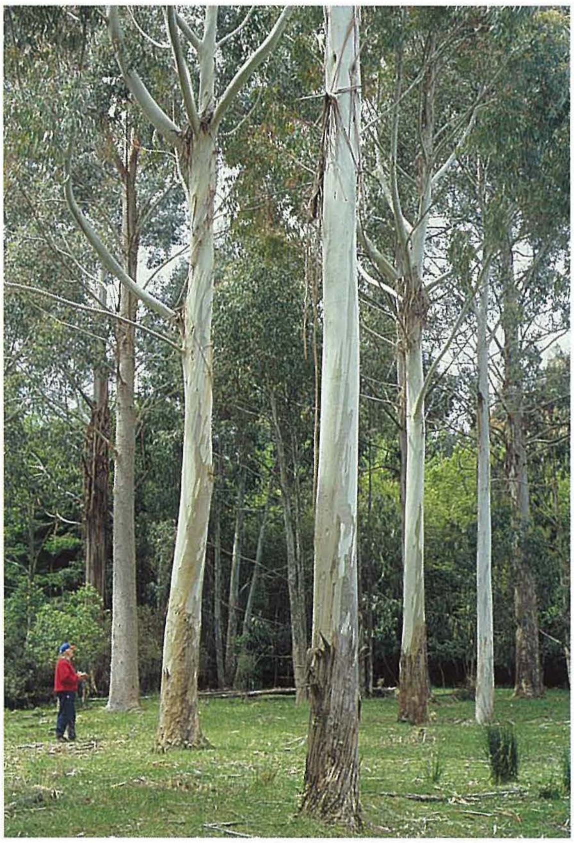


FIG. 14—A stand of *E. fraxinoides* aged 20 years, Longwood Forest, Southland. Note the rough bark at the base of the trunks.

FIG. 15—A mixed-age stand of *E. sieberi* growing at Forest Research, Rotorua. The oldest trees are about 70 years of age.

FIG. 16—A stand of *E. oreades* aged 20 years at Longwood Forest, Southland.

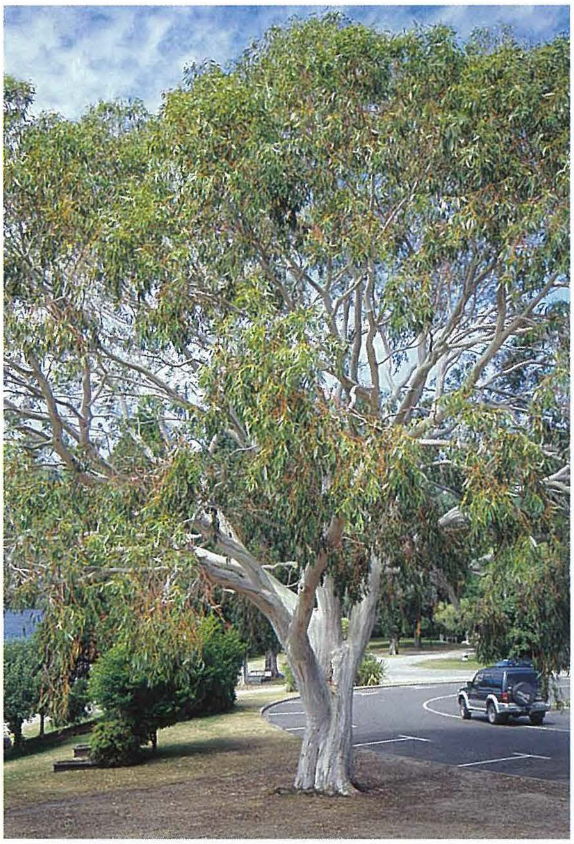


FIG. 17—A large *E. pauciflora* tree (Lake Taupo) with smooth, white bark and glossy leaves.

**FIG. 18—Bark of some common ash eucalypts**

***Eucalyptus regnans*** **(above): the lower trunk shows the typical thin grey-brown rough bark. The upper trunk becomes smooth with light grey bark and partially shed ribbons.**

***Eucalyptus delegatensis*****: lower trunk of mature tree with grey-brown rough bark. The large branches are smooth and creamy white where the rough bark has been shed.**

**A typical lower trunk of *E. sieberi* showing the flaky, slightly furrowed, brown, rough bark.**

**Lower trunk of *E. oreades* with the typical rough grey bark at the base and smooth whitish bark above.**

***Eucalyptus dendromorpha*** **(right): showing the typical thin layer of rough grey-brown bark on its lower trunk. About 2 m above the base the bark starts peeling off to reveal pale smooth bark beneath.**

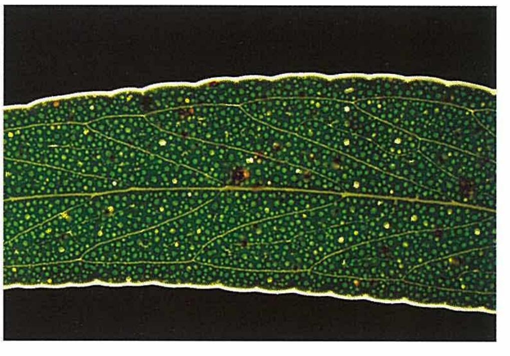
FIG. 19—Lower trunk of *E. fastigata* (left) showing the rough grey-brown stringy bark. This type of bark usually occurs on the trunk and large branches. Leaves of *E. fastigata* (below) are usually bright glossy green and slightly curved. *Eucalyptus dendromorpha* and *E. paliformis* leaves are similar in size and shape but less bright green.

FIG. 20—Lower trunk of *E. obliqua* (left) showing the stringy bark which is grey on the surface and brown where rubbed or damaged. *Eucalyptus obliqua* leaves (below) are usually dark green and wide with distinctly uneven leaf bases. *Eucalyptus regnans* has similar leaves but the leaf bases are usually less uneven.

FIG. 21—*Eucalyptus fraxinoides* (left) lower trunk of a young tree showing smooth, grey-white bark to the base (older trees usually have a few metres of rough bark at the base of the trunk). Adult leaves (below) have uneven bases, hang vertically and show a slightly bluish-green colour typical of the blue-leaved ashes, especially *E. delegatensis*, *E. fraxinoides*, *E. oreades*, and *E. sieberi*.

FIG. 22—The lower trunk of *E. pauciflora* (left) with the smooth bark streaked white, grey, and cream. *Eucalyptus pauciflora* has distinctive thick, usually bluish green leaves (below) which have secondary veins more or less parallel to the midrib.

FIG. 23—*Eucalyptus paliformis*: (left) lower trunk showing the multi-coloured smooth bark. Ribbons of bark hang from the trunk and branch bases. Close-up of a leaf (below) showing the crenulate edges characteristic of this species, narrow angled leaf veins (ca. 20° to the midrib). The abundant light dots are oil glands and crushing the leaves releases the aromatic oils giving the distinctive eucalypt smell.



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# ROLE OF THE SPECIES

## Status of the Resource

The preferred ash eucalypt species for planting in New Zealand have changed considerably since their initial introduction. Initially, *E. delegatensis* was preferred because it was easy to grow and could tolerate cold conditions. However, it is no longer considered suitable for general planting in New Zealand, mainly due to slower growth rates, susceptibility to fungal attack, and susceptibility to collapse and checking of timber during drying. Because it has consistently performed well in colder climates, especially in Southland and Otago, it continues to be planted there on a small scale, especially as a farm species. By the mid-1970s, *E. regnans* had became the predominant species. Despite large-scale planting over 10–15 years, both for short-fibre pulp production and sawn timber, planting was later curtailed by health and utilisation problems. Currently *E. fastigata* is the only ash eucalypt being planted on a significant scale for both pulp and timber production, due to its better health and good sawn timber properties.

Estimates from the major forest growers (as at 1 January 1997) of the areas, by province, of the main ash species, are shown in Table 3 and their age class distribution is given in Table 4.

*Eucalyptus regnans* and *E. fastigata* are strongly concentrated (89%) in the central North Island, reflecting the relatively large areas established there for pulpwood by Carter Holt Harvey Forests Ltd during the 1970s and 1980s. Almost half the area of *E. delegatensis* occurs in Otago/Southland, with the other half being divided between the central North Island, Hawke's Bay, and Nelson/Marlborough. *Eucalyptus delegatensis* is the most common eucalypt (66% of total) used in mixed plantings, usually with radiata pine.

The small, sometimes scattered areas of *E. obliqua* and *E. fraxinoides* reflect the mainly speculative approach to siting and planting of these species. Most (88%) of the ash eucalypts have been planted in the last 20 years; over half of all existing plantations are 15 years old or younger.

**Table 3: Estimated areas* of ash eucalypts in New Zealand as at 1 January 1997**

| **Pure plantings (ha)** | | | | | | |
|---|---|---|---|---|---|---|
| **Region †** | ***E. regnans*** | ***E. fastigata*** | ***E. delegatensis*** | ***E. obliqua*** | ***E. fraxinoides*** | **Total** |
| Northland | 8 | | 14 | 16 | | 38 |
| Auckland | 194 | | | > 1 | 6 | 201 |
| Central North Island | 4687 | 2691 | 672 | 10 | 17 | 8 077 |
| East Coast | 62 | 53 | 33 | > 1 | | 149 |
| Hawke's Bay | 486 | 19 | 970 | > 1 | 51 | 1 527 |
| Southern North Island | 55 | 4 | 56 | 5 | | 120 |
| Nelson/ Marlborough | 430 | 11 | 599 | 10 | 3 | 1 053 |
| West Coast | 78 | 1 | 170 | 11 | | 260 |
| Canterbury | 2 | | 1 | > 1 | | 4 |
| Otago/ Southland | 109 | 42 | 1794 | 3 | 135 | 2 083 |
| **Pure total (ha)** | **6111** | **2821** | **4309** | **59** | **212** | **13 512** |
| Total (%) | 91 | 93 | 73 | 60 | 99 | 85 |
| **Mixed Plantings (ha)** | **577** | **202** | **1575** | **39** | **3** | **2 396** |
| (%) | 9 | 7 | 27 | 40 | 1 | 15 |
| **TOTAL AREA (ha)** | **6688** | **3023** | **5884** | **98** | **215** | **15 908** |

* Main forest owners only. † For regional boundaries see Appendix 3 (pages 56–58).

**Table 4: Area* (ha) of ash eucalypts by age class (years) (as at 1 January 1997)**

| | 0–5 | 6–10 | 11–15 | 16–20 | 21–25 | 26–30 | 31–35 | 36–40 | 41–45 | 46–50 | 50+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *E. regnans* | 141 | 633 | 1508 | 3076 | 589 | 123 | 40 | >1 | | | | 6 111 |
| *E. fastigata* | 514 | 1141 | 329 | 815 | 20 | | > 1 | > 1 | | | | 2 821 |
| *E. delegatensis* | 183 | 1332 | 1042 | 875 | 573 | 237 | 27 | 14 | 10 | 5 | 11 | 4 309 |
| *E. obliqua* | 12 | | 16 | 22 | | 3 | 3 | | | < 1 | 2 | 59 |
| *E. fraxinoides* | | 34 | 170 | 8 | | | | | | | | 212 |
| **TOTAL AREA** | **850** | **3140** | **3065** | **4796** | **1182** | **363** | **71** | **16** | **10** | **6** | **13** | **13 512** |

*Pure stands only, major forest owners.

## Growth and Yield

The potential radiata pine-like growth rates of eucalypts and their wood and utilisation properties have made them attractive to growers on a wide range of sites. Additionally, a desire to diversify from the large areas of radiata pine has also led to further plantings, mainly by the small landowners. Eucalypts have been widely planted in New Zealand, and have frequently grown well, although species' performance and growth have sometimes been patchy and unpredictable. Considerable growth variation has occurred in the ash eucalypts across a wide range of sites and silvicultural treatments.

Early reports give examples of tree growth obtained in the past from ash eucalypts (see Table 5). More recent sample plot growth data from a range of stands are given in Table 6.

Generally, older stands of *E. fastigata* illustrate the potential of this species to grow well, and to produce and retain high volumes of wood over a long period of time at relatively high stockings. The growth of *E. delegatensis* in New Zealand has not only been variable, but has also usually been less than *E. fastigata* or *E. regnans.*

**Table 5: Examples of tree growth obtained from early reports**

| Species | Location | Age (yr) | DBH (cm) | Height (m) |
|---|---|---|---|---|
| *E. fastigata* | Wairarapa | 18 | 38 | 24 |
| | Whakarewarewa | 50 | | 46 |
| | Gordonton | 87 | 264 | 31 |
| *E. regnans* | Taranaki | 27 | | 33–40 |
| | Newstead | 50+ | 212 | 57 |
| | Newstead | 50+ | 201 | 58 |
| | Newstead* | 50+ | 383 | 54 |
| | Waitati† | 80+ | 93 | 69 |
| *E. obliqua* | Wairarapa | 15 | 25 | 21 |
| | Taranaki | 27 | | 30 |
| | Hawke's Bay | 30 | | 24–37 |
| *E. delegatensis* | Hawke's Bay | 26 | 38 | 37 |

dbh = diameter at breast height
* This tree was recorded as the tallest of any species in New Zealand (71.3 m) in 1964, until the leader was subsequently broken off by the wind, thereby reducing the height (Burstall and Sale 1984).
† New Zealand's tallest tree in 1982 (Burstall and Sale 1984).

**Table 6: Examples of stand growth data from sample plots in various locations**

| Species | Location | Age (yr) | Stocking (stems/ha) | Height (m) | DBH (cm) | Volume ($m^3$/ha) | MAI* ($m^3$/ha/yr) |
|---|---|---|---|---|---|---|---|
| *E. fastigata* | Kaingaroa | 63 | 133 | 56.1 | 88.2 | 1230 | 21.3 |
| | Hunterville | 61 | 730 | 35.9 | 48.8 | 1614 | 26.5 |
| | Marlborough Sounds | 55 | 350 | 58.6 | 103.0 | 1072 | 19.7 |
| *E. regnans* | Waitati | 60 | 486 | 44.7 | 43.9 | 726 | 12.1 |
| | Rotoehu | 32 | 250 | 51.7 | 59.3 | 1226 | 38.3 |
| | Esk | 22 | 105 | 34.4 | 63.6 | 445 | 20.3 |
| *E. obliqua* | Waipoua | 38 | 500 | 36.0 | 47.1 | 1188 | 31.3 |
| *E. delegatensis* | Esk | 22 | 120 | 34.2 | 58.5 | 418 | 19.0 |
| | Whirinaki | 28 | 524 | 31.6 | 38.9 | 713 | 25.0 |
| | Longwood | 43 | 600 | 30.3 | 40.9 | 946 | 22.0 |

*MAI = mean annual increment

In *E. fastigata* and *E. regnans* stands particularly, rapid early height growth usually indicates weed-free establishment (see Table 7).

**Table 7: Growth of young *E. regnans* after establishment treatments on pasture, near Hamilton**

| Treatment | Height (m) at 14 months | % Survival |
|---|---|---|
| No weed control, no fertiliser | 1.5 | 22 |
| No weed control, fertiliser | 2.5 | 6 |
| Weed control, no fertiliser | 3.2 | 83 |
| Weed control, fertiliser | 3.6 | 94 |

Poor siting, poor establishment techniques, or the use of slow-growing provenances can result in considerably reduced growth. Early height increment may be reduced as a result of thinning or pruning. Consistent diameter growth of 1–3 cm per annum can be maintained throughout the rotation given favourable conditions. However, the impact of fungal infection or insect attack on tree growth has not been quantified. Diameter at breast height and height of *E. regnans* on various sites from ages 4–20 years in Kinleith Forest are shown in Table 8 (Poole *et al.* 1991 and Frederick *et al.* 1985).

**Table 8: Growth of *E. regnans* at different ages in Kinleith Forest**

| Age (yr) | Stems/ha | DBH (cm) | Height (m) | Volume ($m^3$/ha) | MAI ($m^3$/ha/yr) |
|---|---|---|---|---|---|
| 4 | 2050 | 10.5 | 11.6 | 103 | 25.7 |
| 7 | 1850 | 17.1 | 19.5 | 371 | 53.0 |
| 10 | 1075 | 25.0 | 22.7 | 537 | 53.7 |
| 13 | 1300 | 21.6 | 23.8 | 542 | 41.7 |
| 17 | 1250 | 24.1 | 29.5 | 854 | 50.2 |
| 20 | 900 | 25.2 | 31.9 | 544 | 32.3 |
| 20 | 610 | 35.5 | 39.0 | 920 | 51.8 |

Because of the shortage of data for individual species, growth rates for height, diameter, and volume have been combined (Fig. 24–26) for the five main species—*E. fastigata, E. regnans, E. obliqua, E. delegatensis*, and *E. fraxinoides*. These results have been derived from sample plots across a range of New Zealand locations. As relative growth rates and tree form are known to differ between species, a better understanding of their development over time is awaited as new data become available through the work of the Management of Eucalypts Cooperative (see Box 2).

### *Comparison with radiata pine*

The growth rates of ash eucalypts are comparable to those of radiata pine. Growth data from two sites (Table 9) support this assertion. At the Kaingaroa site the *E. fastigata* had considerably outgrown the radiata pine both in diameter growth and in volume production. While the eucalypts were grown on to age 63 (see Table 6), the pine was felled at age 39. Volumetric data for *E. regnans*, *E. delegatensis*, and *P. radiata* on the Esk site show that growth patterns change between the species over time (Fig. 2). Although the growth of the pine was ahead of, or similar to, that of the eucalypts at age 13, by age 22 the volume of the eucalypts was significantly greater.

Over a 50-year rotation, ash eucalypts have produced final volumes ranging from 800 to 1000 $m^3$/ha. By comparison, average gross wood yields for lightly thinned, improved *P. radiata* aged 40 years at moderate site indices usually range from 1000 to 1200 $m^3$/ha.

**Table 9: Comparison of ash eucalypt and radiata pine growth on two sites***

| Location | Age (yr) | Species | Stocking (stems/ha) | Mean DBH (cm) | Mean ht (m) | Volume ($m^3$/ha) | MAI volume ($m^3$/ha/yr) |
|---|---|---|---|---|---|---|---|
| Kaingaroa | 39 | *E. fastigata* | 183 | 61.7 | 39.6 | 724 | 18.5 |
| | | *P. radiata* | 193 | 47.2 | 43.7 | 514 | 13.2 |
| Esk | 13 | *E. regnans* | 120 | 43.5 | 24.1 | 182 | 14.0 |
| | | *E. delegatensis* | 130 | 38.2 | 22.7 | 196 | 15.0 |
| | | *P. radiata* | 115 | 47.6 | 21.4 | 199 | 15.5 |
| Esk | 22 | *E. regnans* | 105 | 63.6 | 34.4 | 509 | 23.1 |
| | | *E. delegatensis* | 120 | 58.5 | 34.2 | 512 | 23.3 |
| | | *P. radiata* | 90 | 66.5 | 31.6 | 353 | 20.4 |

*All species were grown under a sawlog regime

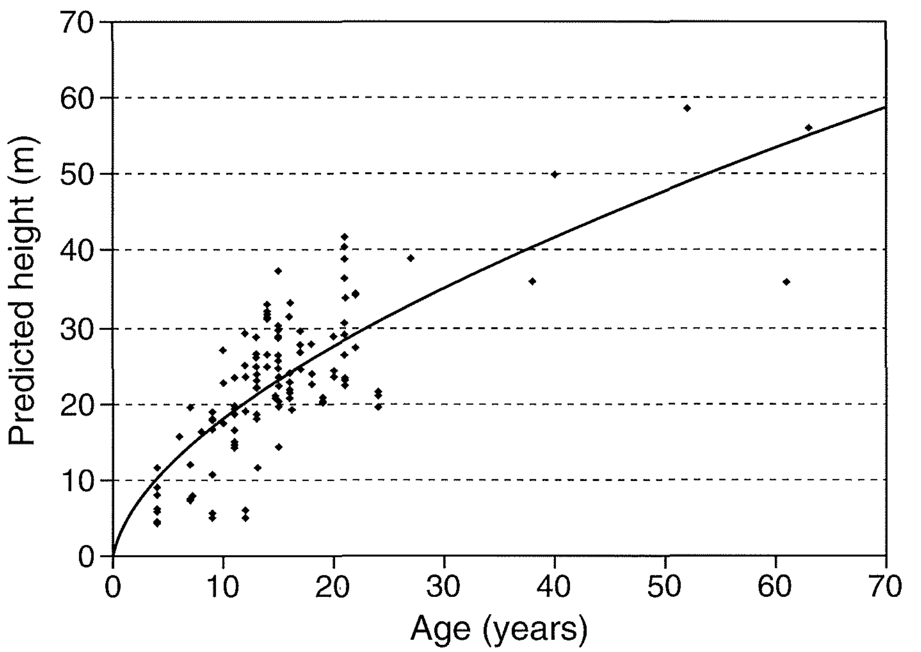


**Fig. 24—Height growth for five species of ash eucalypts in New Zealand**

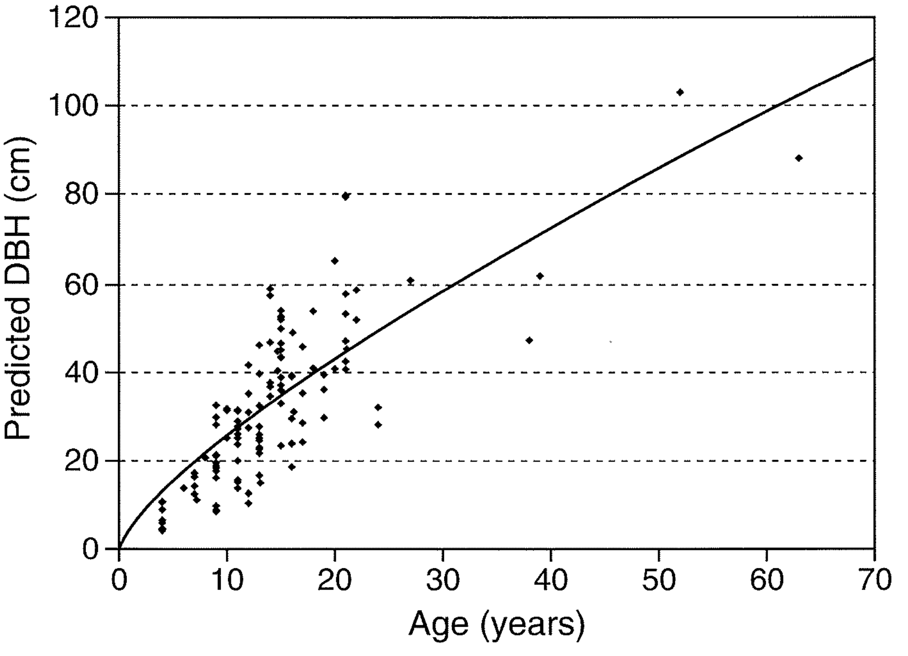


**Fig. 25—Diameter growth for five species of ash eucalypts in New Zealand**

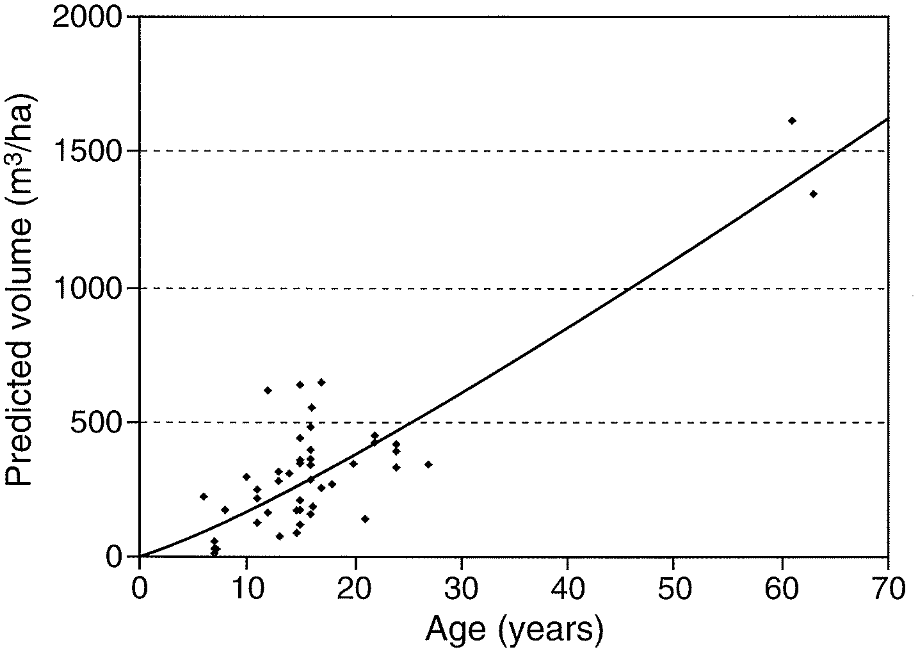


**Fig. 26—Volume production for five species of ash eucalypts in New Zealand**

### Box 2—Management of Eucalypts Cooperative

This Forest Research/Industry Research Cooperative was established in 1986 and the members are the main eucalypt growers in New Zealand. The objectives are to research factors controlling growth, yield, and quality of commercially grown eucalypts, to develop a growth and yield database, and eventually computer-based models. A major part of its work programme over the last 10 years has been the investigation of the growth and yield of *E. regnans* and *E. fastigata*. Apart from rapidly increasing the growth and yield database by establishing and measuring permanent sample plots and regime trials, the Cooperative has developed a general growth model for *E. regnans*.

In addition to the growth and yield work, sites in a central North Island forest were investigated in another Cooperative project and it was shown that within-stand variability of *E. regnans* tree growth was mainly affected by aspect, landform, depth of topsoil, and soil pH.

Since 1995 the industry and research focus has shifted from the ash eucalypts to investigating the growth and yield of *E. nitens*, including the recent development of a growth model.

## Silviculture

### *Siting and species choice*

The ash eucalypts have generally been planted in the cooler parts of New Zealand, but where winter ground temperatures do not fall below -8°C. While they have grown with some success in the warmer coastal areas, their popularity has rested upon their ability to tolerate cold conditions and withstand frosts. There is considerable variation in cold tolerance both within provenances and between species. Warmer northerly aspects are preferred for planting, but frost hollows and areas with poor air circulation should be avoided as early-season or late-season frosts can be very damaging. All of the ash eucalypts require at least 750 mm of rain per annum and grow best on moist, well-drained soils.

*Eucalyptus fastigata*
Although not common north of Auckland it has grown on a wide range of other North Island sites, especially in the central North Island, where it has grown at altitudes up to 550 m. *Eucalyptus fastigata* has shown considerable potential at a number of sites in the Nelson and Marlborough districts, especially in sheltered northerly locations. Although frost tender when young, *E. fastigata* soon becomes hardy and some provenances can tolerate temperatures as low as -10°C.

*Eucalyptus regnans*
During the past 50 years the planting of *E. regnans* has gradually extended over mid-altitude sites in eastern and southern areas of the North Island. In the South Island it tends to be planted mainly at lower altitudes in the east but successful farm plantations do exist at 550 m at Moa Flat, in west Otago. Various provenances of *E. regnans* will stand severe frosts—down to -12°C—but, as with other ash eucalypts, success on warmer sites e.g., Northland, has been extremely variable. The successful large plantings for short-fibre pulp production in the central North Island cover an extensive range of site and soil types. *Eucalyptus regnans* and the other ash species are sensitive to salt winds.

*Eucalyptus obliqua*
This species has considerable potential on a wide range of sites in both the North Island and the South Island. It has shown considerable promise on drier sites in the Wairarapa, Manawatu, and Marlborough regions. The excellent timber properties of *E. obliqua* may be compromised by growth variability on some sites and by attack from insects and leaf-spot fungi.

*Eucalyptus delegatensis*
This species has always been regarded as the "cold country" eucalypt, and has been commonly planted at higher altitudes in both the North Island and the South Island. While it has survived at 850 m in the Craigieburn Range and has grown well at Moa Flat (550 m) and at Millers Flat in Central Otago, *E. delegatensis* has also succeeded at lower altitudes

at Longwood Forest in Southland. It has done well at 760 m at Kaweka Forest on the east coast of the North Island, but by contrast it grew poorly on a number of sites on the Bay of Plenty coast, e.g., Rotoehu Forest. However, both here and in other forests further north e.g., Tairua Forest, the growth of the species was particularly poor compared to those species more suited to the warm climate, such as *E. saligna, E. muelleriana, E. pilularis, E. globoidea,* and *E. botryoides*.

### *Species performance trials*

Fourteen ash eucalypts were planted at six North Island and four South Island sites ( Table 10). The species' performance up to age 19 years is judged by comparing the mean dbh, mean height, and the respective MAIs of trees growing at each site (Tables 11–20). At the two sites near Kaikohe (Table 11) *E. fastigata* has grown particularly well in the warm environment, out-performing the other species present (C.J.A. Shelbourne *pers. comm.*) At Rotoehu Forest and the Rotorua site *E. fastigata* and *E. regnans* have performed best (Tables 12 and 13). Other species which have performed well at Rotoehu are *E. fraxinoides, E. oreades, E. obliqua,* and the Otway messmate (*E. obliqua* x *E. regnans*). In contrast, *E. delegatensis* was less suited to the warm conditions at Rotoehu. At Kinleith Forest (Table 14) *E. fraxinoides, E. regnans,* and *E. oreades* grew particularly well, though it is a pity that *E. fastigata* was not planted in this trial. On the cooler climate site at Waiotapu (Table 15) *E. obliqua, E. regnans,* and the Otway messmate grew well, with satisfactory performance also from *E. fraxinoides, E. delegatensis,* and *E. fastigata.* On the cold site at Matea (Table 16) growth was considerably less due to the cold conditions and severe frosts encountered throughout the year. At this site the hitherto untried species *E. dendromorpha* out-performed *E. delegatensis,* the species usually favoured for higher altitudes and severe conditions. At a relatively sheltered site in Golden Bay, all species grew well, indicating that, given good conditions, growth can be particularly impressive (Table 17). On the fairly dry site at Stoke (Table 18), all of the species performed reasonably well, except for *E. pauciflora.* By age 3 on a harsh site at Eyrewell Forest (Table 19), growth was significantly less than the other sites. The most promising species were *E. regnans, E. delegatensis,* and *E. fraxinoides.* At Longwood Forest, *E. regnans* grew satisfactorily (Table 20), whereas excellent growth of *E. fraxinoides* was observed; as a result, it was planted more widely. However, most subsequent *E. fraxinoides* plantings proved to be of variable or indifferent quality.

The species trial results underline the need to maintain long-term observations of the performance of ash eucalypts, as assessment rankings may change dramatically as the trees get older. The results from these trials illustrate the unpredictable behaviour of the different species across a range of site types. Although trial results (Tables 11–20) present a fragmented picture, *E. fastigata, E. regnans,* and *E. obliqua* show the best potential growth and yield. Of the other species, *E. fraxinoides* grew well on a number of sites, although the good form of the trees at Longwood Forest was not repeated elsewhere. *Eucalyptus sieberi* may be worthy of further evaluation for some selected sites.

**Table 10: Species trials—locations and climate categories**

| Location | Latitude (°S) | Altitude (m) | Climate category |
|---|---|---|---|
| Kaikohe | 35°24' | 130 | Warm |
| Rotoehu | 37°51' | 150 | Warm |
| Rotorua | 38°10' | 300 | Cool |
| Tokoroa | 38°18' | 350 | Cool |
| Waiotapu | 38°21' | 400 | Cool |
| Matea | 39°00' | 900 | Cold |
| Golden Bay | 40°48' | 50 | Warm |
| Stoke | 41°20' | 100 | Warm |
| Eyrewell | 43°27' | 115 | Cool–Cold |
| Longwood | 46°15' | 100 | Cool–Cold |

**Table 11: Comparison of tree growth for species on two sites near Kaikohe, ages 7, 9, and 11 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 7 | 20.8 | 3.0 | 18.6 | 2.7 |
| *E. fastigata* | 9 | 24.0 | 2.7 | 22.6 | 2.5 |
| *E. fastigata* | 11 | 31.5 | 2.9 | 27.5 | 2.5 |
| *E. regnans* | 11 | 30.6 | 2.8 | 27.4 | 2.5 |

**Table 12: Comparison of tree growth for species at Rotoehu Forest, age 9 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 9 | 32.4 | 3.6 | 18.0 | 2.0 |
| *E. regnans* | 9 | 28.0 | 3.1 | 18.9 | 2.1 |
| *E. obliqua* | 9 | 19.5 | 2.1 | 16.6 | 1.8 |
| *E. delegatensis* | 9 | 17.6 | 1.9 | 10.7 | 1.2 |
| *E. fraxinoides* | 9 | 29.7 | 3.3 | 17.8 | 2.0 |
| *E. sieberi* | 9 | 17.5 | 1.9 | 14.2 | 1.6 |
| *E. oreades* | 9 | 29.8 | 3.3 | 18.6 | 2.1 |
| *E. obliqua* x *regnans* | 9 | 26.0 | 2.9 | 19.0 | 2.1 |
| *E. andrewsii* | 9 | 23.0 | 2.5 | 13.7 | 1.5 |
| *E. stenostoma* | 9 | 19.1 | 2.1 | 11.5 | 1.3 |

**Table 13: Comparison of tree growth for species at Rotorua, age 4 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 4 | 8.9 | 2.2 | 8.0 | 2.0 |
| *E. regnans* | 4 | 10.7 | 2.7 | 9.0 | 2.2 |

**Table 14: Comparison of tree growth for species at Kinleith Forest, age 11 years**

| Species | Age | DBH (cm) | MAI (cm/yr) |
|---|---|---|---|
| *E. regnans* | 11 | 23.1 | 2.1 |
| *E. obliqua* | 11 | 15.3 | 1.4 |
| *E. delegatensis* | 11 | 15.1 | 1.4 |
| *E. fraxinoides* | 11 | 23.6 | 2.1 |
| *E. sieberi* | 11 | 16.1 | 1.5 |
| *E. oreades* | 11 | 22.1 | 2.0 |

**Table 15: Comparison of tree growth for species at Waiotapu, in Kaingaroa Forest, ages 9 and 13 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 13 | 25.0 | 1.9 | 18.0 | 1.4 |
| *E. regnans* | 13 | 25.8 | 2.0 | 23.0 | 1.8 |
| *E. delegatensis* | 13 | 22.5 | 1.7 | 18.0 | 1.4 |
| *E. regnans* x *fastigata* | 9 | 19.0 | 2.1 | | |

**Table 16: Comparison of tree growth for species at Matea, in Kaingaroa Forest, age 9 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 9 | 8.5 | 0.9 | 5.0 | 0.5 |
| *E. regnans* | 9 | 8.8 | 1.0 | 5.6 | 0.6 |
| *E. delegatensis* | 9 | 9.7 | 1.1 | 0.6 | 0.1 |
| *E. dendromorpha* | 9 | 12.8 | 1.4 | 8.0 | 0.9 |
| *E. triflora* | 9 | 6.8 | 0.7 | 5.5 | 0.6 |

**Table 17: Comparison of tree growth for species at Golden Bay, age 14 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 14 | 34.4 | 2.5 | 31.3 | 2.2 |
| *E. regnans* | 14 | 36.6 | 2.6 | 33.0 | 2.4 |
| *E. obliqua* | 14 | 37.5 | 2.7 | 31.1 | 2.2 |
| *E. fraxinoides* | 14 | 37.5 | 2.7 | 24.8 | 1.8 |

**Table 18: Comparison of tree growth for species growing at Stoke, age 19 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 19 | 35.9 | 1.9 | 20.1 | 1.1 |
| *E. delegatensis* | 19 | 29.6 | 1.6 | 20.8 | 1.1 |
| *E. fraxinoides* | 19 | 39.3 | 2.1 | 20.3 | 1.1 |
| *E. sieberi* | 19 | 36.7 | 1.9 | 22.5 | 1.2 |
| *E. pauciflora* | 19 | 20.1 | 1.1 | 14.6 | 0.8 |

**Table 19: Comparison of tree growth for species at Eyrewell Forest, Canterbury, age 3 years**

| Species | Age | Height (m) | MAI (m/yr) |
|---|---|---|---|
| *E. fastigata* | 3 | 1.3 | 0.4 |
| *E. regnans* | 3 | 2.0 | 0.7 |
| *E. obliqua* | 3 | 1.3 | 0.4 |
| *E. delegatensis* | 3 | 1.8 | 0.6 |
| *E. fraxinoides* | 3 | 1.7 | 0.6 |
| *E. sieberi* | 3 | 1.2 | 0.4 |
| *E. pauciflora* | 3 | 1.1 | 0.4 |

**Table 20: Comparison of tree growth for species at Longwood Forest, Southland ages 4 and 11 years**

| Species | Age | DBH (cm) | MAI (cm/yr) | Height (m) | MAI (m/yr) |
|---|---|---|---|---|---|
| *E. fastigata* | 4 | 4.5 | 1.1 | 4.3 | 1.1 |
| *E. regnans* | 4 | 5.9 | 1.5 | 5.8 | 1.4 |
| *E. obliqua* | 4 | 4.2 | 1.0 | 4.5 | 1.1 |
| *E. delegatensis* | 4 | 4.6 | 1.1 | 4.5 | 1.1 |
| *E. fraxinoides* | 4 | 6.5 | 1.6 | 6.2 | 1.5 |
| *E. sieberi* | 4 | 3.3 | 0.8 | 3.8 | 0.9 |
| *E. oreades* | 4 | 4.6 | 1.1 | 4.5 | 1.1 |
| *E. obliqua* x *regnans* | 4 | 7.0 | 1.7 | 6.3 | 1.6 |
| *E. regnans* | 11 | 28.8 | 2.6 | 19.3 | 1.7 |
| *E. delegatensis* | 11 | 31.1 | 2.8 | 19.7 | 1.8 |

***Site preparation***

Good initial site preparation, especially cultivation (which loosens soil, allowing easier root penetration and better weed control), is important for the successful establishment of eucalypts. It is essential that weed competition is kept to a minimum during the first 2 years to allow trees to become successfully established. Some proven options for eucalypt site preparation include:

- Pre-plant spraying for weed control, 2–8 weeks in advance of other operations, using a systemic herbicide, e.g., glyphosate, to kill root systems of grass, fern, and blackberry.

- Mechanical site preparation, including V-blading, deep ripping, rotary hoeing, and mounding. (Mounding is an excellent protective measure against ground frost.)

- Post-plant spraying. Depending on the range of weeds present, Gallant™ and Versatil™, alone or in mixture, can be used with relative safety, not only in the period of dormancy, but also in the more active stage. Provided care is taken, Gardoprim™, which does have some limited knockdown ability, is suitable for application over bare-rooted seedlings, especially when grass is short. If using container-grown stock (especially peat pots) caution with the application of herbicides should be observed. The dangers of accidental spray-drift damage to eucalypt foliage should be kept in mind at all times while carrying out post-planting spraying.

***Planting***

Eucalypt seedlings should preferably be planted within 48 hours of lifting in the nursery. Bare-rooted seedlings should be packaged in polythene-lined multi-walled bags or cardboard planting boxes, and stored and transported in planting crates. It is critical that the seedlings are not allowed to dry out. Most ash eucalypts can be planted as 1/0 bare-rooted stock, although the use of container-grown seedlings, root trainers, or peat pots is increasing. The advantages of using containers include the more efficient use of specific seed origins, the growing of nursery stock for a particular planting time, and more convenient holding-over of seedlings in the nursery.

Seedlings must be carefully planted, ensuring that the soil is packed firmly around the root system to minimise distortion. The "positive pull-up" technique is useful as it helps to straighten the roots within the planting hole. On sites where mechanical cultivation is not possible, a good spade cultivation of the planting spot will suffice.

The addition of fertiliser to the trees after planting is beneficial, especially when applied in combination with soil cultivation and weed control. Although fertiliser experiments have been carried out on only a small number of sites, it is generally accepted that nitrogen should be applied to trees on pumice soils, and both nitrogen and phosphorus should be applied on other soils. About 1–2 months after planting, nitrogen and phosphorus fertilisers should be applied at 90–120 g/tree and urea at 60 g/tree in a slot at least 20 cm from the tree so as to avoid stem or root damage.

***Stand management***

Ash eucalypts have been grown by some large companies in New Zealand primarily for short-fibre pulp, although farm foresters and the former New Zealand Forest Service planted areas specifically for veneer or sawlog production. Stand management has varied accordingly; all objectives bar pulp production require a series of thinnings and prunings to achieve the desired product.

The removal of branches from the first 6 m of tree bole in *E. regnans* and *E. fastigata* is necessary for the production of clearwood. A certain amount of natural branch shed may be expected but pruning should be carried out before branches exceed 2.5 cm. The removal of branches always provides an opportunity for fungal infection to set in. To reduce the level of silverleaf infection (see p. 12) pruning should be carried out during fine weather to allow the stubs to dry out quickly. Pruning for clearwood should be carried out at regular intervals. Although pruning up to 6 m in two pruning lifts is standard practice, it is especially important to remove any large and steep branches above the pruned height. The effect of branch removal on tree growth is currently under investigation at Forest Research.

The number of trees planted and retained must relate to the chosen objective, namely, sawn timber, veneers, or pulp. While 1100 stems/ha is regarded as a good initial stocking for both regimes, subsequent stand management will be different. One benefit of this relatively high initial stocking is that it can accommodate some lapses in establishment techniques, as well as allowing for variable tree quality. Stands of *E. regnans* and *E. fastigata* grown for pulpwood on a 10- to 15-year rotation generally do not require thinning. However, in sawlog regimes at least one or two thinnings may be required to reduce the stand to final crop stocking. The first thinning to waste, at about age 5 years, generally removes poor and malformed trees. Subsequent thinnings follow crop tree selection criteria such as spacing, form and size, and leave final crop stockings of 100–200 stems/ha. Thinnings are usually timed to coincide with canopy closure, i.e., when the crowns of the trees are touching. Opening up the stand helps to maintain even growth, whereas close stocking may lead to suppression or death of a proportion of the stems and increased growth on the larger ones. A suggested regime for sawlog and pulp production is shown in Table 21.

**Table 21: Suggested silvicultural regime for eucalypt sawlog and pulp production**

| Crop type | Rotation age (yr) | Initial stocking (stems/ha) | Predominant mean height (m) | Pruned height (m) | Number pruned (stems/ha) | Thin to final crop (stems/ha) |
|---|---|---|---|---|---|---|
| Sawlog | 25–30* | 1100 | 10 | 4.5 | 500 | 500 |
| | | | 16 | 6.0 | 200 | 200 |
| Pulp | 10–15 | 1100 | | | | |

* Approximate—depends on site, growth, size and sawmill capability.

## Utilisation—Timber and Veneer

Contributed by Tony Haslett† and John Roper†

### *Current timber usage*

The sawing, grading, drying, and marketing of eucalypts in New Zealand has been carried out sporadically over the last 50 years or so. However, during the 1990s, two sawmills installed specialised eucalypt sawmilling and drying equipment in order to provide high-quality products to the domestic market. In addition, a large number of small, portable sawmills are now operating throughout the country.

*Eucalyptus fastigata* is the only ash eucalypt currently being utilised as sawn timber, and even this is on a very limited scale. Of the other ash species, *E. obliqua* has established a good reputation for timber production due to its slightly higher density, and *E. sieberi* and *E. fraxinoides* have both been successfully used on a small scale as mature trees have become available. Both *E. regnans* and *E. delegatensis* are now little used due to the major disadvantage of higher levels of drying degrade, mainly from internal checking and collapse.

High-quality logs of *E. fastigata* from unpruned stands over 40 years old have produced significant amounts of clear, knot-free timber. The growth rings are close and wood density relatively high under these conditions. Total sawn timber recovery from quarter-sawing mature logs with diameters of approximately 50 cm is around 50% ((timber volume/ log volume) x 100%). Of the recovered timber about 50–60% is in high quality quarter-sawn clears and cuttings grade, around 20–25% is flat cut and in turnery squares, 15–20%

† New Zealand Forest Research Institute Ltd.

is in low quality dunnage. Growth stresses in these logs seem to be lower than in similar-sized, faster-grown, and younger logs of the same species. The first pruned trial stand of 29-year-old *E. fastigata* has been successfully quarter-sawn, dried, and marketed commercially. Trial results show that butt-log pruning has given a yield of 67% high-grade clear and cuttings-grade lumber; the remaining 33% was in lower grades, including dunnage. Overall, the grade yield from all sawlogs (including pruned butt logs and unpruned second and third logs) in this stand was similar to the much older unpruned plantations utilised to date.

## *Wood properties*

*Appearance*

The ash eucalypts have an attractive mahogany- or ribbon-like grain when quarter-sawn, but tend to be rather bland when flat-sawn. The colour varies from pale to light brown in *E. regnans*, *E. fraxinoides*, *E. fastigata*, and *E. obliqua*, but may be pinkish brown in *E. delegatensis* and *E. sieberi*. The growth rings are difficult to distinguish on the green log-end, except for *E. delegatensis*, which generally has distinct latewood bands. The growth rings in dried sawn timber on the end-grain are generally distinct for all species.

*Wood density*

All ash eucalypts have a high degree of moisture saturation in both the heartwood and the sapwood, and have green densities greater than 1000 kg/m$^3$. The wood density of New Zealand-grown material is significantly lower than the "old growth" of the same species in Australia. However, plantation-grown timber in both countries is expected to be similar in quality. A summary of the wood properties of New Zealand-grown ash eucalypts over 25 years old, covering a range of sites and unknown provenances, is shown in Table 22.

All ash eucalypt species have low-density wood in the core. This becomes "brittle heart" when compressed (crushed) by the growth stresses in the maturing tree and frequently contains shakes. Basic density increases in the older wood surrounding the core in the "pith to the bark" direction and also vertically up the stem. The average density will therefore be strongly dependent on the age of the tree at the time of sampling.

*Mechanical and strength properties*

Generally, the mechanical properties of the ash eucalypts are very similar to tawa. The ash eucalypts are substantially stiffer, stronger, and harder than New Zealand-grown softwoods such as rimu, kauri, radiata pine, and Douglas-fir. This gives them particular advantages in furniture making where the high strength and hardness are useful.

**Table 22: Wood properties of New Zealand-grown ash eucalypts over 25 years old, compared to *Beilschmiedia tawa* (tawa) (Haslett 1988 and Britton 1999)**

| Species | Density (kg/m$^3$) | | Shrinkage Tangential | Radial | Modulus of rupture (MPa) | | Modulus of elasticity (GPa) | | Compression parallel (MPa) | | Hardness (kN) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture content | 12% | Basic | (%) | (%) | Green | 12% | Green | 12% | Green | 12% | Green | 12% |
| *E. fastigata* | 615 | 495 | 5.0 | 2.7 | 76.2 | 120.8 | 11.2 | 13.2 | 35.8 | 59.6 | NA | 4.2 |
| *E. regnans* | 585 | 465 | 5.5 | 3.4 | NA | 119.0 | NA | 13.4 | NA | 59.2 | NA | 6.3 |
| *E. obliqua* | 610 | 540 | 4.7 | 2.4 | 72 | 113.7 | 9.9 | 14.1 | 31.9 | 55.5 | 4.1 | 5.2 |
| *E. delegatensis* | 585 | 470 | 6.5 | 3.2 | 71.0 | 113.2 | 10.4 | 12.4 | 31.3 | 57.6 | 4.1 | 4.8 |
| *E. fraxinoides* | 560 | 525 | 5.8 | 2.8 | NA | 119.0 | NA | 13.4 | NA | 59.2 | NA | NA |
| *E. sieberi* | 630 | 510 | 6.3 | 2.8 | 65 | 120.6 | 9.9 | 14.2 | 32.4 | 69.1 | 4.3 | 6.3 |
| Tawa | 645 | 584 | NA | NA | 70 | 114.4 | 10.2 | 13.2 | 31.4 | 39.2 | 4.3 | 4.8 |

Tangential = flat-sawn width shrinkage
Radial = quarter-sawn width shrinkage
Basic density = oven-dry weight (kg)
MPa = megapascals
GPa = gigapascals
kN = kilonewtons
Green volume (freshly felled material) (m$^3$)
NA = not available

*Iron-tannin staining*
When sawing and slicing the light-coloured ash eucalypts an intense blue-black iron tannin stain sometimes appears. This develops on cut surfaces within seconds of contact with iron in saws, roll cases, veneer slicing knives, etc. After fading during drying the normally superficial stain can be dressed off.

Veneer slicing knives can be made of high chrome steel to reduce veneer staining. The stain can also be reduced by treatment with a dilute solution of oxalic acid ($C_2O_4H_2.2H_2O$) prior to veneer drying.

*Kino or gum vein*
Kino may become trapped within the wood of a tree in the form of a thin vein, ring, or pocket and is a degrading feature of otherwise clear timber.

The formation of kino is thought to be caused by damage to the cambium or by environmental stress on the tree. The severity of kino in logs can vary markedly from nothing at all to severe degrade within trees of the same stand. The boards that are lightly or moderately affected with kino are sold as a "natural feature" grade in Australia.

*Heartrot*
Ash eucalypts are prone to heartwood decay associated with shakes, and branch defects within the stem. Fungal hyphae can be seen in the shakes or decayed branch stubs and the surrounding wood may have a wet, discoloured look which may be classed as incipient decay. However, this discolouration frequently fades on drying to become indistinguishable from the surrounding heartwood. Generally, decay has been regarded as a minor source of degrade in utilisation trials, and it is associated with low-grade compression heartwood (approximately 150–200 mm at the centre of the log).

## ***Sawn recovery***

*Growth stresses*
The centre of eucalypt logs can be under severe compression, while the outer wood can be under tension. When these growth stresses are released by cross-cutting into logs, the log can end-split. This end-splitting gets worse with time as the log dries out. Therefore, logs should be cross-cut just before sawing.

*Sawing patterns*
Quarter-sawing is preferred for converting logs of ash eucalypts into timber. There is less internal checking in quarter-sawn boards, and any collapse can be reduced by steam reconditioning. Also, the attractive mahogany- or ribbon-like grain is revealed to best advantage. In contrast, flat-sawn (crown-cut) boards seem to suffer from more checking, have more shrinkage in width and the grain pattern is considered less attractive. Both quarter- and intermediate-sawn boards will have a similar appearance and similar properties.

In quarter-sawing, large flitches are cut from around the central zone and then re-sawn in a radial- or quarter-sawn dimension. The growth stresses released may cause the flitch to bend dramatically away from the log and the boards produced will exhibit crook. A breast bench or moving saw edger can be used to remove the crook and straighten the timber. Alternatively, the timber may be dried in a wide flitch, and then ripped straight on a sawbench prior to use. This saw—dry—rip (SDR) sequence has the added advantage of revealing any degrade associated with compression heart once the timber is dry.

*Conversion and grade yield*
To produce quarter-sawn boards, the logs have to be rotated to ensure that the grain angle of the boards remains consistent and therefore the grade conversions from these logs will tend to be lower than from those logs that are flat-sawn. Large-diameter logs should be used if ash eucalypts are to be quarter-sawn by conventional techniques. Logs from 40 cm s.e.d.* upwards can be quarter-sawn with greensawn lumber recovery of 50% of log volume or more. In general, the larger the log diameter, the better the grade of timber produced.

* small end diameter.

### *Peeling*

Peeling of eucalypt logs can be problematic because of the tendency towards end-splitting and heartrot. In spite of this, the veneer is strong and stiff and should give good structure to products made from it. The production of laminated veneer lumber (LVL), currently under investigation, is an exciting new prospect for eucalypts.

### *Slicing*

Most ash species slice well. Over the years small amounts of *E. regnans* and *E. delegatensis* have been processed without any problems and have been used as office panelling. More recently, both *E. obliqua* and *E. fastigata* have been sliced successfully in trials at Interior Timbers, Rangiora (Ron Hickmott, *pers. comm.*). Both quarter-sawn and flat-sawn flitches (including some obtained from young, fast-grown pruned logs of *E. fastigata*) have produced high-grade veneer.

Veneers of the ash species are easy to slice, and dry well without significant collapse, checking, or buckling. Eucalypt veneers, which have an attractive grain and are relatively hard, are suited for use as a glued overlay on furniture and in other applications where appearance is important (see enclosed sample).

### *Drying*

The main problems encountered in drying eucalypt timber are associated with cell collapse and internal checking. Quarter-sawn timber is preferred for drying as it generally has less surface checking and any collapse can be reduced by final steam reconditioning.

Cell collapse (excessive abnormal shrinkage) occurs early in drying, and it can show as "wash-boarding" early in the drying process. Collapse after air drying can be remedied by steam reconditioning at 100°C and 100% RH.

Internal checking in the early-wood bands of low-density wood is a more serious problem; it is frequently associated with cell collapse. Even if steam reconditioning reduces collapse and closes the checks, the discontinuity in the wood fibres remains, leading to much poorer machining, turning, finishing, and staining properties.

Generally, the younger the log and the lower the density of the timber, the greater will be the drying degrade problems.

The ash eucalypts are a medium- to high-shrinkage species. It is of critical importance that they be installed at the correct equilibrium moisture content when used for flooring, joinery, and furniture. For example, if the wood is installed when bone dry, then it may absorb moisture at a later stage and buckle. If, on the other hand, it is too wet, it may later shrink to leave gaps.

*Drying schedule*

The recommended sequence for drying ash eucalypts is:

Green timber
(quarter-sawn preferred)
↓
air dry in fillet
↓
dry to 25% moisture content
↓
steam reconditioning (if necessary) 100% RH/100°C
↓
kiln dry at moderate schedules (e.g., 55°C–70°C to 8–10% mc)
plus final reconditioning

### *Markets for timber and veneers*

The mahogany- or ribbon-like ribbon grain of quarter-sawn or sliced ash eucalypts provides an attractive interior timber when given a clear or lightly stained finish.

Plantation-grown logs show wider growth rings with strong ribbon-grain effects. This is more striking than in old-growth stands where the timber has a closer, more uniform grain with fewer highlights.

Uses for solid timber include high quality furniture such as dining room suites and dressers. Joinery products include staircases, balustrades, and kitchen units, frequently complemented by sliced veneer panels, used, for example, as kitchen cupboards or panelled walls (Fig. 27 and 28). The relative strength and stiffness of the timber makes it suitable for dowels. The central core is frequently affected by collapse, checks, and decay, and consequently it is limited to such uses as dunnage and firewood.

**FIG. 27—Desk made of lightly stained *E. regnans* timber with *E. fraxinoides* panels.**

**FIG. 28—Staircase and joinery made from *E. fastigata*.**

### *Durability and preservative treatment*

*Natural durability*

Some eucalypt species enjoy a reputation for natural heartwood durability outdoors and in ground contact. However, with the ready availability of CCA*-treated radiata pine, the use of these timbers in such situations has declined.

In eucalypts, heartwood normally comprises a large percentage of the log with only a relatively narrow band of sapwood on the outside (frequently 50 mm or less). Natural durability ratings (Table 23) are based on the average time taken for the heartwood of mature trees (at least 40 years old) to fail when in contact with the ground. Timber from individual trees can vary widely. The results must be applied with caution to younger, faster-grown trees.

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* Copper chrome arsenate.

**Table 23: Heartwood durability of ash eucalypts**

| Species | Heartwood durability (years in ground) | Sapwood insect susceptibility | |
|---|---|---|---|
| | | *Lyctus* | *Anobium* |
| *E. fastigata* | 5–15 | S | NS |
| *E. regnans* | 5–10 | S | NS |
| *E. obliqua* | 15–20* | NS | NS |
| *E. delegatensis* | 5–10 | S | NS |
| *E. sieberi* | 10–15 | NA | NA |

* = Very variable S = Susceptible
NS = Not susceptible NA = Not available
This information was provided by D. Page (*pers. comm.*) and was adapted from Haslett (1988).

*Preservative treatment*
Interior use: the sapwood of most species is susceptible to *Lyctus* spp. attack, but is not susceptible to *Anobium* spp. (the common house borer). The green wood of most ash eucalypts can be successfully treated with boron compounds using diffusion treatments. However, such treatment is often unnecessary because the quantity of sapwood in the cut timber is small and is not susceptible to borer.

Exterior use: the sapwood can be treated with CCA preservative but the heartwood cannot. Therefore, exterior use is limited by the natural durability of the heartwood, which is only moderate and variable both within and between species. Consequently, the use of ash eucalypts in ground contact or outside situations is not generally recommended.

## Pulp Utilisation

Contributed by Merv Uprichard†

### *Pulpwood*

Since the early 1970s, ash eucalypts have been planted in New Zealand as a potential source of short-fibre pulp, to complement long-fibre radiata pine pulp in conventional blends for the manufacture of fine-quality paper products. This was a departure from pioneering efforts at pulp production which began in Australia during the 1920s using material obtained from natural eucalypt stands. Little was known about the prospects of pulpwood production from eucalypt plantations, except that rotations were likely to be short, and that fast growth would be necessary. However, subsequent developments overseas, notably in Brazil, provided encouraging information on the practicality of using fast-growing eucalypt species, including inter-specifc hybrids propagated clonally as a source of pulpwood. In the Brazilian experience, selected clones were found to produce pulpwood economically at rotation ages of 5–10 years. Although it is unlikely that the very high growth rates obtained in the tropics could be duplicated in New Zealand, it remains to be determined whether ash eucalypt pulpwood can be produced economically on our best sites on short rotations (e.g., 10–12 years).

Studies of pulp yields of fast-growing ash eucalypts were carried out in the 1970s in PAPRO‡ laboratories (see Tables 24 and 25). In general terms, eucalypt pulps have about half the tear strength of softwood pulps, but are similar in other respects. Further studies on *E. fastigata* (Table 26) showed that kraft fibre properties vary according to the density of the log.

Overall, these studies showed that good pulp yields can be obtained from New Zealand-grown ash eucalypts, that the pulps produced have good strength properties, and that improvement through individual tree selection is possible. Initially, *E. regnans*, and *E. delegatensis* were of most interest for medium-density pulp production. However, *E. fastigata* can produce a slightly higher-density pulp yield provided a higher alkali charge is applied during pulping.

† Formerly of New Zealand Forest Research Institute Ltd, now at 8a Rutland St, Rotorua.

‡ Pulp and Paper Research Organisation.

**Table 24: Kraft pulps—eucalypts**

| Species | Age (yr) | Basic density (kg/m³) | Total yield (%) | Kappa number |
|---|---|---|---|---|
| *E. fastigata* | 16 | 490 | 50.2 | 29 |
| *E. regnans* | 17 | 410 | 54.6 | 14 |
| *E. delegatensis* | 18 | 374 | 51.1 | 17 |
| *P. radiata* | NA* | 420 | 46.0 | 30 |

* Not available
Kappa number is an estimate of the lignin content of a pulp.

**Table 25: Eucalypt pulp properties at 4000 revolutions under standard PFI mill conditions**

| Species | Tear index | Burst index | Tensile index | Scattering coefficient |
|---|---|---|---|---|
| *E. delegatensis* | 9.1 | 9.8 | 114 | 210 |
| *E. fastigata* | 10.4 | 9.5 | 120 | NA |
| *E. regnans* | 11.8 | 9.8 | 110 | 260 |
| *E. obliqua* | 11.1 | 8.8 | 91 | 250 |
| *P. radiata* | 16.0 | 6.5 | 85 | 170 |

Tear index = measure of the resistance of paper to tearing
Burst index = the "pressure" required to burst the paper surface under standard conditions
Tensile index = tensile strength of a paper strip extended at a constant rate
Scattering coefficient = measure of paper opacity; a high score means that the paper is hard to see through
NA = not available

**Table 26: Wood and kraft pulp properties of 29 *E. fastigata* trees**

| Properties | Mean | Range |
|---|---|---|
| Basic density (kg/m³) | 458 | 404–534 |
| Pulp yield (%) | 53 | 48–57 |
| Handsheet bulk (cm³/g) | 1.42 | 1.58–1.29 |

*Eucalyptus fastigata* and a non-ash species (*E. nitens*) are currently being planted on a relatively wide scale for short-rotation pulp production in New Zealand.

## Future Role

The two principal roles of ash eucalypts in New Zealand, as a source of solid wood and as pulpwood, have evolved historically and are likely to remain essentially unchanged.

The ash eucalypts best known in New Zealand (*E. fastigata, E. regnans, E. obliqua*, and *E. delegatensis*) are all tall forest trees of south-eastern Australia producing pale, easily worked wood. These species are considered as minor forestry species in New Zealand, though on some sites they are able to compete with radiata pine for volume production on a per-hectare basis. Furthermore, although the wood of the ash eucalypts is regarded as being of low density relative to other eucalypts, it is generally denser, heavier, and stronger than radiata pine. The wood has a range of speciality uses, including furniture, high quality joinery, cabinet-making, sliced veneers, turnery, handles, and panelling.

A further significant attribute of the ash eucalypt species is their yield of shorter and more slender fibres than pine when the wood is broken down in pulp-making. Used as a blending additive, eucalypt pulp improves the density and enhances the quality of the final product and makes possible the manufacture of finer, stronger papers than can be produced from pine alone. Experience has shown, however, that the two roles, (i.e., growing for solid wood or growing for pulp), need to be pursued separately. One cannot effectively combine them while growing trees under one silvicultural system (B. Poole, *pers. comm.*).

Although radiata pine will continue to be the mainstay of the New Zealand forest industries, a need persists for complementary species to meet end-use requirements where higher standards in decorative features, dimensional stability, strength, and surface hardness are necessary. The ash eucalypts, particularly *E. fastigata*, may be expected to contribute directly to these markets but the precise extent to which they will be favoured over other eligible timbers is not immediately obvious. Overall similarities in processing and wood properties mean that the commercially viable ash species may be processed together, and may be marketed collectively as "ash eucalypts" rather than as individual species. They are a suitable substitute for tawa, the native hardwood previously used, as well as certain imported tropical timbers such as ramin. However, unlike tawa the ash eucalypts continue to present great challenges in processing and drying, inevitably complicating their development as sources of solid wood products. Furthermore, fungal diseases are still affecting some species, particularly when sub-optimally sited, which tends to influence commitment to extensive commercial enterprises, such as planting for pulp production.

Technology for sawing and drying eucalypt timber exists in Australia, but has not yet been applied in New Zealand. A primary requirement would be to increase tree size by a change in silvicultural programmes, or rotation length, so that quarter-sawing could be more or less universally adopted as general practice. In this regard breast height diameters of 50–80 cm and rotations of about 40 years might be acceptable targets. A secondary requirement would have to be the planting in a given locality of a sufficiently large area of the required species to develop a working circle within which timber could be supplied in perpetuity to an established processing plant. This would represent a new and hitherto unprecedented initiative within the industry, but given such a situation, the necessary skills for sawing and drying could be evolved and technical difficulties permanently overcome.

Tree improvement techniques offer one way of enhancing the prospects of the ash eucalypts. This involves selection and deployment of trees with the best wood properties, drawn from the most vigorous, disease-resistant, and site-adaptable material at species and family level.

In the future, some species of ash eucalypt may be grown as sources of speciality solid wood or short-fibre pulp or utilised by developing technologies such as LVL. However this will depend not only on selecting the better species, e.g., *E. fastigata*, but also on finding solutions to both processing and health problems. A sudden increase in the popularity of ash eucalypt timber is not expected. Rather, it is probable that levels of interest may remain static, or may even decline as the present mature resource is exhausted.

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# SEED USERS' GUIDE

## A. Collection and Extraction of Seed
**(*Eucalyptus fastigata, E. regnans, E. obliqua, E. delegatensis*)**

| | |
|---|---|
| **Age of first flowering** | Occasionally 3–6 years (on sites conducive to flowering). Usually 7–9 years. |
| **Flowering** | December (especially *E. obliqua*) to early March, mainly February. |
| **Fruit maturation period** | *E. fastigata*, *E. regnans*, and *E. delegatensis* can take 2–3 years from flower primordia production to ripe seed. Seed in capsules can be mature 9 months after pollination, but natural seed-shed is normally 2 years from pollination. |
| **Seed collection** | Any time of year, but best after November, by which time there should be 2 years' seed crop on the trees. |
| **Periodicity of crop** | Some seed is usually produced each year. |
| **Harvesting** | From prunings, thinnings, clearfelling, and from standing trees using cherry pickers, climbing, or branch hooks. |
| **Mature fruit recognition** | Capsules initially shiny green, duller later. Mature capsules should contain dark, free-running seed. |
| **Seed extraction** | Kiln for 6 hours at 50°C, or air-dry, e.g., in glasshouse. |
| **Seed recovery** | **(a)** Seed plus chaff per kilogram of fresh capsules<br>*E. fastigata*—80 g average<br>*E. regnans*—69 g average<br>*E. obliqua*—66 g average<br>*E. delegatensis*—75 g average<br>**(b)** Sound seed/chaff—about 20% by weight.<br>**(c)** Approx. No. viable seeds per kilogram clean seed<br>*E. fastigata*: 45 000–90 000<br>*E. regnans*: 150 000–300 000<br>*E. obliqua*: 40 000–60 000<br>*E. delegatensis*: 30 000–100 000<br>*E. fraxinoides*: 50 000–70 000 |
| **Storage conditions** | Airtight containers at 50°C. |
| **Storage duration** | Several years, if moisture content is below 10%. |
| **Stratification** | Soak for 24 hours in cold water followed by 4 weeks at 4°C. |
| **Expected germination** | In excess of 90% (provided mature capsules selected). |

## B. Nursery Practice

For bare-rooted seedlings the seed of eucalypt species can be sown successfully in mixture with sawdust, using a Stan Hay sower. In the past, fluid drilling has been carried out satisfactorily on an operational scale (M. Hennessy*, *pers. comm.*). However, because of the high price and small size of the seed and the limited scale of most projects, it is more commonly hand-sown into trays and later pricked out into the nursery beds, root trainers, or containers, e.g., peat pots or pot tray (plug) seedlings with side slits. Seedlings raised in containers can be successfully planted outside the normal time of late autumn to early winter.

For sowing in trays: use a 50:50 mixture of peat and perlite (expanded pumice) without fertiliser. Place in an unheated glasshouse, but maintain above 10°C at night.

***Nursery regimes for container seedlings***

**(a) 10- to 12-week regime:** prick out into containers using forceps as soon as emerged seedlings can be handled. Use three-parts peat to one-part pumice, plus a slow-release fertiliser (e.g., MagAmp), at 2.25 kg/m$^3$. Leave in glasshouse until first true leaves are 2–3 cm in length (about 4 weeks). Protect against frost, fungal disease, and insect attack. Harden off and grow on unchecked for 10–12 weeks. Plant during cooler and moister times of the growing season.

**(b) Starvation regime:** eucalypt seedlings will remain alive for a long time in a nutrient-deficient (starved) state, growing rapidly as soon as nutrients and water are made available. Such starving produces seedlings which are hardier, more drought resistant, and with a greatly improved survival rate after planting. Sow seedlings in June–July. Harden off under 30% shade, and plant September–November.

Either: retain seedlings in seed trays until wanted for pricking out (they will survive unharmed for at least 13 months if only lightly watered).

Or: raise according to the 10- to 12-week regime, but then keep them in the containers on a "water only" diet (less water is required as nutrient levels in the sowing/potting mix decrease).

**N.B**. Bare-rooted planting stock should be undercut, lateral pruned, and well wrenched. For further details, see "Growing Eucalypts in Containers", What's New in Forest Research No. 80 (1987).

***Weeding***

Emergence of weeds after sowing or transplanting can be a problem in some nurseries. Weed control can be achieved by applying oxyfluorofen over the top of the actively growing (green) seedlings, at 0.5 litres/ha. Where hardened-off (red) seedlings are transplanted, higher doses ( up to 2 litres/ha) can be used initially, but this dosage should be dropped back to 0.5 litres/ha once the seedlings flush.

* Previously employed by NZ Forest Products Ltd.

## C. Recommended Seed Sources

The majority of recommended local seed sources in the ash eucalypts date from the intensive experimental work undertaken by Forest Research during the 1970s and 1980s. Many of the sources are located within forests previously owned by the State, or in those owned by private forest companies (see Table 27).

***E. fastigata***

Seed imports should be selected from high elevation sources in New South Wales at the northern end of the species' natural range. Within New Zealand, seedlots collected from the plantations at Oakura, Taranaki, can be assumed to produce offspring of moderate frost hardiness and good early vigour.

***E. regnans***

Suggested imports should be from upland, interior, central-southern Tasmanian sources (e.g., Moogara). Should plantings of *E. regnans* be considered on milder sites, then origins with less frost tolerance could be used e.g., Strzelecki Ranges, Victoria.

***E. obliqua***

No seed stands have been formally approved in *E. obliqua*; however, there are stands of good growth and form.

***E. delegatensis***

Comprehensive provenance/progeny trials were established in 1978 at Rotoaira and Longwood Forests, from which seed of better provenances should be sourced.

***E. fraxinoides***

There are stands of *E. fraxinoides* showing good growth but of variable form.

**Table 27: New Zealand seed sources for the main ash eucalypts**

| Species | Forest/Compartment | Year planted | Area (ha) | EXP No. | Seedlot No. | Provenance |
|---|---|---|---|---|---|---|
| *E. fastigata* | Kaingaroa/1076 | 1980 | 6.4 | RO 1832/1 | HO 68/616 | Barrington Tops, NSW |
| | | | | | HO 78/46 | Oberon, NSW |
| | Kaingaroa/1104 | 1980 | 8.8 | RO 1832/2 | HO 78/46 | Barrington Tops, NSW |
| *E. regnans* | Kinleith/Wiltsdown | 1977 | | RO 1906 | | Tasmania and Victoria |
| | Golden Downs/101 | 1977–80 | 2.0 | NN 342/1 | 9/79/2393 | Tasmania and Victoria |
| | Cambridge Nursery | 1982 | 0.8 | | | Tasmania |
| | R. Regnault/Rotorua | 1982 | | | 9/4/82/080 | Tasmania and Victoria |
| | Longwood/6 | 1982 | 0.5 | SD 604/2 | 9/4/82/080 | Tasmania and Victoria |
| *E. obliqua* | No recommended seed stand | | | | | |
| *E. delegatensis* | Kaingaroa/327 | 1979 | 0.4 | RO 664/11 | FRI 78/2303 | Tasmania |
| subsp. *tasmaniensis* | Wairakei Tourist Park/6 | | 2.6 | | HO66/560 | Maydena, Styx Valley, Tasmania |
| *E. delegatensis* | Lake Taupo/844 | 1984 | 10 | | 9/0/83/083 | Alexandra, Victoria |
| subsp. *delegatensis* | | | | | 8/0/83/017 | Swifts Creek, Victoria |
| *E. fraxinoides* | Kaweka/200 (1 & 2) | 1983 | 7.4 | WN 367 | 9/0/82/074 | New South Wales |
| | Kaweka/200 (06) | 1984 | 11.4 | | 8/0/83/08 | Pikes Saddle, Tallaganda, NSW |
| | Longwood/26 (1) | 1983 | 3.8 | | 9/0/82/74 | New South Wales |

Note: Seedling and clonal orchards of *E. regnans* and *E. fastigata* have been established by the Eucalypt Breeding Cooperative but are not yet in production. Some seed stands have been thinned.

# GLOSSARY

**Alternate:** when the leaves are scattered along the stem and not opposite each other.

**Bow:** longitudinal curvature of the face of a piece of lumber which does not affect the edge. It is measured as deviation from a taut string line, drawn from end to end, to the adjacent face of the piece at the maximum point of deviation.

**Capsule:** woody fruit, containing the seeds.

**Concolorous:** the same colour on both sides (leaves).

**Coppice leaves:** leaves on sprouts formed from a cut stump or from vigorous new shoots near the base of the trunk. They are usually juvenile at first but further development of the shoot will result in intermediate and then adult-type leaves.

**Crook (or spring):** longitudinal curvature of the edge of a piece of timber which does not affect the face. It is measured as deviation from a taut string line, drawn from end to end, to the adjacent edge of the piece at the maximum point of deviation.

**Disc:** a ring of distinctive tissue around the top of the capsule. The disc may be raised (ascending) or sunken (descending), and may be wide or narrow.

**Discolorous:** the upper and lower surfaces are different in colour.

**Dull:** the leaf surface is not shiny unless viewed very obliquely.

**Entire:** smooth, not serrated or toothed.

**Exserted:** raised above the surface.

**Falcate:** curved like the blade of a sickle. Leaves with a curved midrib are falcate.

**Glossy:** the leaf surface is shiny.

**Half-barked:** the upper trunk and branches are smooth-barked while the lower trunk has persistent bark.

**Internal checking:** a discontinuity in the wood fibres resulting in a hole where the walls of adjacent cells have been torn apart by stresses associated with water tension in the cell lumens during the drying process. This phenomenon is commonly associated with some cell collapse of the earlywood, and is seen between two adjacent latewood bands.

**Kino:** a dark, reddish exudate (gum) formed at an injury site in eucalypts.

**Lanceolate:** lance-shaped, pointed.

**Mallees:** multi-stemmed from ground level with fine stems arising from a bulbous root-stock; usually less than 10 m tall.

**Operculum:** the cap of the flower bud.

**Opposite:** when a pair of leaves are attached to the same point on the stem.

**Pedicel:** the individual stalk of each flower arising from the top of the peduncles; usually round in cross-section but in some species they are square or two-angled. Buds with no pedicel are sessile.

**Peduncle:** the enlarged stalk holding a cluster of flowers. It may be round, square or flattened in section.

**Peppermint bark:** the typical bark of the peppermint group of eucalypts, which is persistent with relatively short fibres, interlaced, and finely fissured longitudinally.

**Provenance:** the original geographic source of seed, pollen or propagules.

**Rough bark:** bark which is persistent for many years and is only lost in small quantities by abrasion or weathering.

**Sessile:** without a stalk.

**Shakes:** partial or complete longitudinal separation between adjoining layers of wood due to factors other than drying, usually originating in the centre of a standing tree.

**Smooth bark:** deciduous bark that is shed annually, usually in spring. The surface texture is usually smooth and the portions that are shed fall away in flakes or ribbons from all the major branches and all but the lowest portions of the trunk.

**Stocking:** persistent rough bark around the base of the tree trunk.

**Stringybark:** bark which can be readily pulled off in strings. The fibres are long, thick, furrowed and interlaced beneath; the outer layers are weathered to a grey or grey-brown colour. When rubbed between the palms the bark breaks down into a mixture of fibres and powder.

**Valves:** the 3–5 triangular sections at the top of the capsule which are raised in mature capsules to release the seeds. Valves may be sunken and difficult to see inside the capsule or exserted and very conspicuous.

# APPENDICES

## Appendix 1: Full list of ash eucalypts

The ash eucalypts can be divided into three sub-groups on the basis of seedling leaf colour and arrangement. The **green-leaved ashes** have shiny green seedling leaves with raised oil glands which are opposite for a few pairs; the **blue-leaved ashes** have dull green or bluish seedling leaves which are opposite for a few pairs; and the **black sallies** have dull grey-green seedling leaves which are opposite for many pairs. Brooker (2000) provides a formal classification of these species into series and subseries. Several newly described species have not been listed because they are not considered sufficiently distinct to be recognised as separate species.

* Indicates the species is recorded as present in New Zealand. The use of these common names is discouraged in New Zealand to avoid them being confused.

### *Green-leaved ashes*

| | | |
|---|---|---|
| * | ***E. apiculata*** R.T. Baker & H.G. Sm.<br>Includes *E. laophila* L.A.S. Johnson & Blaxell.<br>A small mallee confined to the central tablelands of New South Wales. | narrow-leaved mallee ash |
| | ***E. approximans*** Maiden ssp. ***approximans***<br>A tall mallee of restricted distribution in the northern tablelands and ranges of New South Wales. | Barren Mountain mallee |
| | ***E. approximans*** ssp. ***codonocarpa*** (Blakely & McKie) L.A.S. Johnson & Blaxell<br>Includes *E. microcodon* L.A.S. Johnson & K.D. Hill.<br>A mallee of restricted and disjunct distribution in the northern tablelands of New South Wales and adjacent areas of Queensland. | mallee ash |
| | ***E. burgessiana*** L.A.S. Johnson & Blaxell<br>Includes *E. obstans* L.A.S. Johnson & K.D. Hill.<br>A mallee or small tree of very restricted distribution in the Blue Mountains of New South Wales. | Faulconbridge mallee ash |
| | ***E. cunninghamii*** Sweet<br>A small mallee restricted to the Blue Mountains of New South Wales. | cliff mallee ash |
| * | ***E. dendromorpha*** (Blakely) L.A.S. Johnson & Blaxell<br>Includes *E. spectatrix* L.A.S. Johnson & Blaxell.<br>A small- to medium-sized tree of restricted distribution in the coastal tablelands and ranges of New South Wales. | Budawang ash |
| * | ***E. fastigata*** Deane & Maiden<br>A medium to very tall tree from the tablelands and ranges in New South Wales and eastern Victoria. | brown barrel |
| * | ***E. kybeanensis*** Maiden & Cambage<br>A mallee or small tree found at high altitudes in south-east New South Wales and eastern Victoria. | Kybean mallee ash |
| | ***E. langleyi*** L.A.S. Johnson & Blaxell<br>A mallee restricted to two stands on the southern coast of New South Wales. | green mallee ash |

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| * | ***E. obliqua*** L'Hér.<br>A very widely distributed tree in New South Wales, Victoria, and Tasmania. Also found in adjacent areas of Queensland and South Australia. | messmate stringybark |
| * | ***E. paliformis*** L.A.S. Johnson & Blaxell<br>A small tree restricted to one mountain in the ranges of south-eastern New South Wales. | Wadbilliga ash |
| * | ***E. regnans*** F. Muell.<br>A very tall tree occurring in the mountains of eastern Victoria and in Tasmania. | mountain ash |
| * | ***E. stricta*** Spreng.<br>A mallee of scattered distribution on the central tablelands and coast of New South Wales and in eastern Victoria. | Blue Mountains mallee ash |
| * | ***E. triflora*** (Maiden) Blakely<br>A small tree of restricted distribution on plateaux in south-eastern New South Wales. | Pigeon House ash |

***Blue-leaved ashes***

| | | |
|---|---|---|
| * | ***E. andrewsii*** Maiden ssp. ***andrewsii***<br>A medium-sized tree from the tablelands and coastal scarps of north-east New South Wales and nearby areas in Queensland. | New England blackbutt |
| * | ***E. andrewsii*** ssp. ***campanulata*** R.T. Baker & H.G. Smith<br>A medium to tall tree from the northern tablelands and coastal scarps of New South Wales and adjacent areas in Queensland. | New England blackbutt |
| * | ***E. consideniana*** Maiden<br>A small- to medium-sized tree from the tablelands and coast of New South Wales and eastern Victoria. | yertchuk |
| * | ***E. delegatensis*** R.T. Baker ssp. ***delegatensis***<br>A medium to very tall tree found in the ranges of southern New South Wales and eastern Victoria. | alpine ash |
| * | ***E. delegatensis*** R.T. Baker ssp. ***tasmaniensis*** Boland<br>A medium to very tall tree widespread in Tasmania. | gum-topped stringybark |
| * | ***E. fraxinoides*** Deane & Maiden<br>A medium to tall forest tree in highlands and coastal ranges of south-eastern New South Wales and just over the border in Victoria. | white ash |
| | ***E. gregsoniana*** L.A.S. Johnson & Blaxell<br>A small mallee from the higher parts of the central and southern tablelands of New South Wales. | Wolgan snow gum |
| * | ***E. haemastoma*** Sm.<br>A small- to medium-sized tree of coastal New South Wales. | scribbly gum |

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|---|---|
| ***E. lacrimans*** L.A.S. Johnson & K.D. Hill<br>A small tree from high altitude areas in southern New South Wales. | weeping snow gum |
| * ***E. luehmanniana*** F. Muell.<br>A mallee restricted to coastal scrub near Sydney in New South Wales. | yellow-top mallee ash |
| ***E. montivaga*** A.R. Bean<br>A medium-sized tree found sporadically along the coastal ranges of Queensland. | |
| ***E. multicaulis*** Blakely<br>A mallee from the central coast and adjacent ranges of New South Wales. | whipstick mallee ash |
| ***E. olida*** L.A.S. Johnson & K.D. Hill<br>A small- to medium-sized tree from the northern tablelands of New South Wales. | |
| * ***E. oreades*** R.T. Baker<br>A small- to medium-sized tree found in a few disjunct areas of New South Wales and southern Queensland. | Blue Mountains ash |
| ***E. pauciflora*** ssp. ***acerina*** Rule<br>A mallee or small tree of restricted distribution on the high plateau of eastern Victoria. | snow gum |
| ***E. pauciflora*** ssp. ***debeuzevillei*** Maiden<br>A small tree of restricted distribution in subalpine areas of south-eastern New South Wales. | Jounama snow gum |
| ***E. pauciflora*** ssp. ***hedraia*** Rule<br>A mallee or small tree restricted to one subalpine area of eastern Victoria. | snow gum |
| * ***E. pauciflora*** ssp. ***niphophila*** Maiden & Blakely<br>A small tree of subalpine areas in New South Wales and Victoria. | snow gum |
| * ***E. pauciflora*** Spreng. ssp. ***pauciflora***<br>Includes *E. pauciflora* ssp. *parvifructa* Rule.<br>A small- to medium-sized tree of tablelands and mountains from south-eastern Queensland, New South Wales, Victoria, and Tasmania, with one population in south-eastern South Australia. | snow gum |
| * ***E. piperita*** F. Muell. ssp. ***piperita***<br>A small- to medium-sized tree from the coast and tablelands of New South Wales. | Sydney peppermint |
| * ***E. piperita*** ssp. ***urceolaris*** (Maiden & Blakely) L.A.S. Johnson & Blaxell<br>A small- to medium-sized tree from the south coast and southern tablelands of New South Wales. | Sydney peppermint |

| | | |
|---|---|---|
| * | ***E. planchoniana*** F. Muell.<br>Small- to medium-sized tree found on the north coast of New South Wales and adjacent areas of Queensland. | needlebark stringybark or bastard tallowwood |
| * | ***E. racemosa*** Cav.<br>Includes *E. sclerophylla* (Blakely) L.A.S. Johnson & Blaxell and *E. signata* F. Muell.<br>Small- to medium-sized tree from coastal New South Wales and south-eastern Queensland. | scribbly gum |
| | ***E. remota*** Blakely<br>A mallee or small tree restricted to Kangaroo Island in South Australia. | Kangaroo Island ash |
| | ***E. rossii*** R.T. Baker & H.G. Sm.<br>Small- to medium-sized tree widespread in the tablelands of New South Wales. | scribbly gum |
| * | ***E. sieberi*** L.A.S. Johnson<br>A medium to tall tree of the tablelands and coast of southern New South Wales, Victoria, and north-eastern Tasmania. | silvertop ash |
| | ***E. sphaerocarpa*** L.A.S. Johnson & Blaxell<br>Medium to tall tree restricted to one location on tableland in east-central Queensland. | Blackdown stringybark |
| * | ***E. stenostoma*** L.A.S. Johnson & Blaxell<br>A medium-sized tree on the south coast of New South Wales. | Jillaga ash |

***Black sallies***

| | | |
|---|---|---|
| * | ***E. mitchelliana*** Cambage<br>A small tree growing only on the Buffalo Plateau in north-eastern Victoria. | Mount Buffalo gum |
| | ***E. moorei*** Maiden & Cambage<br>This species name is used here in a broad sense to include *E. latiuscula* (Blakely) L.A.S. Johnson & K.D. Hill, *E. serpentinicola* L.A.S. Johnson & Blaxell and *E. dissita* K.D. Hill.<br>A mallee found in several locations along the coastal ranges in New South Wales. | narrow-leaved sally |
| * | ***E. stellulata*** DC<br>Includes *E. copulans* L.A.S. Johnson & K.D. Hill.<br>A mallee or small- to medium-sized tree widespread in higher areas of New South Wales and eastern Victoria. | black sally |

## Appendix 2: Characteristics of the ash eucalypts compared to other common eucalypt groups in New Zealand

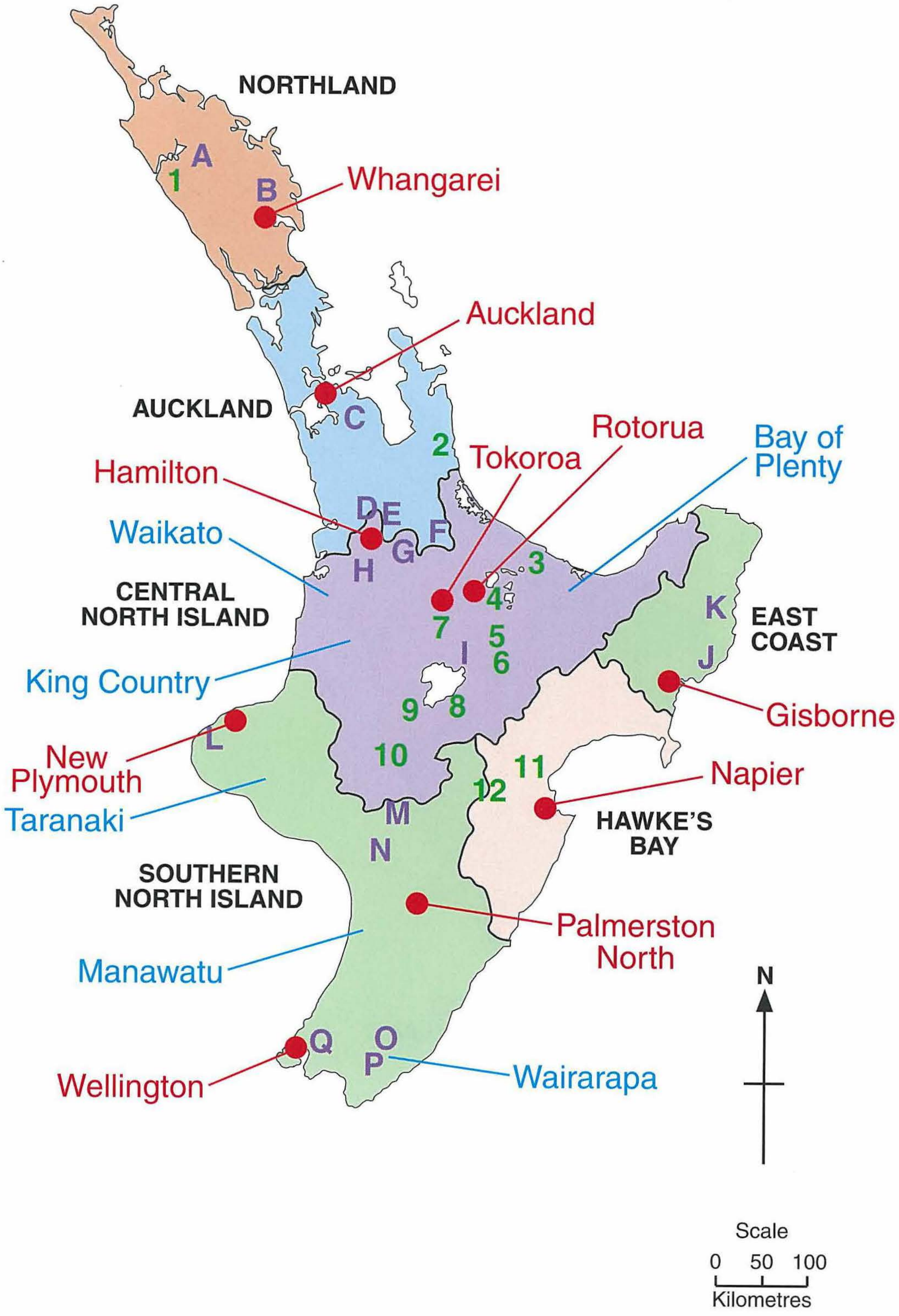
| | **Bark** | **Leaves on mature trees** | **Flower buds** | **Capsules** |
|---|---|---|---|---|
| **Ashes** | Smooth or rough on trunk, smaller branches smooth barked. | Adult leaves pendulous, lanceolate or falcate with uneven base, concolorous. Veins 5°–40°. | Long peduncle. Pedicels up to 7 mm long, occasionally absent. Usually club shaped and in clusters of 5–27. | Not tightly clustered, longer than wide. Disc broad, descending to ascending. |
| **Blackbutts** e.g., *E. pilularis* | Fibrous on most of the trunk, smooth above. | Many pairs of opposite, stalkless leaves on coppice growth. Adult leaves pendulous, lanceolate or falcate with uneven base, concolorous. Vein angle 30°–40°. | Peduncle flattened, 10–25 mm long. Pedicels up to 7 mm long, occasionally absent. Clusters of 7–15. | Not tightly clustered, subglobular to pear-shaped. Disc level to ascending. |
| **Stringybarks** e.g., *E. muelleriana* *E. globoidea* | Stringy bark on branchlets (thick, furrowed, long-fibred and can be pulled off in long strips). | Adult leaves pendulous, lanceolate or falcate with uneven base, concolorous to slightly discolorous. Vein angle 20°–40°. | Peduncles round to angular or flattened. Pedicels absent or very short. Clusters of 7–11. | Tight clusters, subglobular, often broader than long. Disc ascending. |
| **Peppermints** e.g., *E. radiata* *E. elata* *E. amygdalina* | Most peppermint-barked (thin, finely fibrous, interlaced), few smooth throughout. | Strong peppermint smell. Many pairs of opposite, stalkless juvenile leaves on coppice growth. Adult leaves pendulous, lanceolate, concolorous. Vein angle 10°–30°. | Small, stalked or almost sessile. Clusters of 3–40. | Not tightly clustered, small. Disc descending to ascending. |
| **Ribbon gums** e.g., *E. viminalis* | Smooth or rough, not stringy. | Often opposite, stalkless juvenile leaves on lower branches and coppice growth. Adult leaves pendulous, lanceolate, concolorous. Vein angle 20°–50°. | Peduncles angular to flattened. Pedicels absent or short. Occasionally solitary, usually in 3s or 7s. | Not tightly clustered, small to large, variable in shape. Disc descending to ascending. |
| **Mahoganies** e.g., *E. saligna* *E. botryoides* | Smooth or rough, not stringy. | Adult leaves alternate, horizontally held, lanceolate, discolorous. Veins at wide angle (45°–70°). | Peduncle flattened. Pedicels absent or short. Clusters of 7–11. | Not tightly clustered, goblet-shaped. Disc usually descending, sometimes level. |

## Appendix 3: Forest and place names

| Number | Forest |
|---|---|
| 1 | Waipoua |
| 2 | Tairua |
| 3 | Rotoehu |
| 4 | Whakarewarewa |
| 5 | Kaingaroa, including Matea and Waiotapu |
| 6 | Whirinaki |
| 7 | Kinleith |
| 8 | Lake Taupo |
| 9 | Rotoaira |
| 10 | Rangataua and Karioi |
| 11 | Esk |
| 12 | Kaweka |
| 13 | Golden Downs |
| 14 | Nemona |
| 15 | Mahinapua |
| 16 | Craigieburn |
| 17 | Eyrewell |
| 18 | Rowallan |
| 19 | Longwood |
| 20 | Dusky |

| Letter | North Island Places |
|---|---|
| A | Kaikohe |
| B | Kamo |
| C | Papakura |
| D | Gordonton |
| E | Newstead |
| F | Hinuera |
| G | Cambridge |
| H | Te Awamutu |
| I | Wairakei Tourist Park |
| J | Tolaga Bay |
| K | Tokomaru |
| L | Oakura |
| M | Taihape |
| N | Hunterville |
| O | Carterton |
| P | Greytown |
| Q | Taita |

| Letter | South Island Places |
|---|---|
| a | Marlborough Sounds |
| b | Picton |
| c | Tuamarina |
| d | Wairau |
| e | Stoke |
| f | Reefton |
| g | Cheviot |
| h | Rangiora |
| i | Homebush |
| j | Oamaru |
| k | Millers Flat |
| l | Moa Flat |
| m | Waitati |


NORTHLAND
A
1
B
Whangarei
Auckland
AUCKLAND
C
2
Rotorua
Tokoroa
Bay of Plenty
Hamilton
D
E
F
Waikato
G
H
3
CENTRAL NORTH ISLAND
4
K
EAST COAST
7
5
King Country
I
6
J
Gisborne
9
8
L
New Plymouth
10
11
Napier
12
Taranaki
M
HAWKE'S BAY
N
SOUTHERN NORTH ISLAND
Palmerston North
Manawatu
N
Q
O
P
Wairarapa
Wellington
Scale
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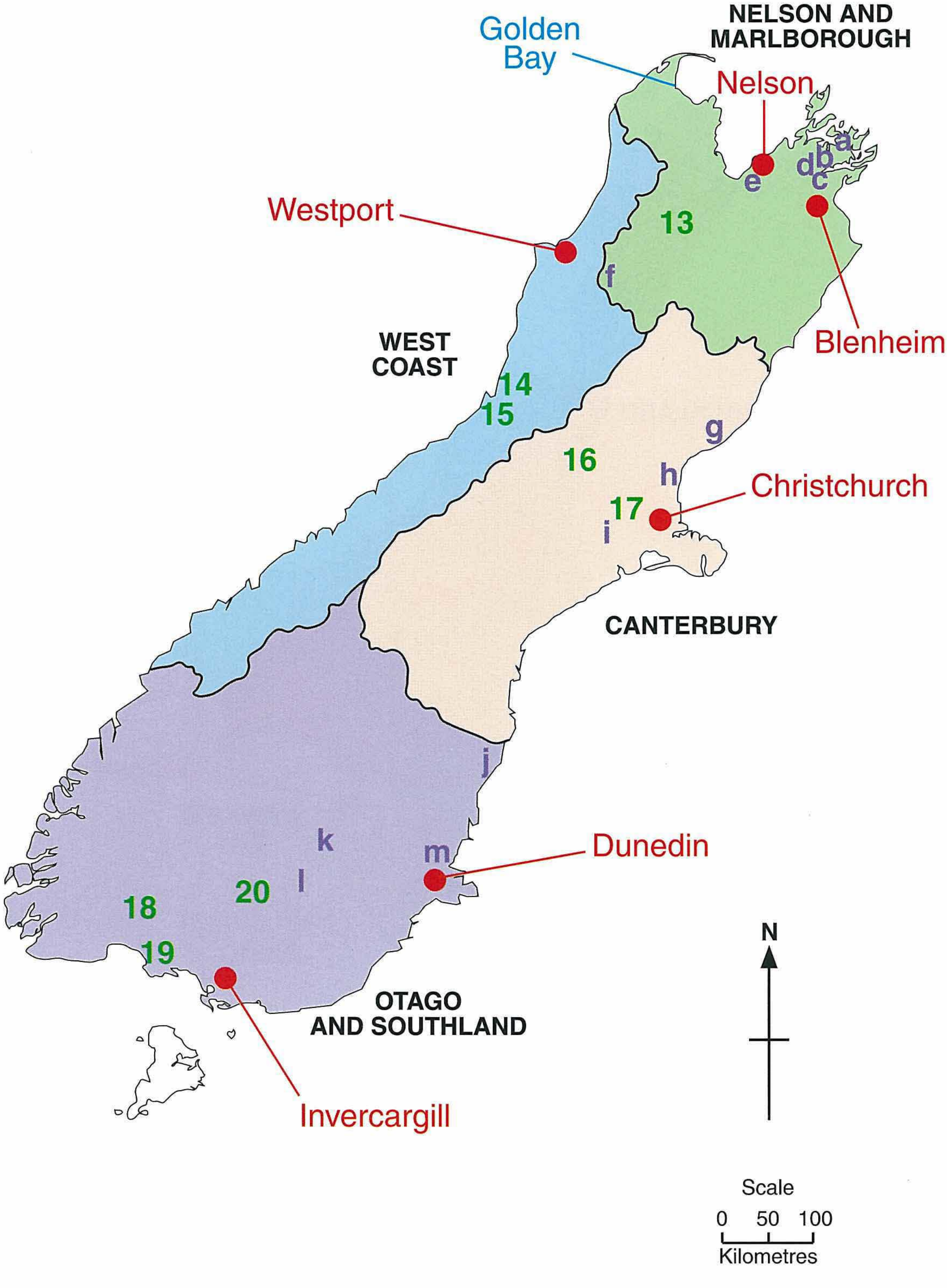
Kilometres



NELSON AND MARLBOROUGH
Golden Bay
Nelson
a
b
d
c
e
13
Westport
f
Blenheim
WEST COAST
14
15
g
16
h
Christchurch
17
i
CANTERBURY
j
k
m
Dunedin
l
20
18
19
OTAGO AND SOUTHLAND
Invercargill
N
Scale
0 50 100
Kilometres

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