

INTRODUCED
FOREST TREES IN NEW ZEALAND:
RECOGNITION, ROLE, AND SEED SOURCE



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

This FRI 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 mountain pine; *Pinus uncinata* Mirbel — mountain pine
5. *Pinus attenuata* Lemmon — knobcone pine
6. The spruces — *Picea sitchensis* (Bong.) Carrière, *Picea abies* (L.) Karsten, ornamental spruces
7. The silver firs — *Abies* spp.
8. *Pinus pinaster* Aiton — 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

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F.B. Knowles and J.T. Miller



NEW ZEALAND
FOREST RESEARCH INSTITUTE
LIMITED

Private Bag 3020, Rotorua, New Zealand

OPPOSITE: Coast redwood farm woodlot, aged 22 years, on G. Brann's property, eastern Bay of Plenty.
The trees have been pruned to 10 m.



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ABSTRACT

This booklet, the thirteenth in the Bulletin No. 124 series, provides an account of the redwoods and related species* in New Zealand. It deals mainly with coast redwood (*Sequoia sempervirens*) and giant sequoia (*Sequoiadendron giganteum*), and more briefly with dawn redwood (*Metasequoia glyptostroboides*) and swamp cypresses (*Taxodium* spp.). Topics covered include the introduction, history, role, recognition, and prospects of redwoods in New Zealand.

KEYWORDS: *Sequoia sempervirens*, *Sequoiadendron giganteum*, *Taxodium distichum*, redwoods, exotic species, New Zealand, provenance trials, recognition, role, seed.

INTRODUCTION AND HISTORY

Sequoia sempervirens, coast redwood, and *Sequoiadendron giganteum*, giant sequoia (sometimes also known as Sierra redwood, Wellingtonia, or California big tree), are the sole species in the genera *Sequoia* and *Sequoiadendron*, members of the family Taxodiaceae.

They are exceptionally large-growing and long-lived species and are amongst the tallest, largest and oldest trees in the world. Living trees of *Sequoia sempervirens* have been estimated to be at least 2000 years old and the largest *Sequoiadendron giganteum* to be about 3200 years old. Both species are native to western North America where they are valued for their majestic appearance and for their easily worked, stable, versatile and very durable wood.

It has been estimated that *Sequoia sempervirens* has been planted over at least 4500 ha since its introduction to New Zealand; however most of the earlier plantings failed to establish. *Sequoiadendron giganteum* has been planted in forests on an experimental basis only, and on a very small scale, but is often used as an amenity tree, especially in the South Island.

Taxodium distichum, swamp cypress (also called baldcypress), is the commonly cultivated species of the genus *Taxodium*, and *Metasequoia glyptostroboides*, dawn redwood, is the sole species in the genus *Metasequoia*. These genera are also members of the family Taxodiaceae. *Taxodium distichum* is native to south-eastern North America while *Metasequoia* is from southern China. Both are deciduous species, popular in New Zealand as ornamental trees.

Natural Distribution

Both coast redwood and giant sequoia occur naturally in western North America, coast redwood near the Pacific coast and giant sequoia at mid to high elevations on the second mountain range in from the coast. They occupy quite separate restricted areas, all in California, except for two small groves of coast redwood in the extreme south west of Oregon. Coast redwood occurs within a narrow coastal belt about 720 km long and 8-60 km wide (approximately latitude 42°05'N to 35°50'N) from southernmost Oregon to the south of Monterey County, California. Giant sequoia occurs at similar latitudes (between 35°05'N and 39°03'N) but is found about 220 km further inland and at much higher elevations, on the western slopes of the Sierra Nevada in central California (Fig. 1).

Coast redwood occupies about 700,000 ha. It occurs almost continuously in the northern half of its range, but in the southern part its distribution along the coast becomes more patchy. Frequent

* *Cryptomeria* and *Cunninghamia* will be dealt with in future bulletins

summer fogs are a feature of this coastal belt and provide a humid atmosphere which appears to be a governing factor determining the natural distribution. In altitude, coast redwood ranges from sea level to over 900 m a.s.l. but is most abundant between 30 m and 760 m a.s.l. It grows best on river flats, where it forms pure stands, and on moister slopes below 300 m, but also occurs on drier rocky slopes, in mixture with other conifers and hardwoods. Its most common associate is Douglas fir (*Pseudotsuga menziesii*), while others include grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*). In the south, its range overlaps that of radiata pine (*Pinus radiata*).

Giant sequoia, like coast redwood, is confined within a narrow belt running north to south. However, unlike the former species, it occurs in over 70 scattered groves over a distance of about 420 km covering a total of only about 14,000 ha. Over the northern two thirds of the range there are eight disjunct populations 10-90 km apart, while the southern third contains at least 65 populations 8 km or less apart with scattered trees between these populations. Groves of giant sequoia are found at altitudes ranging from 830 m to 2700 m a.s.l., but most are between 1400 and 2200 m. Usually it grows on coarse, well-drained granitic or alluvial soils on mountain slopes, doing particularly well in shallow grassy basins. Within its range, annual precipitation, occurring as rain or snow, generally exceeds 1000 mm, although there is little rainfall during the growing season. Giant sequoia rarely occurs in pure stands and it commonly associates with white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), incense cedar (*Calocedrus decurrens*) and Californian black oak (*Quercus kelloggii*).

Taxodium, a genus of two closely related species*, is native to southeastern and central North America. *Taxodium distichum* occurs naturally in the southeastern and central United States (Fig. 2), along the Atlantic coast from southern Delaware to southern Florida, along the Gulf of Mexico into Texas, and northward through southwest Oklahoma and Arkansas to southern Illinois and southwest Indiana. It grows best on stream banks and damp alluvial land, where it sometimes forms dense, almost pure stands, and it can survive and even grow reasonably well on sites that are under water most of the time. Usually it occurs below 30 m a.s.l., but isolated stands are found up to 530 m in Texas. *Taxodium mucronatum* is found naturally from Guatemala through Mexico to southwest Texas.

Metasequoia glyptostroboides, dawn redwood, occurs naturally in China, only in the isolated Shui Sha valley in the northwest part of Hupeh province and just into Szechuan (latitude 30°10'N, longitude 108°35'E,) (Fig. 3). It occurs within an area of about 800 square kilometres at 700-1350 m a.s.l. and grows best in moist shady localities in ravines and on stream banks.

History In New Zealand

Coast redwood was planted between 1860 and 1870 at many localities in New Zealand including Mt Peel in South Canterbury, Lyttleton, Hutt Valley, Wanganui and Auckland. Between 1870 and 1880 several importations of seed of both coast redwood and giant sequoia were made from California and one of coast redwood from Oregon. Other early importations of seed probably came from England. Between 1870 and 1890 further plantings were recorded at Waikato, Greendale in Canterbury, and in Otago. Coast redwood was first planted in State Forest about 1900 at Whakarewarewa. One of the finest stands in the country is 6 ha of coast redwood planted in 1901 in mixture with larch as part of a larger area in Whakarewarewa Forest. Known as the 'Redwood Memorial Grove' it was informally dedicated to the New Zealand Forest Service men who lost their lives in the two world wars. It now attracts many visitors and tourists. Coast redwood was subsequently planted sporadically in the Rotorua district but by 1912 results of these plantings were described as 'disappointing'. However, small areas did succeed and attempts by both private

* See page 9 for discussion of the currently recognised species of *Taxodium*

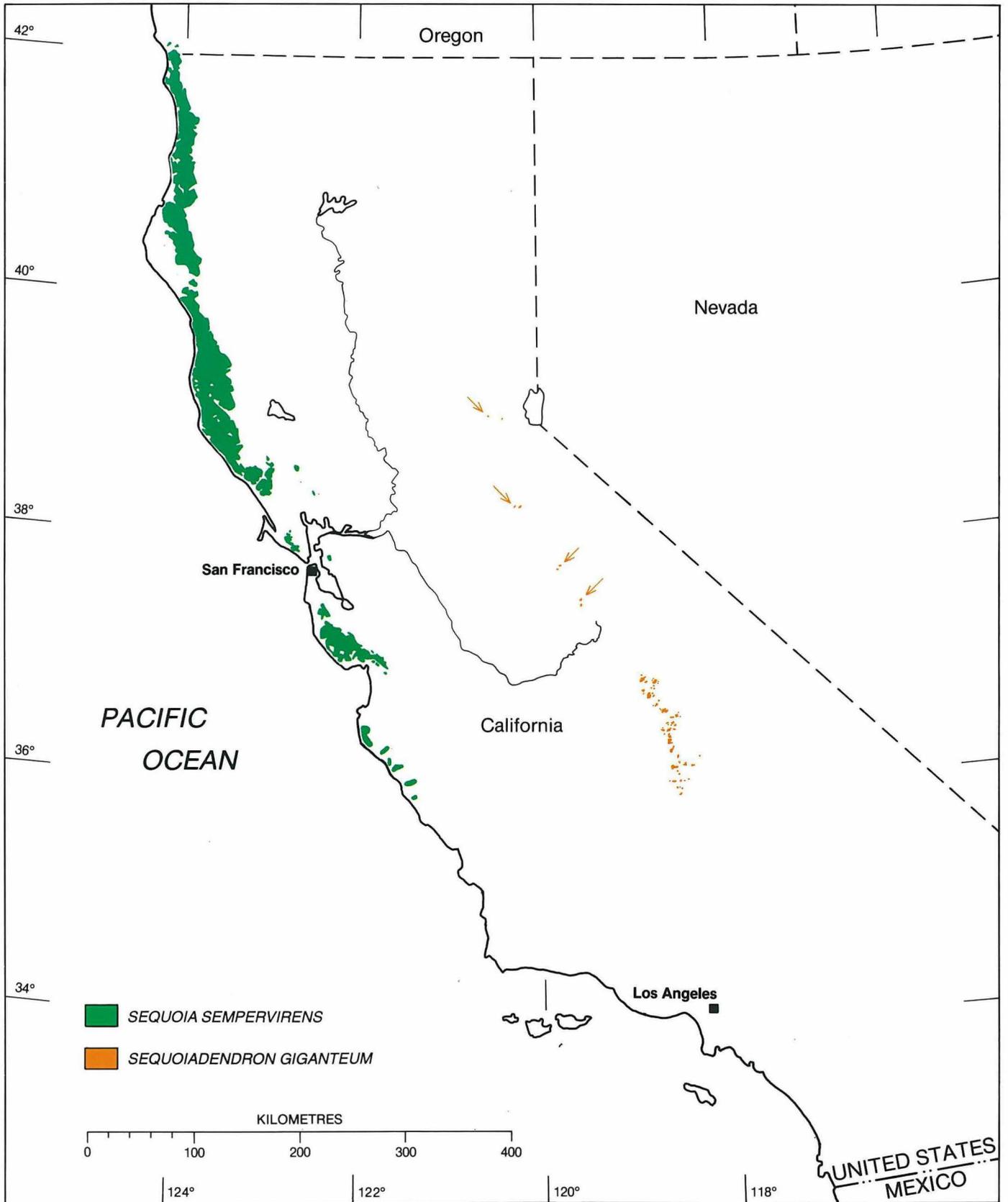


Fig. 1 – Natural distribution of *Sequoia sempervirens* and *Sequoiadendron giganteum* (based on Little, 1971).

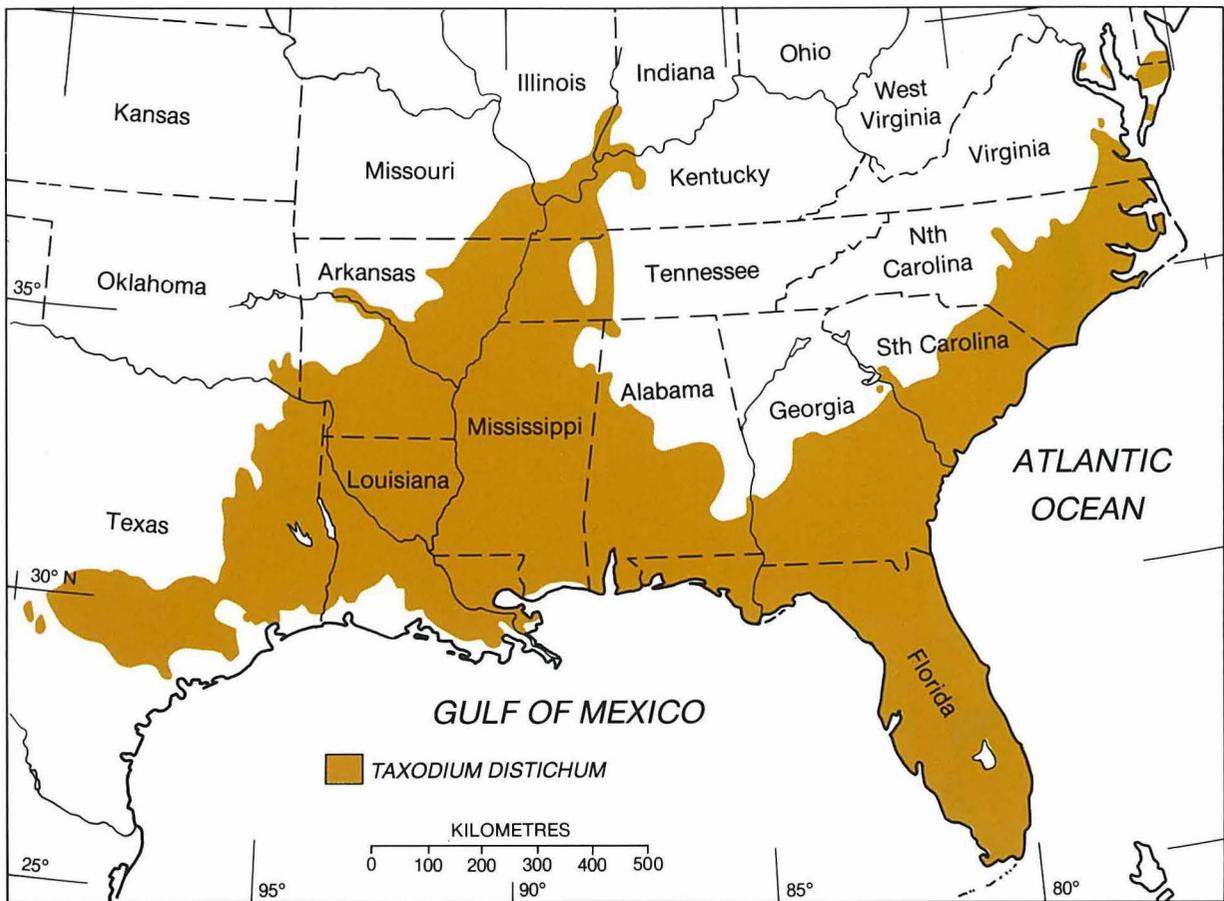


Fig. 2 – Natural distribution of *Taxodium distichum* (based on Langdon, 1958 and Little, 1971).

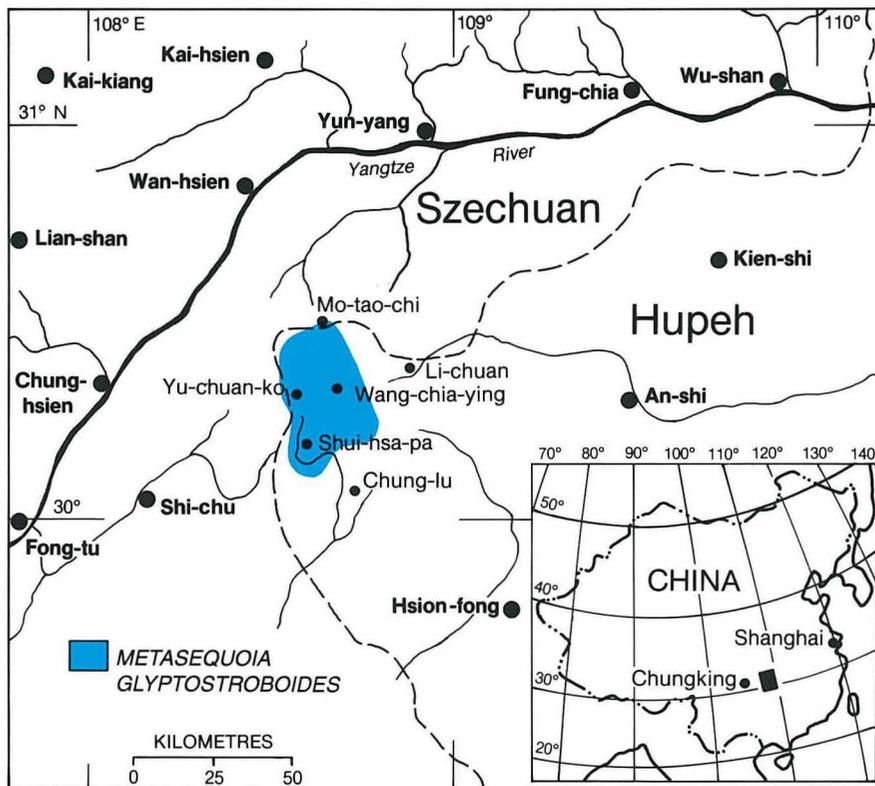


Fig. 3 – Approximate natural distribution of *Metasequoia glyptostroboides* (after Chu and Cooper, 1950 and Hu and Cheng, 1948). Inset shows location of map area.

companies and the state to grow this species continued. Large areas (totalling at least 4000 ha) were planted in both the North and South Islands between 1920 and 1945. Most failed, apparently due to unsuitable siting and/or insufficient site preparation and weed control.

Seed imported by the Forest Service between 1922 and 1930 came from Mendocino and Humboldt counties in California and from Oregon. By 1961, under all ownerships, there were approximately 112 ha of coast redwood in pure stands, 110 ha in the North Island and 2.4 ha in the South Island. A further 137 ha were in mixed stands, 129 ha in the North Island and 8 ha in the South Island.

Although giant sequoia was known to European explorers of California as early as 1833 its existence was not publicised until 1852, which seems remarkable in view of its immense size. It was introduced to New Zealand about 1860 from Veitch's nursery in Devon by J.B.A. Acland, the owner of Mt Peel Station in Canterbury. Trees from this introduction still survive, of which the tallest (at Raincliff Station in Canterbury) had reached 46.6 m when measured in 1982 (Burstall and Sale, 1984) and another at Orari Station had a diameter at breast height of 332 cm in 1992. Since this first introduction, giant sequoia has been planted as an ornamental throughout most of New Zealand, particularly in the southern part of the South Island where there are now a number of very large specimens.

Taxodium distichum, swamp cypress, is recorded by Ludlam, 1868, as growing in his garden at Hutt near Wellington. He described it as "not worth growing, never seeming to throw up a leader". However, a specimen 75 ft tall was recorded by T. Mason growing at Taita in 1896. Since its introduction it has been planted frequently throughout the country as an ornamental.

Metasequoia glyptostroboides, dawn redwood, although a relatively recent introduction to cultivation, can be traced back in fossil history to the Cretaceous period 136 million years ago and is often referred to as a 'living fossil'. It was first described in 1941 from fossil material but in the same year living trees were found growing wild near Chungking by a Chinese botanist. It was described and named from living material in 1948 when it was introduced to Great Britain and North America. It is now widely cultivated in temperate regions. Seed of dawn redwood was bought into New Zealand in 1949 from China via the Smithsonian Institute in Washington. A tree from this seed is growing on the driveway to the homestead at Eastwoodhill, Gisborne.

Provenance Variation

Coast redwood

Although coast redwood is one of the most valuable timber and amenity species in the United States, relatively little is known about its provenance variation. Significant population variability has, however, long been considered likely in view of the extent of its range. The natural distribution of coast redwood spans approximately 6°20' of latitude; extending as much as 60 km inland from the coast over much of the range with local differences in soil types, temperatures and precipitation.

In 1979, eight experimental seedlots from latitudes 37°N to 40° 52'N in California, were supplied to the New Zealand Forest Research Institute by Professor W.J. Libby, University of California, and were used to establish a small provenance trial in Rotoehu Forest near Rotorua in 1981. A seedlot representing the 6 ha stand in Whakarewarewa Forest (the 'Redwood Grove') was included in the trial. Early growth was very variable due to differences in microsite and in weed competition. When assessed at age 12 years the local Whakarewarewa provenance (of unknown ancestry) was shown to be the shortest of the nine tested, and to be significantly less in mean breast-height diameter (143 mm) than the most vigorous of the imported lots (207 mm) which had been collected as seed from an unrecorded locality (probably in the northern third of the range) by the



Fig. 4 – Habit of redwood species. Coast redwood aged approximately 75 years, Long Mile, Whakarewarewa Forest , Rotorua (left); giant sequoia, open-grown at Rangiora (right).

Simpson Timber Company based at Korbel, California. Reasons for the poor performance of the Whakarewarewa trees are uncertain, however inbreeding or poor parental selection are possible causes. No other significant differences between provenances were discernible from this trial.

A range-wide clonal test of coast redwood was initiated in California in 1983. Two hundred redwood clones from 90 provenances (two clones per provenance), together with a selection of plus trees and “famous” trees, were collected in 1984 as seedlings or as cuttings from live-tree or stump sprouts. Provenance differences in early growth rate have been indicated by these tests. Although some consistency was recorded within stands in height, crown diameter, tree shape and heat tolerance, provenances from the southern region of the natural range grew significantly faster (W.J. Libby, pers. comm.).

Hedged archives established at locations in California and in France have since been treated to supply cuttings for distribution in the USA or overseas. Redwood clones from the collection were received in New Zealand in January 1992 by Tasman Forestry Ltd and approximately 50,000 plantlets from 35 clones have been raised so far by tissue culture propagation. The company plans to establish both replicated field clonal tests and demonstration stands in the near future. This work should provide the opportunity and basis for the most comprehensive studies of redwood in New Zealand to date.

Giant Sequoia

Although there is some variation in habit and size, giant sequoia generally has a more consistent form than most conifers, and is genetically less variable than might be expected considering the extent of its natural distribution. This spans roughly 400 km north to south (in disjunct populations) with an elevation range exceeding 1800 m. Although giant sequoia is much less genetically variable than coast redwood, the few reported overseas studies of population variation indicate significant variation in hardiness (related to elevation of origin). There are also indications of differences between populations in growth rates and tree form, particularly crown shape and basal taper. In other tests, growth of seedlings from open-pollinated trees occupying isolated open-grown positions was poorer than that of seedlings originating from trees located within larger groves or plantations (Libby, in Weatherspoon *et al.*, 1986). Updating of provenance trial results in the USA and in Europe should in future provide an improved basis for choice of provenances for specific locations.

Small seed samples were obtained by the New Zealand Forest Research Institute in the 1970s from 16 groves of giant sequoia in California, and also from Raincliff in Canterbury, and provenance trials were established in 1977 at five South Island locations: Rai (Nelson), Hanmer, Craigieburn and Geraldine (Canterbury), and Beaumont (Otago). Generally, where shelter and soil moisture were adequate, the trees established very well. When assessed in 1983 (aged six years) the best trees had reached 1.5–2 m in height. At that age, no obvious provenance differences were detected although there was considerable variation between individuals within provenances at all sites, some of which could clearly be ascribed to the effects of weed competition.

The trial at Beaumont, which included nine provenances and was planted on a sheltered, moist but free-draining site, continued to grow well (Fig. 5). Trees were reassessed at age 12 years (in 1989) by which time the tallest individual trees exceeded 10 m. Mean heights ranged from 5.3 to 6.7 m, differing significantly over the extremes of the range (Raincliff and McKinley provenances were significantly shorter than the remaining seven provenances) (Table 1).

TABLE 1— Mean values for growth and form of *Sequoiadendron giganteum* aged 12 years (planted in 1977) in NZ FRI provenance trials at Beaumont Forest

| Lot | Provenance | No. of trees | Ht (m) | Diam. (mm) | Volume (m ³) | Ann. ht increment 1987-1989 (m) | Malf. score* |
|-----|-----------------------|--------------|--------|------------|--------------------------|---------------------------------|--------------|
| 13 | Nelder | 15 | 6.4 | 187 | 0.11 | 0.75 | 8.1 |
| 12 | Whitaker/Redwood Mtn | 24 | 6.2 | 179 | 0.09 | 0.75 | 8.7 |
| 14 | North Calaveras | 24 | 6.7 | 173 | 0.09 | 0.80 | 8.9 |
| 10 | Mountain Home | 23 | 6.0 | 162 | 0.07 | 0.65 | 8.6 |
| 6 | Giant Forest | 24 | 6.1 | 159 | 0.07 | 0.80 | 9.0 |
| 11 | Wheel Meadow | 24 | 5.7 | 150 | 0.06 | 0.65 | 8.8 |
| 2 | Black Mountain | 23 | 5.9 | 151 | 0.06 | 0.70 | 8.7 |
| 9 | McKinley | 23 | 5.4 | 140 | 0.05 | 0.60 | 9.0 |
| 20 | Raincliff Forest (NZ) | 16 | 5.3 | 140 | 0.06 | 0.55 | 9.0 |

* Malformation score: 0 = poor form
9 = good form

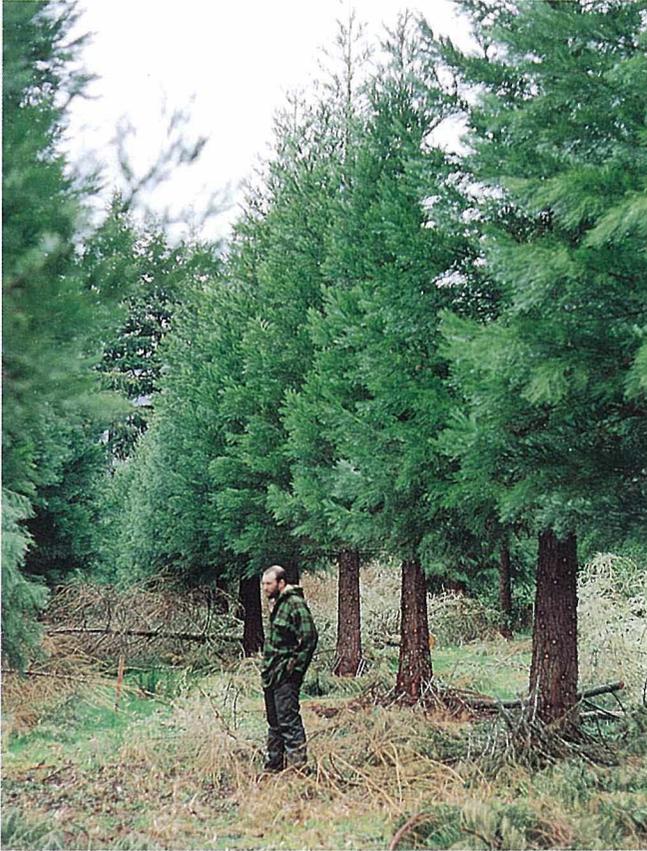


Fig. 5 – Species-provenance trial of *Sequoiadendron giganteum*, aged 16 years, originally interplanted with a filler of European larch. Compartment 602 Beaumont Forest, west Otago.

Pests and Diseases

The redwoods are generally healthy species both in their natural environment and in cultivation in New Zealand. Insects have caused only minor problems in coast redwood in New Zealand including girdling of twigs and branches by the longhorn beetle *Navomorpha lineata* and defoliation by some tortricids and by caterpillars of the common forest looper moth, *Pseudocoremia suavis*. Damage by caterpillars of the gregarious tineid *Hierodoris atychioides*, while generally insignificant, can be quite noticeable and unsightly. The huhu beetle, *Prionoplus reticularis*, can attack the heartwood of trees where this has been exposed by damage. In North America redwood seedlings are highly susceptible to several damping-off fungi. Grey mould, caused by species of *Botrytis* spp., is a serious disease of seedlings of both species especially in warm weather. On one occasion severe *Botrytis* mortality occurred among seedlings of giant sequoia at Rangiora Nursery in Canterbury.

A canker fungus, *Botryosphaeria* sp., is causing concern on giant sequoia in Europe, particularly in France. It causes the death of twigs and branches, often resulting in deformed crowns and sometimes mortality in young trees especially when they are under stress. There have been a number of reports of minor damage only, caused by *Botryosphaeria*, to both coast redwood and giant sequoia in New Zealand. A root-rot fungus, *Armillaria* sp., has killed many hundreds of young giant sequoia trees in Europe, especially on sites where hardwoods previously grew (Libby, 1981).

Generally, coast redwood and giant sequoia have a high degree of immunity to fatal attacks by fungi or insects because of the high tannin content of their wood. However, in North America, stem-rots entering the tree through wounds and scars are common. In New Zealand young trees of coast redwood are prone to damage by browsing animals, and deer and possums can cause severe damage by destroying the main shoots. Although giant sequoia foliage is generally unpalatable the bark may sometimes be stripped by cattle and goats. Older trees are well protected from fire by the very thick

bark which does not burn readily even under intense heat and living crowns of both species are highly fire resistant. The ability of coast redwood to survive fire is a driving factor for its current planting in fire-prone areas of southern France (W.J. Libby, pers. comm.).

RECOGNITION

Sequoia, *Sequoiadendron*, *Taxodium* and *Metasequoia* all belong to the Taxodiaceae, an ancient family of nine to ten* genera and approximately 16 species of medium-sized to huge trees found in East Asia, North America and Tasmania. *Taxodium*, *Metasequoia* and *Glyptostrobus* are deciduous; the other six to seven genera are evergreen. Most species have thick fibrous, often soft bark and leaves that are mostly linear but sometimes scale-like. Cones are ovoid or globose, woody with peltate (shield-like) scales and often narrowly winged seeds. Hart and Price (1990) make a case for all genera of Taxodiaceae except *Sciadopitys* to be included in the Cupressaceae to which they are closely allied.

Sequoia and *Sequoiadendron* are both evergreen and are closely allied in their vegetative morphology. However they are easily distinguished by their very different lower branch leaves (Fig. 6)—in *Sequoia* like those of a yew in a comb-like arrangement and in *Sequoiadendron* (and on leading and reproductive shoots of *Sequoia*) stiff, sharp and scale-like. *Taxodium* and *Metasequoia* both have feathery foliage (Fig. 6) and are similar in general appearance and in their deciduous habit, shedding lateral twigs (rather than individual leaves) in the autumn. They are most easily differentiated from each other by the placement of leaves, buds and shoots—opposite in *Metasequoia* and alternate in *Taxodium* (Fig. 7). Botanical details of *Sequoia*, *Sequoiadendron*, *Taxodium distichum* and *Metasequoia* are summarised in Table 2.

Sequoia, *Sequoiadendron* and *Metasequoia* are all monotypic, i.e., with only one species in each genus. In the past there has been considerable disagreement over the number of species within *Taxodium*. Three species, *T. distichum*, *T. mucronatum*, and *T. ascendens*, have commonly been recognised. The differences between these species, particularly between *T. distichum* and *T. ascendens*, are, however, minor and there is considerable overlap between them. Currently, *T. ascendens* is usually treated as a variety of *T. distichum* — *T. distichum* var. *imbricarium* Croom, pondcypress, sometimes also known as *T. distichum* var. *nutans*. It has stiff erect branches and short leaves (5–12 mm) appressed to the shoot. *Taxodium mucronatum* Tenore is more distinct although varietal status (as *T. distichum* var. *mexicanum* (Carrière) Gordon) has also been suggested (Hart and Price, 1990). It differs from *T. distichum* mainly in being semi-evergreen, retaining leafy shoots until winter or even spring (although in cooler climates it may become deciduous) and in having cones that are frequently more elongated, often warty and sometimes glaucous. It rarely produces 'knees' (see Table 2) and is considerably less cold-hardy in cultivation.

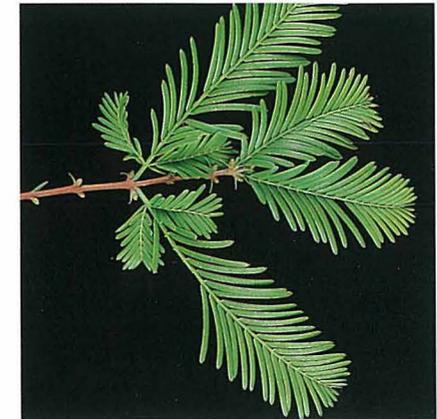
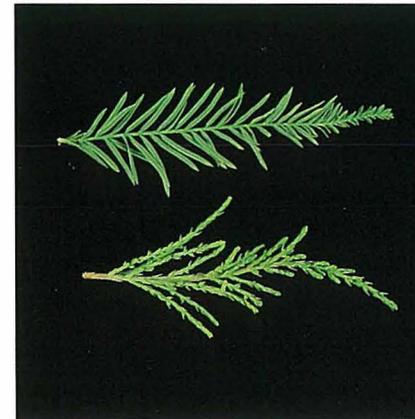
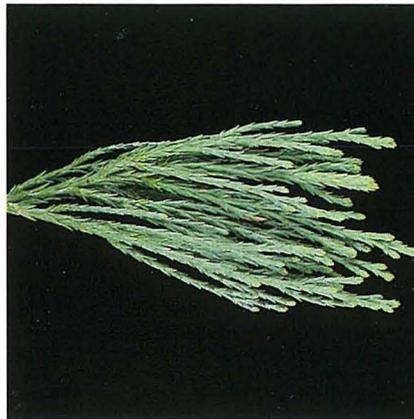
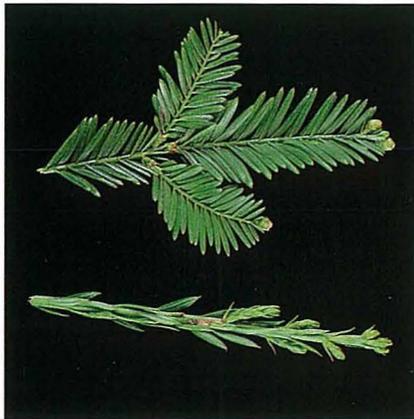
Another closely related species occasionally planted in New Zealand as an ornamental is the Chinese swamp cypress, *Glyptostrobus pensilis* (Staunton) K. Koch [previously known as *Glyptostrobus lineatus* (Poiret) Druce]. It is the only species in the genus *Glyptostrobus* and occurs naturally in south east China. It is deciduous to semi-evergreen and superficially closely resembles *Taxodium* but differs in having pear-shaped cones (ovoid to roundish in *Taxodium*), with longer stalks (1.3–2 cm), cone scales with triangular teeth, and smaller, thin-coated seeds with obvious wings in contrast to the thick, horny coated seeds found in *Taxodium*. It needs a very damp site to thrive.

There has been one report of a hybrid between *Sequoia sempervirens* and *Sequoiadendron giganteum*, but attempts to repeat this by control-pollinations have failed.

* *Sciadopitys* is now generally considered to differ sufficiently from Taxodiaceae and Cupressaceae in aspects of vegetative morphology and in chromosome number and pollen type to justify placement in a separate family, *Sciadopityaceae* (Hart and Price, 1990).

TABLE 2: Recognition of *Sequoia*, *Sequoiadendron*, *Taxodium* and *Metasequoia*

| | <i>Sequoia sempervirens</i> (D. Don) Endl. coast redwood | <i>Sequoiadendron giganteum</i> (Lindley) J. Buchholz giant sequoia | <i>Taxodium distichum</i> (L.) Richard swamp cypress, baldcypress | <i>Metasequoia glyptostroboides</i> Hu et Cheng dawn redwood |
|------------|--|---|---|---|
| Habit | Massive <u>evergreen</u> tree growing to well over 100 m tall in its natural habitat and to over 60 m in New Zealand. Young trees conic, branches widely spaced, horizontal, upturned near tip. Older trees remain narrow crowned, but may become flat topped. Trunk tapering gradually, often flared and irregularly fluted near base. | Massive <u>evergreen</u> tree growing to over 90 m in its natural habitat and to over 50 m in New Zealand. Young trees conic, with a long narrow pointed top and a broader base, but crown may eventually become rounded or irregular. Lower branches drooping downwards, upturned at ends. Trunk becoming massive as tree ages, columnar, often flared and buttressed at base. | Large <u>deciduous</u> tree growing to 30-50 m in its natural habitat and to at least 30 m in New Zealand. Young trees conic, becoming broader with long level branches, often up-swept in old trees. Often densely branched and very twiggy, sometimes sparse. Trunks often buttressed; older trees, particularly when in or near water, frequently with knee-shaped hollow outgrowths from a few centimetres to 1 m or more high from roots around tree base. | Large <u>deciduous</u> tree growing to at least 40 m in its natural habit and to over 20 m in New Zealand. Crown narrow, conic in young trees, becoming broader and rounded with age, branches often upswept, branchlets and sometimes lower branches drooping, usually dense in open, very sparse in shade, trunk gradually tapering, base often strongly fluted and flared. |
| Bark | Orange-brown and loosely stringy in young trees, becoming reddish brown and <u>very thick</u> (15-30 cm), soft, spongy, fibrous and deeply furrowed (Fig.8). | Red-brown to dark brown in young trees, shredding, <u>becoming very thick and fibrous</u> in older trees (to at least 50 cm on large trunks), soft, deeply fissured and ridged, separating into loose light reddish- brown scales. | In young trees usually thin and scaly, pale brown or reddish brown, becoming fibrous with age and furrowed into long scaly fibrous ridges, can be peeled in long strips, weathering to grey brown. | When young, orange-brown or red-brown, flaky; when older, often dark greyish brown becoming fissured (often deeply), fibrous and stringy, peeling off in narrow strips. |
| Branchlets | Young shoots green for first 2-3 years, ridged, becoming reddish or greyish brown, <u>buds surrounded by many loose scales</u> , bud scales turning brown and persisting at base of young shoot. | Green at first, more or less covered by attached leaf bases, becoming brown, <u>much divided into dense, bushy clusters, buds hidden, minute, without scales.</u> | <u>Alternate, of two types</u> : (1) Persistent shoots (from the branches), green maturing to brown. (2) Deciduous shoots arising in spring from buds along the persistent shoots, 5-10 cm long, green, slender, dropping in autumn with the leaves. | <u>Opposite. Of two types</u> - (1) Persistent, pink-brown to reddish brown, with buds. (2) Deciduous, arising in spring from buds on persistent shoots, leaving bud scales at base of shoot, green, 9 cm or more in length, without buds, falling in autumn. |
| Foliage | Leaves spirally arranged, hard, slightly prickly, <u>of 2 kinds</u> : (1) On side branches — <u>in a comblike arrangement on either side of shoot</u> , linear-oblong, 1-2.5 cm long, about 2 mm wide, dark green to blue green above, <u>two broad whitish bands below</u> , tips abruptly sharp-pointed, base twisted, petiole (leaf stalk) lacking. (2) On leaders and fertile shoots — widely spaced, scale-like, about 7 mm long, dark yellow-green, tip horny, incurved. | Leaves spirally arranged all around the shoot, pointing forward, <u>of one kind only, scale-like</u> , rigid, harsh to the touch, <u>small (3-7 mm long)</u> but can be up to 12 mm on vigorous shoots), dull grey-green or blue-green at first, becoming dark green and shiny by the 3rd year, triangular with a broad flat stalkless base, tapering to a sharp pointed tip. | Leaves <u>deciduous, of 2 types</u> : (1) On deciduous shoots crowded in 2 rows in a <u>feather-like arrangement</u> , about 1 cm long, 2 mm wide, slender, abruptly pointed, pale green in spring, becoming yellowish green in summer, 2 greyish bands on underside, <u>turning to rich reddish brown before falling in autumn</u> . (2) On persistent shoots, spirally arranged, small, scale-like, pressed against branches. | Leaves <u>deciduous, in opposite pairs</u> in a comb-like arrangement on either side of the shoot, downcurved at the tips, about 1-2.5 cm long (on seedlings or young trees to at least 5 cm long), about 2 mm wide, soft, linear, stalkless, blue-green or yellow-green above, 2 pale bands below, <u>turning red-brown in autumn before being shed with the deciduous branchlets.</u> |



Female cones

When mature, pendulous on short shoots, ovoid, about 1.5-3 cm long, 1.5-2 cm wide, green at first, becoming reddish brown to dark brown, weathering to grey-brown with about 15-20 hard leathery, ridged and wrinkled scales. Seed ripening in one year, shed in autumn soon after ripening, cones then persist on tree for several months.



Solitary at the end of shoots - (but appearing bunched), erect in 1st year, pendulous in 2nd, ovoid, 3.5-9 cm long, 2.5-5.5 cm wide, taking 2 years to ripen, green in 1st year, ripening usually to brown in 2nd year, with about 25-40 wedge-shaped, hard fibrous scales, wrinkled, with a fold along the centre line. Cones persist unopened on the tree for many years (live seed held up to 30 years in California).



Solitary or in clusters of 2-3 in leaf axils near branchlet ends, roundish, about 2-3 cm long, with a short stalk to 3 mm long, brownish purple when ripe, resinous, with a few 4-sided scales with obscure central spines, scales breaking away irregularly as soon as cone ripens, ripening in one year.



Solitary at the ends of lateral branchlets, pendulous, ovoid, nearly squarish in cross-section 1.5-2.5 cm long with a long stalk (2-4 cm long) green at first, maturing to dark brown, with 20-30 woody scales, outer surface of each with a horizontal groove, cone ripening in one season.



Male cones

3-4 mm long, globular, whitish yellow, pollen shed in winter.

4-8 mm long, borne in large numbers at the ends of shoots, stalkless, turning yellow and shedding pollen in early spring.

Pendulous at branchlet tips, slender, purplish, tassel-like, lengthening to at least 20 cm when ripe, appearing in late autumn, shedding pollen in late winter or spring.

Pendulous at branchlet tips, opposite, in few-branched panicles to at least 25 cm long when mature (see Fig. 6), shedding pollen in July.

Seeds

About 3-7 per fertile cone scale (about 60 per cone), 3.5-6 mm long, elliptic to oblong, reddish brown with 2 wings equal to or narrower than the seed.

2-9 per fertile cone scale, 4-8 mm long, oblong, flat, grey-brown, narrow with two broader often very unequal yellow-brown wings.

2 per cone scale, both not always developed, 6-15 mm long, irregularly triangular with projecting flanges along edges, seed coat thick, horny, warted.

2-9 (usually 5-6) per fertile scale, 4-6 mm long, usually obovate, light brown with a paler broad, thin encircling wing.



Comments

Readily distinguished from *Sequoiadendron giganteum* by its linear leaves up to 2.5 cm long in a comb-like arrangement, leaves of 2 forms, buds with loose scales, smaller cones and softer bark. Young trees superficially resemble *Taxus baccata* but are easily distinguished from this species by blue white bands under the leaves.

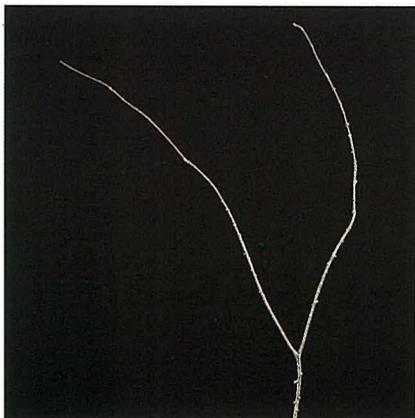
Sequoiadendron giganteum is distinguished by its small, scale-like grey-green or blue-green leaves, harsh to the touch and pointing forwards all around shoot, hidden buds without scales, bunched upturned branchlets, and large cones taking 2 years to ripen. *Cryptomeria japonica* has superficially similar scale-like leaves but they are markedly longer (1-1.5 cm) and stand out distinctly from the twig, curving inwards at the tip.

Taxodium superficially resembles *Metasequoia* but is easily distinguishable by alternately placed leaves, twigs and buds (opposite in *Metasequoia*), and much smaller leaves. Otherwise the deciduous habit, 'knees' in damp places, fine feathery foliage and roundish cones with horny coated seeds are distinctive in combination.

Metasequoia is distinctive in having leaves, buds and deciduous shoots all in opposite pairs and buds occurring below branchlet insertions. Deciduous leaves turning red-brown in autumn and solitary squarish long stalked female cones are also distinctive.

(a) *Sequoia sempervirens*(b) *Sequoiadendron giganteum*(c) *Taxodium distichum*(d) *Metasequoia glyptostroboides*. Note male cones in pendulous panicles.

Fig. 6 – Branchlets showing typical foliage and female cones.



(a)



(b)

Fig 7 – Branchlets of (a) *Taxodium distichum* and (b) *Metasequoia glyptostroboides* in winter. Note placement of branchlets and buds; alternate in *Taxodium*, opposite in *Metasequoia*.



Sequoia sempervirens



Sequoiadendron giganteum



Taxodium distichum



Metasequoia glyptostroboides

Fig. 8 – Typical bark of mature trees.



Fig. 9 – Giant sequoia in species trial, Ribbonwood Station, Omarama, 650 m a.s.l. Above: aged 3 years, below: aged 9 years.

ROLE OF THE SPECIES

Siting and Establishment

Coast redwood

Coast redwood has been tried in many parts of New Zealand resulting in a few spectacular successes, e.g., the Redwood Grove at Whakarewarewa (Fig. 10), and in some scattered well-grown stands, particularly in the northern half of the North Island. However there have also been widespread failures for reasons which have not always been fully ascertained. Probable causes or contributing factors have been poor planting, competition from weeds, lack of sufficient moisture and frost damage. Absence of suitable mycorrhizal associates (soil fungi which facilitate uptake of nutrients by the tree) may have also sometimes contributed. Coast redwood seems to thrive best in sheltered inland localities such as valley floors, gully bottoms and river flats with deep, fertile, moist but well-drained soils, relatively high humidity, and a reasonably high, well-distributed rainfall, and it has done particularly well on such sites in the northern half of the North Island. It has grown successfully up to about 500 m a.s.l. in the North Island and up to about 300-400 m a.s.l. in inland Canterbury.

Coast redwood is very sensitive to climate and site factors when young, and retarded or checked early growth is common when conditions are less than ideal. Seedlings and young trees have a high soil moisture requirement and root competition from weeds, and especially grass, can seriously



Fig. 10 – Stand of coast redwood aged about 90 years, Redwood Grove, Rotorua.

retard early growth and contribute to establishment failure. Coast redwood is very shade tolerant and can recover from almost indefinite suppression. It maintains a remarkable capacity, even when quite old, to accelerate growth rates when released from competition.

Young trees are intolerant of exposure and shelter from strong winds is necessary. Valley bottoms often provide ideal sites and early growth is frequently better when coast redwood is planted with other sheltering vegetation. For example, it may be planted with a nurse crop such as radiata pine, Douglas-fir or larch, under cutover native forest or under a high open canopy of kanuka. Although in North America redwood grows naturally quite close to the coast, it does not tolerate salt-laden coastal winds and is generally quite sensitive to wind. The sheltered lower parts of established trees may do well in windy areas but tops are often repeatedly wind-burnt and do not grow above the level of sheltering vegetation or buildings. Young trees can be damaged by frosts below -9°C and can be cut back repeatedly by heavy or severe frosts.

A suggested establishment regime for coast redwood is as follows:

- Prepare planting site by cultivating — ripping, or rotary hoeing — or spot spray an area of about 1 square metre for each tree.
- Plant top quality, well-conditioned, large, vigorous, bare-rooted seedlings (or cuttings) with abundant fibrous roots.
- Keep planting site completely weed-free for at least 2 years, e.g., by cultivating, or by spraying at least a square metre area with glyphosate (e.g., 'Roundup', 'Touchdown') before planting and applying a pre-emergence spray (simazine, atrazine or terbuthylazine) after planting. These chemicals are available under various proprietary names such as 'Gardoprim' and 'Gesaprim'. Apply spray with care to avoid contact with any part of the tree. For later weed control, 'Gallant' (haloxyfop) will control grasses and 'Versatill' (clopyralid) will control most broadleaved weeds without damaging the trees. 'Prefix-D' (dichlobenil) granules applied around trees will maintain control of a wide range of grasses and broadleaved weeds.
- On less fertile sites it may be helpful to apply fertiliser (e.g., 'Amophos 12.10.10' at a rate of 250 g per tree) in the first and second year after planting. Place fertiliser in four diametrically opposed slits at the dripline of the tree. In North America redwood has responded quickly and dramatically to fertiliser and/or supplemental water on poor or dry sites (W.J. Libby, pers. comm.).

Table 3 summarises the results of a trial in the Gisborne area using the above regime and clearly demonstrates its benefits.

TABLE 3 – Growth of coast redwood near Gisborne in the first 3 years after planting showing the effects of grass control and fertiliser (adapted from Bowles, 1980)

| | Mean height increment (cm) | | | Ground-level diameter (mm) at end of 3rd year |
|---|----------------------------|----------|----------|---|
| | 1st year | 2nd year | 3rd year | |
| Fertilised, Grass controlled | 42 | 67 | 89 | 68 |
| Not fertilised, Grass controlled | 30 | 49 | 75 | 49 |
| Not fertilised, Grass not controlled | 14 | 24 | 58 | 31 |

Giant sequoia

In New Zealand giant sequoia has been planted in State Forests on an experimental basis only and little information is available on establishment or response to site in this country. In general it has established well in provenance trials in the South Island, particularly where there has been good shelter and adequate soil moisture, as at Hanmer and Beaumont. However, there is a very good stand which was established without shelter on a very dry site (< 400 mm) near St Bathans in Otago (C.G.R.Chavasse, pers. comm.). As with coast redwood, young trees of giant sequoia respond well to the elimination of weed competition.

In its natural habitat and in Europe giant sequoia tends to grow best on slopes with good air and soil drainage. Climatic factors are less restricting than for coast redwood and it is more tolerant of winter cold, surviving and growing well in areas of Europe that commonly experience temperatures of -20°C and occasionally -30°C (Libby, 1981). It also tolerates greater exposure and drier soils than coast redwood. Wet soils, however, frequently result in butt rot which can be lethal and it is particularly intolerant of wet, acid, peaty soils and dislikes high summer humidity. Overhead light is essential — giant sequoia is much less shade tolerant than coast redwood.

Giant sequoia resists uprooting even in extremely high winds. Tops can be broken off, but a new leader readily forms. The scattered specimens of giant sequoia in Canterbury survived a windstorm in 1975 which severely damaged plantations of other species, including radiata pine.

Silviculture

Coast redwood

Formulating the most appropriate silvicultural schedule for coast redwood poses some problems and there is still some uncertainty regarding suitable prescriptions for spacing and tending. One of the basic problems is to establish redwoods at sufficiently wide spacings to accommodate their ultimately very large size, without promoting coarse branching. Generally, thinning is considered necessary when the initial spacing is less than about 6 x 6 m (278 stems per hectare). At these stockings lower branches are soon killed and must be pruned off if dead knots, which have been a major cause of defect in New Zealand-grown coast redwood, are to be avoided. Thinning of coast redwood usually results in vigorous coppice regrowth (Fig. 11) which is resilient and hard to control manually. There is evidence that its palatability to sheep can be exploited and that coppice shoots can be effectively restricted by grazing (G.C. Brann, pers. comm.). However, the wool of sheep allowed to graze under redwoods can be downgraded due to entanglement of dead twigs and foliage.

In North America the production of coppice shoots (sprouts) from cut stumps is encouraged to allow rapid re-establishment of the crop after clear felling. Once established on a site, redwood can be difficult to eliminate because of its coppicing habit.

Interplanting of redwoods with a second species, as a nurse species, as an intermediate yield species, or simply for amenity purposes can avoid the need to thin the redwoods and hence the problem of coppice regrowth. Larch, eucalypts, pines, cypresses, silver fir (e.g., *Abies concolor*), or other species can be planted to restrict redwood crown spread, branch size, or stem taper. Many imaginative options exist for use of different species in conjunction with redwoods, the main constraint being that mixtures have generally proved difficult to manage and have had to be addressed on a case-by-case basis.

Irrespective of the approach taken, planting to attain a final crop stocking of between 250 and 300 stems per hectare and pruning to 8-10 m to achieve a small defect core is likely to prove the best management option.



Fig. 11 – A stand of coast redwood aged 62 years, East Cape. The stand was thinned 6 months previously and the stumps are coppicing prolifically.

Giant sequoia

Little is known about the silvicultural requirements of giant sequoia. Common overseas practice is to plant it as a 1:6 mixture with one or more other conifer species at about 3 m centres. Subsequently the percentage of giant sequoia in the stand can be adjusted according to its performance and to requirements.

As with coast redwood, dead knots are a major utilisation problem in giant sequoia and early pruning is necessary to produce any appreciable volume of clear timber. A more cylindrical stem has been reported to result from pruning (Weatherspoon *et al.*, 1986).

Growth And Yield

In their natural stands, coast redwood and giant sequoia both reach extremely large sizes, owing to their longevity and ability to continue rapid growth into old age. The largest stands of timber in the world, in terms of volume, occur in the North American native redwood forests where coast redwood regularly attains heights of 60-100 m and has reached 112 m, with volumes of up to 14,000 m³/ha.

In the best plantations of coast redwood in California height growth averages 0.5–0.7 m per year and diameter growth 1.3–2.0 cm. On a good site, dominant trees have reached 46 m in height at 50 years and up to 67 m at 100 years, with diameters of open-grown trees up to 213 cm at 108 years. Height growth is most rapid before age 35 years. For managed stands the expected yield at 100 years ranges from about 700 m³/ha on low-yield sites to over 3500 m³/ha on high-yield sites (Burns *et al.*, 1990), with typical mean annual increments of 22 m³/ha. In French plantations current annual increments of 30-40 m³/ha/year are commonly achieved and stands producing in excess of

producing in excess of 50 m³/ha/year have been measured (W.J. Libby, pers. comm.), similar to those in New Zealand as shown in Table 4 below.

On sheltered fertile sites in New Zealand coast redwood can readily attain top heights exceeding 35 m and diameters exceeding 65 cm at 50 years. Yields of coast redwood (mean annual increments up to 21 m³/ha/year at stockings of 200-300 stems per hectare — see Table 4) can be equal to those of other fast growing species such as *Pinus radiata*. A strong feature of the redwoods is their ability to sustain good current annual increments at ages over 60 years.

TABLE 4 –Growth and yield of *Sequoia sempervirens* in Rotorua and Southland*

| Location | Age (yrs) | Stocking (stems/ha) | Mean top height (m) | Mean diameter breast height (cm) | Basal area (m ² /ha) | Volume (m ³ /ha) | MAI (m ³ /yr) | CAI (m ³ /yr) |
|---------------------------|-----------|---------------------|---------------------|----------------------------------|---------------------------------|-----------------------------|--------------------------|--------------------------|
| Rotorua | 47 | 203 | - | 68 | 74 | - | 17.3 | |
| (Whakarewarewa) | 57 | | 46 | 75 | 91 | 987 | 19.1 | 30.7 |
| | 68 | | 49 | 83 | 109 | 1300 | 19.1 | 22.6 |
| | 78 | | 52 | 88 | 122 | 1539 | 20.0 | 18.7 |
| | 86 | | 57 | 92 | 134 | 1804 | 21.0 | 34.2 |
| West Otago (Conical Hill) | 57 | 321 | 28 | 43 | 45 | 351 | 6.2 | |
| | 66 | | 33 | 53 | 70 | 612 | 9.3 | 24.5 |
| | 74 | | 38 | 63 | 101 | 969 | 13.1 | 52.1 |

*Source: NZ FRI stand record system

The tallest coast redwoods in the Redwood Memorial Grove at Whakarewarewa, Rotorua are now over 60 m in height and up to 196 cm in diameter. The largest coast redwood in terms of volume recorded by Burstall and Sale (1984) was a tree 53.5 m tall with a diameter of 214 cm planted about 1856 at Wakapuaka near Nelson.

Giant sequoia is the world's largest tree volumetrically although coast redwood and at least two other species (Douglas fir and *Eucalyptus regnans*) grow taller. The 'General Sherman' tree in Sequoia National Park is generally considered the world's largest living entity. In 1986 it had an estimated bole volume of 1490 m³. Mature giant sequoias commonly average 76 m high and reach 6 m diameter above the butt swell. Heights up to 94 m have been recorded. The largest giant sequoia (and the largest exotic conifer recorded by Burstall and Sale (1984)) in New Zealand is a tree at Frankton near Queenstown which when last measured was 37.7 m tall and had a breast height diameter of 427 cm. The tallest specimen recorded by Burstall and Sale was growing at Wanaka Station in competition with other trees and was 51.1 m tall with a diameter of 295 cm. Another specimen growing at Wanaka Station was 50 m tall and 370 cm in diameter when measured in 1992.

Measurements taken in 1982 of three surviving trees from the original (around 1860) plantings of giant sequoia in Canterbury were as follows:

| | <u>Height</u> | <u>Diameter</u> |
|-------------------|---------------|-----------------|
| Raincliff Station | 46.6 m | 303 cm |
| Mt Peel | 39 m | 293 cm |
| Orari Station | 30.4 m | 310 cm |

The Raincliff tree had put on 7.6 m in height and 21 cm in diameter in 12 years.

The size which may ultimately be attained by New Zealand redwoods is a matter of speculation. Theoretically, undisturbed specimen trees should have at least 3 to 4 centuries of growth ahead of them. In America lightning strike has often temporarily halted height growth of large old trees.

Little information is available on the growth and yield of swamp cypress and dawn redwood in New Zealand. Specimen trees of dawn redwood, aged 32 years, at Nelson, Manawatu, Gisborne and New Plymouth, averaged 20 m high and about 90 cm in diameter. A single swamp cypress in New Plymouth was 12 m high and 42 cm dbh at 23 years. Another at Rotorua was 20 m tall and 90 cm dbh at about 60 years when measured in 1968 and 28.9 tall and 119 dbh at about 85 years.

Wood Properties And Uses

Coast redwood produces wood that is soft and straight-grained, easy to work, odour free, non-resinous and free of oily materials. There is little shrinkage and once dry it is very stable. The sapwood is almost white and surrounds deep reddish brown heartwood which, when exposed to light, changes to mellow nut brown. In North America the heartwood is durable. The sapwood is highly susceptible to decay but can be treated to equal or exceed heartwood durability. New Zealand-grown coast redwood timber has not exhibited the degree of durability, particularly in the ground, shown in North America.

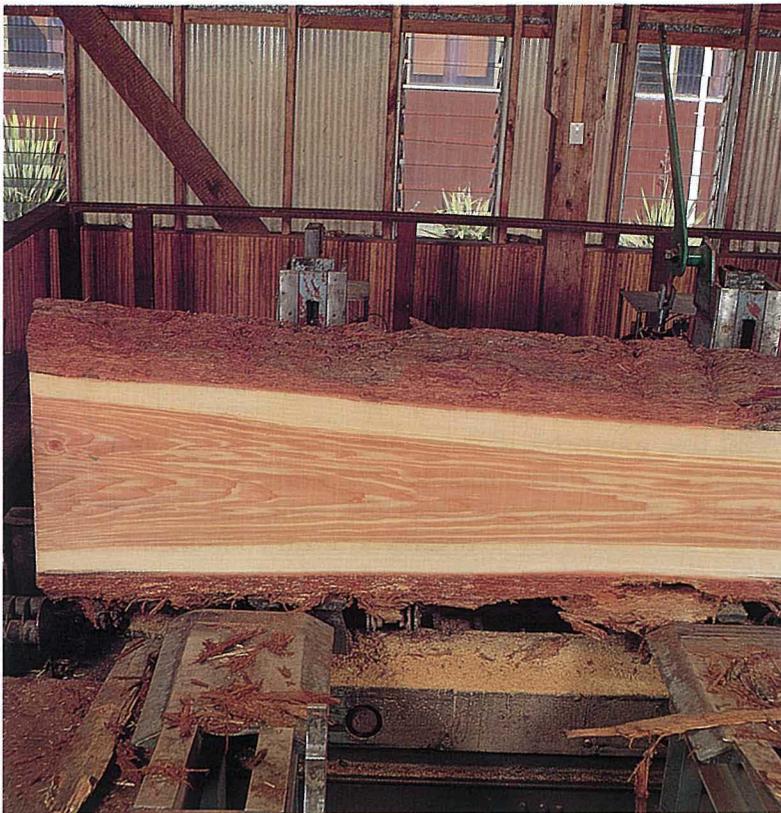


Fig. 12 – Bandsawing an 80-year-old coast redwood log, Rotorua

In North America, coast redwood timber is widely used for general building purposes and is particularly sought after for weatherboarding, outdoor decks, lawn furniture, decorative interior panelling, sashes and doors. It is also in demand for spa pools, tanks, vats, cooling towers and other purposes for which its very high natural durability and lack of odour are an advantage. Large quantities have been exported. In New Zealand, imported coast redwood timber is used for joinery and exterior finishing.

New Zealand-grown timber comes from trees that are relatively young and rapidly grown and it tends to have a large core of soft, brittle, low-density wood with wide annual rings surrounding the pith. Density and strength of the timber are generally lower than in North American material which tends to be from older, more slowly grown trees. However, New Zealand-grown coast redwood timber is of

widely varying quality. The worst is substantially inferior to second-growth trees from the United States and the best compares favourably with both virgin and second-growth material. Some of the best New Zealand-grown timber tested has come from a fast growing shelterbelt indicating that rapid growth is not necessarily the cause of poor timber quality. In the natural North American stands the quality of wood also varies greatly from tree to tree and even between adjacent trees. Strength and stiffness properties of New Zealand-grown redwood of average density are about 70% of those for *Pinus radiata* of equivalent grade (Table 5).

TABLE 5 - Comparison of wood properties of New Zealand-grown *Sequoia sempervirens* (1) and *Pinus radiata* (2)

| Species | Density (kg/m ³) | | | Shrinkage air-dry (%) | | | | Modulus of rupture | | Modulus of elasticity | | Maximum crushing | | Hardness (kN) | |
|-----------------------------|------------------------------|---------|-------|-----------------------|-----------------|--------|-------------------|--------------------|-----|-----------------------|-----|------------------|-----|---------------|-----|
| | Basic | Air-dry | Green | Vol- ume | Tangen- tial | Radial | Longitu- dinal | (MPa) | | (GPa) | | (MPa) | | (kN) | |
| | | | | | | | | Green | Dry | Green | Dry | Green | Dry | Green | Dry |
| <i>Pinus radiata</i> | 420 | 500 | 955 | 7.0 | 4.7 | 2.2 | 0.10 | 40 | 90 | 5.8 | 9.0 | 16 | 38 | 2.5 | 4.2 |
| <i>Sequoia sempervirens</i> | 335 | 380 | 910 | 4.8 | 3.2 | 1.5 | 0.02 | 56 | 63 | 6.4 | 6.6 | 24 | 36 | 1.8 | 1.9 |

(1) Mean values typifying 50-year-old trees

MPa = megapascals

kN = kilonewtons

(2) Mean values typifying 35-year-old trees

GPa = gigapascals

**Fig. 13 – Converting large coast redwood log on site using portable sawmill.****Fig. 14 – New Zealand-grown coast redwood used as exterior cladding on a Rotorua house.**

Much New Zealand-grown coast redwood is degraded by the number and character of the knots, particularly in the zone between the pruned log (if any) and the green crown. Clears from pruned butt logs can be of excellent quality.

Coast redwood is not an approved species for framing timber in New Zealand. However, where strength is less important, there are many uses for the light, moderately durable and stable heartwood. Durability tests at the Forest Research Institute have confirmed the suitability of appropriately graded New Zealand-grown heartwood for weatherboards and it has been used successfully for horizontal weatherboards and vertical cladding (Fig. 14) with a natural finish. It has also been used for the cores of fire doors.

When used externally, hot dipped galvanised stainless steel or copper nails should be used. Any material containing sapwood needs to be treated with preservative or painted. For construction purposes, larger dimensions would be required than for radiata pine timber of similar grade. Because of the lower density and consequent poorer nail holding ability, special nails (e.g., twisted or cement-coated) or additional fasteners, may be required to ensure strong assembly. The best quality timber can be used for exterior joinery, including sashes, using galvanised or non-ferrous nails. Timber which is defect-free or which contains only intergrown knots is suitable for interior joinery and finish. It yields excellent panelling, especially with a clear finish—the rich colour of the wood providing very pleasing effects (Fig. 15).

The timber can be readily air-dried without significant degrade but care is needed in kiln drying as it is prone to collapse if temperatures over 40°C are used early in drying. Once dry it is very stable. The heartwood is moderately durable and can be used untreated but can only be expected to last 5-10 years in ground contact. The sapwood has a low durability, equivalent to that of untreated radiata pine. It can be treated by using boron salts in a green diffusion process. The treatment is satisfactory where a traditional paint finish is used, but it is not suitable for stain-finished wood because the boron salts can leach out. The sapwood cannot be treated by pressure processes with water-borne preservatives.

The wood of giant sequoia and coast redwood contains a variety of chemical compounds which are extractable with water and neutral organic solvents such as alcohol, benzene and ethyl ether. Colour, susceptibility to decay, and insect resistance, as well as other wood properties are specifically related to the quantity and nature of the extractives present; these vary according to age and location within the tree.

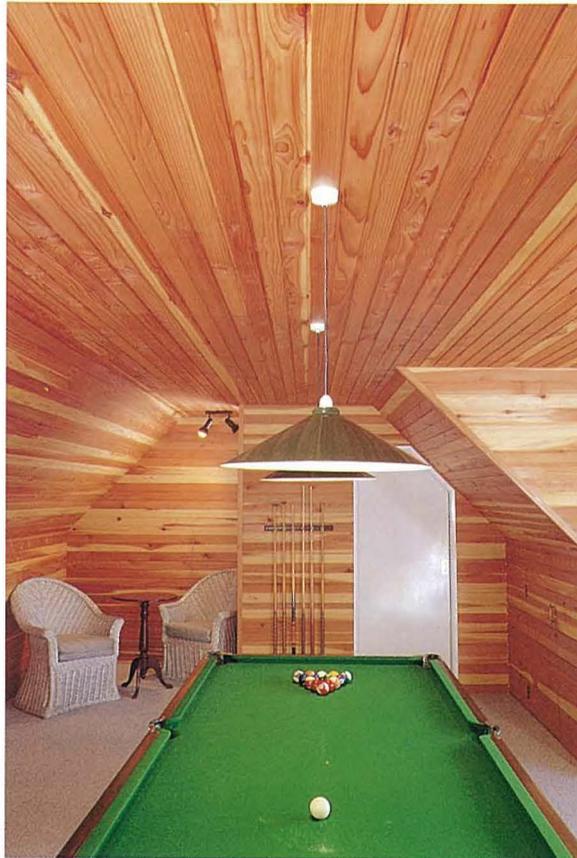


Fig. 15 – Games room lined with New Zealand-grown coast redwood.

Table tops, veneers, bowls and other turned products are produced from redwood burls in North America. Burls are irregular lumps or conrescences resulting from the abnormal growth of dormant buds and commonly occur near the base of coast redwood trees.

The wood of giant sequoia closely resembles that of coast redwood, being soft and light in weight, although relatively strong for its specific gravity. However, it is generally coarser in texture. The sapwood forms a pale yellow band beneath the bark while the heartwood is reddish brown — darker than that of coast redwood and with a purplish cast. It soon weathers to a dark chocolate brown.

In the United States, use of old-growth giant sequoia timber is limited by lack of availability as most of the groves are now in National Parks. Because of a tendency to shatter during harvesting it early on acquired a reputation for being brittle. Second-growth wood, however, is similar in many mechanical properties and generally comparable to or slightly better than that of coast redwood. It is

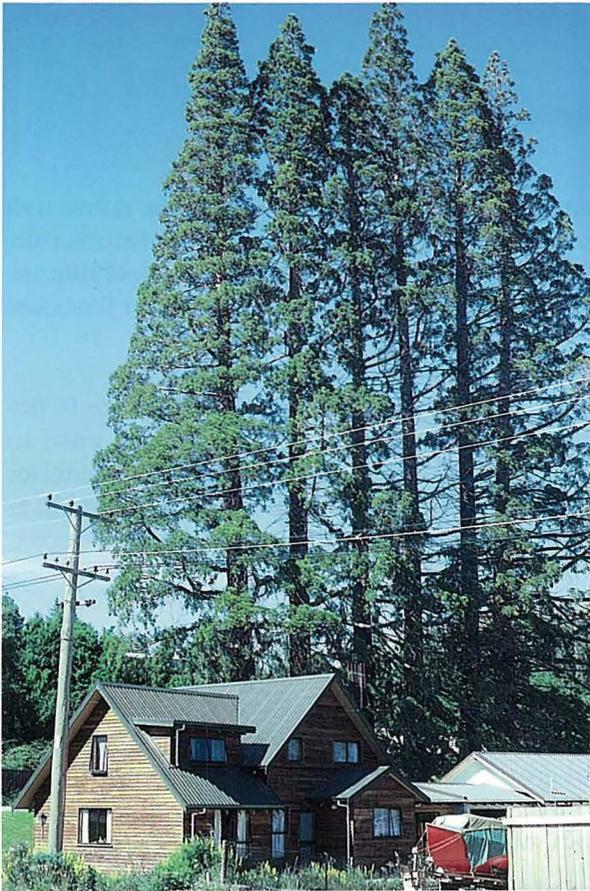


Fig. 16 – House at Wanaka clad in locally grown giant sequoia. Shelterbelt of giant sequoia in background.

among the most durable of woods and its major value is for use where decay resistance and stability are important. Its main uses are for farm buildings and other light construction work, fence posts, stakes and shingles and panelling. Little information is available on the wood properties of giant sequoia in New Zealand. Timber from untended shelterbelts has been used on a small scale for weatherboards (Fig. 16) and interior finishing. The logs were easy to saw but dead knots caused some problems.

A study of wood properties of a 15-year-old ornamental dawn redwood tree 7m high, from the Rotorua area, which had been killed by *Armillaria* root rot fungus was undertaken at the Forest Research Institute. The study showed that basic density of the wood (293 kg/m^3) was very low compared with wood densities found in the main exotic conifers grown in New Zealand.

The timber of swamp cypress grown in New Zealand has not been tested, however in North America swamp cypress is an important timber tree. The heartwood is dark-coloured, light in weight and very durable in damp conditions. It is used for construction of buildings, decks, and bridges, and also for sashes, doors, boxes, crates, water tanks, silos and fencing.

Present Extent

In November 1990, the area of coast redwood remaining in plantations previously under the administration of the New Zealand Forest Service was estimated to be 381 hectares. Of this, 246 hectares was in pure stands and the rest was planted in mixture with other species. The North Island had 361 hectares with 20 hectares in the South Island. Only 12 hectares of giant sequoia was recorded, all in the South Island. Age class distribution for coast redwood is given in Table 6.

TABLE 6 – Estimated areas (ha) of coast redwood (*Sequoia sempervirens*) as at 1990*

| Age Class (years) | North Island (pure) | North Island (mixed) | South Island (pure) | South Island (mixed) |
|----------------------|------------------------|-------------------------|------------------------|-------------------------|
| 0-10 | 37 | 63 | 8 | |
| 11-20 | 139 | 4 | 3 | 1 |
| 21-30 | 2 | 28 | | |
| 31-40 | 3 | 2 | | |
| 41-50 | 29 | 15 | | |
| 51-60 | 5 | 15 | 3 | 5 |
| over 60 | 17 | 2 | | |
| TOTAL | 232 | 129 | 14 | 6 |

* Source: NZ FRI stand record system; areas will be underestimated because of incomplete records of plantings in the private sector.

Future Role

Coast Redwood

Coast redwood, one of the most valuable timber and amenity species in the United States, grows well and healthily in some areas of New Zealand. Although it seems assured of a modest future role, particularly for farm woodlots, more investigation is required into siting, establishment techniques, silvicultural requirements and the most appropriate genetic material before the potential for coast redwood in this country can be predicted.

As a woodlot tree, its imposing appearance, relatively fast growth, and high resistance to fire and disease are strong advantages, as are good above-ground durability and general ease in woodworking. Its relatively light and brittle timber is best suited to specialist uses such as exterior cladding, joinery, and panelling, for which it is in demand. However, the minimum rotation length is around 50 to 80 years and cultural requirements are exacting. To reach its full potential, coast redwood requires:

- A sheltered, fertile, well-drained site with adequate ground moisture and a reasonable rainfall spread throughout the year.
- Thorough site preparation and virtually complete exclusion of weed competition for at least the first two years after planting to avoid poor initial growth and checking.
- Careful pruning and maintenance of green branches above the pruned stem to avoid dead knots in the wood.

If these requirements can be met, and it is viewed as an investment for future generations, the planting of coast redwood could provide an attractive and potentially rewarding proposition. Coast redwood may have promise for erosion control. Its widely spreading root system remains alive and can coppice quickly after felling. It has some ability to survive smothering by landscape sediment and flood debris, particularly where the sediment is coarse grained (Marden, 1993). Deep fine-grained sedimentation can lead to anaerobic conditions which the tree is unable to tolerate.

The extent of past failure probably gives an unnecessarily pessimistic impression of the potential of coast redwood in New Zealand. Use of good-quality planting stock and careful attendance to its establishment, siting and silvicultural requirements should allow considerably more success in growing coast redwood in the future.

Giant Sequoia

Less is known of the requirements and performance of giant sequoia in New Zealand. Site factors appear less restricting than for coast redwood and it has a higher tolerance of cold and windy and exposed sites and dry soils. It has been common practise to plant giant sequoia in the South Island as individuals, in groups for amenity, or as a shelterbelt species and it has proved exceedingly windfirm. Now mostly aged 50-80 years these trees are almost always healthy and show no sign of slowing diameter growth, although height growth seems to be slow to exceed 50 metres. Most have developed large lower branches and massively flaring butts, reflecting their open situation.

Swamp Cypress and Dawn Redwood

Swamp cypress and dawn redwood, although unlikely to be utilised commercially to any extent in New Zealand, are valuable landscape subjects. Swamp cypress grows well in damp and swampy ground where few other trees would thrive. Dawn redwood makes an excellent specimen tree and is fast growing on sheltered, moist, fertile sites. Both species provide seasonal interest and variety, becoming particularly attractive in spring with their fresh light green feathery foliage and later with their autumn leaf colourings. (Figures 17 and 18).

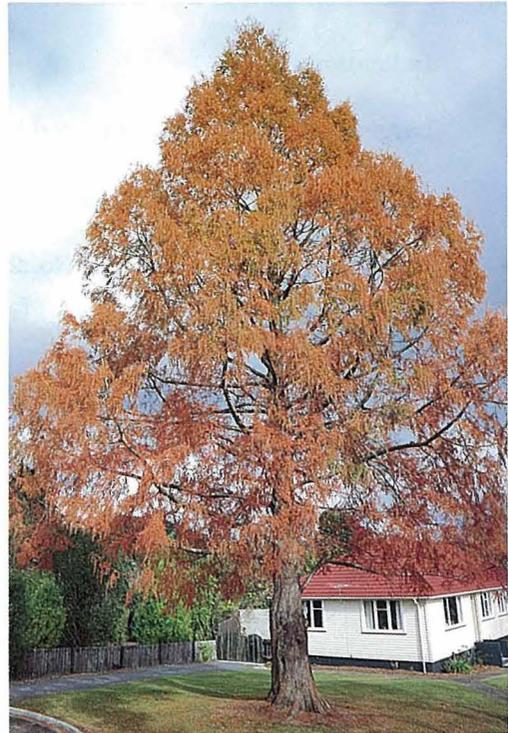


Fig. 18 – *Metasequoia glyptostroboides* (dawn redwood) showing autumn colour, Rotorua.

Fig. 17 – *Taxodium distichum* (swamp cypress) in autumn, Christchurch Botanic Gardens.

Vegetative Propagation

Cuttings from young trees of both coast redwood and giant sequoia root easily, but rooting becomes more difficult with increasing age. Cuttings from mature trees are difficult to root and frequently grow in branch form (plagiotropic form) for some years.

Breeding studies in California (Libby and McCutchan, 1978) showed that cuttings of outstanding mature trees could be rooted at a rate of about 10% and in a warm dry environment induced to produce male and female strobili very early. Controlled pollinations could then be made. The resultant seedlings were hedged to induce sprouting, producing an average of 20 new cuttings every 6-8 weeks. By the time they were a year old many seedlings had produced over 100 cuttings. Such repeated hedging appeared to keep the donor seedlings in a juvenile condition.

Tissue culture rejuvenation of outstanding mature redwood clones has the potential to provide a valuable source of future genetic material. Near-complete rejuvenation of material from 40-80 year old trees selected for growth and form has been achieved in France and in California (Rydellius and Libby, 1993). Rejuvenated plants can be hedged to produce cuttings. Recently rooted redwood cuttings rarely suffer from the fungal diseases to which seedlings are so prone.

Vegetative propagation of giant sequoia from cuttings taken from one-year-old seedlings was successfully carried out at FRI nursery, Rangiora, between 1975 and 1977 to increase seedling stock for the establishment of a species and provenance trial in the South Island.

Indications were:

- Larger cuttings (7-10 cm) rooted better than smaller cuttings (3-5 cm).
- Cuttings rooted better under polythene than on a mist bench.
- Hormone treatment (Seradix No. 2 (0.3% IBA)) as a powder dip did not alter rooting success.
- Cuttings rooted better in October than later.

There were no significant differences in rooting between provenances.

Metasequoia roots easily from both softwood and hardwood cuttings, although rooting becomes more difficult as the tree becomes older. *Taxodium* can be rooted from cuttings taken in late summer or autumn.

Seed and Regeneration

In both coast redwood and giant sequoia seed production is strongly site-dependent. On good sites mature trees produce vast quantities of seed, but in both species the germination rate is variable and frequently very low (see Seed Users' Guide).

Young trees, particularly of giant sequoia, often produce only infertile seed, generally because male cones are not produced until later in the life of the tree. Seed of both species is small and light, generally limiting seed dispersal to a radius of about 100 m although it may be carried further in air currents—up to 140 m has been recorded for giant sequoia. In New Zealand, coast redwood frequently regenerates from seed in the vicinity of planted trees and sometimes invades disturbed indigenous forest, e.g., second-growth kauri forest in Coromandel Forest Park. Giant sequoia occasionally regenerates in the immediate vicinity of planted trees.

Healthy coast redwood has a remarkable ability, seen in few other conifers, to produce sprouts from buds which begin to develop at the junction of the root and the shoot soon after germination (Fig. 19). These buds proliferate to form a basal burl containing many hundreds, and eventually many thousands of live buds, which can sprout within a few weeks and at any time of the year, if stimulated to do so by felling (Fig. 11) or other damage to the tree such as by fire, wind or logging. The sprouts quickly develop their own root system and can reach two metres or more in their first year. Sprouts can also arise from adventitious buds on lateral roots and along almost the entire trunk length after damage.

Seedlings, saplings and trees in thrifty condition produce sprouts almost without exception when damaged or otherwise stimulated. Failure to produce sprouts may result from damage to the basal burl or, in very old trees, from excessively thick bark and/or overgrowing of buds by woody tissue (Rydelius and Libby, 1993).

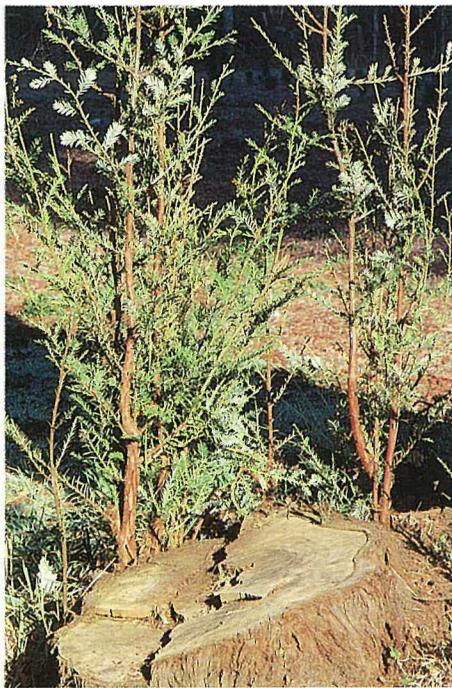


Fig. 19 – Recently cut stump of *Sequoia sempervirens* showing coppice sprouts.

Giant sequoia only occasionally produces sprouts from roots or stumps but tall broken stubs and crowns will sprout vigorously if there is enough live foliage below the breakage. Cut stumps of swamp cypress will produce healthy sprouts, particularly during the dormant season and when the tree is young.

Seed of *Sequoia sempervirens*, *Sequoiadendron giganteum* and *Taxodium*, currently from North American sources, is obtainable through Proseed New Zealand Ltd, Private Bag 3020, Rotorua. Seed can also be collected from a number of localities in New Zealand. Plantation sources or group plantings are to be preferred to single trees to avoid risk of inbreeding. Dominant trees of good form should be selected for seed collection.

If their exacting site and management requirements can be met coast redwood and giant sequoia can grow into very imposing trees and eventually provide decorative, stable, easily worked timbers. They particularly merit consideration where soil stabilisation, shelter and aesthetic values are important, and where planting can be viewed as a long-term investment.

SEED USERS' GUIDE

A. Collection And Extraction Of Seed

| | <i>Sequoia sempervirens</i> | <i>Sequoiadendron giganteum</i> |
|------------------------------|--|---|
| Age of first coning: | Occasionally as early as 6-8 years. Usually 16-18 years, sometimes much later. | Female cones appear much earlier than male cones. Male cones may not appear until the tree reaches 30-40 years. |
| Seed available in quantity: | Approx. 20 years. | Approx. 50 years. Large cone crops associated with reproductive maturity do not usually occur before about 150 years in California. |
| Pollen production: | Winter to early spring. | |
| Cone maturation period: | Cones ripen within one year. | Cones take two years to ripen. |
| Periodicity of crop: | Some seed most years. Good crops every 3-5 years. | |
| Harvesting: | Cones collected by handstripping branches or with secateurs. (In North America squirrel caches are a regular source of seed for forest nurseries.) | |
| Recognition of mature cones: | Collect cones in autumn as soon as they turn yellowish and/or scales begin to separate. Mature cones remain on tree for several months after seed-shed. | Mature cones usually red-brown to dark brown. Cones containing ripe seed can remain unopened on tree for many years. |
| Seed extraction: | Air- or fan-dry cones for 10-30 days, stirring as necessary, or kiln dry at 120-130°F for half a day. Separate seed by screening, blowing, or shaking cones in a paper bag. Avoid exposing seed to sunlight. | |
| No. of seeds per kg: | 130,000-500,000 (av. about 268,000) | 150,000-300,000 (av. about 200,000) |
| Storage conditions | Dry store in dark at 4°C | |
| Stratification: | Not necessary. Germination may however be hastened by stratification for 4-6 weeks at 3-4°C after soaking in water for 24 hours. | |
| Storage duration: | 3-5 years | 2 years only |
| Expected germination: | 10-30% (or occasionally up to 50%). Large number of empty or non-viable seeds. | 6-10% (occasionally up to 40%) |

B. Nursery Practice

Coast redwood and giant sequoia should be planted out as well-conditioned, bare-rooted 1-or 2-year-old seedlings (or cuttings) with abundant fibrous roots. The suggested schedule is based on that used for seedling-grown coast redwood at the Forest Research Institute nursery in Rotorua.

Dust moist seed with "Thirodust", a fungus and bird repellent.

Sow in spring to a depth of not more than 3 mm in a sheltered seedbed and cover with 50% shade cloth. Because of its low germination rate the seed cannot be precision sown. It should be dribbled at approximately 25 viable seed per metre of drill, or broadcast sown at approximately 700 viable seeds per square metre. Drill sown seedlings should be thinned to an average density of 15 seedlings/metre of drill or lined out at about 15 cm spacing.

Keep under shade cloth until late April, then remove to allow climatic conditioning. Coast redwood typically has two cotyledons at germination, giant sequoia three or more.

Seedlings of coast redwood need plenty of moisture. Seedlings of giant sequoia are, however, very prone to *Botrytis* attack and humid conditions should be avoided for seedlings of this species.

| | |
|-------------------------------|--|
| Fertiliser: | Incorporate a slow release nitrogenous fertiliser at 250kg/ha into the seedbed before sowing. Three inter-row dressings of a complete granular fertiliser (15:10:7:2 Mg at 500 kg/ha) can be applied at two month intervals after sowing (mid-September, mid-November and mid-January). |
| Weedicides: | Keep weed free. After sowing apply oxyfluorfen ("Goal") at 0.48 kg ai/ha. Repeat applications as necessary after seedlings are 5 weeks old. Some hand weeding is also usually necessary during the post-emergence period. In line-out beds simazine or propazine may be used. |
| Conditioning: | Undercut at a depth of 10 cm prior to lining out. Undercut lined out seedlings at 12-14 cm depth during February or March prior to the winter of planting, then wrench at 4 week intervals. Lateral prune as required, generally at 6 week intervals. |
| Insect pests: (Tortricids) | Inspect weekly during growing season. If necessary, spray with permethrin ('Ambush') or deltamethrin ('Décis') at label rates. |
| Lifting: | Care must be taken during lifting to avoid damaging the prolific fibrous root mass resulting from repeated wrenching and lateral pruning. Dip roots in water immediately before packing plants in polythene bags, in readiness for planting out. |

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