NEW ZEALAND
FOREST RESEARCH INSTITUTE
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FRI BULLETIN NO. 124

INTRODUCED FOREST TREES IN NEW ZEALAND

Recognition, Role, and Seed Source

16. *Cryptomeria*, *Thuja* and *Tsuga*

F.B. Knowles and J.T. Miller

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COVER PHOTOGRAPHS: *Thuja plicata*, Golden Downs, Nelson (left), *Cryptomeria japonica*, Rotorua (centre), *Tsuga heterophylla*, Hanmer, Canterbury (right).

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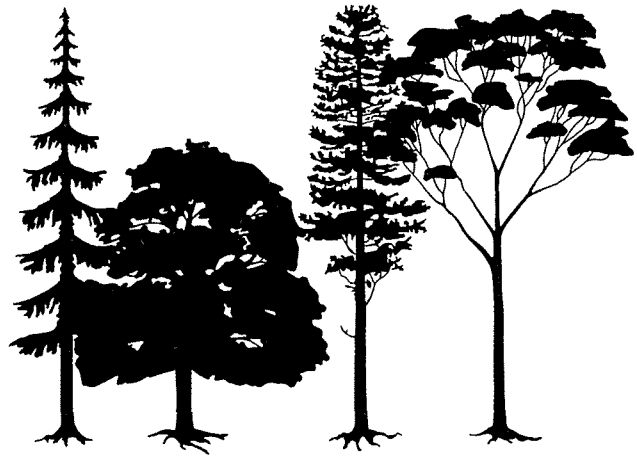

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***Cryptomeria japonica* aged 83 years, Whakarewarewa Forest, Rotorua.**

CONTENTS

ABSTRACT

This booklet, the sixteenth in the Bulletin 124 series, provides a general account of *Cryptomeria japonica, Thuja plicata* and *Tsuga heterophylla* in New Zealand. It covers their introduction and history, variation, recognition, performance and role as introduced forest species and the location of seed sources.

KEYWORDS: *Cryptomeria japonica*, *Thuja plicata*, *Tsuga heterophylla*, introduced species, New Zealand, provenance trials, recognition, role, seed.

INTRODUCTION AND HISTORY

Cryptomeria japonica (Japanese cedar), *Thuja plicata* (western redcedar) and *Tsuga heterophylla* (western hemlock) are medium sized to tall evergreen coniferous trees. *Cryptomeria* and *Thuja* have been grown and tested extensively in New Zealand while *Tsuga* has been tried to a lesser extent. Although commercially important in their countries of origin, these three species have so far remained of minor significance as timber species in New Zealand forestry.

Cryptomeria japonica is the only generally recognised species in the genus *Cryptomeria*, a member of the family Taxodiaceae. In Japan, where it occurs naturally and has been widely planted for many centuries, *Cryptomeria* is a major timber yielder and is of very strong cultural significance. It is widely venerated, being planted in temple gardens and avenues and some old trees are designated national monuments. The genus *Thuja*, belonging to the family Cupressaceae, contains six species, four from Asia and two, including *Thuja plicata*, from North America. *Tsuga*, a member of the family Pinaceae, consists of approximately ten species in North America and Asia. *Tsuga heterophylla*, the tallest growing of these species, is from western North America. *Thuja plicata* and *Tsuga heterophylla* are, with Douglas-fir and Sitka spruce, major timber species of the Pacific Northwest of North America.

Natural Distribution

Cryptomeria japonica

Cryptomeria japonica has been cultivated and utilised for many centuries and the boundaries of its natural distribution have been obscured. Tsumura and Ohba (1993) give the natural range in Japan as from Aomori Prefecture, Northern Honshu (40°42'N) to Yakushima Island (35°20'N). It occurs naturally in scattered patches throughout this area (Fig. 1) both in pure stands and mixed with other conifers and hardwoods. It also occurs in southern and central China as *C. japonica* var. *sinensis*. In the natural forests of Japan it reaches an elevation of 1830 m a.s.l. in the south of its range and 760 m in the north but grows best at altitudes between 300 m and 1070 m. Annual rainfall in its natural range varies between 1000 mm and more than 2500 mm and mean annual temperatures are between 6°C and 18°C.

Thuja plicata

Thuja plicata has a wide natural distribution in the coastal ranges of western North America from south-east Alaska to north-west California and in a separate inland region in the Rocky Mountains extending from south-east British Columbia to northern Idaho and western Montana (Fig. 2). It occurs from sea level in the far north to 2130 m in the northern Rocky Mountains but grows best on mild, humid, high rainfall sites along the coast ranges in Washington and Oregon. On exposed, high elevation sites in the Rocky Mountains it is reduced to a shrub. Rich moist soils suit it best and it survives on waterlogged soils where few other trees will grow. Although found on a wide variety of sites, and capable of surviving on soils low in nutrients where it can become dominant, it has relatively high water requirements and grows slowly on dry soils. Sometimes pure stands occur on streamsides and alluvial flats but usually it grows in mixture with other species. Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*) and grand fir (*Abies grandis*) are

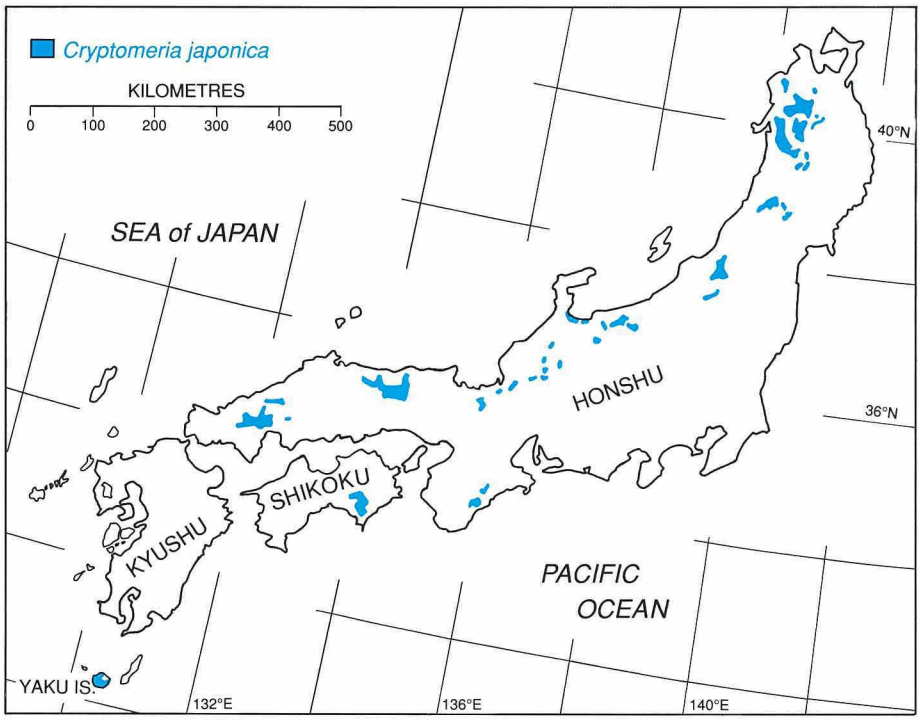

Fig. 1 - Approximate natural distribution of *Cryptomeria japonica* in Japan (based on Ahuja and Libby, 1993).

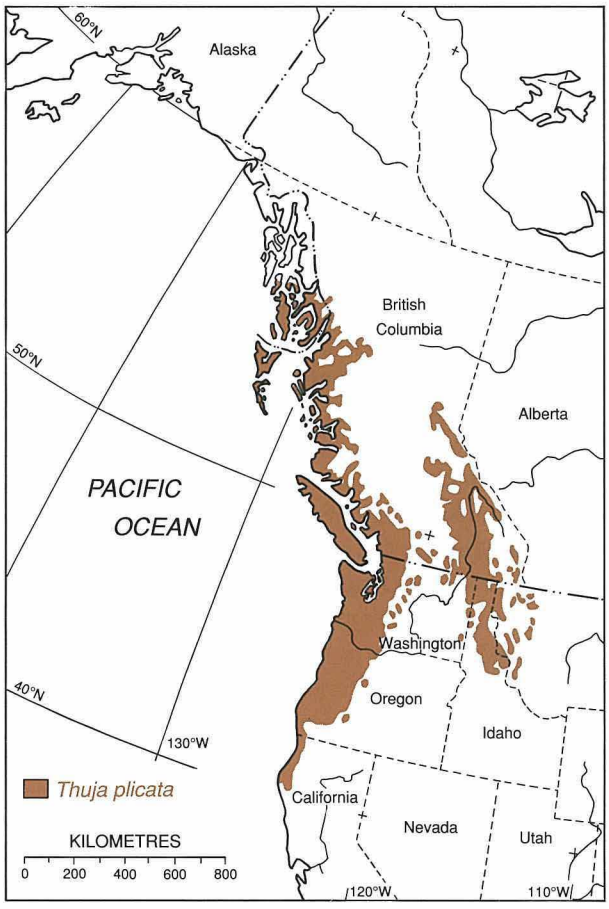

Fig. 2 - Approximate natural distribution of *Thuja plicata* (based on Little, 1971).

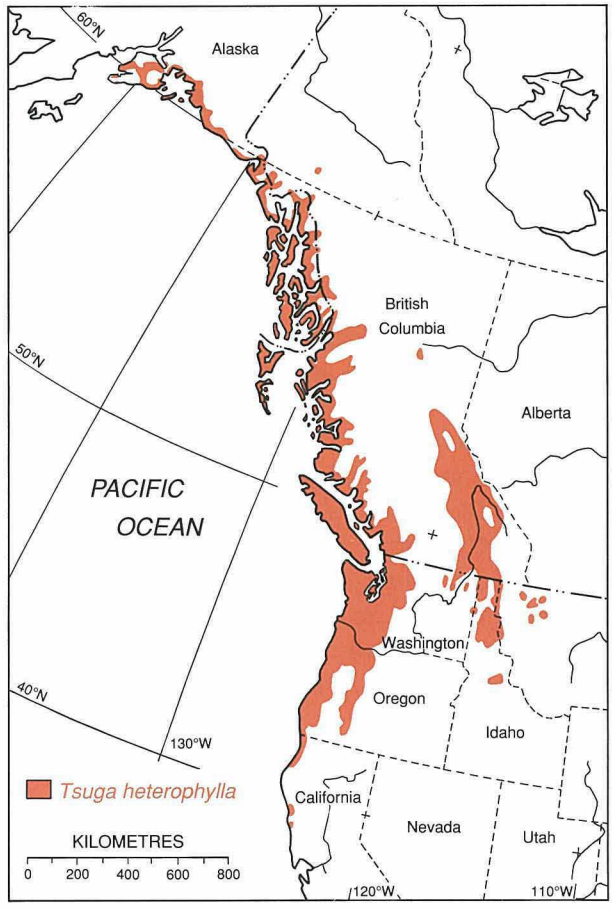

Fig. 3 - Approximate natural distribution of *Tsuga heterophylla* (based on Little, 1971).

among its main associates. It is often the dominant species in association with *Tsuga heterophylla* in areas where the shrub *Gaultheria shallon* is an abundant component of the vegetation.

Tsuga heterophylla

Tsuga heterophylla also has a wide natural distribution in western North America. It extends down the Pacific coast in a narrow strip from Prince William Sound in Alaska to northwest California and occurs inland in a separate area in the Rocky Mountains from south-east British Columbia to northern Idaho (Fig. 3). In British Columbia and Alaska, along the coast mountains and on the coastal islands it is the dominant species. It occurs from sea level to 600 m along the coast and reaches 1800 m in the Rocky Mountains. The best stands however, occur between sea level and 700 m in the humid coastal belt between Alaska and Oregon. *Tsuga heterophylla* grows well on a variety of soils, particularly moist soils with a high organic content, but does not tolerate highly calcareous soils and does not do well in heavy clay. Annual precipitation over its range varies between 500 mm and 3800 mm, decreasing towards the interior. Near the coast, *T. heterophylla* sometimes forms pure stands but more commonly occurs in mixture with other species, notably Sitka spruce (*Picea sitchensis*), Pacific silver fir (*Abies amabilis*), western redcedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*). *Tsuga heterophylla* can regenerate as a pioneer species, for example after extensive windthrow.

History in New Zealand

Cryptomeria japonica

Cryptomeria japonica was recorded growing at Lyttelton and at Hutt Valley near Wellington in the 1860s (Weston, 1957) and was planted in Yatton Park, Tauranga about 1866 (Burstall and Sale, 1984). Other early plantings were in Westland in the 1870s, at Taita near Wellington, at Greendale in Canterbury, and in Nelson and Auckland. Since its introduction it has been widely planted in shelterbelts and gardens throughout New Zealand and to a small extent in forests, mainly in the North Island and in the northern part of the South Island. The State Forest Service first tried it in Whakarewarewa Forest in 1913 but it was not planted again until 1926 (Weston, 1957). By 1955 there were more than 300 ha in pure stands, about 295 ha in the North Island, 12 ha in the South Island and 140 ha in mixtures with other species. Most of these plantings were established between 1937 and 1953 when it was frequently used for enrichment of logged indigenous forest. In 1971 the total area in *Cryptomeria** was estimated to be 190 ha, 90% of which was in the North Island. Sources of early seed are unknown but in 1930 the Forest Service obtained small experimental seedlots from Akita in northern Japan and Yoshino in southern Japan.

Thuja plicata

Thuja plicata was planted in Lyttelton in 1866 by Potts and in 1868 at Hutt Valley near Wellington and probably at Wanganui. About the same time it was planted at Mt Peel in Canterbury and in 1877 was recorded at Oamaru. It was tried in State Forests at Rotorua in the late 1890s and at Waiotapu Forest near Rotorua in 1906. By 1911 it had also been planted on a small scale at Whakarewarewa Forest near Rotorua, at Hanmer Forest in Canterbury and Conical Hill and Tapanui Forests in Otago (Weston, 1957). Since then *Thuja* has been planted in most parts of New Zealand, for shelter, in plantations and as an ornamental species. By 1957 there were 1400 ha in pure stands in State Forests, 1150 ha in the North Island and 250 ha in the South Island with an additional 275 ha in mixture. The planting rate in 1957 was estimated to be 20-40 ha annually. Sources of the earliest introductions are unknown. Seed imported by the Forest Service between 1927 and 1939 came mainly from British Columbia with some from Washington and one seedlot from Oregon.

Tsuga heterophylla

Tsuga heterophylla was planted at Greendale in Canterbury about 1890 by T.W. Adams. From 1931 it was planted in Kaingaroa and Golden Downs State Forests. By 1940 small areas had also been planted at Hanmer in Canterbury, Mahinapua in Westland, Erua in Tongariro National Park, and at Mikimiki in the eastern Tararua Range near Wellington (Weston, 1957).

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* The generic names, *Cryptomeria*, *Thuja* and *Tsuga*, when used alone in this bulletin, refer to the species *Cryptomeria japonica*, *Thuja plicata* and *Tsuga heterophylla*.

However, much of that which was planted failed and *Tsuga* has been little planted since. By 1957 there were about 14 ha in pure stands, 8 ha in the North Island, 6 ha in the South Island and 39 ha in mixture. Sources of the first introductions are unknown. Seed imported by the Forest Service between 1927 and 1930 came from coastal British Columbia and seed imported between 1931 and 1933 came from central and south-west Washington (mostly Cowlitz County).

Provenance Variation and Genetic Improvement

Cryptomeria japonica

While the form of *Cryptomeria* in New Zealand is generally good, growth has been slower than that of many other species.

In 1964 clonal material of *Cryptomeria* was imported into New Zealand from Japan, priority in selection being given to trees likely to produce optimum growth rates in New Zealand. The material consisted of 33 clones from the island of Kyushu and one clone from Honshu east of Tokyo. Kyushu is the most southerly and has the mildest climate of the main islands in Japan.

When it arrived in New Zealand, some material was found to be infected with scale insect and some had die-back at the branch tips. Diseased material was destroyed and the rest set as cuttings (of which none survived), or propagated as grafts (which suffered heavy mortality). In all, 20 grafted clones survived and cuttings from these were planted out at the Forest Research Institute experimental area at Long Mile, Rotorua. To compare these Japanese clones with New Zealand material, selection was made in 1970 of 15 plus trees, six in Pureora Forest and nine in plantations belonging to the Te Awamutu Borough Council. These were also set as cuttings in the Long Mile experimental area.

The Japanese clones performed poorly and were abandoned in 1978. By contrast the New Zealand clones were uniform in growth and form and in 1994, at 21 years, had a mean diameter of 35.6 cm and a mean height of 17.8 m. No further breeding material of *Cryptomeria* has been imported.

Thuja plicata

Three seedlots of *Thuja plicata* were imported between 1954 and 1956, from British Columbia, Oregon and California. These seedlots, together with a New Zealand seedlot of unknown ancestry from Conical Hill Forest in west Otago, were established at four North Island and five South Island sites between 1959 and 1962. Survivals were reasonably high, but most of the trials suffered severely from weed competition and growth was generally slow. Assessment at 33 years of one of the trials (at Whakarewarewa, Rotorua), see Table 1, showed that trees of a Californian seedlot (Fig. 4), from the southern part of the natural range of *Thuja plicata*, grew significantly better than the others which, as a group, performed very similarly.

Tsuga heterophylla

To investigate the most suitable seed origins of *Tsuga heterophylla* for planting in New Zealand, eight seedlots were imported from natural stands in North America between 1955 and 1958. Two seedlots were from Washington, three from Oregon and three from California. Provenance trials were established between 1957 and

TABLE 1 – Growth* of *Thuja plicata* aged 33 years in a provenance trial at Whakarewarewa

FRI code	Origin	Stocking (stems/ha)	Mean diam. (cm)	Mean top ht (m)	Basal area (m^2/ha)	Volume (m^3/ha)
456	Horseshoe Bay, British Columbia	701	29.8	19.3	48.9	352
599	Conical Hill Forest, New Zealand	446	30.1	19.0	31.8	226
764	Mt. Hood National Forest, Oregon	595	28.0	19.3	36.6	260
765	Mad River, California	655	45.4	21.9	106.0	813

* Based on small plots, irregularly thinned

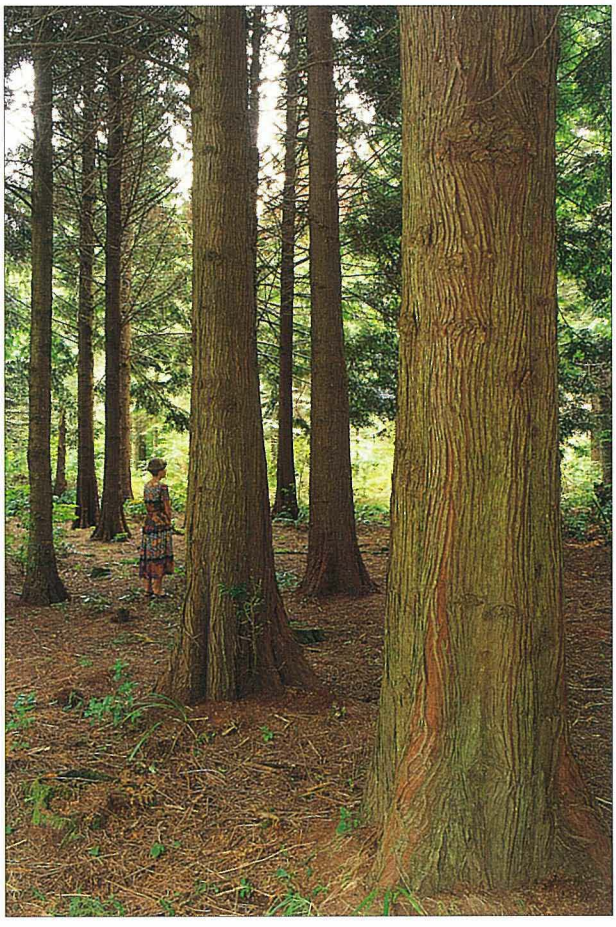


Fig. 4 - Above: *Thuja plicata* aged 33 years, Rotorua. Trees on the right from the Californian seedlot (Mad River) have grown significantly better than those of other origins.

Fig. 5 - Above and below: a stand of *Tsuga heterophylla* aged 33 years, growing in a provenance trial in Whakarewarewa Forest, Rotorua.

TABLE 2 – Growth* of *Tsuga heterophylla* aged 32 years in a provenance trial at Whakarewarewa

FRI code	Origin	Stocking (stems/ha)	Mean diam. (cm)	Mean top ht (m)	Basal area (m^2/ha)	Volume (m^3/ha)
455	Cascadia, Oregon	323	30.2	19.7	23.1	165
629	S. of Olympia, Washington	538	31.9	20.0	43.1	312
748	N.E. of Darrington, Washington	806	21.5	17.7	29.1	181
749	Lola Pass Rd, Mt Hood, Oregon	800	20.5	15.2	26.5	145
750	E. of Blue Lake, California	484	34.1	20.1	44.3	325
751	Junction of Highways 101 and 299, California	376	35.8	21.5	37.9	280
752	E. of Mendocino, California	591	30.2	20.7	42.2	301

* Based on small plots, irregularly thinned

1962 at fourteen sites, ten in the North Island and four in the South Island. Some of the North Island trials grew slowly. They suffered from weed competition and were severely attacked by the leafroller caterpillar *Planotortrix*. Unseasonable frosts also caused damage. However, the trial at Whakarewarewa (Fig. 5), was well maintained and grew well, suggesting that the indifferent performance at other sites could have been largely the result of neglect. The Whakarewarewa trial was assessed in 1994 at 32 years (Table 2). Provenance differences were slight, but trees of southern origin tended to be more vigorous.

In the four small trials established in the South Island, performance was fairly uniform with no large provenance differences apparent. At Hanmer, where the *Tsuga* grew well when underplanted in thinned *Larix decidua*, the most vigorous trees (Lot 751) originated from the southern part of the species range in California.

Pests and Diseases

Cryptomeria japonica

Although a number of pathogens have been recorded on *Cryptomeria* in New Zealand most have caused minor damage not seriously affecting growth, and the species is generally healthy in this country. The foliage is prone to attack by the greenheaded leafroller caterpillar, *Planotortrix excessana*, especially when planted under cutover native forest or other introduced plantation species. The native looper caterpillar, *Pseudocoremia fenerata*, can cause damage to the leaves. The spider mite, *Oligonychus hondoensis*, specific to *Cryptomeria japonica* and with the potential to be a serious pest, has been recorded from two Auckland sites. In horticultural shelterbelts the two-spotted mite, *Tetranychus urticae* has caused severe bronzing and defoliation. The two-toothed longhorn beetle, *Ambeodontus tristis*, sometimes bores into logs or timber and may cause serious damage.

The root rot fungi *Armillaria* spp. and the root and butt fungal pathogen, *Junghuhnia vincta*, also known as *Poria vincta*, have been recorded sporadically on *Cryptomeria*. Cypress canker caused by the fungus *Seiridium unicorne* has been recorded once.

Since *Cryptomeria* is very palatable to possums, they must be controlled to allow successful growth. Deer and goats often cause damage by nipping off the leaders of young trees resulting in multiple leader growth. If leaders are damaged in older trees, height growth is often inhibited although diameter growth may continue.

Thuja plicata

As with *Cryptomeria*, *Thuja* has largely been free of major insect and fungal damage in New Zealand, although a number of minor pathogens have been recorded attacking it. Caterpillars of *Planotortrix excessana* can damage the foliage and the two-toothed longhorn beetle, *Ambeodontus tristis*, damages the wood, gaining access to the heartwood through dead branches and logging scars. Damage to dead wood and the heartwood of living trees can also be caused by larvae of the huhu beetle, *Prionoplus reticularis*, while dry sapwood may occasionally be attacked by the common house borer, *Anobium punctatum*. Butt-rot is common in older trees. In Britain, the inner core of quite young trees can be hollow at the stump, however the rot does not necessarily progress quickly. Cypress canker, caused by the fungi *Seiridium cardinale* and *S. unicorne*, is recorded infrequently on *Thuja plicata* but is not severely damaging. As with *Cryptomeria*, the root rot fungi *Armillaria* spp. and the root and butt pathogen *Junghuhnia vincta* have been sporadically recorded. In Britain the fungus *Keithia* (*Didymascella*) *thujina* has killed large numbers of young trees in the nursery which has severely restricted the production of planting stock and has prompted the use of cuttings of some maturity. *Thuja plicata* is susceptible to damage by rabbits, hares and possums. Possums can cause serious damage especially if numbers are high.

Tsuga heterophylla

Because of its minor forestry role little information is available on insect and fungal pathogens of *Tsuga heterophylla* in New Zealand. As with *Cryptomeria* and *Thuja*, the root rot fungi, *Armillaria* spp., have been recorded and tortricid insects have caused severe damage, particularly when *Tsuga* has been established as an underplant. In North America butt rots and root rots are common, especially in old-growth stands. *Heterobasidion annosum* is the most serious root pathogen and can be a severe problem in thinned stands, colonising stumps and wounds and spreading by root grafts. On inland sites, infection by Indian paint fungus, *Echinodontium tinctorium*, often occurs comparatively early in the life of the tree and causes extensive decay of overmature stands in the Rocky Mountains. Neither of these fungi has been recorded in New Zealand.

Although *Tsuga* has not been as susceptible as many other species to possum browsing, hares sometimes cause significant damage to young trees.

RECOGNITION

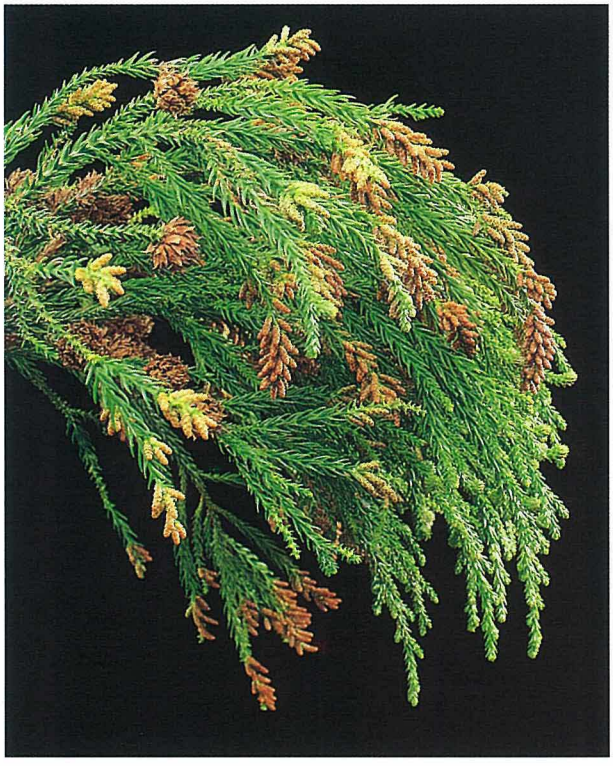
Cryptomeria, belonging to the family Taxodiaceae, *Thuja*, to the family Cupressaceae and *Tsuga* to the family Pinaceae, are all quite different botanically. The principal characteristics of *Cryptomeria japonica*, *Thuja plicata and Tsuga heterophylla* are summarised in Table 3.

Cryptomeria

Cryptomeria has narrow, awl-shaped leaves, spirally arranged round the shoot. The stalkless, pointed leaves are directed forward and curved inwards. The cones are globular and rough with inward curving hooks. *Cryptomeria japonica* var. *sinensis* Siebold et Zucc., from China, occasionally treated as a separate species (*C. fortunei*), differs from typical *C. japonica* in being more open in form with more slender branchlets, longer and thinner leaves, seed scales with shorter, softer teeth and usually two seeds per scale (typical *C. japonica* has three to five). *Cryptomeria japonica* 'Elegans', commonly grown for ornamental purposes and shelter, is a cultivar in which juvenile foliage is permanently retained. The foliage is in dense bunches and is grey-blue, turning reddish purple in the autumn. The tree itself is broad and rounded in shape at first but later tends to develop several main stems or huge secondary branches causing gaps in the outline and sometimes it bends over in a hoop.

Thuja

The genus *Thuja* resembles *Chamaecyparis* with small, scale-like, overlapping leaves and flattened branchlet systems forming frond-like sprays of foliage. It differs mainly in having (usually) larger leaves and in the quite different cone which is erect and conical with thin tapering scales which are outward pointing when mature.



Cryptomeria japonica

Thuja plicata

Tsuga heterophylla

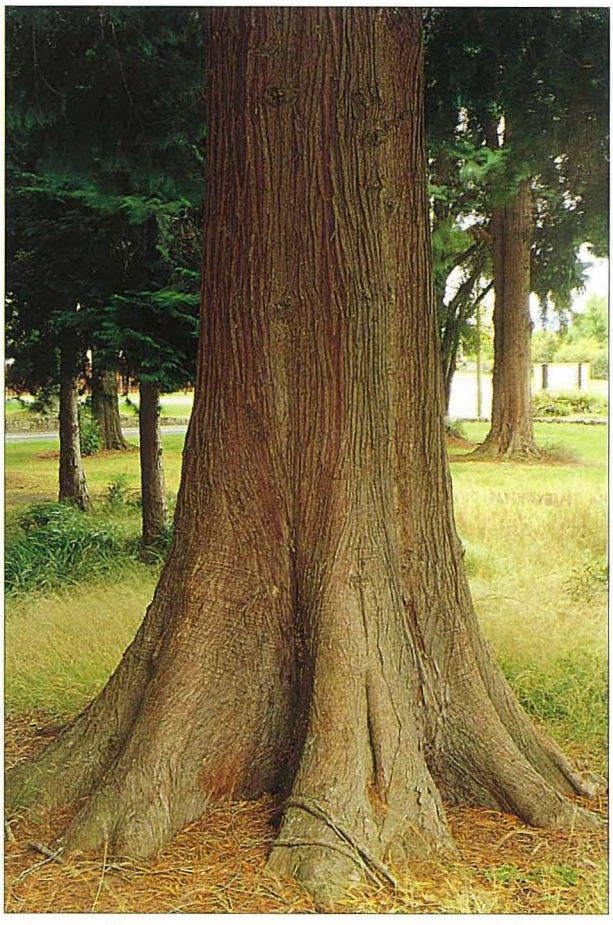
Fig. 6 - Branchlets showing typical foliage and mature cones.

In addition to *Thuja plicata*, two other species of *Thuja* are sometimes planted in New Zealand as ornamentals. *Thuja occidentalis* L., northern white-cedar, which is native to Canada and north eastern United States, is often used as a hedge plant. It differs from *T. plicata* in not having white or silvery markings on the underside of the foliage and in having more prominent glands on the back of the leaves. It has smaller cones (about 8 mm long while those of *T. plicata* are 10-15 mm long) with 4 fertile scales (usually 6 in *T. plicata*). *Thuja occidentalis* has given rise to a number of cultivars, and slow growing and dwarf fastigiate and pyramidal forms (Fig. 11) are commonly cultivated as ornamentals.

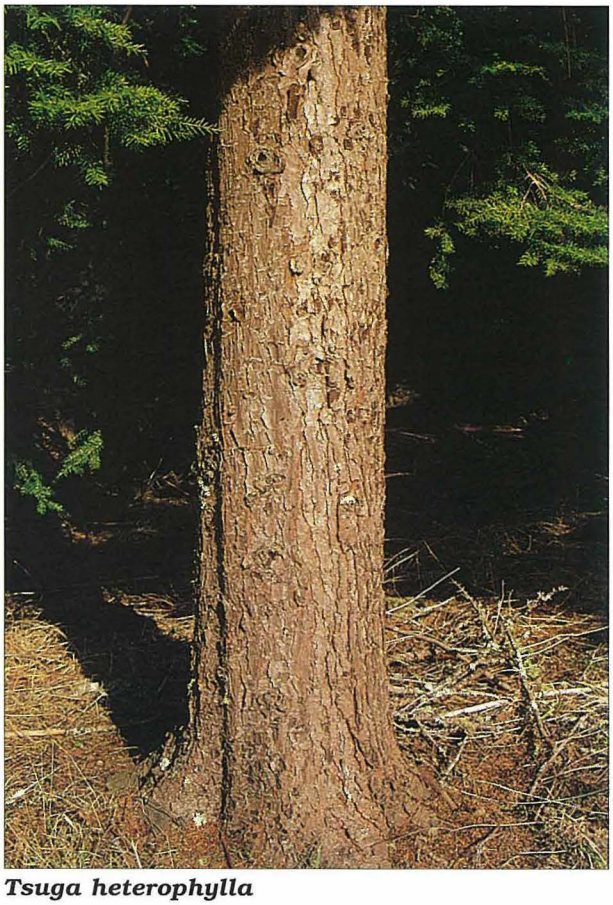
Thuja orientalis L. from North China, Japan, Manchuria and Korea is also planted in New Zealand as an ornamental. Placed by some taxonomists in the genus *Platycladus*, it has a very distinctive habit with the foliage held in vertical planes radiating from the centre of the plant. In its natural form it becomes a gaunt, sparsely foliaged tree with a few upswept branches, but the forms commonly seen in New Zealand are slower growing, more compact cultivars (Fig. 12). When crushed the foliage is not strongly scented and the leaves are very small and without whitish markings on the underside. The cones are about 15-20 mm long, ovoid, fleshy and covered with a whitish bloom when immature and have strongly hooked cone scales. The seeds have no wings.

Thujopsis dolabrata (L.f.) Siebold et Zucc., Hiba, from Japan, is very closely related to *Thuja*. It has broader branches and larger flattened leaves glossy dark green above and with very conspicuous white or silvery markings on the underside (Fig. 13). The cones resemble those of *Thuja* but are more globose and have 3-5 seeds per fertile scale. In Japan *Thujopsis dolabrata* is an important forest tree providing general purpose timber that is light, soft, fragrant, durable and easily worked. It often forms pure stands and occurs from sea-level to 600 m in the north of its range and to about 1800 m in the south. Its larger northern form is a tree up to 30 m tall but the more southern form frequently found in cultivation is often smaller and more shrub-like. In New Zealand, where it usually forms a heavy, open-foliaged large shrub

Cryptomeria japonica



Thuja plicata



Tsuga heterophylla

Fig. 7 - Typical bark of mature trees. The bark of *Cryptomeria* and *Thuja plicata* is fibrous, coming away in long vertical strips while that of *Tsuga heterophylla* is fissured into rough scaly ridges. Note the widely flared trunk base typical of *Thuja plicata*.

Fig. 8 - *Cryptomeria japonica*, Rotorua: (left) young tree, showing conical habit, and (right) mature tree (diameter 64 cm, height 24 m).

or small tree, *Thujopsis* has been planted as an ornamental, often in its variegated form, and as a windbreak and is sometimes seen in old gardens.

Tsuga

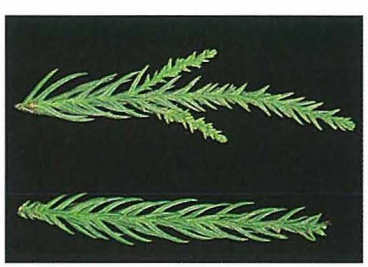
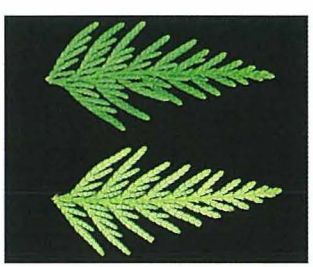
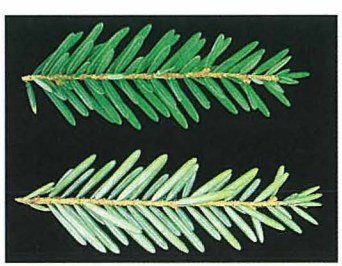
Trees of the genus *Tsuga*, the hemlocks, tend to have a graceful appearance with slender, usually drooping shoots and delicate foliage. *Tsuga* is related to *Picea* (the spruces) and, like *Picea*, sheds its leaves on drying. The leaves of *Tsuga* tend to be in two sets of different lengths on the same branches. Except for *Tsuga mertensiana* which has spruce-like cones, the cones of *Tsuga* are very small.

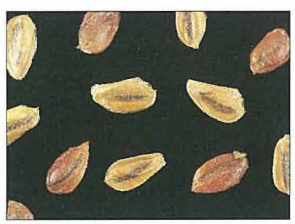
Tsuga heterophylla is the most common *Tsuga* species in New Zealand but several others are occasionally planted as ornamentals in parks and gardens. *Tsuga mertensiana* (Bong.) Carrière, mountain hemlock, from north western North America, has a distinctive narrow-columnar crown, pendulous grey-blue foliage, and thick leaves pointing forwards all round the shoot. The cones of *Tsuga mertensiana* are cylindrical, and larger, (2-8 cm x 1-3 cm) than those of the other *Tsuga* species. *Tsuga canadensis* (L.) Carrière, eastern hemlock, from eastern North America, is distinguished from *Tsuga heterophylla* by its broad crown, dark, heavily ridged bark and leaves more obviously narrowed towards the tip. From all other *Tsuga* species it is distinguished by the line of leaves reversed over the shoot with their white undersides uppermost. *Tsuga caroliniana* Engelm., Carolina hemlock, is found in the Appalachian Mountains of North America from south-west Virginia to northern Georgia. It has long slender branches with slender, distant leaves and a sparsely foliaged appearance. The cone has downy scales which spread widely when the cone is mature. In New Zealand the other species of *Tsuga* generally grow more slowly than *T. heterophylla*.

Fig. 9 - *Thuja plicata*: (left) at Rotorua, and (right) in Christchurch Botanical Gardens.

Fig. 10 - *Tsuga heterophylla*: (left) at Rotorua, and (right) in Christchurch Botanical Gardens.

TABLE 3 – Recognition of *Cryptomeria japonica*, *Thuja plicata* and *Tsuga heterophylla*

	***Cryptomeria japonica* (L.f.) D.Don Japanese cedar**	***Thuja plicata* D.Don western redcedar**	***Tsuga heterophylla* (Raf.) Sarg. western hemlock**
Habit (Figs. 8-10)	A tall tree to over 45 m high with breast height diameters to at least 145 cm in New Zealand and to over 60 m in height with diameters to over 200 cm in its native habitat. Crown conic when young, usually becoming more rounded with age. Branches horizontal or drooping. In the open, very large lower branches may develop. Trunk tapered but becoming more parallel-sided with age, often with well defined buttresses.	Tall tree to 40 m high with diameters to over 100 cm in New Zealand, and to over 60 m tall with diameters to at least 220 cm in its natural habitat. Pyramidal crown becoming rounded with age, leading shoot more or less erect, branches horizontal to erect, branchlets mainly drooping, frond-like, lower branches sometimes very heavy and sometimes curving upwards. They may form layered shoots. Trunk widely flared at the base, often bottle-shaped.	Tall tree to over 35 m high with diameters to over 100 cm in New Zealand, and to over 70 m high in its natural habitat with diameters to more than 200 cm. Crown distinctive, narrow-conic with an arched and drooping leading shoot, older trees become broader and more columnar, branches slender, arching and drooping at tips, foliage on underside partly drooping.
Bark (Fig. 7)	Reddish brown weathering to grey-brown, fibrous, at first detaching in small squarish plates, becoming thick and deeply fissured into long, often spiralled ridges, peeling away in long strips.	Reddish, or greyish brown, thick and fibrous, divided by irregular narrow fissures into broad ridges, coming away in narrow strips or plates and appearing ragged with fibrous loose ends.	Reddish or purplish brown, weathering to grey-brown, in young trees smoothish, later becoming thicker and fissured into rough, scaly ridges. Older trees have reddish inner bark, streaked with purple.
Foliage	Leaves awl-shaped, spirally arranged round the shoot, pointing forwards and curving inwards towards the shoot, mostly 8-15 mm long, first leaves of the year shorter than later ones, juvenile foliage usually longer (up to 20 mm) and more spreading than adult foliage. Leaves deep shiny green to grey-green, rather stiff, bluntly pointed with a spreading base clasping the shoot.	Leaves scale-like in opposite and alternating pairs, appressed to and hiding the branchlet, ovate, 2-4 mm long, longer on leading shoots, glossy dark green above, usually faintly streaked white to form a butterfly-like pattern below, more or less sharply pointed, often with a distinct gland. On side shoots, leaves may be smaller, blunter and without glands. Foliage emits a fruity, pineapple-like scent especially when pressed or crushed.	Leaves linear, spirally arranged in two sets of differing lengths, above the shoot short (c. 5 mm) and nearly upright, below the shoot longer (15-18 mm) and spreading sideways or in a comb-like arrangement, pale green above when fresh, soon turning blackish green when picked, two broad whitish bands below, flat, grooved above, margins finely toothed, leaf stalk twisted.
			
Branchlets (Fig. 6)	Long, cord-like, in open bunches, erect, horizontal or drooping, green when young, becoming red-brown after 2-3 years, without hairs.	In flat frond-like sprays, pale bluish green or yellowish green at first, becoming reddish or purplish brown in the second year. Branchlets rather than individual leaves, are shed.	Slender, reddish or yellowish brown at first, later dark greyish brown, finely ridged and grooved, for first two years covered in short brown hairs mixed with longer whitish hairs.

Female cones	Solitary at the end of short branchlets, c. 20 mm long, globular, usually 15-25 mm across, green at first, becoming brown when ripe, composed of 20-30 scales each with a curved hook on the outer side and 5-6 pointed rigid processes on the upper margin. The cones have a remarkable ability to 'sprout' on the tree producing a terminal shoot up to 4 cm long.	On the end of short shoots, erect, cylindrical or flask-shaped, 10-15 mm long, green when young, becoming brown when ripe at the end of the first summer, with 8-12 semi-woody leathery scales (4-6 scales fertile), each scale with a thin, triangular reflexed point.	Numerous, on the ends of branchlets, drooping, oblong when closed, more roundish when open, 12-22 mm (occasionally to 30 mm) long, 15-25 mm wide when open, light green or grey-green at first, occasionally tinged violet, ripening to brown. Scales 15-25 per cone, thin with roundish margins, bract scales dark purple, triangular, hidden.
			
Male cones	Appear in early spring in the leaf axils at the ends of the shoots, crowded in short spike-like clusters, each with numerous pollen sacs.	Appearing in spring on branchlets near the base of the shoot, reddish to yellowish, cylindrical to globular.	Clustered among leaves at the end of the shoots, crimson before shedding pollen, becoming yellow.
Seeds	3-5 per cone scale, 5-8 mm long, red-brown to dark brown, irregularly oblong or triangular, each edge with a narrow rudimentary wing.	2-3 per fertile cone scale, c. 6 mm long, light chestnut brown, almost surrounded by 2 slightly unequal, lighter coloured wings.	Ovoid-oblong, 2-3.5 mm long, light brown, with occasional oil vesicles, nearly surrounded by an ovate, transparent, light yellowish brown wing 4-10 mm long.
			
Comments	Resembles *Sequoiadendron giganteum* but in *Cryptomeria* leaves are longer (8-15 mm) whereas in *Sequoiadendron* they are mainly 3-7 mm. *Cryptomeria* leaves are more pointed and bend out from the shoot (in *Sequoiadendron* they are closely pressed to the shoot). The foliage of *Cryptomeria* also resembles that of *Araucaria cunninghamii* but in *A. cunninghamii* the leaves end in bristle-like points, whereas those of *Cryptomeria* are bluntly pointed. Young trees of *Taiwania* have similar but relatively broader, flatter, longer pointed leaves.	*Thuja plicata* superficially resembles *Chamaecyparis lawsoniana* but is easily distinguished by its broader, strongly fruit-scented foliage, very different (upright) cones, a more or less erect leading shoot (the tip of *C. lawsoniana* droops) and paler, less well defined markings on the underside of the leaves. These whitish markings on the underside of the leaves distinguish *T. plicata* from *T. orientalis* and *T. occidentalis*, the other species of *Thuja* likely to be encountered in New Zealand.	Distinguished from other conifers by the combination of slender shoots, leaves short and nearly upright above the shoot, longer and spreading below, leaves falling when dry leaving a cushion-like base, and very small cones. *Tsuga heterophylla* differs from other *Tsuga* species in having an unforked trunk, spire-like leader and a drooping leading shoot.

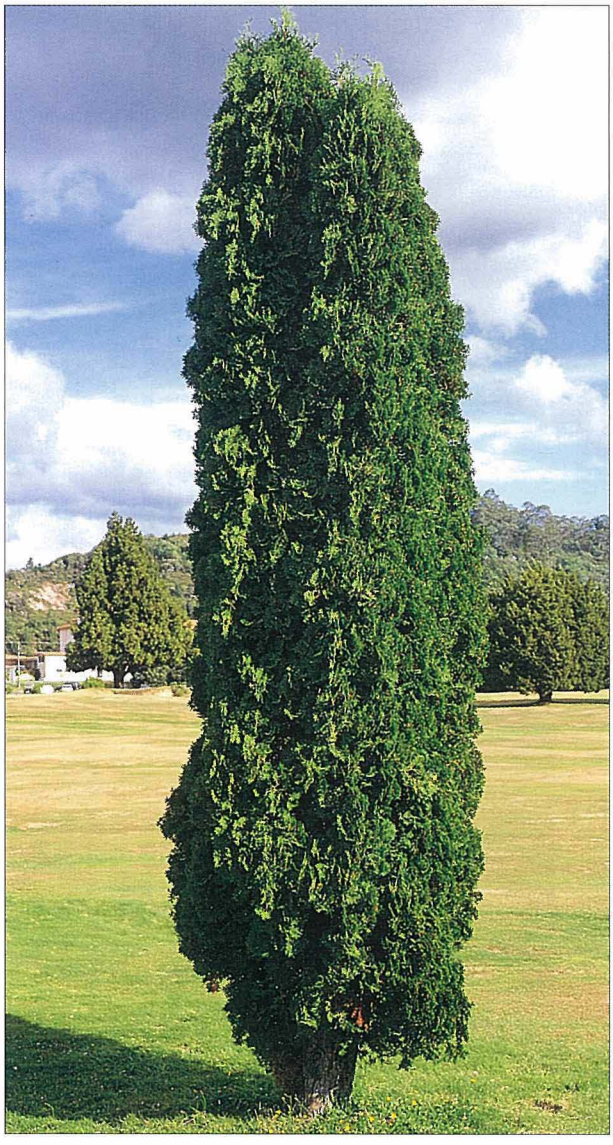


Fig. 11 - A commonly cultivated form of *Thuja occidentalis*. (Top) habit, (below) foliage and cones.

Fig. 12 - Habit, foliage and cones of a commonly cultivated form of *Thuja orientalis*.

Fig. 13 - Foliage of *Thujopsis dolabrata*. Note the conspicuous white markings on the underside.

ROLE OF THE SPECIES

Siting and Establishment

Cryptomeria japonica

Cryptomeria grows best on moist, fertile, relatively sheltered sites in warm lowland areas. It tolerates a wide range of soils, including heavy clays provided these are well drained. It does not thrive on waterlogged soils, very dry soils, or on exposed sites subject to strong desiccating winds. Moisture is a strong limiting factor in the siting of *Cryptomeria* and a rainfall of at least 1000 mm per annum is required for good growth. The best growth has been recorded where the rainfall is between 1000 and 2500 mm annually. *Cryptomeria* is reasonably tolerant of cold but can be damaged by late frosts.

When underplanted in indigenous forest in the central North Island *Cryptomeria* has succeeded at altitudes up to 760 m but generally has grown best below 600 m. Although light shade is well tolerated, young trees can be strongly suppressed by dense shade, and, while remaining healthy, grow slowly or not at all. However, when released from suppression the trees recover well. The shade tolerance of *Cryptomeria* has led to widespread planting as an enrichment species in logged native forest where it has been one of the few species to compete successfully with native hardwood second growth.

Cryptomeria is comparatively windfirm, at least when young. Although it will not withstand extremely exposed coastal conditions it can tolerate some salt wind.

Cryptomeria is reasonably easy to establish, both as seedlings and as rooted cuttings.

Thuja plicata

Thuja shares with *Cryptomeria* a preference for moist but free draining, sheltered, fertile sites and is generally unsuitable for constantly waterlogged, dry or exposed positions. Like *Cryptomeria* it prefers areas with a moderately high rainfall. However, unlike *Cryptomeria* it grows best in cooler climates and tends to grow poorly from Auckland north. Some of its best growth has been in the central North Island and in parts of Canterbury, Westland and Otago/Southland.

Thuja withstands considerable cold and mature trees have tolerated -10°C of frost. It has survived in trials at 1100 m in the upper Rangitata catchment in Canterbury. However, to survive and perform satisfactorily at high elevations it requires good shelter from drying winds.

As with *Cryptomeria* the shade tolerance of *Thuja* favoured its use as an underplanted species in logged indigenous forest but again, while it persists and remains healthy, little or no growth occurs beneath a canopy.

Thuja has a wide-spreading, shallow but strong root system and is generally windfirm. Although reasonably easy to establish, young trees may fail when not given shelter, particularly on dry sites, and have often been established with a nurse cover.

While the trees are young, the site should be kept reasonably free from weed competition to maintain good early growth. On the other hand there have been examples (e.g., at Berwick Forest in the 1950s) where *Thuja* demonstrated a remarkable ability to emerge through dense bracken, eventually to form well stocked stands.

Tsuga heterophylla

Provided shelter is good, *Tsuga* is reasonably tolerant of site; however, like *Cryptomeria* and *Thuja*, it grows best on moist, well drained soils, particularly soils with a high organic content. Sheltered gully situations in cool, high rainfall areas are probably ideal. *Tsuga* appears best suited to altitudes between 300 m and 900 m in the North Island and up to about 600 m in the South Island. It is a very hardy species and will withstand heavy frosts.

Tsuga has been used mainly as an interplanting species and although it will survive under heavy shade, like *Cryptomeria* and *Thuja* it grows best where the crowns have full light. As with *Thuja*, young trees require shelter and reasonable freedom from weed competition during establishment.

Silviculture

Cryptomeria japonica

Most *Cryptomeria* in New Zealand has been planted at high initial stocking levels (c. 1.5 x 1.5 m) and has been pruned either too late or not at all. *Cryptomeria* usually has small branches that self prune to some extent, so that in some New Zealand trees, clean shaft-like boles typical of older trees in Japan have developed. Despite this, bark encased knots can still cause problems and limit potential utilisation. Spacing and tending schedules to alleviate or avoid this problem are required. *Cryptomeria* wood is not inherently strong, and is more suitable for appearance than for structural uses and needs to be clear of knots (i.e. clearwood) or to contain only small inter-grown knots that do not check during drying.

Based on the limited silvicultural information available, the tending schedule below is suggested for *Cryptomeria* in New Zealand.

- **Initial stocking** - 1670 trees/ha (2 x 3 m)
- **Thin** - at 15 yrs thin to 800 stems/ha
  - at 20-30 yrs thin (once or twice) for firewood or roundwood down to 400 stems/ha
- **Prune** - to 6 m in 3 lifts (2 m, 4 m, 6 m) to achieve a diameter over stubs (DOS) of 16 cm or less
- **Clear fell** - at 40-60 years

Any such regime needs to be flexible and subject to modification according to site and individual grower's objectives.

Because of its shade tolerance, *Cryptomeria* was planted in the past in cutover indigenous forest and in mixtures with other introduced species such as *Acacia melanoxylon* and *Eucalyptus saligna.* However, where *Cryptomeria* is outstripped in growth and becomes shaded, although it usually remains healthy, height and diameter growth are significantly reduced. Mixed plantations have proved more difficult to manage than pure plantations.

Cryptomeria has been used extensively as a shelterbelt species by horticulturalists (especially kiwifruit growers) particularly in the Bay of Plenty and Northland. Such shelterbelts are almost invariably trimmed to restrict width. *Cryptomeria* is also commonly used on grazing or arable farms as a supplementary species in radiata pine shelterbelts to block low draughts. Some fan pruning of the *Cryptomeria* may be required on the windward side to retain the crown depth and restrict width.

Thuja plicata

Thuja presents some silvicultural challenges. Its stems tend to taper rapidly and become fluted at the base (Figures 7 & 14), downgrading the timber in value. As well, *Thuja* is inclined to produce epicormic branches after pruning and is susceptible to attack by stem borers if damaged during thinning. Minimisation of these problems requires relatively high initial stocking rates and particular care during thinning. Pruning is essential if the timber is to be used for special purposes such as joinery. However, the stands need to be reasonably dense before the first pruning to avoid problems with the formation of epicormic branches which cannot be eliminated.

The following tending schedule, based on available data, is suggested, subject to modification according to site and individual requirements.

- **Initial stocking** - 1670 trees/ha (2 x 3 m)
- **Thin** - at c. 6 m high & c.12 cm diam thin to 600 stems/ha
- **Prune** *(to achieve a diameter-over-stubs (DOS) of 16 cm or less)* - at c. 12-16 yrs - to 2.3 m (height c. 7 m)
  - at height c. 9 m - to 4 m
  - at height c. 12 m - to 6.5 m
- **Clear fell** - at c. 45-70 years

Tsuga heterophylla

Little is known about the tending requirements for *Tsuga* in New Zealand and plantings have often suffered from silvicultural neglect. Much of the *Tsuga* was interplanted in indigenous forest or underplanted in plantations in which its growth and form were usually poor. As with

Cryptomeria and *Thuja*, light is essential for optimum growth, although it remains healthy under shade. When planted in the open, much better growth has resulted. In Europe *Tsuga heterophylla* can be one of the fastest growing conifers in full sun.

In dense, even-aged stands natural pruning tends to take place early and tree crowns are short and narrow with trunks of good form.

If grown as an understorey species or at wide initial spacing without appropriate tending, persistent branches and poor form substantially reduce timber quality.

In provenance trials at Whakarewarewa in Rotorua, growth rates and volumes have been similar for *Thuja* and *Tsuga*. However, in the trials at Whakarewarewa and Hanmer Forests the trees are responding vigorously to thinning carried out after 20 years at mean heights of about 11-13 m. A tending schedule for *Tsuga* similar to that for *Cryptomeria* is suggested, subject to the same modifications for site and individual requirements.

Growth and Yield

Cryptomeria japonica

In Japan, *Cryptomeria*, when planted on the best sites on old forest land, is one of the largest volume producers of plantation grown species anywhere in the world, with a mean annual increment up to 32 m^3 per hectare on a 50 year rotation. Heights in its natural habitat range from 42 m to 55 m and occasionally over 60 m with diameters from 90 cm to 220 cm.

The largest recorded specimen of *Cryptomeria* in New Zealand in terms of volume, planted in Tauranga about 1866, is over 37 m tall and over 145 cm in diameter (Burstall and Sale, 1984) and a tree in Rotorua, thought to be the tallest in the country, was 45.6 m in height in 1995. In New Zealand the best growth has been in the central and northern parts of the North Island with growth rates similar to, or slightly better than those recorded in Japan.

Fast early growth tends to be a characteristic of *Cryptomeria* with a mean average height growth of approximately 1 m per annum in a young stand at Ruatoria, north of Gisborne. At 19 years these trees had a mean top height of 17.8 m and the stand, at 940 stems per hectare, had a mean annual increment of 39.4 m^3/ha.

Other recorded mean annual height growths ranged from 0.3 m per annum in Westland to 0.75 m per annum in Northland. A 41 year old stand, growing at 840 stems/ha, at Pureora in the central North Island had a basal area of 102 m^2/ha and a volume of 840 m^3/ha. The mean top height of these trees was 24.5 m.

Table 4, derived from sample plots, gives an indication of the performance of *Cryptomeria* in New Zealand to date.

TABLE 4 – Growth and yield of *Cryptomeria japonica* in New Zealand

Forest	Age (yrs)	Stocking (stems/ha)	Mean top ht (m)	Mean diam. (cm)	Basal area (m^2/ha)	Standing volume (m^3/ha)	MAI* (m^3/ha)
Omahuta	44	400	25	35	38	337	**11.5
(Northland)	44	988	24	31	76	653	14.8
Pureora	41	519	23	45	82	690	16.8
(Central North Is)	41	840	25	39	102	840	20.4
Ruatoria	13	970	13	30	69	380	29.2
(Gisborne)	19	940	18	38	112	750	39.4
Mahinapua (Westland)	60	1410	19	26	78	560	9.3

* MAI = mean annual increment
** Includes production thinning

Thuja plicata

In North America, *Thuja plicata* grows relatively slowly and does not reach maximum size until about 350 years. At 80 years, mean heights of 30 m and diameters of 50 cm have been recorded. Exceptional trees can reach 60 m with occasional diameters of 3-5 m but heavy buttressing and hollow stems resulting from heart rots are common.

In New Zealand plantation-grown trees have reached heights of over 35 m and diameters of over 60 cm at 65 years. However, the yield from the small areas planted in *Thuja* has been extremely variable and growth has been relatively slow. Twenty seven sample plots monitored in stands aged 35-84 years in the central North Island, Westland, Otago and Southland showed that height growth was relatively uniform at each site over a wide range of ages. Best height growth for age was in the central North Island (Rotorua, Pureora and Whirinaki) with a mean height increment of 52 cm per year compared to Otago/Southland with 42 cm per year and Westland with 31 cm per year. Volume growth showed a similar trend with mean annual increments of 17.6 m^3/ha/yr in the central North Island, 10.5 m^3/ha/yr in Southland and 11.8 m^3/ha/yr in Westland, however at all sites volumes varied considerably (see Table 5).

The most impressive performances were in a twice-thinned stand at Rotorua which at 66 years had a mean height of 36 m, a mean diameter of 54 cm and a total volume of 1520 m^3/ha and in an unthinned 71 year old stand at Conical Hill in West Otago (Fig. 14, right) growing at 1310 stems/ha, which had a mean height of 35 m and a total volume of 1600 m^3/ha. This stand was felled in 1992 at 81 years. Recovered volume was 1023 m^3/ha of which 65% were logs of export quality.

Mean annual volume increment for Rotorua and Pureora at 17.6 m^3/ha/yr is about equal to Douglas-fir but well behind that for radiata pine and is only achieved at relatively high stockings.

Tsuga heterophylla

In North America, *Tsuga heterophylla* often grows slowly initially but once established in full overhead light, grows rapidly and can attain a large size. An annual height growth of 60 cm is not uncommon. Twenty-year-old stands

TABLE 5 – Growth and yield of selected plots of *Thuja plicata* in New Zealand*

Forest	Age (yrs)	Stocking (stems/ha)	Mean top ht (m)	Mean diam. (cm)	Basal area (m^2/ha)	Standing volume (m^3/ha)	MAI** (m^3/ha)
Pureora, Central N.I	41	469	22.5	54.1	108	786	19.1
	41	1753	23.7	31.2	134	1145	27.9
Whakarewarewa, Rotorua	66	559	35.6	54.2	129	1522	23.0
	84	177	37.1	77.0	82	986	11.7
Whirinaki, Central N.I.	39	2820	15.1	22.0	107	576	14.7
	43	780	16.4	33.3	68	393	9.1
Hokonui, Southland	48	405	19.7	37.0	44	301	6.3
	48	573	19.5	20.8	20	156	3.3
	48	1581	19.0	21.4	57	385	8.2
Berwick, Otago	35	2538	14.6	18.9	71	423	12.4
Conical Hill, West Otago	71	1310	35.1	34.8	124	1604	22.5
Mahinapua, Westland	47	2376	13.5	12.6	29	147	3.1
	58	1162	23.8	39.0	138	1197	20.6

* Source: FRI permanent sample plot system

**MAI = mean annual increment

Fig. 14 - *Thuja plicata*: (left) aged 84 years, Whakarewarewa Forest, Rotorua, mean top height 37 m, mean diameter 77 cm; (right) unthinned stand aged 78 years, Conical Hill Forest, West Otago. When the Conical Hill stand was felled in 1992 at age 81 years the recoverable volume of wood was 1023 m^3/ha.

containing 4940 stems/ha can yield volumes from 28 m^3/ha on poor sites to 182 m^3/ha on the best sites. In New Zealand the small amount of *Tsuga* has provided very little information on which to assess its performance. However, in provenance trials in the South Island, *Tsuga* attained heights of 12-14 m within 20 years by which time its annual growth was about 1 m. In a provenance trial in Rotorua (see Table 2), at 32 years mean top heights ranged from 15.2-21.5 m and mean diameters at breast height (dbh) from 20.5-35.8 cm. By contrast a 32 year old stand at Hanmer Forest in Canterbury, containing 914 stems/ha, had a mean top height of 14.6 m, a basal area of 12 m^2/ha and a mean dbh of only 14.6 cm.

In North America heights of 50-60 m and diameters over 100 cm are not uncommon in *Tsuga heterophylla*, with a maximum recorded height of 79 m and a maximum diameter of about 275 cm. In New Zealand an individual tree at Queenstown, recorded by S. W. Burstall, was over 37 m in height and 99 cm in diameter in 1970.

Wood Properties and Uses

The wood of both *Cryptomeria* and *Thuja* is coarse-grained, fragrant, soft, light in weight and of low density with considerably lower strength values than those of radiata pine. The wood of New Zealand grown *Tsuga* has been little used but North American grown *Tsuga* is fairly hard and of moderate density and strength although not as strong as Douglas-fir. It competes strongly with radiata pine on the Asian market. The wood properties of New Zealand grown *Cryptomeria* and *Thuja* and North American grown *Thuja* and *Tsuga* are given in Table 6.

Cryptomeria japonica

Cryptomeria sapwood is yellowish or whitish and the heartwood, of which there is a relatively high proportion, is warm red-brown with yellow or

Fig. 15 - Garage clad in New Zealand grown *Cryptomeria*, Rotorua.

dark brown streaking. The heartwood is moderately durable and stable.

Because of the relatively low strength of *Cryptomeria* timber, it can only be used where strength and hard wearing qualities are not important. New Zealand-grown wood has an average air-dry* (12% moisture content) density of about 384 kg/m^3 compared with radiata pine at about 500 kg/m^3. The mean basic density of four trees from Tokomaru was 331 kg/m^3 with little density variation between trees. Radiata pine of similar age from the same area had a mean basic density of 464 kg/m^3.

Ideally, *Cryptomeria* timber should be carefully air-dried to below 30% moisture content prior to final kiln drying to 12% moisture content for interior use and 16% for weatherboards. For a faster result, kiln drying could be used, taking care not to exceed 40°C early in drying.

* Air-dry density = air-dry weight/air-dry volume
Basic density = oven-dry weight/green volume
Oven-dry = dried at 105°C until the weight is constant

Uses

In Japan *Cryptomeria* is widely used for decorative panelling, house framing, joinery, gateways, structural laminates, posts, ornamental poles for buildings, beams and arches, furniture frames, boxes, wine barrels and wooden sandals.

In New Zealand the timber has been little used other than on a small scale for farm timber, including rails. With its attractive appearance, fragrance and good woodworking properties (it saws easily and takes nails and screws well) material from appropriately tended stands should be suitable for specialist uses such as panelling (Fig. 16) and other decorative uses and for joinery in which flatsawn contrasting earlywood/latewood bands can be an attractive feature. It can be used for exterior cladding (Fig. 15) and has been tried for the corestock of fibreglass boats.

The resin exudate may lead to glueline difficulties in making up laminates and veneers, otherwise it is an attractive timber to work with for these purposes. In Japan the heartwood has a natural durability of about 15 years. New

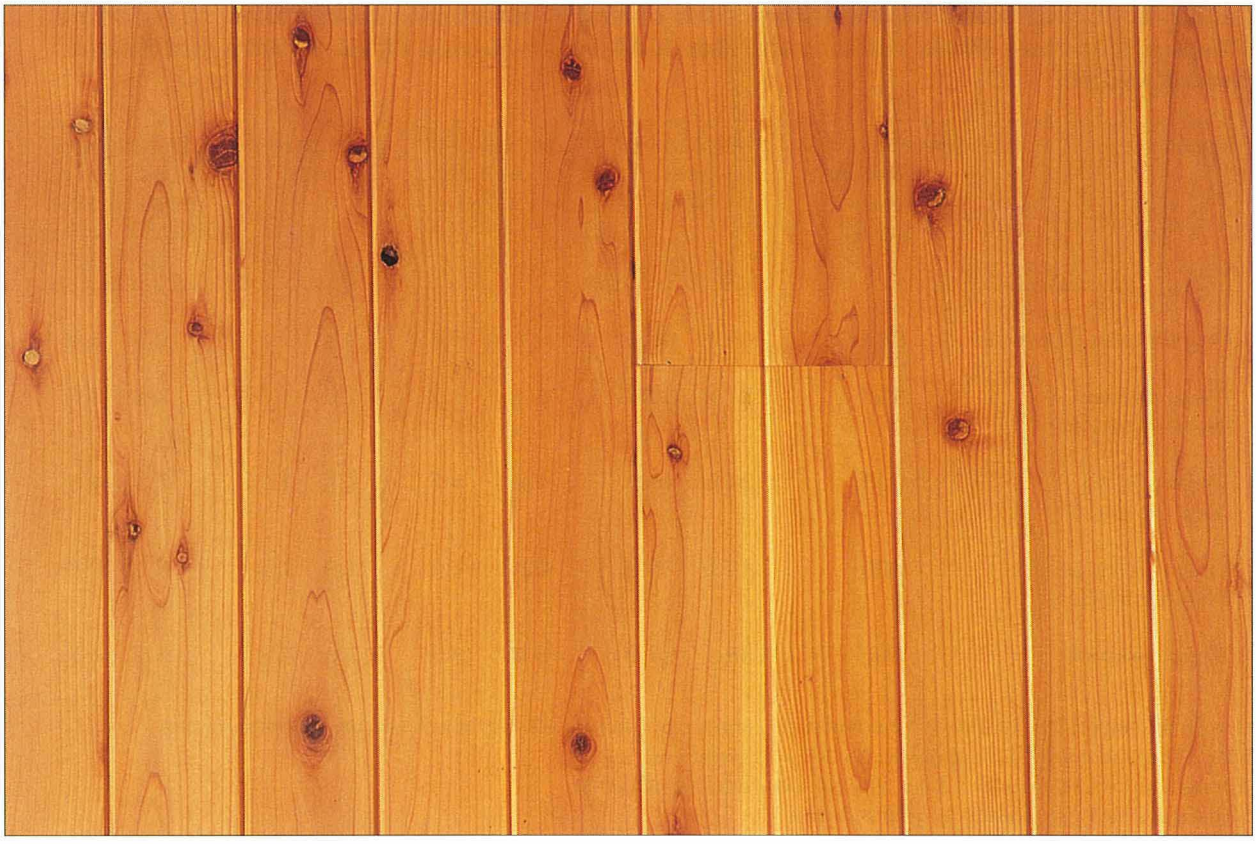


Fig. 16 - *Cryptomeria* panelling, Farm Forestry pavilion, Mystery Creek, Hamilton.

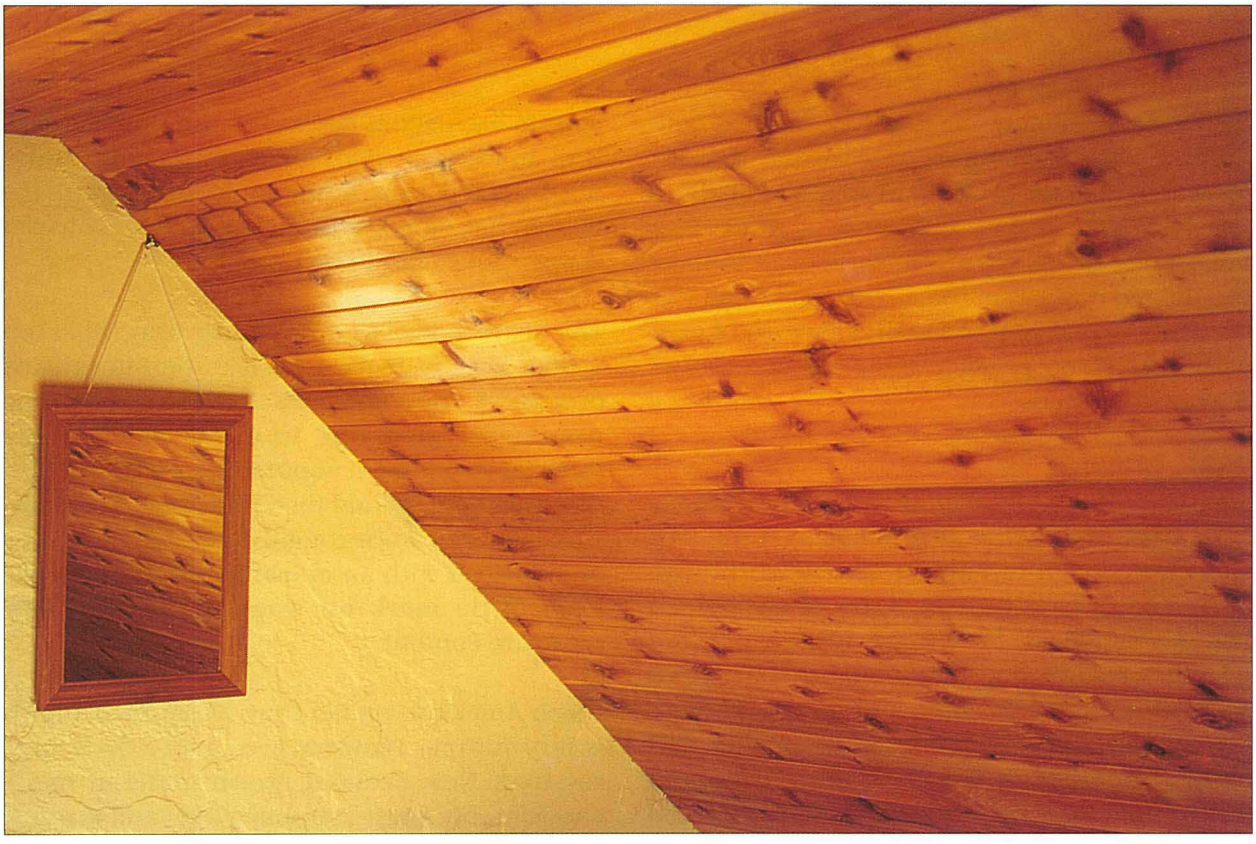


Fig. 17 - Ceiling sarked with locally grown *Thuja plicata*, Castle Rock Station near Lumsden, Southland.

TABLE 6 – Comparison of wood properties of New Zealand grown *Cryptomeria japonica*, *Thuja plicata* and *Pinus radiata* and North American grown *Thuja plicata* and *Tsuga heterophylla*

Species	Density at 12% moisture content (kg/m³)	Modulus of rupture (MPa)		Modulus of elasticity (GPa)		Hardness (kN)		Percentage shrinkage from green to 12% moisture content	
		G	D	G	D	G	D	R	T
Cryptomeria japonica	384	45.5	66.1	5.8	7.2	1.4	1.8	1.3	3.5
Thuja plicata (North America)	359	37.8	54.4	6.1	7.2	1.2	1.6	2.4	5.0
Thuja plicata (New Zealand)	323	34.0	49.5	4.4	4.7	1.4	1.7	2.3	4.3
Tsuga heterophylla (North America)	430	47.0	78.0	9.6	11.3	1.8	2.4	5.4	8.5
*Pinus radiata**	500	38.1	85.8	5.5	8.2	2.3	3.6	2.2	4.7

G = green timber; D = timber at 12% moisture content; R = in radial direction; T = in tangential direction

MPa = megapascals; GPa = gigapascals; kN = kilonewtons

Strength values refer to 20 x 20 x 300 mm clearwood specimens.

* Based on medium density 30 year old trees

References: N.Z.F.S. Timber Information Sheets; Bier, 1983; Forest Products Laboratory U.S.D.A. 1974 "The Wood Handbook"; The New Zealand Forest Service, 1970 "Timber Design Data Handbook"; Mullins and McKnight, 1981; FRI data.

Zealand grown material, however, is rated non-durable with an average service life of 5-10 years for stakes (similar to that for radiata pine). Both heartwood and sapwood have been difficult or impossible to treat with preservatives in most of a limited number of trials. The heartwood was particularly resistant to treatment with oil-borne or water-borne preservatives using vacuum pressure methods.

Thuja plicata

Typically, *Thuja* logs contain a high percentage of heartwood which varies in colour from dark chocolate brown to reddish or pinkish brown, surrounded by a narrow band of pinkish or whitish sapwood. New Zealand-grown *Thuja plicata*, while intrinsically similar to that grown in North America, is coarser grained and more knotty with poorer dimensional stability and lower durability. It is also slightly lighter in weight, making it one of the lightest commercial softwoods.

New Zealand-grown *Thuja* is easily worked and takes glue, stain and paint well. Providing sharp cutters are used it machines and finishes well. Nail holding is poor to medium and, since unprotected iron nails corrode or stain the timber, hot-dipped galvanised, stainless steel or copper nails should be used.

The heartwood of New Zealand grown *Thuja* has a high level of moisture saturation (averaging over 200% and sometimes as high as 300%) and needs careful drying to avoid collapse and internal checking. It should be air-dried to 30% moisture content and then kiln dried. The moisture content can be roughly checked by writing on the wood with an indelible pencil which will leave little mark on wood drier than 30% moisture content.

North American timber from old-growth stands is very durable. However, even after a 60-80 year rotation, New Zealand grown material has a considerably lower extractive level and is much less durable. As with *Cryptomeria* it has an average in-the-ground service life of 5-10 years for stakes. The heartwood is very difficult to treat with preservatives, even under pressure.

Uses

In North America, *Thuja plicata* timber is highly valued because of its durability and workability. Uses include exterior cladding and joinery, interior finishing, shingles (for which it is particularly renowned) and many other purposes where resistance to fungal attack is important. The Indians of the Pacific Northwest carved totem poles from *Thuja plicata* and used it to build canoes.

In the past, western redcedar was one of the most important timbers imported into New Zealand although in recent years its use has declined due to the increasing popularity of aluminium joinery. For the year ending 31 December 1993, sawn timber imports of western redcedar amounted to 21,000 m^3. Its high durability, stability and light weight make it particularly suitable for joinery, exterior cladding and window frames, shingles, glasshouse construction and garden furniture. It has also been used for posts and poles, interior finishing (panelling and mouldings), incubators, pencils and carving.

New Zealand grown *Thuja* is not strong enough for most structural uses but the heartwood is durable out of ground contact and is suitable for a variety of purposes where strength is not critical. Its main use has probably been for exterior cladding and it can make good panelling and sarking (Fig. 17). In the past roundwood was used for posts and poles using a cold soak creosote bath treatment but penetration was variable and performance in ground contact has been unreliable. The low wood density and high extractive content (sometimes in excess of 30%) detract from the potential of *Thuja* as a source of pulp.

Tsuga heterophylla

The wood of *Tsuga heterophylla* is light, straight-grained, resin free, fairly strong and durable. A thin band of nearly white sapwood surrounds the yellowish brown heartwood. Little is known about the wood properties or utilisation of western hemlock grown in New Zealand. In North America it is a valuable species with a wide range of uses and is often processed and sold mixed with Douglas-fir. It is increasingly planted in Europe where it is favoured for its relatively fast growth, versatility of utilisation and ornamental qualities.

Uses

Indigenous western hemlock is used in North America and exported as a preferred species for general construction purposes on account of its strength, ease of working and good nailing characteristics. It takes polish well. Uses include framing, flooring, interior finish, shingles, veneer, plywood, boxes, crates and railway sleepers.

Very good pulping characteristics result in its extensive use in North America for paper manufacture. It provides an important source of fibre for groundwood, thermomechanical, kraft and sulphite pulps.

Other uses for *Cryptomeria*, *Thuja* and *Tsuga*

Cryptomeria, *Thuja* and *Tsuga* all have considerable aesthetic appeal as ornamentals when suitably sited. *Tsuga* can be particularly attractive with its stately form, beautiful foliage and delicate pendulous branches. Both *Cryptomeria* and *Thuja* are useful shelter trees.

Cryptomeria has been used extensively as shelter for horticultural crops (particularly kiwifruit) in the Bay of Plenty (Fig. 18), Northland and Taranaki and often serves as supplementary shelter in radiata pine shelterbelts. Its early growth is quite fast, it responds well to trimming and its shade tolerance allows it to be planted on the shady side of multi-row shelterbelts. A clone, 'Egmont', selected for its vigour and tight compact form, has been propagated and widely used for horticultural shelter, particularly in Taranaki (D. Sampson *pers. comm.*). *Cryptomeria* has been widely planted for aesthetic and shelter purposes on farms and in parks and large gardens. The cultivar 'Elegans' is often planted as an ornamental tree, especially at higher altitudes where its colourful reddish purple foliage livens the winter scene and provides landscaping contrast and interest (Fig. 19). Over 60 ha of *Cryptomeria* was planted for water catchment afforestation in the Hunua Ranges, south of Auckland, but most of these stands have been converted to radiata pine. The bark of *Cryptomeria* has been used for roofing in Japan.

Thuja plicata is also a good shelterbelt species on suitable sites and is planted for this purpose particularly in Otago and Southland. It retains its branches to ground level for a long time and responds well to trimming. It can be planted at

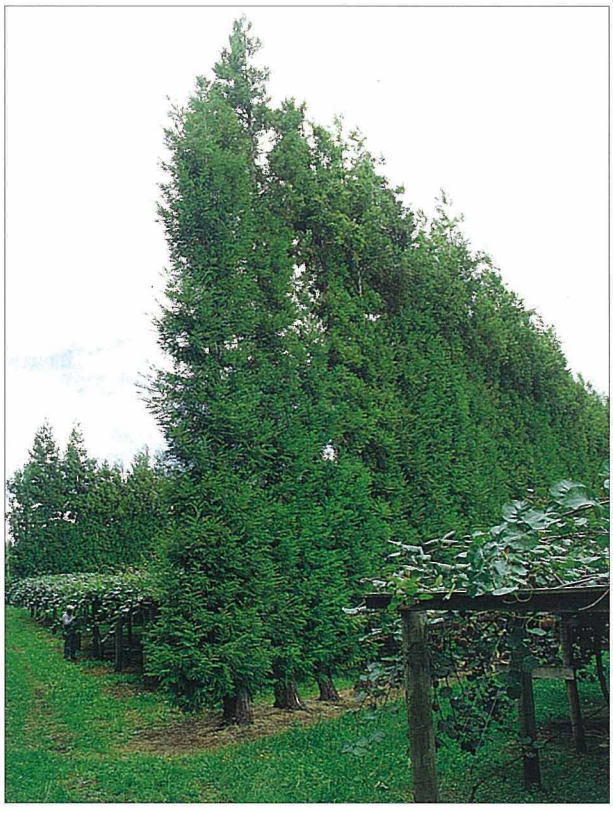


Fig. 18 - *Cryptomeria japonica* planted as shelter for kiwifruit, Tauranga.

Fig. 19 - *Cryptomeria japonica* 'Elegans' with typical reddish purple winter foliage.

1-2 m spacing in a single row or hedged by annual or biennial trimming to provide dense shelter for homestead, stock or crop protection. If tall windbreaks are required, trees can be planted 2-3 m apart and alternate trees pruned to improve wind permeability and provide eventual sawlogs. With its pleasing pyramidal shape *Thuja plicata* has amenity value and can make a handsome specimen tree.

In North America, perfumes, insecticides, medicinal preparations, veterinary soaps, shoe polishes and deodorants are manufactured using oil from *Thuja* leaves. Extractives and residues are used in lead refining, boiler water additives and glue extenders. Substantial quantities of foliage are used for floral work in Britain. The rough, stringy inner bark of *Thuja plicata* was used by the native North Americans for ropes, mats and baskets. *Tsuga heterophylla* bark is rich in tannin and it has been used extensively in North America for tanning leather.

Present Extent

In 1990 the total area of *Cryptomeria japonica, Thuja plicata* and *Tsuga heterophylla* remaining in plantations previously under the administration of the New Zealand Forest Service, was estimated to be 925 hectares. Of this, 227 ha were in *Cryptomeria*, 680 ha in *Thuja* and 28 ha in *Tsuga* (Table 7). *Cryptomeria* consisted of 205 ha in pure stands and 22 ha in mixtures with other species. *Thuja* consisted of 460 ha in pure stands and 220 in mixtures while 25 ha of the *Tsuga* was in mixtures and only 3 ha in pure stands.

Over 80% of the *Cryptomeria* was in the North Island whereas 87% of the *Thuja* and about 70% of the *Tsuga* were in the South Island. The majority of the plantings were over 10 years old - only 22 ha of *Cryptomeria* and 9 ha of *Thuja* having been planted between 1980 and 1990. No planting of *Tsuga* was recorded during this time.

Future Role

Cryptomeria japonica, Thuja plicata and *Tsuga heterophylla* are all important timber producing species in their countries of origin. However, in New Zealand their site limitations and slow early

TABLE 7 – Estimated areas* (pure and mixed stands) of *Cryptomeria japonica*, *Thuja plicata* and *Tsuga heterophylla* as at 1990

Age class (years)	*Cryptomeria japonica* (ha)	*Thuja plicata* (ha)	*Tsuga heterophylla* (ha)
0-10	22	9	-
11-20	77	68	2
21-30	21	110	22
31-40	13	92	2
41-50	89	65	-
51-60	1	220	2
over 60	4	116	-
Total	227	680	28
North Island	188	89	8
South Island	39	591	20
Proportion in pure plantations	90%	68%	11%

*Areas will be underestimated because of incomplete records for the private sector.
Source: FRI data base

growth rates compared with radiata pine, and the poor durability and low density wood of *Cryptomeria* and *Thuja* seem likely to restrict these species to a very minor future role in commercial forestry in New Zealand.

Cryptomeria has a well established role as a shelter tree, particularly for horticulture in warmer and wetter parts of the North Island. Because of its relative resistance to cypress canker it can be substituted for macrocarpa and Lawson cypress in localities where canker is a problem. *Cryptomeria* may also have a minor role as a farm woodlot species in warmer, wetter North Island areas where its attractive appearance and fragrant, decorative, easily worked timber may appeal. However, consideration needs to be given to its susceptibility to possum damage and the potential contamination of sheep wool by small, dead branchlets.

Cryptomeria could possibly be grown for export to Japan where it is widely used and highly regarded. However the Japanese are particular about factors such as timber colour, width of growth rings and possibly seed source. Precise requirements in these respects would require careful investigation.

Like *Cryptomeria*, *Thuja* may have a limited forestry role on moist but well drained fertile and sheltered sites, particularly in the South Island. If the trees are suitably tended and the wood carefully dried, it should produce timber of sufficient quality for out of ground contact uses such as weatherboards, panelling and joinery and has an assured role as a shelter and amenity species.

Tsuga has been little used in New Zealand and slow growth and poor survival rates have not increased enthusiasm for the species but, if carefully sited and suitably tended, it grows healthily, and has the potential to produce a useful, easily worked, medium density timber on rotations of about 50 years. It is very attractive ornamentally and may appeal where aesthetic diversity and values are considered important.

Recently, breeding programmes have been initiated in the Pacific Northwest of North America in both *Thuja plicata* and *Tsuga heterophylla*. Seed from this source, particularly of *Tsuga*, will provide improved material for future trial plantings and may improve prospects for *Tsuga* in New Zealand.

Fig. 20 - Natural regeneration of *Thuja plicata*, Conical Hill Forest, West Otago.

Vegetative Propagation

Cryptomeria, *Thuja* and *Tsuga* can all be propagated by stem cuttings in spring or autumn. Rooting can be improved by dipping or soaking in a solution of indolebutyric acid (IBA). All three species can also be propagated by grafting. *Tsuga*, in particular, grafts readily and the growth of grafts has been reported to be better than that of rooted cutting material.

Thuja plicata can reproduce naturally by layering, by the rooting of fallen branches and by branch development on fallen trees, especially saplings. *Tsuga* can also be propagated by layering. If seedlings of *Tsuga* die back to the soil surface they often sprout again from buds near the root collar. However, sprouting does not occur from the base of larger saplings. Methods for micropropagation (tissue culture) of all these species have been developed, but there are constraints of cost efficiency and difficulties in applying the techniques to material from mature trees.

Regeneration

Cryptomeria occasionally regenerates in New Zealand in the vicinity of planted trees particularly in cutover native forest and also in and around plantations. In Mahinapua Forest, Westland, it was reported to be regenerating freely on drier sites. *Thuja plicata* also occasionally regenerates on partially open sites in the vicinity of parent trees (Fig. 20). Natural regeneration of *Tsuga* has not been recorded to date in New Zealand.

***Cryptomeria japonica*, *Thuja plicata* and *Tsuga heterophylla* are attractive healthy species in New Zealand when appropriately sited. However, uncompetitive growth rates and the low density timber of *Cryptomeria* and *Thuja* have tended to detract from their commercial potential. *Cryptomeria* and *Thuja* have established roles as shelter and amenity species while *Tsuga* is particularly attractive aesthetically, factors which should ensure their continued presence in the New Zealand countryside.**

SEED USERS' GUIDE

A. Collection and Extraction of Seed

	Cryptomeria japonica	*Thuja plicata*	*Tsuga heterophylla*
Age of first coning:	Usually 7-10 years	Usually about 11-13 years	Approx. 20 years
Seed available in quantity:	Approx. 10 years	Approx. 20-30 years	Approx. 25-30 years
Pollen production:	August - September	Spring	Spring
Periodicity of crop:	Good crop every 3 years	Good crops produced in South Island only every 3-5 years	Good crops every 2-8 years. Light crops in intervening years
Cone maturation period:	..... Cones ripen in first year		
Cone collection:	..... Late summer to autumn		
Harvesting:	..... Climbing where necessary .... Cones collected by hand stripping or with secateurs		
Mature cone recognition:	Cones turn reddish brown	Cones green when immature, turn yellow then cinnamon brown when ripe	Cones change from yellowish green to purplish or brown when ripe
Seed extraction:	..... Spread cones to dry or kiln dry at about 38°-40°C .... Seed can be separated by sieving or winnowing		
No. of seeds/kg:	230,000-500,000	700,000-900,000	485,000-1120,000 (av. about 665,000)*
Storage conditions:	..... Dry store, sealed (below 10% moisture content) at about 4°C		
Stratification:	Stratify for 2-3 weeks at 3-4°C. Soak in cold water for half a day	Stratify for about 4 weeks at 3-4°C	Usually germinates well without stratification but germination can be improved with cool moist stratification at 4-5°C
Storage duration:	Up to about 3 years	Not more than 3 years	2-5 years
Expected germination:	15-40%	30-50%	10-95% - (average about 50%)

* North American data (*Tsuga heterophylla* - seeds/kg)

B. Nursery Practice

Cryptomeria, *Thuja* and *Tsuga*, should be planted out as well-conditioned, bare-rooted seedlings or cuttings with abundant fibrous roots.

Cryptomeria and *Thuja* are usually grown as 1/1 (two-year old transplanted stock). In the Forest Research Institute nursery they are sown in seed trays in the glasshouse in autumn, pricked out into copper-coated Lannen ecopots and lined out in spring (October, November). *Cryptomeria* and *Thuja* can also be grown as 2/0 (two-year old) seedlings. Seed is sown in spring to a depth of not more than 3 mm in a sheltered seedbed and covered with 50% shade-cloth. Seed should be dribbled at approximately 25 viable seeds 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 per metre of drill or lined out at about 15 cm spacing. Seedlings should be kept under shade-cloth until late April when the shade-cloth should be removed to allow climatic conditioning.

Tsuga seedlings grow more slowly and are usually best grown for up to three years in the nursery as 1/2, 2/1, or 3/0 stock. *Tsuga* can be treated as for *Cryptomeria* and *Thuja* but is best covered with 50% shadecloth for the first two growing seasons. The suggested tending schedule (below) is based on that used for seedling-grown *Cryptomeria*, *Thuja* and *Tsuga* at the Forest Research Institute nursery in Rotorua.

Fertiliser: Incorporate a slow release nitrogenous fertiliser at 250 kg/ha into the seed-bed 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 (2 litres product/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 (several commercial formulations) or propazine (Gessamil 50 W P) 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 (Perigen 500) or deltamethrin ('Decis') 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. Keep roots moist prior to planting out.

C. Recommended Seed Sources

	Locality	Year planted	Remarks
Cryptomeria japonica	Teutenberg's Farm, Muriwai, Gisborne	1933	Shelterbelt of 28 trees; good form. Seed stand RO 38.
	Block 10, Long Mile, Whakarewarewa, Rotorua	1973	25 trees, established as cuttings representing 15 clones of plus trees, selected in 1970 in Pureora and Pirongia Forests. Trees have maintained excellent form; very little malformation.
	Cpt. 303, Ruatoria Forest, Gisborne	1976	Trees of excellent form.
Thuja plicata	Cpts. 11, 25, 33, 44, Berwick Forest, Otago	1947-1949	Total area c. 20 ha.
	Cpts. 5, 7, 8, 10, Longwood Forest, Southland	1951-1954	c. 40 ha.
	GTI Plot R338/15, Long Mile, Whakarewarewa, Rotorua	1962	Seedlot No. 56/765 from Mad River, California. A high-performing seedlot (see Table 1).
Tsuga heterophylla	Cpt. 8, Hanmer Forest, Canterbury	1960	A trial including five provenances.
	GTI Plot R338/17, Long Mile, Whakarewarewa, Rotorua	1962	Provenance trial containing eight seedlots from Oregon and Washington (see Table 2).

Seed of *Cryptomeria japonica, Thuja plicata* and *Tsuga heterophylla* can be collected from other localities in New Zealand. Plantation sources, shelterbelts, or group plantings are to be preferred to single trees to avoid the risk of inbreeding. Dominant trees of good form should be selected for seed collection.

Periodically, seed of these species is available from Proseed New Zealand Ltd, Private Bag 3020, Rotorua.

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