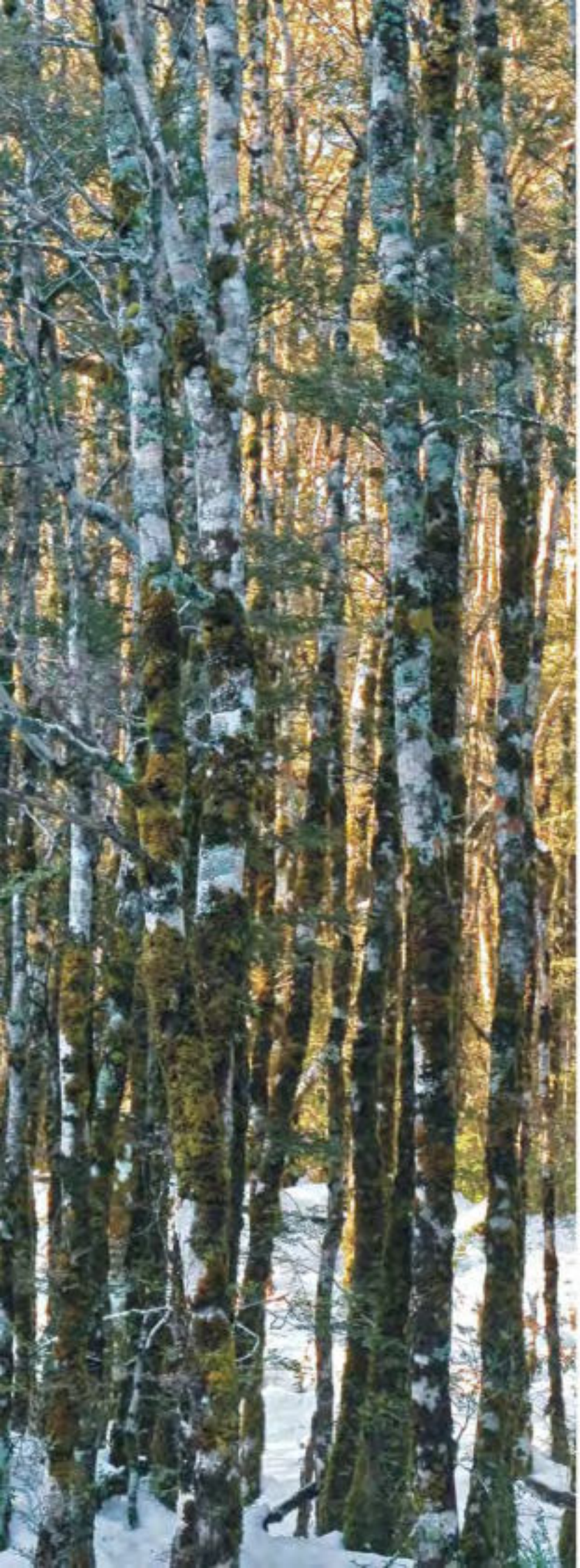
# The New Zealand BEECHES

## ESTABLISHMENT, GROWTH, and MANAGEMENT

Mark Smale, David Bergin and Greg Steward

Photography by Ian Platt





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**Front cover:** *High altitude mountain beech forest, Lewis Pass.*

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# THE NEW ZEALAND BEECHES

## Establishment, growth, and management

Mark Smale, David Bergin and Greg Steward

Photography by Ian Platt

***New Zealand Indigenous Tree Bulletin No. 6***

Scion, Private Bag 3020, Rotorua,
New Zealand

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# INTRODUCTION

The New Zealand beeches (*Nothofagus*) are amongst our best-known and most important native trees. Two-thirds of the remaining native forest in New Zealand is beech forest of various kinds, and many major tourist routes pass through it. These forests are some of the more distinctive in the country and are better understood than most others. After the conifers and tawa (*Beilschmiedia tawa*), the beeches have been historically the most significant native timber species and now constitute the over half the native timber resource left in the country.

The beech forests played a critical role in the native forest conservation controversies of the 1970s. Although other factors were undoubtedly at work, proposals for large-scale clearfelling and utilisation of beech in State Forests in north Westland (New Zealand Forest Service 1973) triggered the debate that culminated eventually in the Government re-structuring its land-administering and research departments. As a result, most of the remaining beech forests were, despite their undoubted potential for management, effectively removed from management for timber production by legislation in 1987. Nevertheless, substantial areas of manageable beech forest remain in freehold and Maori tenure.

Despite the long-appreciated potential of beech forests for sustainable management and the undoubted qualities of their timber for a variety of uses, management for wood production has remained an elusive goal because of perceived difficulties in both silviculture and wood processing. A sustained, integrated industry comprising sustainable forest management and established processors and markets has scarcely developed.

The New Zealand beeches produce high-quality functional and decorative timbers, so there is increasing interest in managing them, particularly in sustainably-managed natural forest and to a lesser extent in plantations. This bulletin provides up-to-date information on the ecology, establishment and management for timber production of beeches. The first half gives an overview of the characteristics of the New Zealand beech species, including their ecology and distribution. The second half focuses on the management requirements of the species relating to establishment by natural regeneration and planting, tending, productivity, and wood quality and processing. Finally, a set of guidelines is provided for managing the beech species to meet multiple objectives including timber production.

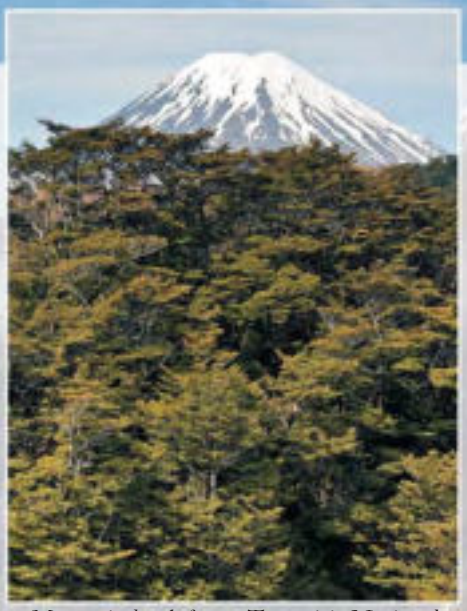
This bulletin draws heavily on John Wardle's 1984 monograph on the New Zealand beeches which has been extensively consulted and, unless otherwise referenced, is the primary source.

# PART 1 - THE BEECH SPECIES

Five entities are recognised in *Nothofagus* in New Zealand, comprising four species, one of which has two varieties.

1. *Nothofagus menziesii* (Hook.f.) Oerst. Silver beech
2. *Nothofagus fusca* (Hook.f.) Oerst. Red beech
3. *Nothofagus truncata* (Col.) Ckn. Hard beech
4. *Nothofagus solandri*
   a. var. *solandri* (Hook.f.) Oerst. Black beech
   b. var. *cliffortioides* (Hook.f.) Poole. Mountain beech

Leaf shape is the major characteristic used for distinguishing the species and varieties, so it is not necessary to resort to flowers or other anatomical features to determine the species. Unlike some South American species, all of the New Zealand beeches are evergreen, broadleaved trees. The common occurrence of natural hybrids among species except silver beech was noted long ago (Cockayne 1926).



*Mountain beech forest, Tongariro National Park, central North Island.*

## How they were named

The European botanists who first described plants in the Southern Hemisphere often named them after similar plants in the Northern Hemisphere. New Zealand's beeches were first thought to resemble birches (*Betula*). Later, they were described as true beech (*Fagus*). From Roman times, *fagus* refers to the edible nuts when European beech was a widespread and valued tree for nut production, and produced wood for fuel and timber (Poole 1987).

In 1850, the German-Dutch botanist Carl Blume recognised that the Southern Hemisphere (southern) beeches were different enough from the northern species to warrant their own genus, *Nothofagus*, meaning false beech.

The scientific names of the New Zealand beeches refer to bark and/or leaf colour (*fusca*, meaning dusky, i.e., dark-coloured, for red beech); leaf shape (*truncata*, meaning truncated, i.e., cut off, for hard beech); early botanists (*menziesii* for Archibald Menzies, a Scottish doctor and naturalist who visited the Pacific, for silver beech, and *solandri* for Daniel Solander, the Swedish naturalist on Captain Cook's first voyage, for black/mountain beech); or resemblance to other plants (*cliffortioides*, resembling *Cliffortia,* a southern African tree, for mountain beech).

The common names reflect colours associated with them (red beech for its red-tinted leaves; silver beech for the colour of its bark; black beech for the sooty mould that occurs on the honeydew on the outer bark), wood quality (hard beech for being difficult to saw), or habitat (mountain beech for its upland habitat).

Hard beech was earlier often known as 'clinker' beech, probably in reference to the large amount of waste generated by it during sawing. The generic Maori name for beech is *tawhai*, with *raunui* ('large leaf') appended for the larger-leaved species and *rauriki* ('small leaf') for the smaller-leaved species.

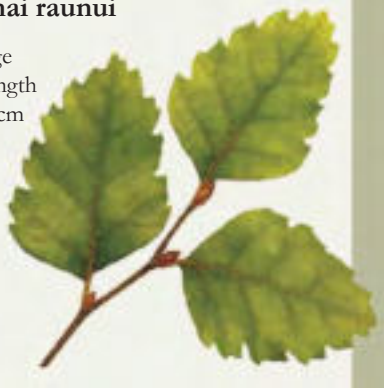
## SPECIES DIFFERENCES AT A GLANCE

### Red beech

(*Nothofagus fusca*)

**Tawhai raunui**

Average leaf length = 3-4 cm



- Largest beech species in New Zealand.
- Mature trees average 24–30 m in height, trunks 1.4–2.0 m in diameter, but can reach larger dimensions.
- Mature trees can have massive crowns, large flanges at the base of the trunk, and root buttresses.
- Prefers deep, well drained, fertile soils of lower to mid-slopes and river terraces. Generally the least tolerant of unfavourable conditions.
- Generally the fastest growing of the New Zealand beeches, with diameter growth rates averaging over 2 mm/yr.
- Commonly grows with silver beech, less commonly with hard beech, and a wide range of other species, especially kamahi.

### Hard beech

(*Nothofagus truncata*)

**Tawhai raunui**

Average leaf length = 3 cm

- Can grow as tall as red beech, but its trunk is more slender; diameters average 0.6–1.2 m.
- Large trees can develop basal flanges and buttressed roots.
- Tolerates poorer and drier soils than red beech.
- The most frost-sensitive of the beeches (-7°C).
- Slightly slower growing than red beech, with diameter growth rates averaging 1.9 mm/yr.
- A lowland species that grows further north and with a wider range of other species than other beeches.
- The most poorly known of the beech species.

### Black beech

(*Nothofagus solandri* var. *solandri*)

**Tawhai rauriki**

Average leaf length = 1.5 cm

- Usually reaches 20–25 m in height, with a trunk diameter similar to that of hard beech.
- Trunks do not usually form flanges or buttresses.
- Variation in leaf shape may reflect hybridisation.
- Tolerates poor and droughty soils, and very low rainfall (750 mm/yr).
- Growth rates can attain those of red beech but are usually slower (1.5 mm/yr).
- A lowland and upland species that reaches the Hauraki Gulf.

## SPECIES DIFFERENCES AT A GLANCE

### Mountain beech

(*Nothofagus solandri* var. *cliffortioides*)

**Tawhai rauriki**

Average leaf length = 1 cm

- Smallest New Zealand beech, reaching 15–20 m high, with a trunk diameter of 0.5–0.75 m.
- On exposed or elevated sites, can be reduced to bushes only 45 cm high.
- Snow drifts and avalanches can make trunks grow horizontally for several metres before turning upright.
- Tolerates more poorly drained and less fertile soils, and heavier frosts (-13°C) than other beeches.
- Grows on generally colder sites than other beeches.
- A montane and subalpine species that grows at higher altitudes (from 700 m above sea level up to the treeline) than other beeches.
- Forms extensive single-species stands east of the Southern Alps.

### Silver beech

(*Nothofagus menziesii*)

**Tawhai**

Average leaf length = 1 cm

- Trees average 20–25 m high with trunk diameters of 0.6–1.5 m.
- Like mountain beech, can grow as bushes at high altitude, and can develop partly horizontal trunks in deep snow.
- A hardy tree tolerant of heavy frost (-12°C) and snowfall and a wide range of soil types.
- Denser foliage than other beeches.
- Generally the slowest growing of the New Zealand beeches; diameter growth rates average 1.2 mm/yr.
- Grows under generally higher rainfall than other beeches.
- Often grows alone in high rainfall areas, but also mixed with other beeches, particularly red and mountain, and podocarps such as rimu.
- Grows at similar altitudes to mountain beech, but less tolerant of infertile or poorly drained soils.

*Photographs are not to scale. Average length of leaves for each species are indicated.*

## THE BLACK/MOUNTAIN BEECH QUESTION

Black beech and mountain beech were originally named as separate species, *Fagus* (later *Nothofagus*) *solandri* and *F.* (later *N.*) *cliffortioides*. At the extremes of their ranges, they have distinctly different foliage. However, the occurrence of intermediate forms led to their description later as two varieties (geographic races) of a single species. They are best regarded as the lowland and upland ends of a continuous spectrum ('cline'), with intermediate forms not clearly referable to either variety occurring at sites intermediate between populations of black and mountain beech. Over much of their respective ranges, they are reasonably distinctive.

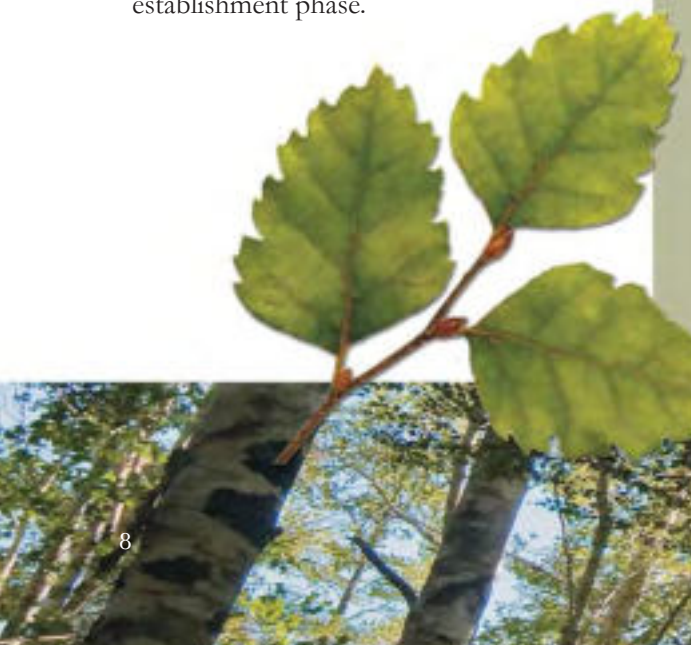
# PART 2 - DISTRIBUTION

## THE NEW ZEALAND BEECHES

The beech species grow alone or in combination through much of the North and South Islands, from Kaitaia to the Southland coast, but not on Stewart Island or the subantarctic islands. Pure beech forest comprises almost half (about 3 million hectares) of New Zealand's remaining native forest. Forests of beech mixed with other tree species make up another quarter (about 1.3 million hectares). Beech trees are found in most of the native forest left in the South Island, but in less than half that in the North Island. They are absent only from limited areas of upland North Island like Mt Egmont/ Taranaki and the southern Ruahine and northern Tararua Ranges, but most famously from a 150 km long stretch of the west coast of the South Island known as the 'beech gap'. Their general distribution reflects the interaction between their soil and climatic tolerances and their poor competitive ability with many other tree species in the establishment phase.

## THE 'BEECH GAP' - AN ENIGMA

There is a well-known conspicuous gap of about 150 km in the distribution of the beech species on the west coast of the South Island, between the Taramakau and Paringa Rivers, where beech forest is replaced at all altitudes by forest in which warm-temperate hardwood elements dominate. Similarly, there is a conspicuous absence of beech in the northern third of the Tararua Range and the southern part of the Ruahine Range, and there are other anomalies such as relict stands in the northern North Island and the absence of beech from Stewart Island. The reason for these anomalies in beech distribution and particularly the 'beech gap' in Westland has fuelled decades of debate. This has often ranged around changes in forest distribution and pattern with past cycles of glaciation to more local catastrophes such as fire and volcanism.

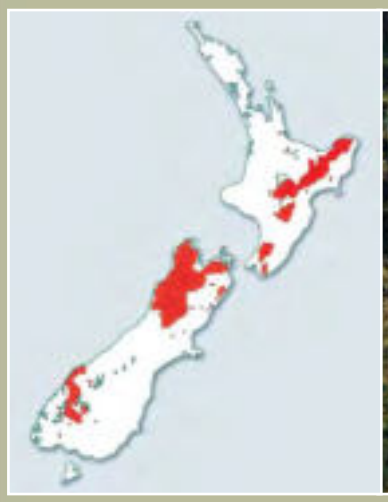


Like forests everywhere, the composition, structure and stability of beech forests are influenced by long-term climatic change. During increases and decreases in temperature, there would have been retreats and advances of beech forest up and down New Zealand. With increasing temperature, as the beeches belong to the subantarctic element they have the capacity to endure cold, and therefore would have retreated to the mountains and more inhospitable lowland sites, while more tropical elements of the New Zealand flora advanced southward. Conversely, as temperatures decreased, the more tropical elements would have been driven northward and the beech forests followed.

Volcanism and fire have played an important role in the distribution of forests. Beeches are largely absent from the extensive west Taupo forests, devastated by volcanism 1800 years ago. Extensive burning by early Maori, particularly in the drier eastern regions, and later by early European settlers for pastoral farming, destroyed much drier beech forest. Nevertheless, the occurrence of most beech forest on relatively poor soils under inimical climates at higher elevations has ensured their survival through waves of human colonisation.

Cockayne (1926) suggested that the beech gap in Westland could be due to insufficient time for it to have moved back since the end of the last glaciation. Others suggest that beech competes less effectively with existing vegetation where rainfall is high and fog frequent. Still others suggest a change to cooler drier conditions and that major changes in species distributions are still occurring.

**Hard beech** is very scattered through the northern third of the North Island, being common only on the Bay of Plenty side of the axial ranges and in north Taranaki. Absent from the central North Island, it re-appears in the southern part of the island and is again common in the Marlborough Sounds and the northwestern South Island, with an outlier in south Westland near Haast.



**Red beech** in the North Island occurs locally on the Kaimai-Mamaku uplands but is common on the axial ranges from near East Cape to Wellington, with a gap in the southern Ruahine and northern Tararua Ranges. It is also common in northwestern South Island and again in west Otago, with scattered stands in Marlborough, Canterbury, south Westland and Southland.

**Black beech**, the lowland form of *N. solandri*, occurs from Little Barrier Island and the Bay of Plenty coast southward, being common in inland Taranaki and in the southeastern North Island (Aorangi Range). It has a scattered distribution in the South Island.

**Mountain beech**, the upland form of *N. solandri*, is common on the central volcanoes of the North Island and in the central (Kaimanawa, Kaweka) section of the axial ranges, where the free-draining young volcanic soils mitigate the wet climate. It is widespread through much of the South Island, and forms much of the surviving forest east of the Main Divide.

**Silver beech** in the North Island occurs locally on the Kaimai-Mamaku uplands and is common on the axial ranges from East Cape to the Kaimanawa mountains, re-appearing in the southern Tararua Range. In the South Island, it is common throughout Westland (apart from the beech gap) and western Southland where it is the predominant species, with significant outliers in the southeast (for example, in the Catlins).

As well as growing singly, **red, silver,** and **mountain beech** commonly occur in various combinations within their mutual range. **Black beech** also occurs very locally with **red** and **silver beech**, and **red beech** very locally with **hard beech**. The most widespread alliances are mixtures of **silver** and **red beech**, followed by mixtures of **mountain** and **silver beech**, **silver beech** forests**, black beech** and **mountain beech** forests, and finally forests containing **hard beech** (Wiser et al. 2011). The beeches also grow in combination with a wide range of other native trees, conifers and hardwoods.

# THE SOUTHERN BEECHES

The genus *Nothofagus*, commonly known as southern beech, has traditionally been placed in the beech family (Fagaceae), but is now regarded as belonging to a separate family, Nothofagaceae (southern beech). There are some 35 species of *Nothofagus*, in four groups. The *brassii* group occurs only in New Caledonia and New Guinea, the *fusca* group (including all our species except silver beech) in South America, Australia and New Zealand, the *menziesii* group (including silver beech) also in South America, Australia and New Zealand, and the *antarctica* group solely in South America

*Nothofagus* species form almost continuous forests from coastal to alpine regions on both sides of the South American Andes, with nine species recognised, six of which are deciduous. In New Zealand, none of the beech species are found south of the South Island, even though Stewart Island and the subantarctic islands fall well within the latitudinal range of the genus in South America and planted beech grows well on Stewart Island.

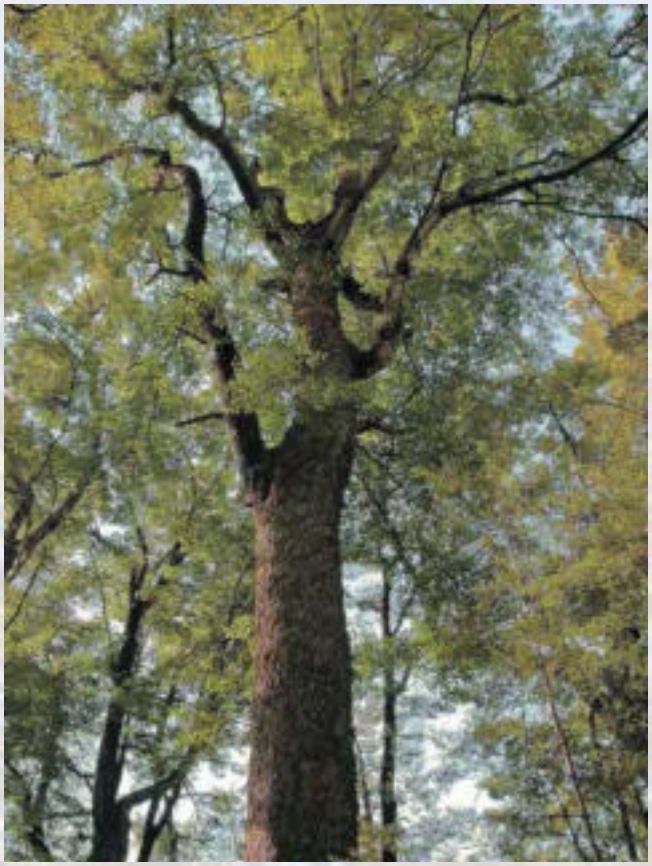
Three species of *Nothofagus* occur in Australia. They form only a minor component of the mainland Australian forests in the east and southeast but are more common in the forests of western Tasmania.

Thirteen species are described for New Guinea and the neighbouring island of New Britain, although the status of some of these is dubious. The genus is a significant if patchy component of the New Guinea forests from lower altitudes to the highlands on smaller, more oceanic islands, forming components of the montane rain forests in the region.

*Distribution of present day* Nothofagus *forests in the Southern Hemisphere (modified from Wardle 1984).*

## TREE DIMENSIONS AND LIFESPANS

**Red** and **hard beech** are large trees, **silver** and **black beech** are medium-sized to large trees, while **mountain beech** is a small to medium-sized tree.



*Large red beech tree.*

**Red beech** is the largest, attaining huge dimensions (up to 40 m or more tall and 3 m in diameter) on the best sites. **Hard beech** tends to be more slender and smaller than **red beech**, with maximum heights of 36 m and diameters of 1.8 m. **Silver beech** is a stouter tree that can reach 30 m in height and 2.6 m in diameter. **Black beech** can reach diameters in excess of 1 m and heights of over 30m. **Mountain beech**, the smallest species, rarely exceeds heights of 20 m and diameters of 1 m. Lifespans broadly reflect dimensions.

**Red beech** and **silver beech** are the longest-lived, up to 600 years. **Hard beech** can live for up to 500 years, and **black** and **mountain beech** 360 years. As usual, average dimensions are considerably smaller and average lifespans much shorter than maximum ones.

*The massive, spreading crown of a mature red beech, surrounded by silver beech.*

*The distinctive layered branching of mountain beech.*

## PLANT DESCRIPTION

### Foliage

**Red**, **hard**, and **silver beech** have toothed leaves, while **black** and **mountain beech** have entire leaves. **Silver, black** and **mountain beech** have distinctive foliage unlikely to be confused with any other species. **Red** and **hard beech** have confusingly similar foliage. **Red beech**

has larger, thinner, duller, more distinctly saw-toothed, paler green leaves than **hard beech**, with a distinctive single protruding tooth at the tip. Juvenile leaves are often strongly tinged with red. **Hard beech** leaves are smaller and more compact, thicker in texture, somewhat glossier, less sharply toothed, and somewhat darker, and their tips have a blunt, cut-off appearance. **Silver beech** has much smaller, rounder, thicker, glossier, darker green leaves than the other beeches, with shallow, rounded teeth. Juvenile leaves are similar. **Black** and **mountain beech** have small, oblong leaves; rounder, duller, and paler green in **black beech**, more triangular, glossier, darker green, and often strongly curled in **mountain beech**. Juvenile leaves are rounder in shape and often tinged red.

## Bark

Like most trees, the bark of beeches changes with age, from pale, thin, smooth bark in younger trees to darker, thicker, furrowed bark in older ones. Horizontal white lenticels give a very distinctive appearance to the bark of young **silver beech**.

*Red beech bark.*

*The dark, furrowed bark of a mature black beech tree.*

*The dark, fibrous bark of a mature hard beech tree.*

*Distinctive banding on developing silver beech.*

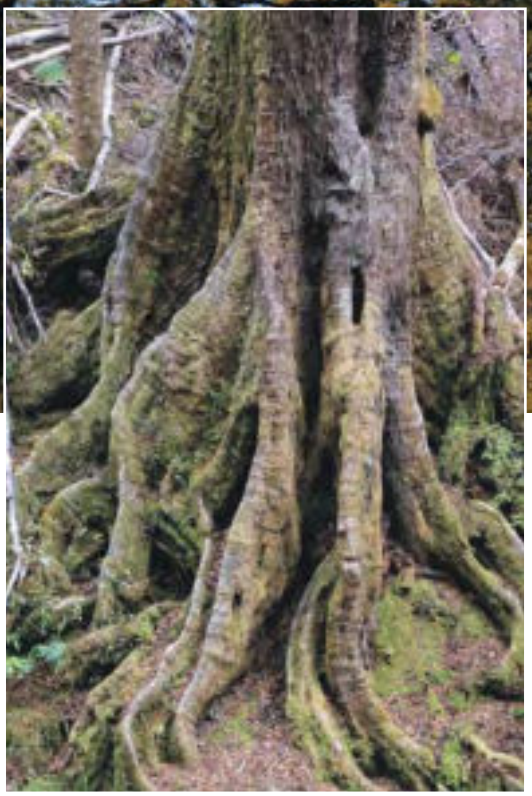
*The slate-grey flaky bark of a mature silver beech tree.*

*The fibrous, fissured bark of a mature mountain beech tree. Note the epicormic shoots, a feature of beeches.*

## Branch and tree form

Form is generally similar in all beeches and as with most trees, varies greatly between trees growing in the open and those within closed stands. Open-grown trees or those planted at wide spacing tend to have short trunks, deep, spreading crowns, and more horizontal branches. Trees within denser stands tend to have longer trunks, shallower, narrower crowns, and more upright branches. With its higher shade tolerance and tendency to grow towards light wells within existing canopies as opposed to canopy gaps, **silver beech** tends to develop somewhat poorer form than the other species (J. Dronfield, pers. com.) Altitude and site fertility also affect form. Trees growing at higher altitudes tend to be shorter. Large individuals, especially of **red**, **hard**, and **silver beech,** commonly develop basal flanges and root buttresses on deep moist soils on terraces.

*Distinctive crowns of silver beech.*



*Large buttresses often develop in older red beech trees on deep moist soils.*

*The straight, cylindrical trunks of black beech forest growing within closed stands.*

*Epicormic shoots are a feature of beeches.*

*The relatively shallow root systems of beeches makes them prone to windthrow, as with this red beech.*

### Roots systems

With relatively shallow root systems, beeches are inherently unstable in wind compared with most other tree species. During strong winds, beech trees may rock, and it is not unusual for the root plate to move several centimetres vertically. Root grafting occurs in all species and may aid stability.

## REPRODUCTION

### Flowering

The beeches are monoecious, that is, male and female flowers are borne on the same tree, but appear to be self-sterile. Trees growing in open conditions reach reproductive maturity from about 20 years onward, somewhat later in closed forest. Flowering occurs any time between early spring (September) and midsummer (January), with flowers pollinated by wind.

*In occasional mast years, the flowers of black beech colour the entire canopy red.*

*Male flowers of red beech.*

## Seed production and dispersal

The dry, nut-like seeds are shed mostly in autumn (March to May), sometimes in spring.

Seed dispersal is poor and usually accomplished by wind and gravity. Seed is relatively heavy and seldom carried more than a few hundred metres from the parent tree. The beeches have light seed crops in most years, with heavier crops at less frequent intervals. In occasional 'mast' years of exceptional flowering and seeding, the male flowers of **mountain** and **black beech** can colour the entire forest canopy red. Masting may be a reproductive strategy, producing more seeds than can be eaten by birds and insects and maximising the benefits of wind pollination (Kelly et al. 2001). It may be triggered by climatic events such as warm weather the previous summer. Recent research indicates that climatic triggers may indirectly trigger masting, for example, through their effect on nitrogen availability (Smaill et al. 2011).


*Viable (left) and non-viable (right) seed of black beech.*

*The white endosperm of a viable seed that has been cut in half.*

*Above: Beech, dispersed mostly by wind and gravity, is advancing very slowly from the edge of an existing stand.*

*Left: By contrast, with its bird-dispersed seed, totara is regenerating readily in this open landscape in the Seaward Kaikoura Range.*

*The distinctive open understorey of high-altitude mountain beech forest.*

## ECOLOGY of BEECH FORESTS

### Distinctive forests

Beech forests are some of the more distinctive natural forests in New Zealand, a fact recognised early by Leonard Cockayne (1928) who described two basic forest 'formations', southern beech forest and conifer-broadleaved forest. Their different appearance and 'feel' both outside and inside results from overwhelming dominance by just one or two beech species, whose characteristics impart an unmistakeable flavour to the forest as a whole, and from open understories.

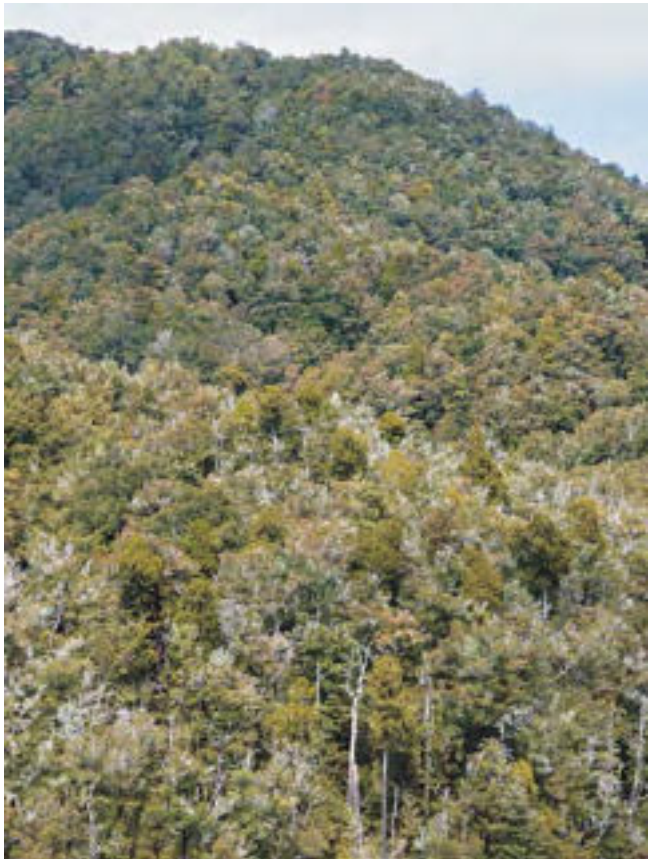
### Relationships with other species

The beeches grow with a range of other species, reflecting their wide distribution.. The most common is kamahi (*Weinmannia racemosa*), an important subcanopy tree in wetter beech forests which, along with rimu (*Dacrydium cupressinum*), is the most widespread native tree. Before widespread logging, rimu was also common in wetter forests at lower elevations in the South Island and remains common in mid-altitude beech forests in the North Island. Hall's totara (*Podocarpus cunninghamii*) is common in wetter forests at higher elevations, but has been reduced by introduced possums (*Trichosurus vulpecula*) in many areas.

Because of its predominantly northern distribution, **hard beech** grows with a wider range of other trees, including northern species like kauri (*Agathis australis*) and tawa, than the other beeches. On fertile valley floors, **red beech** and **silver beech**, singly or together, often grow with the tall conifers rimu, miro (*Prumnopitys ferruginea*), matai (*P. taxifolia*), and kahikatea (*Dacrycarpus dacrydioides*).

*Podocarps (rimu, kahikatea and matai) occupy the wetter fertile terraces with beech dominating on the drier slopes and ridges.*

*Zonation in beech forest in the Lewis River valley. Mountain beech on upper slopes, red beech with its bright green spring flush on midslopes, and silver beech on lower slopes.*



*Hard beech interspersed with rimu on the lower slopes, with hard beech only on the upper slopes and dry ridges.*

*Clear delineation between tawa and hard beech.*

Because they tolerate drier or colder conditions than other beeches, **black** and **mountain beech** can occur in near-monocultures. On infertile terraces at higher elevations, **mountain beech** grows with smaller conifers like mountain cedar/pahautea (*Libocedrus bidwillii*), silver pine (*Lagarostrobus colensoi*), and pink pine (*Halocarpus biformis*).

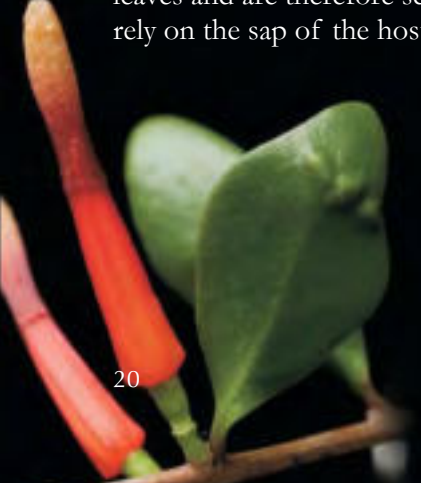
*Mountain cedar growing with mountain beech on an infertile terrace, Rahu Saddle, North Westland.*

*Silver and mountain beech share a harsh site with rata and hardy shrub species.*

## Mistletoe on beeches

Three New Zealand species of mistletoe are sometimes known as the 'beech mistletoes' as their primary host trees are the southern beeches. They form parasitic shrubs up to 3 m across within the canopy of beech trees, and are attached to branches in the crown or occasionally on main trunks of the beeches (Wardle 1984). They are red mistletoe (pikirangi – *Peraxilla tetrapetala*) whose main hosts are **mountain**, **black**, **red** and **silver beech**; Scarlet mistletoe (pirita – *Peraxilla colensoi*) found mainly on **silver beech**; and yellow mistletoe (pirita – *Alepis flavida*) most commonly on **mountain** and **black beech**. All species are found on a range of other hosts, mostly native species. Mistletoes are more commonly found in the South Island but all species are in decline due to a variety of threats, mostly browsing by possums.

The mistletoes can form a spectacular cascade of brightly coloured flowers in late spring and early summer. The flowers are pollinated by native birds and bees (Robertson et al. 1999). Strictly speaking, mistletoes are classified as hemiparasites since they are not totally dependent on the host. They retain green leaves and are therefore self-sufficient photosynthetically, but rely on the sap of the host for moisture and nutrients.



The effect of the mistletoes on the growth of beech trees is not known but may be considerable (Wardle 1984), as they can cause malformation of the trunk and often exceed the crown of the host in total leaf area.

*Top inset: The mistletoe draws water and nutrients from its host through a system of branching suckers that penetrate the bark.*

*Beech reclothes a scar from the Ingangahua earthquake (1968) in the upper Buller Gorge (1968 - left and 2011- right).*

## RESPONSE TO DISTURBANCE

New Zealand beech forests are dynamic, with disturbances causing sudden and dramatic changes that are followed by gradual changes as different kinds of forest develop after disturbance (Odgen *et al.* 1996). A disturbance is a natural (e.g., windfall) or human-induced (e.g., tree harvesting) event that disrupts an ecosystem, causing a change in resources (e.g., light and nutrients) available to plants. Structure and composition vary continuously across individual stands, partly reflecting past disturbance (Glenn-Lewin *et al.* 1992). Geological (e.g., earthquakes, landslides), climatic (e.g., gales, snowstorms, drought), and biological (e.g., insect outbreaks) events can kill stands of trees, leaving gaps in the forest that trigger dynamic responses (Orwin 2009). Avalanches and landslides from mountain tops to valley bottoms can be spectacular in destroying beech forests in alpine regions. Huge avalanche tracks up to 150 m wide can destroy substantial areas of mountain beech forest starting the slow process of forest renewal comprising even-aged stands over these disturbed sites.

Small gaps in more advanced stands can be covered over by expansion of neighbouring tree crowns, with larger gaps usually filled by beech seedlings. Dense patches of shade-tolerant seedlings establish themselves after mast years (when there are exceptional numbers of

*Strong wind and snowfall have combined to damage the canopy of this silver beech forest.*

*Large areas of windthrow in mountain beech forest on terraces (arrows) in the upper Waimakariri River, Canterbury.*

*Canopy trees in black beech forest damaged by heavy snowfall.*

*A large outbreak of scale insects (*Inglesia fagi*) in drought-stressed red/silver beech forest in the Maruia Valley caused extensive dieback on the lower and mid slopes.*

*Mountain beech forest in Canterbury high country.*

flowers and seeds), but their growth is restricted by low light. The seedlings can persist in the understorey for decades. When large trees die, extra light and nutrients become available and the seedlings can grow into trees.

In forests of mixed beech, or beech with other trees, responses to gaps are partly determined by varying shade tolerances, which can vary over the life of a species (Kunstler et al. 2009). For example, in **mountain–silver beech** forest, faster-growing, light-demanding **mountain beech** seedlings initially fill new gaps, but the more shade-tolerant, longer-lived **silver beech** gradually takes over. In **red–silver beech** forest, small gaps tend to be captured by **silver beech** and larger ones by **red beech** (Stewart *et al.* 1991).

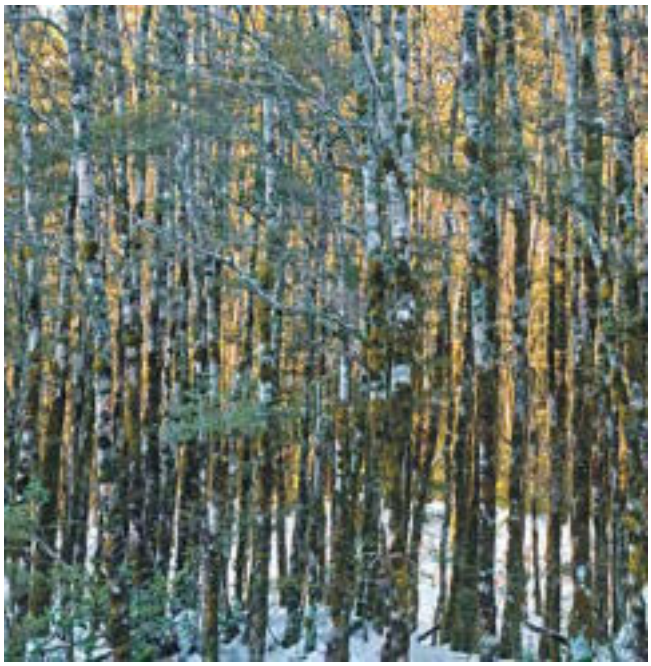
In some places, e.g., **red-silver beech** forest in Maruia valley, the scale of variation caused by disturbance is small, up to 0.1 ha, with only individual or small groups of trees dying (Stewart *et al.* 1991). Small canopy gaps close over by growth of branches of neighbouring tree crowns, rather than expand because of further tree death caused by pinhole borer (*Platypus* spp.) beetles or instability of edge trees. The abundance and growth rate of beech seedlings depends upon species, location in a canopy gap, and the size of canopy gap (Runkle *et al.* 1995). Because canopy gap closure is common, regeneration and hence forest age structure often reflect extensive canopy damage rather than small treefall gaps.

*Heavy snowfall that accumulates at altitude in high basins and steep broken country often results in huge avalanches which destroy significant tracts of beech forest as illustrated in this photo of a side-stream in the upper Wairau River catchment, Marlborough. Natural events such as this are part of the dynamic renewal process of South Island high country beech forests.*

*Huge avalanche tracks up to 150 metres wide through mountain beech forest. The damage is often not restricted to the immediate down-slope path of an avalanche - in extreme cases avalanches that reach the valley floor often continue up the opposite slope for some distance, with the force of the wind created by the avalanche laying waste to forest further uphill.*

**Mountain beech** forest often comprises large–scale mosaic of stands of different ages that tend to die over substantial areas, creating large gaps and initiating the development of new more-or-less even-aged stands.

*Black beech forest regenerating after a heavy snowfall.*



*Dense c.30-year-old mountain beech pole stand, Lewis Pass highway.*

## NATURAL REGENERATION

### Early establishment and survival

Beech seedlings in the early stages of establishment are particularly vulnerable to dry conditions with high losses of seedlings in their first summer and autumn. High losses occur on deep drought-prone litter sites compared to sites with a thin mulch of moss and litter.

Shady levels provide higher moisture conditions so survival tends to be greater initially under shade than in the open. The optimal conditions for red and mountain beech are probably at 35% of full light.

The susceptibility of young beech seedlings to dry conditions, coupled with their specific light requirements, probably accounts for few seedlings surviving into the second year where there is dense ground cover vegetation. Often the best survival can be seen where beech seedlings have established on surfaces elevated above the forest floor such as rotting logs and root mounds.

*Dense crown fern (*Blechnum discolor*), a common ground cover in beech forest often inhibits the establishment of beech regeneration.*

*A large red beech that established on an elevated site (probably a fallen tree) – the roots have grown down around the windfall which over time has rotted away, leaving the tree perched.*

*Elevated root mounds such as this windthrown red beech can provide elevated sites for regeneration of beech seedlings. Inset: Red beech seedling on windthrown red beech.*

### Regeneration characteristics

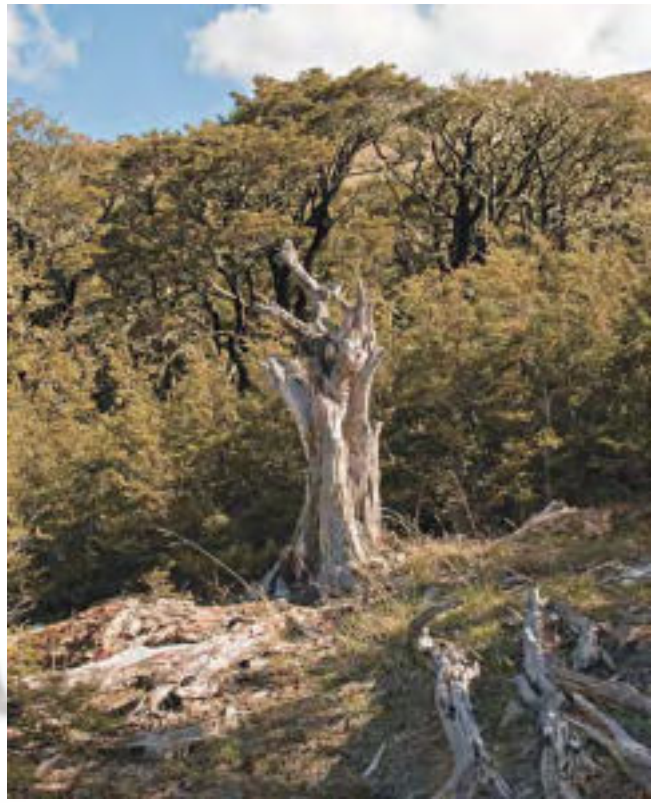
The beeches have markedly different shade tolerances, reflected in the way that old-growth forests regenerate.

**Mountain beech** is the least tolerant of shade, and its canopies are often even-aged or at least have a limited age range. Its forests often regenerate *en masse* after death of existing canopy trees from old age ('cohort senescence') or catastrophic disturbance such as windthrow ('catastrophic' regeneration mode). The 'banks' of seedlings on the forest floor slowly turn over, but grow rapidly if light levels increase enough, as happens when the canopy above dies. However, apparent responses to increased light from canopy gap formation may result at least partly from reduced root competition (Platt *et al.* 2004).

**Silver beech**, whose canopies often comprise trees of a wide range of ages is most tolerant of shade. Its forests often undergo continuous replacement by individual trees or small groups of trees that grow up beneath existing canopy trees or in small gaps ('continuous' regeneration mode). Intermediate between them are **red beech** and **hard beech,** which show both continuous and catastrophic regeneration modes.

*Black beech maintains a bank of seedlings on the forest floor, awaiting canopy opening.*

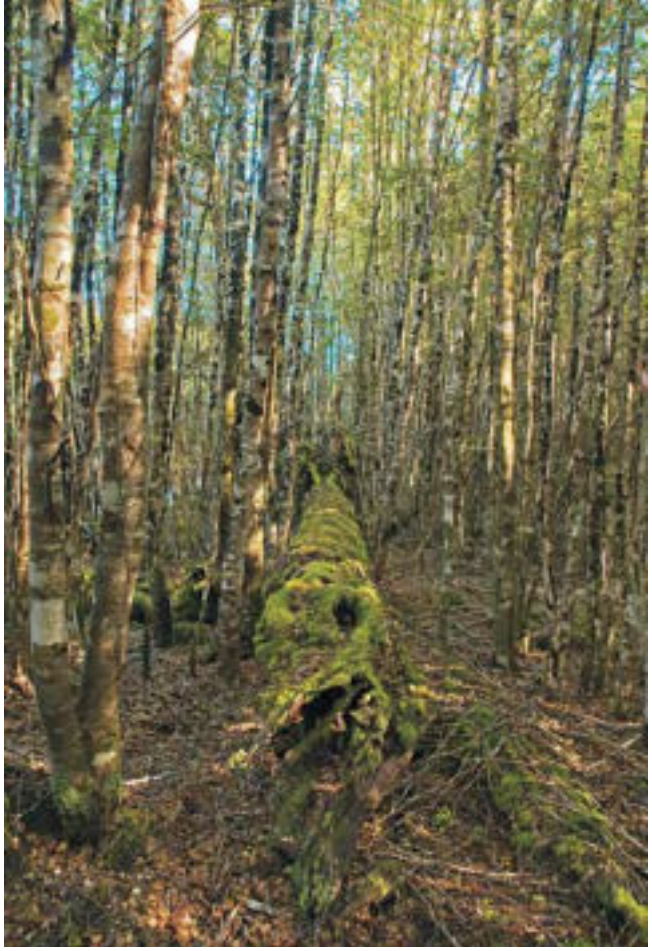
After clearfelling or major site disturbance, beeches regenerate *en masse* on limited areas from surviving small seedlings or by seed rain from nearby stands. Dense even-aged thickets of saplings with stand densities as high as hundreds of thousands of stems per hectare develop. As individuals grow, 'self-thinning' during the following 100 years (mostly the first 50) reduces densities to final stockings of several hundred stems per hectare (Smale *et al.* 1987). Pole stands are common in regions like north Westland where catastrophic disturbance by mining was widespread, but also occur wherever the wind has blown down patches of existing forest, often on shallow soils. Beech seedlings establish more readily on some microsites than others. Fallen logs ('coarse woody debris') and bare soil are suitable, but dense ground layers of ferns are not (June and Ogden 1975).



*Mountain beech regeneration that has developed around the mother tree that has since died and collapsed.*

*Patterns in mountain beech forest created by catastrophic wind and snow events.*

*Beech regenerating vigorously after windthrow of the previous canopy.*



*A dense red beech pole stand has developed after windthrow of the previous stand.*

In **red-silver beech** forest, larger coupes provide better conditions for the regeneration of **red beech** and smaller ones for **silver beech**, reflecting the lower shade-tolerance of **red beech**. Thus a range of sizes of harvested areas will promote a more mixed-species forest, whereas uniform harvesting areas are likely to favour one species over the other (Wiser *et al.* 2007).

*Dense red beech regeneration following clearfelling.*

## Mycorrhizae and the beeches

A group of fungi known as ectomycorrhizae enjoy a mutually beneficial relationship with the New Zealand beeches. Mycorrhizae associated with the beeches and appear as a sheath of fungal hyphae covering the surface of the fine roots. Apart from teatree (*Leptospermum* and *Kunzea)* and *Pomaderris* species, beech is the only widespread New Zealand genus that has ectomycorrhizae.

Mycorrhizal associations are generally assumed to provide some benefit to the host species. Living on the tree roots, the fungi take sugars while in return the beech tree absorbs nutrients which the fungus has absorbed from the surrounding soil. While there is conjecture as to precisely how and to what extent beeches benefit from mycorrhizae, various experiments have shown beech seedlings grow significantly faster with mycorrhizae than those without.

*Mycorrhizae on the roots of mountain beech.*

It has been suggested that the apparent limited ability of the New Zealand beeches to disperse into neighbouring plant communities may be due to a lack of suitable fungi for mycorrhizal associations. It has also been suggested that the apparent ease of the beeches to spread into manuka scrub compared to other shrubland types may be due to the two genera sharing ectomycorrhizal symbionts (Wardle 1984).

An implication for raising and planting of the beeches is the need to ensure that nursery propagation mixes are inoculated by suitable mycorrhizae. This is usually achieved by mixing in a small proportion of duff and top soil collected from beech forest into potting mixes for container-grown seedlings and into nursery beds for raising beech as open-ground stock.

# PART 5 - VALUES of BEECH FORESTS

*Beech forest is a feature of high country landscapes popular with trampers.*

## NON-TIMBER BENEFITS

Beeches contribute a wide range of values and uses. Beech forests are used for walking and tramping, recreational and commercial hunting, sphagnum moss harvesting, beekeeping (using honeydew), and timber production, and provide the backdrop for much tourism. Because most beech forest grows in upper catchments, it also has important soil and water conservation functions (Orwin 2009).

### Amenity (recreation, aesthetics)

Beeches provide the predominant forest cover in our National Parks, so contribute enormously to the aesthetics experienced by recreational users of them. Major scenic highways like the transalpine passes in the South Island and renowned walks like the Routeburn and Milford Tracks pass through extensive tracts of beech forest, which provide important scenic backdrops for travellers and trampers. Even in our productive landscapes, remnants of beech forest exist as attractive shelter and shade on farms.

*Many important tourist routes pass through extensive beech forest. This is the Lewis Pass highway.*

Beech forests support every species of deer (apart from sambar, *Rusa unicolor*) established in New Zealand and simply because they comprise so much of the remaining native forest, are the major habitat for red deer (*Cervus elaphus*) and sika deer (*C. nippon*) and a locally important one for fallow deer (*Dama dama*). They are therefore a major recreational and commercial hunting resource.

*The significant upland forests dominated by the beeches provide critical watershed protection such as this mountain beech forest surrounding an alpine tarn near the summit of the Lewis Pass.*

## Watershed protection

As the predominant forest cover on the mountain ranges of both main islands, forests dominated by red, mountain, and silver beech play a critical role in on-site watershed and downstream flood protection.

*High altitude mountain beech forest.*

*On-going development of beech in a dynamic landscape.*

Fully stocked stands provide interlocking root systems in unstable mountain areas. Dense canopies intercept heavy rainfall and filter runoff from these sites. Without these catchment forests, many of our rivers would have higher sediment levels.

*High altitude mountain beech forest with very little shrub layer.*

## Biodiversity

Although usually simpler in structure and less diverse in composition than conifer-broadleaved forests, beech forests nevertheless provide habitat for a wide range of native flora and fauna, some of which may be specific to beech forest. The honeydew secreted by scale insects from beech sap is an important food source for birds such as honeyeaters.

*Beech forest provide habitat for a wide range of native fauna, like the South Island robin.*

## Carbon storage

In terms of both individual species and forests, beeches are major contributors to carbon storage in native forests with the five beech species accounting for 48% of the total carbon stored in native forest. Amongst native tree species, **silver beech** at nearly 20% and **red beech** at 15% are the biggest contributors to carbon stocks, followed by **mountain beech** at 8% and **hard** and **black** beech at 3% each (Beets *et al.* 2009).

## Honey

There is a small, Canterbury-based industry that exports honey derived from **black beech** honeydew. Attack by the introduced wasps (*Vespula* spp.) which compete for the honeydew can result in loss of weak beehives, especially in lower altitude beech forest with even strong hives susceptible, particularly in autumn months (Wardle 1984).

*Honey from black beech forest provides the basis of a small export industry.*

## TIMBER

Beeches collectively constitute the largest native timber resource remaining in New Zealand, with long-appreciated potential for sustainable management. There are some 165 000 ha of freehold forest with a significant beech component below 900 m asl, dominated by **red** and **silver beech**. It is conservatively estimated that this resource could produce around 200 000 $m^3$ of sawlog-quality timber per annum. Some 45 000 ha of forest with a significant beech component is currently covered by sustainable management plans registered with MAF (Donnelly 2011). Past and present uses of beeches are discussed in a later section.

*Logging in beech forest.*

## SUSTAINABLE TIMBER PRODUCTION

In the early 20th century, beech forest was recognised as a potential sustainable, high-quality timber resource (Cockayne 1921). Since then, foresters have proposed a number of management schemes but because of low native timber prices, cheap imported timber and conservation groups' opposition to harvesting native trees, there has been no large-scale, sustainable beech forestry (Orwin 2009).

*Chipwood logs await transport to the processing plant at Nelson.*

In the 1970s, logging of publicly-owned beech forests in Westland and Nelson was opposed by conservationists. In 1986, conservation groups, the timber industry, and the New Zealand government signed the West Coast Accord, an agreement that allowed for the sustainable management of 130 000 hectares of publicly-owned beech forest for timber production. The government stopped the scheme in 1999 and a year later, all beech logging on public land in Westland ceased when management of all native forest in Crown tenure there was transferred to the Department of Conservation (Orwin 2009).

In Southland, rimu/beech forest on SILNA Maori land (granted under the South Island Landless Natives Act 1906) at Waitutu was destined for harvesting until 1996 legislation protected this block as if it were a national park. The agreement gave the landowners alternative cutting rights to Crown land in western Southland that was already being managed for timber production (Orwin 2009). Now managed according to the Forests Amendment Act 1993, this operation was awarded Smart Wood/Forest Stewardship Council certification in 2004, possibly the first managed Australasian native forest to achieve this stringent international environmental accreditation.

*Aerial harvesting enables timber to be removed with minimal impact on the residual forest.*

## BEECH FORESTRY TODAY

Today's small but potentially valuable native forest industry is based on timber harvested under strict conditions that seek to balance commercial use and intrinsic natural values. Under the Forests Amendment Act 1993, indigenous timber can only be produced from forests that are managed in a way that maintains continuous forest cover and ecological balance. Management systems must ensure that the forests continuously provide a full range of products and amenities, in perpetuity, while retaining the forests' natural values. Only single trees and small groups of trees can be felled for timber production. Controls on sawmills mean they may only mill logs of indigenous species sourced from forests managed according to sustainable management plans or permits, or other approved sources (MAF 2012).

The beech log volume received by registered sawmills in 2011 was just over 10 000 $m^3$, mostly silver beech (Ministry of Agriculture and Forestry, unpubl. data). This represents only about 25% of the volume of beech available for harvesting under approved sustainable forest management plans. Furthermore, approved plans and permits cover only about one-quarter of the potentially manageable resource (Donnelly 2011), so this is a very under-utilised resource.

## NEW ZEALAND SUSTAINABLE FOREST PRODUCTS LP

New Zealand Sustainable Forest Products LP, based in Reefton, is currently the major producer of red beech timber and has been selected by the United Nations Forestry Commission as one of the leading examples of exemplary forest management in the Asia–Pacific region. Its products are marketed under the 'Natural Beech' brand. It also produces silver beech and hard beech.

In 2007, the estate managed by NZSFP comprised 4 500 ha of forest, providing an annual yield of 7 000 $m^3$ of red and silver beech sawlogs, of which red beech comprised 70 percent of the yield. Forests are harvested annually in a sequence to provide a continual reliable log supply to the market.

'Natural Beech' is finished into a variety of products including veneer, furniture-grade timber, dimensional timber, and decking. Several engineered red beech flooring products feature click-lock jointing and pre-finished coatings for ease of installation.

*Air drying of filleted red beech (left) and the kiln used for drying (right), New Zealand Sustainable Forest Products LP sawmill, now located at Reefton.*

*Rough sawn beech awaiting processing into flooring and panelling, New Zealand Sustainable Forest Products LP.*

*Panelling (left) and laminated flooring of red beech (right), New Zealand Sustainable Forest Products LP.*

## Platypus pinhole beetles and the beeches

*The effects of Platypus pinhole beetles and the associated fungal pathogens of the genus* Sporothrix *are of major importance to the beech forests – both ecologically and economically (Wardle 1984).*

There are three species of platypus beetle (*Platypus* spp.) which bore and rear brood in the wood of all five of the beeches. Living trees are frequently attacked but it is likely that the habitat most favourable is recently dead and persistently moist wood. Sawn wood as well as logs can be attacked, but as soon as the surface of the wood dries out, it becomes less attractive.

*Red beech illustrating a clear delineation between the dark stained heartwood and the outer wood. The tree appears to have grown through (and healed after) a period of pinhole attack as shown by the spikes (arrow), with fungal staining at various points around the periphery of the heartwood.*

The living trees of beech which are attacked by platypus beetles are those that are often under stress from a range of factors including competition within the stand, drought or flooding. Some studies suggest fast growing trees may be more susceptible. Older trees with increasing bark thickness appear to be less susceptible but on the other hand, older trees tend to be slower growing.

*The typical black and brown lens-shaped discolouration of the wood of black beech extending longitudinally from the point of infestation and along the tunnels of Platypus beetles leading to the core of dead pathological wood.*

*Centre rot is common in old-growth beech trees.*

*Pinhole damage in red beech sawn timber.*

The success of attack on living trees depends largely on whether the tree or the infected part of the tree dies. If the tree does not die, the attack is aborted as the beetles drown in gum exuded from damaged tree tissue. If the tree or part of it dies, then the brood can be reared.

Beech forests that have been damaged by logging or silvicultural treatment, or by climatic events such as snowbreak or windthrow, provide favourable habitat for platypus infestation. Forest that are predominantly overmature are also vulnerable to severe attack.

Platypus are of major importance in beech forest management and therefore influence the nature of silvicultural and harvesting practices. This includes reducing the amount of suitable brood-rearing wood at critical times when crop trees are most susceptible.

Although the mechanical boring by platypus can detract from the appearance of the wood, the main importance of platypus is its role as a vector for the fungal pathogen genus *Sporothrix*. The platypus tunnels allow transmission of the fungus into the inner sapwood where the pathogen then spreads outwards, killing wood tissue until it reaches limits imposed by wood moisture and the tree's defensive reactions. Severe attack can kill trees, particularly if under water stress from drought, excessive competition or root damage. Trees that survive attack are left with black and brown discolouration in the wood extending longitudinally from the point of infection along the platypus tunnels. Both the length and width of these lens increase towards the inner sap leading to a core of dead pathological wood which is stellate in section. This pathological wood can subsequently develop rot pockets where pathways to the exterior occur via branch stubs or wounds. These are probably the most serious defects encountered in beech sawlogs (Wardle 1984).

## HISTORY OF BEECH PLANTATIONS

### Early experience

Because the beeches regenerate prolifically in existing forests, relatively few plantations have been established. The 1913 report of the Royal Commission on Forestry reinforced existing perceptions that native trees were difficult to establish and too slow-growing to manage for timber production. Nevertheless, the beeches are amongst the fastest-growing of all planted native trees (Pardy *et al.* 1992) and present good prospects for plantations.

### Later planting

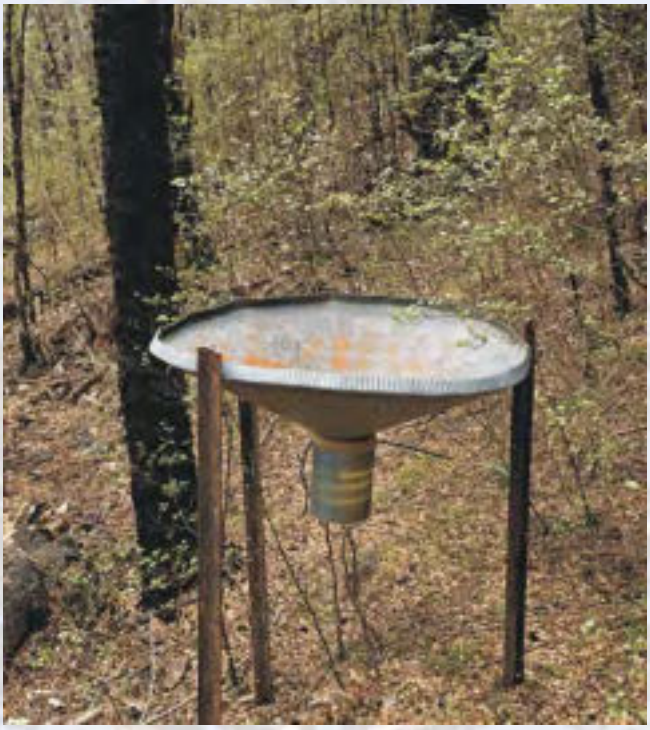
A substantial number of small beech plantations have been established since 1900, mostly in urban parks and on freehold land. An nationwide survey by Pardy *et al.* (1992) showed **red beech** to be the most widely planted species (14 plantations), with **silver** and **black beech** less so (11 each). A more recent survey showed **red beech** (16 plantations) and **black beech** (15) to be the most widely planted species, **silver beech** (7), with only two plantings of **hard beech**.

## RAISING AND PLANTING BEECHES

### Seed collection

Good crops of both **red** and **silver beech** seed occur every few years, and there are sometimes two consecutive years with negligible seedfall. **Hard beech** appears to produce less seed and can have four years with negligible seedfall (Schauber et al. 2002). A common mast seeding interval in **mountain beech** is seven years (Allen et al. 2011). Ripe seed falls between February and June, mostly in March and April. **Silver beech** can have a second smaller peak in spring (Burrows and Allen 1991).

As seed is relatively heavy and only has small wings, most falls within the vicinity of parent trees. Seed can therefore be collected using seed traps placed under trees during the peak of seedfall. Litter can be sieved to separate mostly seed, which then requires drying.



*Seed collection.*

*Silver beech cupules opening to reveal the seeds inside.*

*Beech seed is relatively heavy, and mostly falls beneath the parent tree. This is black beech seed and litter in north Canterbury.*

## Seed storage and preparation

Seed can be stored for up to 8 years, preferably no more than 3 years, in suitable conditions – airtight at 5-10°C and 6% moisture content – but rapidly loses viability otherwise. In preparation for seed sowing and after a long period of dry storage, seed will require soaking and be kept in moist cool storage at 2-4°C for 3 months with free air circulation ('stratification') before spring sowing (Forest Research Institute 1980).

## Propagation

Stratified beech seed is sown in spring into seed trays. Seed is covered to a depth of 6-8 mm with coarse sand and germinated in standard sheltered warm germination facilities. Mycorrhizal innoculation has historically been achieved by mixing in forest duff. Beeches generally have rapid and relatively even germination, with seedlings emerging 2-4 weeks after sowing. All the beeches can be easily raised in nurseries as either container-grown seedlings or as bare-root transplants in open beds. **Red beech** takes up to two years to raise to a 40-60 cm high seedling from sowing whereas **silver beech** may take up to three years.

*Red beech seedlings in the nursery.*

## Planting

Most planting out of nursery-raised stock has involved 2-year-old seedlings of **red**, **silver** and **mountain beech**. Tall (>40 cm) nursery-raised seedlings of **silver beech** can be successfully established on sheltered sites. While **silver beech** tolerates more shade than the faster-growing **red beech**, it has weaker apical dominance and becomes bushy when planted in the open. Side shade is required to improve form. Saplings can be attacked by larvae of the puriri moth (*Aenetus virescens*) in the North Island and larvae of the kanuka longhorn beetle (*Ochrocydus huttoni*) in both islands.

*Planting beech seedlings after harvesting.*

Survival of early plantings by the New Zealand Forest Service was often poor, particularly on open or difficult forest sites. The main causes of failure were smothering by grass, nipping of shoots by rabbits and hares, drought during the first summer (particularly in seedlings transplanted onto mineral soils), unseasonal frosts, and winter desiccation (occurring when cold soil prevents roots absorbing water, aggravated by desiccating winds that increase evapotranspiration from foliage). The optimal conditions for survival and growth of transplanted seedlings in forest are canopy gaps about 20 m wide, or where there is more-or-less continuous light overhead shade. Under these conditions, root competition with the overwood is

slight, but the vigour of grass and other competitors is greatly reduced. In the open, survival prospects for beech are enhanced by first establishing a fast-growing 'nurse' of species such as manuka (*Leptospermum scoparium*), which may share mycorrhizal fungi with beeches, araliads like fivefinger (*Pseudopanax arboreus*) and threefinger (*P. colensoi*), coprosmas and hebes that can ameliorate microclimate above and below ground.

Nursery-raised seedlings of **red beech** generally have better survival in cooler climates; mortality can be high in warmer lowland regions.

*Black beech planted on an open river terrace in North Canterbury.*

Natural regeneration in disturbed natural stands can usually be increased by screefing by tractor or by hand (moving humus layers to expose the underlying mineral soil).

A novel approach being evaluated on a frost-prone North Canterbury site is the use of radiata pine (*Pinus radiata*) to provide initial shelter (Kevin Platt, pers. comm). Planted **black beech** seedlings surrounded by the pines have proved successful in ameliorating site and climatic conditions resulting in high early survival and growth.

*Planted pines around this black beech have provided the shelter required for successful early establishment on this particularly exposed frosty site (left). In contrast, black beech seedlings planted in the open on the same site with no shelter have often died (right).*

## MANAGING BEECHES

### Tending

Beeches have relatively shallow root systems and often grow on shallow soils in windy regions, so are prone to windthrow. Although they have inherently good form, like many species, they – especially **silver beech** – tend to become multi-leadered and develop large branches when grown in lightly stocked stands or in the open. When larger, they are also prone to attack by pinhole borer, especially if close to dead or dying trees.

Thinning is used to promote individual tree growth, thereby shortening rotations, and often to develop even-aged stands. Thinning philosophies have been conditioned by three major constraints:

- maintaining wind-firmness;
- maintaining good form, including controlling branch diameters without pruning; and
- reducing attack by pinhole borer.

### Thinning trials in natural stands

Trials set up by the New Zealand Forest Service from the 1930s to the 1960s show an evolution of tending ideas over time. Early trials maintaining stands at high density until light late thinning showed little response in individual tree growth, and suffered substantial subsequent tree losses through windthrow and/or pinhole borer attack. Thinning larger trees also creates larger gaps which are filled more slowly than smaller ones, an inefficient use of growing space. Later trials from the 1960s onwards involving heavier earlier thinning produced better individual growth responses and more wind-firm stands, but trees needed pruning to ensure good form and control of branch size. Any thinning should be carried out before the trees are susceptible (over 15 cm diameter) to pinhole borer attack (Franklin 1995).

*A thinned and pruned red beech stand at Staircase Creek, North Westland.*

With its relatively high shade tolerance, even-aged **silver beech** stands maintain high stockings, self-thin very slowly, and individual tree growth tends to stagnate. Thinning trials in **silver beech** forest in the Alton Valley in western Southland confirm that heavy early thinning of 20-30 year old stands to 250 stems/ha or less can greatly increase yields of merchantable sawn timber (Easdale *et al.* 2009). **Red** and **hard beech** also benefit from thinning. Trials at Staircase Creek, north Westland, showed that several thinnings between age 13 and 30 years reduced stocking to 190 trees/ha and maximised merchantable stand yield by around 60 years of age (Easdale *et al.* 2010). The intensive tending

demonstrated in these later thinning trials is considered the best option for producing high-quality timber in acceptably short rotations. Several lighter thinnings are currently suggested as preferable to one heavier thinning to reduce the risk of sunscald on residual stems especially on exposed sites. However, they are more expensive than one operation. Over the whole rotation, early thinning involves more cost than late thinning.

Franklin and Beveridge (1977) suggest that pruning should be completed a year or two before final thinning as both operations carried out in the same year can result in increased production of epicormic shoots. Epicormic shoots are not uncommon on open stands of planted beech after stem pruning.

*Even-aged (58-year-old) mixed red and hard beech stands at Staircase Creek, north Westland. The stand above was thinned to 250 stems/ha; the stand below was left unthinned (> 10 000 stems/ha).*

*Inset: Epicormic shoots arising after branch pruning of this 14-year-old planted silver beech, Gore, Southland.*

## GROWTH OF PLANTED STANDS

### Height growth

As with all trees, growth rates of beeches vary widely with site conditions and stocking rates. Nevertheless, general patterns are readily apparent. In natural stands, the height/age relationship usually follows a sigmoidal pattern, with growth rates peaking during the sapling and pole stages (generally between years 20 and 60). Generally, maximum height growth occurs earliest where stems are sheltered by surrounding trees but are far enough away from them to avoid excessive competition.

Maximum annual height growth rates within natural stands are 0.3-0.6 m for **red** and **black beech**. Growth rates of **hard beech** are usually less and **silver beech** considerably less again. Maximum height growth rates usually occur in trees on sheltered sites and fertile soils where the canopy of the forest is open. Thinning trials indicate that height growth can probably be increased, particularly if stands are lightly thinned. One trial in **red beech** showed that in the first year or two, growth was slightly depressed but was enhanced in the subsequent three years. The net effect over a five-year period was that stems in lightly thinned plots grew faster than controls while those in heavily thinned stands grew at the same rate.

In plantations, annual height increment over 80 years averaged 34 cm in **red** and **black beech** and 23 cm in **silver beech** (Pardy *et al.* 1992). A recent nationwide survey of 19 plantations aged between 10 and 110 years confirmed **red** and **black beech** as the fastest growing species, with **silver** and **hard beech** significantly slower (Figure 1, Table 1).

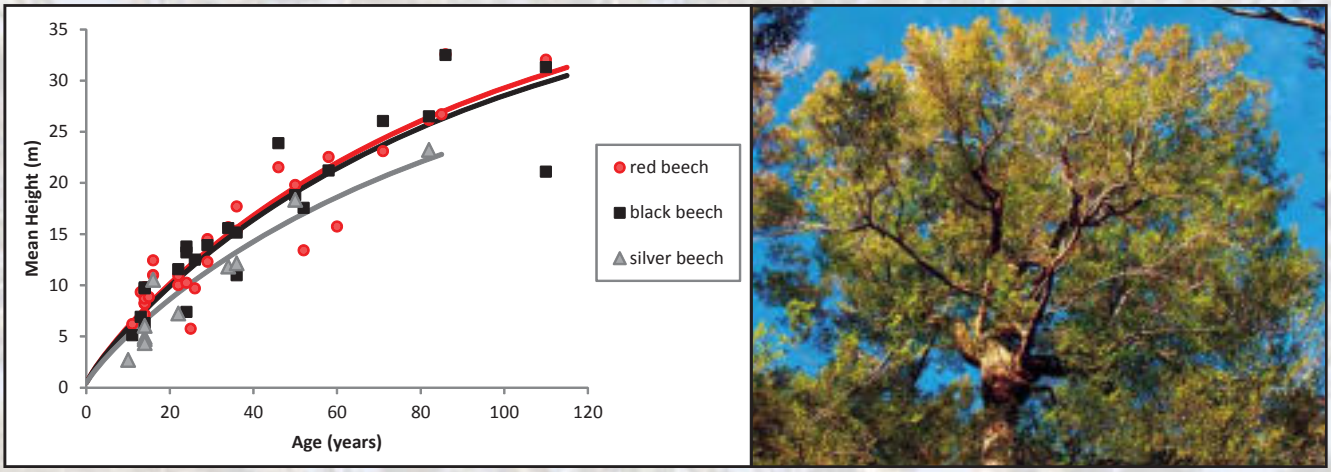



Figure 1: Mean height of beeches in plantations aged between 10 and 110 years.

### Diameter growth

The diameter/age relationship appears more linear than the height/age one (Pardy *et al.* 1992), although diameter growth rates do increase over the life of the tree, albeit at a slowing rate (Hurst et. al. 2007). Although diameter growth rates exceeding 1 cm/year can probably be attained by all the New Zealand beeches, these are only on fertile soils in mild climates in fairly open stands. As the site deteriorates or competition increases (as reflected in stand basal area: Hurst *et al.* 2007), diameter growth rates are reduced.

The effect of stand competition on diameter growth rates can be severe, with growth rates of less than 1 mm/year recorded widely in natural forest. Marked increases in diameter growth occur in smaller (<60 cm DBH) **red**, **hard** and **silver beech** trees at the edges of clearfelled coupes after release from competition (Wiser *et al.* 2005).

In general, **red beech** is the fastest-growing of the beeches, **silver beech** the slowest, with **hard**, **black** and **mountain beech** having intermediate growth rates. In large samples in natural forest, a mean growth

rate of 1.2 mm/year was recorded in **silver beech**, 1.5 mm in **black** and **mountain beech**, 1.9 mm/year in **hard beech**, and 2.1 mm/year in **red beech** (Hurst *et al.* 2007).

In plantations, annual diameter increment over all ages averaged 8.8 mm in **red beech,** 8.3 mm in **black beech** and 8.2 mm in **silver beech** (Pardy *et al.* 1992). The recent nationwide survey of 19 plantations aged between 10 and 110 years confirmed generally similar growth rates among the species, with **red** and **silver beech** the fastest growing (Figure 2, Table 1).

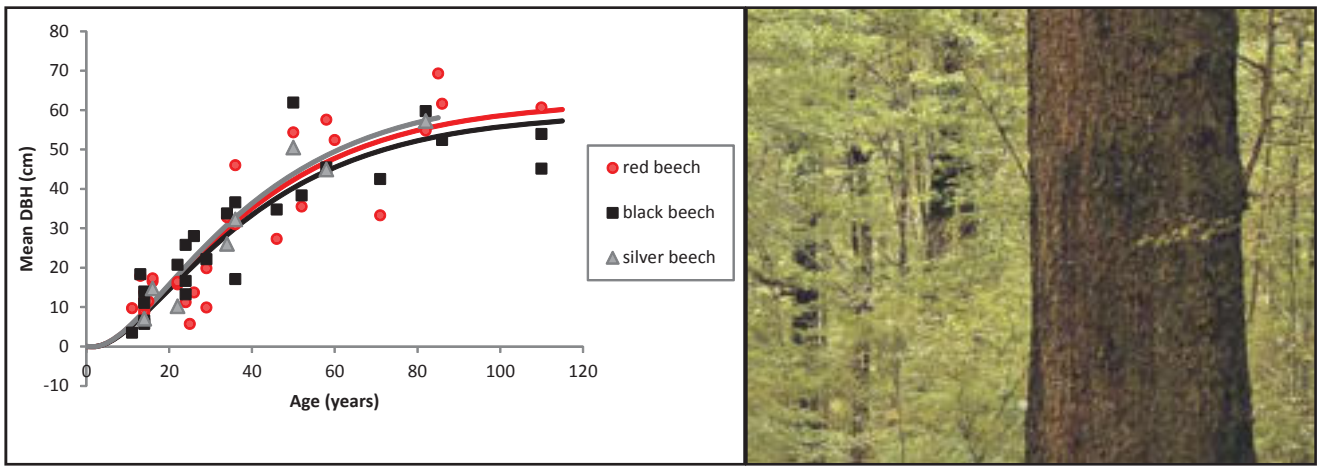



Figure 2: Mean diameter of beeches in plantations aged between 10 and 110 years.

| Age | Height (m) | | | | DBH (cm) | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Red | Silver | Black | Hard | Red | Silver | Black | Hard |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 4 | 3 | 4 | 3 | 1 | 1 | 1 | 1 |
| 10 | 6 | 5 | 6 | 5 | 5 | 5 | 5 | 5 |
| 15 | 8 | 6 | 8 | 7 | 10 | 10 | 9 | 10 |
| 20 | 10 | 8 | 10 | 8 | 15 | 14 | 14 | 14 |
| 25 | 12 | 9 | 12 | 10 | 20 | 19 | 18 | 19 |
| 30 | 14 | 11 | 14 | 12 | 25 | 24 | 22 | 24 |
| 35 | 16 | 12 | 16 | 13 | 30 | 28 | 27 | 28 |
| 40 | 17 | 13 | 17 | 14 | 34 | 32 | 30 | 32 |
| 45 | 19 | 14 | 19 | 15 | 38 | 36 | 34 | 36 |
| 50 | 20 | 15 | 20 | 16 | 42 | 39 | 37 | 40 |
| 55 | 21 | 16 | 21 | | 45 | 43 | 40 | |
| 60 | 22 | 17 | 22 | | 48 | 45 | 43 | |
| 65 | 23 | 18 | 23 | | 51 | 48 | 45 | |
| 70 | 24 | 19 | 24 | | 53 | 50 | 47 | |
| 75 | 25 | 20 | 25 | | 55 | 52 | 49 | |
| 80 | 26 | 21 | 26 | | 57 | 54 | 51 | |
| 85 | 27 | 22 | 27 | | 59 | 56 | 53 | |
| 90 | 28 | 22 | 28 | | 61 | 57 | 54 | |
| 95 | 29 | 23 | 29 | | 62 | 59 | 55 | |
| 100 | 30 | | 30 | | 63 | | 56 | |
| 105 | 30 | | 30 | | 64 | | 57 | |
| 110 | 31 | | 31 | | 65 | | 58 | |

Table 1: Predicted mean height (m) and diameter (cm) of beeches in plantations at various ages.

## Growth and yield

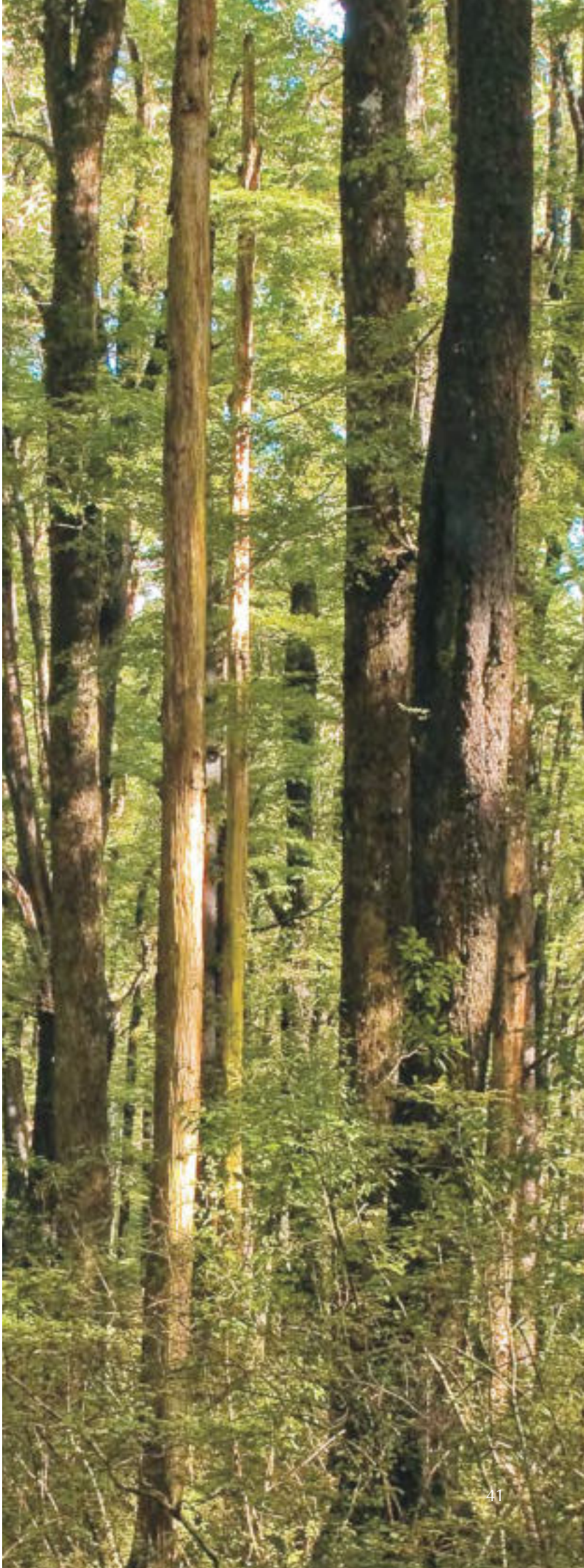
Typical standing wood volumes of sawlog quality in unmanaged virgin beech forest range from 70-200 $m^3$/ha. They tend to be higher in **silver** and **red beech** forest than in **black** and **mountain** or **hard beech**. Volumes in exceptional stands of **red** and **silver beech** can exceed 400 $m^3$/ha.

If smaller and lower-quality sawlogs are included, merchantable volumes are boosted significantly, with about 450 $m^3$/ha in virgin lowland stands of **silver beech**, and over 400 $m^3$/ha in **mountain beech** forest. Mean annual volume increment in 70-80 year old **red beech** is normally 6-9 $m^3$/ha, in **silver beech** 5-8 $m^3$/ha, and somewhat less for **black** and **mountain beech**. Pole stands of **red** and **hard beech** can acquire total volumes in excess of 400 m3/ha over their first 100 years (Smale *et al.* 1987).

## STOCKING RATES AND STEM FORM

Beech forests usually regenerate naturally at very high densities which produce good form, including branch control, in most stems at the expense of fast growth. Nevertheless, younger stands contain appreciable numbers of poorly-formed (multi-leadered) stems, some of which persist to the final stocking. It was suspected that thinning could lead to excessive branching and early crown formation and hence poor tree form, so foresters tended to be conservative in their silviculture of natural beech forest. With their stronger apical dominance as saplings, **red** and **black beech** will tolerate earlier and heavier thinning than **silver beech**, which tends to form a crown earlier when grown under open conditions. Normal (growing season) and winter dessication as well as sunscorch can lead to dieback of apical shoots, leading to replacement by lateral shoots and consequent poor form.

Planted stands at wide spacing require pruning of lower branches and occasional double leaders otherwise invariably many trees end up with poor form. Even at stem densities of 2000 stems per ha (2 m spacing between trees), beech will require both branch and stem form pruning to ensure the development of a branch-free lower trunk.



*A 30-year-old plantation of black beech established at 3 m spacing (1100 stems per ha), Banks Peninsula. Without tending, beech planted at wide spacing typically have poor form comprising short boles and large branching to low levels.*

*These beech planted at 1800 stems per ha by John Purey-Cust (inset) 14 years earlier have required pruning of lower branches and removal of occasional multiple leaders to produce a single branch-free lower bole.*

*Left: A densely planted 30-year-old black beech grove showing multiple stems and coarse branching, Matawai Park, Rangiora.*

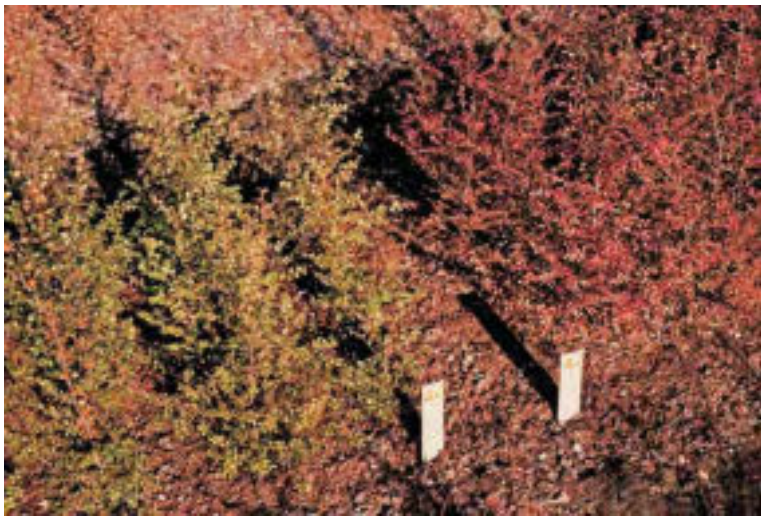
## PROVENANCE VARIATION

Variation in growth and morphology of nursery-raised seedlings from different parts of the country was studied by Wilcox and Ledgard (1983) primarily to give guidelines for defining zones for seed collection and transfer. A further driver was to identify superior seed sources, should the species be planted extensively for production forestry. Seed of all species was collected from natural stands throughout the country, and seedlings raised in replicated provenance experiments at a nursery in Rotorua and in Rangiora, near Christchurch.

**Silver beech** appeared to be a genetically variable species, whereas **red beech** seemed comparatively uniform. **Hard beech** was poorly represented in the study, but a central North Island provenance grew fastest at Rotorua and slowest at Rangiora. The **black beech** and **mountain beech** complex showed considerable variation between provenances in the size, shape, colour and arrangement of leaves, as well as the branching habit and growth rate of seedlings. Seedlings of **black beech** grew faster than those of **mountain beech**, had a characteristic interlacing habit, with distant, more rounded leaves, and were partially deciduous in winter (Wilcox and Ledgard 1983). Genetic variation was evident in seedling growth between provenances collected from an altitudinal gradient in north Canterbury, but altitudinal variation was not evident in duration and pattern of shoot growth in the seedlings at Rangiora (Ledgard and Norton 1988).

A third form of *Nothofagus solandri* was recognised by Wilcox and Ledgard (1983) with seedlings intermediate between those of **mountain beech** and **black beech**, from well-drained lowland sites in the South Island. The erect seedlings with relatively large leaves are amongst the fastest-growing of all the New Zealand beeches.

When planting or seeding beeches, local provenances should be used wherever possible to minimise the risk of planting trees ill-adapted to the sites, and to avoid indiscriminate mixing of provenances from different ecological regions (Wilcox and Ledgard 1983).



*Seed for the beech provenance trials was collected from a number of sites throughout New Zealand.*

*The beech provenance trial 4 years after planting at the Forest Research Institute's Rangiora Nursery.*

## WOODSIDE FOREST, OXFORD

In 1980, forester and scientist John Wardle acquired 84 ha of regenerating 80 to 90-year-old black beech forest in the Canterbury foothills north of Oxford, where he has progressively refined a silvicultural system to produce high-quality timber. The property is divided into 6 blocks, defined by topography, and managed for the production of 45 cm DBH sawlogs over rotations averaging 50-55 years. Dried timber is supplied in a variety of forms (e.g., firewood, sawn timber, tongue-and-groove flooring) to end users. The forest is intensively managed, with about 1 ha thinned and pruned annually. Stands are progressively thinned from age 15 years from some 50,000 stems/ha down to about 800 stems/ha, concentrating on reducing competition around selected 'crop trees' with intervening patches of forest left dense to reduce sunscald and winter desiccation in crop trees and for ecological reasons. All crop trees are pruned.

This operation has been selected by the United Nations Forestry Commission as one of the leading examples of exemplary forest management in the Asia–Pacific region, was awarded the Transpower-Landcare Trust Award for Innovation in Sustainable Forestry, and was the New Zealand Farm Forestry Association's 'South Island Farm Forester of the Year' in 1995.

*Thinned and pruned sapling thicket of black beech.*

*Thinned and pruned black beech a few years later. Increased light has allowed other species to develop in the ground layer.*

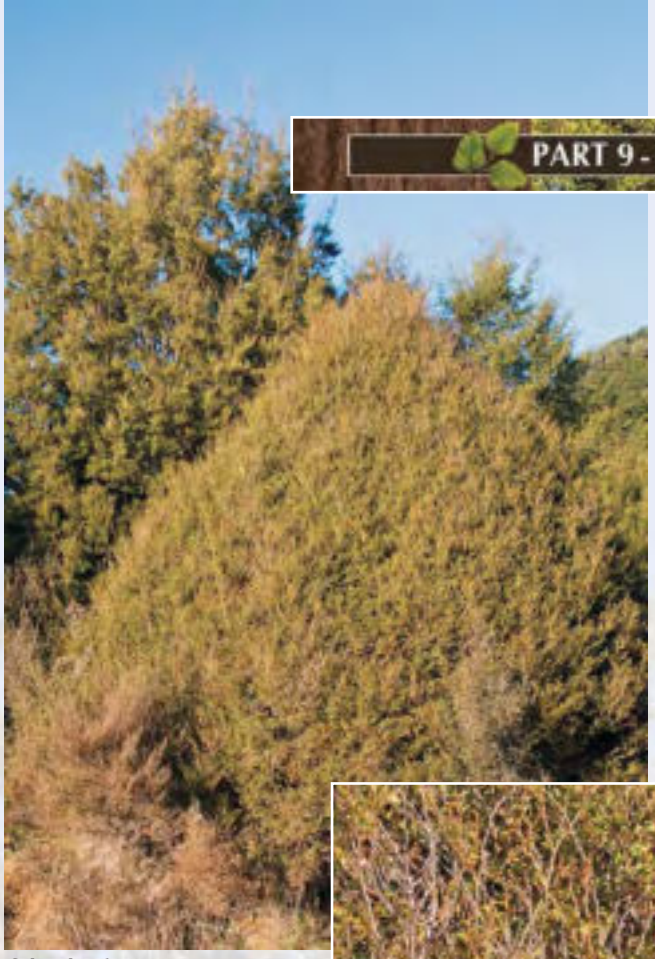
*Heavily thinned and pruned natural black beech pole stand, Woodside Forest, Oxford. Increased light has allowed other species to develop in the ground layer.*

*Black beech logs extracted from sustainably managed beech forest at Woodside Forest, Oxford awaiting milling.*

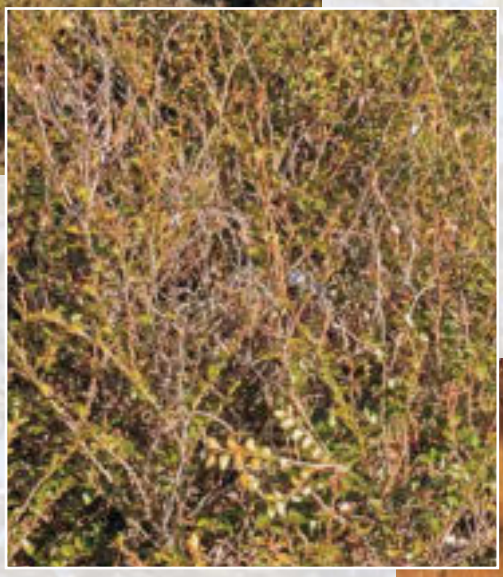
*Purpose-built shed for air-drying sawn black beech timber.*

*Thinned black beech - snow is able to pass through the canopy resulting in less damage.*

*Black beech firewood produced from defect logs.*



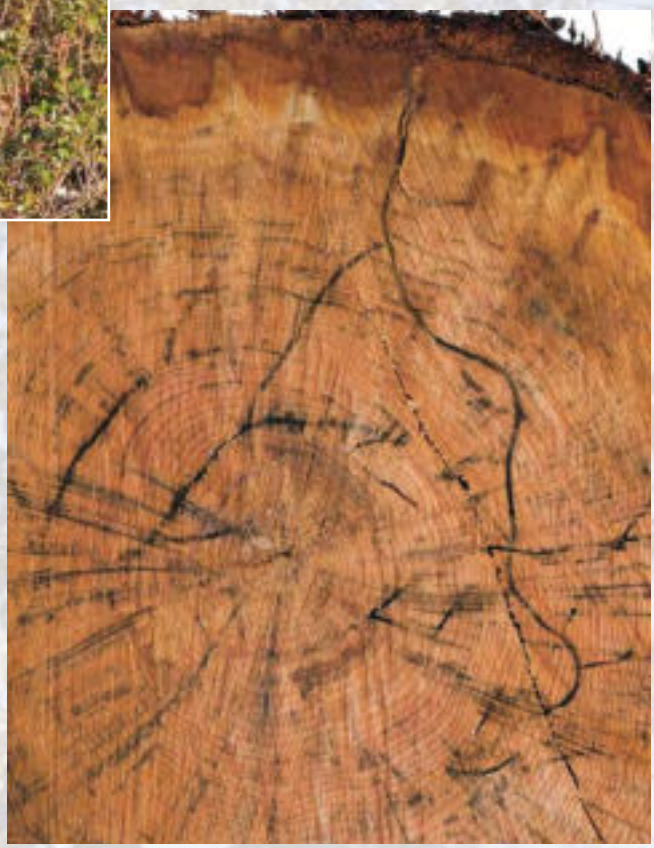
*Silver beech on an open site showing signs of insect attack (likely a mite) on growing tips, resulting in the development of a compact form. Beech can be trimmed to achieve a compact form and can make an attractive hedge.*



*Inset: Close-up illustrating insect attack on branch tips.*

The ubiquitous presence of pinhole borer in beech forest is a major constraining factor in their management. Base populations are maintained by dead and dying trees. Living trees are not often attacked unless their diameter is greater than about 15 cm, and they are under stress, or there is an attractant such as logs, stumps or trees under stress nearby (Franklin 1995), producing a network of fine tunnels within the wood. Pinhole borer can aggravate the damage caused by natural disasters and weather. Pinhole beetles attracted to moist, dead wood in damaged forests carry the *Sporothrix* sp. fungus, which kills trees and prompts a new outbreak of pinhole beetle.

The widespread presence of puriri/ghost moth, whose larvae bore much larger tunnels than pinhole borer in live wood, severely limits production of high-quality beech timber in the North Island. As with pinhole borer, attack by this insect is often associated with fungi which further damage wood.



*Black streaks in a red beech log result from pinhole borer and associated fungal attack.*

## ANIMALS

### Leaf- and wood-eating insects

Many native leaf-eating insects feed on beech canopies. Among the most important are caterpillars of the moth, *Proteodes carnifex*, which periodically partially defoliate thousands of hectares of **mountain beech** forest in outbreaks that last several years. The leaf-mining weevil, *Neomycta pulicaris,* and the tineid moth, *Heliostibes vibratrix,* attack the newly flushed foliage of **hard beech**, particularly when weakened by drought (Hosking & Hutcheson 1986). Outbreaks of the sap-sucking scale insect, *Inglisia fagi,* in **red-silver beech** forest in the Maruia valley suffering drought stress are reported to have selectively killed **red beech** and favoured growth of residual **silver beech** (Hosking & Hutcheson 1986).

## Galls and witches broom

Galls are abnormal outgrowths of plant tissues caused by a range of agents including fungi, bacteria and insects. Galls can occur on the branches, buds and leaves of beech trees. For instance, three of the fungal species of *Cyttaria* attack **silver beech,** causing woody galls on branches and stems. They may result in loss of vigour of saplings and poles, although their overall effect is considered insignificant. The beech strawberry fungus (*Cyttaria gunnii*) has distinctive orange-yellow golf-ball-like fruiting bodies. The galls are perennial and keep growing as long as the host branch or stem is alive.

*Fruiting bodies of fungal parasite* Cyttaria *on silver beech.*

Leaf and bud galls associated with insect and mite attack are common (Wardle 1984). Eriophyid mites cause leaf pouch or leaf pocket galls and bud galls on all five beech species. One species of mite, *Aceria waltheri*, causes the characteristic 'witches broom', an abnormal growth on **silver beech**. Local infestations can be significant with occasionally severe deformation of young beech.

*Witches Broom on silver beech - often mistaken for silver beech flowers, it is a gall which is abnormal tissue development in the growing shoots that is caused by infestation of a tiny mite* Aceria waltheri.

## Honeydew

Some beech forests in the South Island are infested with native sooty beech scale insects (*Ultracoelostoma* spp.). These insects live in the bark of beech trees, drawing off the sap, then excreting sugary liquid drops known as honeydew. The black colour of trees and plants with a honeydew source is due to the growth of a black sooty mould (*Capnodium* sp.) on the surplus nectar exuding over the plant and sometimes even the ground.

*Heavy sooty mould on black beech can strangle/inhibit undergrowth and ground cover development.*

Beech scale insects infest all species of beech except **silver beech**. They are particularly common in the beech forests in the foothills of the Southern Alps and the upper South Island. Honeydew is an important food for native insects and nectar-feeding birds such as tui (*Prosthemadera novaezealandiae*), bellbirds (*Anthornis melanura*) and kaka (*Nestor meridionalis*). Lizards, possums, rats, honeybees and the introduced wasps (*Vespula* spp.) have also been recorded feeding on honeydew.

For five months each year, introduced wasps eat at least 90% of the honeydew and also prey on insects, spiders and other invertebrates, further reducing the food of native animals (Orwin 2009). The behaviour of at least three bird species – kaka, tui, bellbirds – is affected by the reduction of honeydew, including more time expended on foraging.

*The sweet substance excreted by the beech scale insect forms as a tiny silver droplet at the end of their hair-like anal tube. This honeydew provides a rich source of food for native birds and bees including this honey bee on a black beech trunk.*

The black velvety look that is the distinctive feature of most beech tree trunks in the South Island is a covering of a fungus called 'sooty mould'. The sooty mould grows on honeydew that has dripped down the trunks. The fungus has a distinctive sweet smell, very nostalgic for Cantabrians such as writer Dame Ngaio Marsh, who entitled her autobiography *Black Beech and Honey Dew.*

## Introduced pests

Rodents may be the most widespread pests in beech forests. In mast years, when large numbers of male beech flowers fall, caterpillars have ample food and their numbers increase. Seed- and insect-eating birds also have a good breeding season. But rats and mice also prosper, competing with the birds for food. With more rodents come more stoats, which eat the rodents and then prey on the birds. This cycle may have helped cause the major decline in kaka numbers and the near-extinction of mohua/yellowheads (*Mohoua ochrocephala*) and orange-fronted parakeets (*Cyanoramphus malherbi*).

## Browsing

Although possums and deer have had widespread impacts on the composition of beech forests as a whole, depleting palatable associated species in all tiers (possums) or lower tiers (by deer), none of the beeches is a preferred food of either possum or deer.

*Like deer, possums have widespread effects on the composition of beech forests, particularly sub-canopy and shrub species, although beeches themselves are not a preferred food.*

Nevertheless, the diets of browsing mammals change as forests become depleted of preferred species, and beech foliage is eaten at times by both possums and deer. Survival and growth of **red** and **silver** - and probably **mountain beech** - seedlings was reduced in the Kaimanawa Mountains by sika and red deer (Husheer et al. 2003). On critical sites and even regions, for example in **mountain beech** forest in the Kaweka Range where sika deer are common, browsing of seedlings by deer is reducing the level of canopy replacement (Allen & Allan 1997). Seral vegetation within beech forest tends to be more palatable to browsing mammals than the surrounding forest, so succession back to forest can be delayed by them.

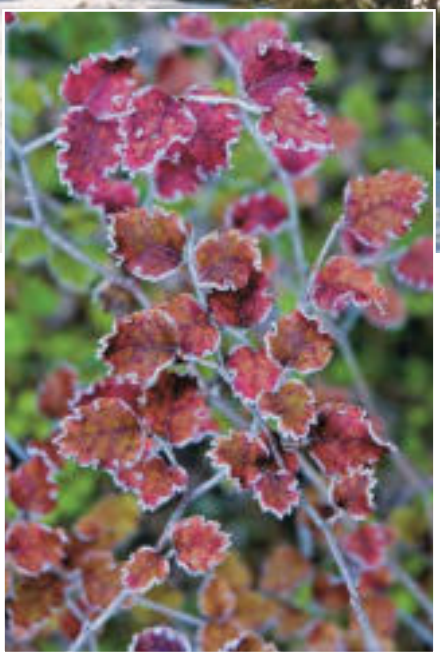
*Introduced mammals like red deer have had widespread impacts on beech forest.*

## CLIMATE

### Frost and winter desiccation

**Mountain beech** (-13°C) and **silver beech** (-12°C) are very tolerant of frost, **red** (-8°C) and **hard beech** (-7°C) much less so (Wardle 1991; Neuner & Bannister 1995). Seedlings are susceptible to foliar damage or death from frost, especially during the spring growth flush, and unseasonal frost is a major cause of failure of open-planted seedlings.

*Winter dessication in mountain beech can kill seedlings and saplings on open alpine sites.*



*Seedlings of red beech are susceptible to damage from frost.*

Winter desiccation occurs when soil temperatures are so low that actively-growing plants cannot take up water. This can be aggravated by desiccating winds that increase evapotranspiration from foliage and like frost, it can kill seedlings and saplings growing in open situations. However, injury related to winter desiccation and frosting does not usually affect beech trees or seedlings growing naturally within a stand and does not often kill larger saplings and trees in the open.

It is suggested that winter desiccation is a major factor in preventing extension of beech forest to sites above the timberline. Unseasonal frosts have been identified as one the major causes of failure of attempts by the New Zealand Forest Service to establish nursery-raised seedlings of mountain, silver, red and black beech (Wardle 1984).

## Drought

Drought can kill individual trees and even stands of all the beech species. Although insect and fungal pathogens are often involved as well, drought is the primary factor weakening trees and predisposing them to attack (Hosking & Hutcheson 1986, Hosking & Hutcheson 1988, Hosking & Kershaw 1985).

*Mountain beech is the most cold-tolerant of the beeches.*

## WOOD PROPERTIES

New Zealand beeches are medium-density hardwoods with a straight grain and a fine, even texture. They have excellent sawing, machining, turning and nailing properties. They also stain, glue, and finish well. Beech wood performs well where strength, stability and appearance are required and are especially good for turnery, joinery, and cabinetry (Donnelly 2011). Globally, there are few timbers that can match them for evenness of texture in all directions. Their properties have been fully documented by Clifton (1990). Inconsistencies within species are partly due to the hybridisation that occurs among them, silver beech excepted. The heartwood and sapwood of all species are impervious to borer (*Anobium* spp.) attack.

Drying has been an important issue with beeches, with heartwood slow to dry and prone to warping, checking and collapse. Silver–the main commercial species–is the easiest to dry, and can be kiln-dried from the green state. Black beech is also moderately easy to dry. Red beech historically has been difficult to dry in larger thicknesses, hard beech even more so, largely because of tension wood in both species. Details of suitable drying schedules are provided by Clifton (1990).

*Black beech makes fine furniture such as this chest of drawers made by Dag Guest.*

## Black and mountain beech

The difficulties in the taxonomic separation of **mountain** and **black beech** and in the placement of the various provenances with characteristics intermediate between the two has led to inconsistencies in describing wood properties and allocating uses to the two entities (Wardle 1984).

**Mountain beech** has not been widely milled. Its wood has a similar but lighter appearance than **black beech**, and is less strongly differentiated into heartwood and sapwood. It is less durable in ground contact than **black beech** and more difficult to dry.

The heartwood timber of **black beech** is reddish-brown when freshly cross-cut, with a mid-dark brown surface face on sawing, often with blackish streaks. After drying, the timber lightens to a straw colour, with darker streaks which are possibly pathological. The sapwood is whitish-yellow when freshly sawn, seasoning to a whitish brown or amber. **Black beech** timber is strong and stable. Durability is variable. Neither the sapwood nor the heartwood is subject to rot except in high hazard conditions. True heartwood can survive for long periods in the ground, provided it does not contain pathological heartwood. Tension in **black beech** wood can lead to dulling of saws and machine knives and like other high-density timbers, there may be problems with seasoning. It has good machining, bending and finishing properties and takes stains well.

**Black beech** is moderately easy to dry. Shrinkage of the heartwood can be high, up to 6% from green to 12% moisture content in the tangential direction, and 4% radially. Unlike today, the beeches were used by early settlers for some quite large construction projects, such as the Waiau Ferry Bridge.

### WAIAU FERRY BRIDGE

**Built with black beech in 1864, demolished by a gale-force nor'wester in 1874**

*From:*
*'The Amuri – A County History'*
*by W J Gardner*

"…In design and construction, it was a spirited response to the challenge of inadequate materials and an unpromising site, and helped to make the reputation of John Blackett, its designer, who later became engineer-in-chief for the colony. Its high arch, rising 120 feet above the water, was built entirely of four-inch by three-inch scantling; no other dimension of timber was used except for the decking. The roadway was 320 feet long and seven and a half feet wide.

The construction of the bridge was a triumph also for the contractor, Henry Handiside. Two three-quarter inch cables, seven and a half feet apart, spanned the site acting as a support for a travelling platform and crane, and as a guide in construction. "With a single plumb bob, the work could be checked as it progressed". While the men below climbed from one position to another, tools and timber were moved to the required spot. There were no accidents. Handiside's price was £2,160, £1000 less than than the figure of his tender. He worked with difficult timber imported from Nelson via Saltwater Creek. 'Black birch' he wrote to the Superintendent, "may be good when up, but is dreadful stuff to work with". George Rutherford claimed that there was better timber in Lottery Bush and trusted that "no one interested in sawmills or in the shipping interest" could have influenced the government. The transport of the timber to the site was a major undertaking in itself. Handiside drew a sketch of his dray stuck in the unbridged Glen Allan cutting. "It required 16 bullocks to take the dray out of this position. Had the dray upset, it would have rolled to the bottom and killed half the team".

The bridge was opened in May 1864, but no record of any ceremony has survived. Though held by four long stay wires the structure was somewhat flexible. Blackett, in reporting on the oscillation of one inch in the centre did not consider it detrimental, but thought it might "give timid travellers an idea of danger". He had seen, on one occasion, ten horses and sixteen men cross the bridge which did not appear to move in the least, but two horses taken rapidly across, seemed to cause the greatest sway. …

… On the night of 22 November 1874 a nor'west gale sent the whole structure crashing into the river. It was an ill wind for the district, but the settlers further down the river picked up some very valuable timber (Weekly Press 31 August 1910, quoting from an article printed in the London Illustrated News during 1864. Roberts (Maori nomenclature p.37) states that 35,000 feet of black beech was used. The foreman was W.H. Barnes)."

*From:*
*"Much ado...." Hanmer Springs 1883 – 1983*
*by Rosemary Ensor*

..."Mr & Mrs Blake often spoke of Handisides wonderful bridge, and how it would sway when one was crossing it. There was a little gate at each end of the bridge. Once they both were crossing it: Mr Blake was riding a young horse. He rode on to open the gate, Mrs Blake following, carrying her baby girl on the saddle in front of her. As Mr Blake opened the gate it somehow swung back and struck the horse which reared and broke away, careering back across the bridge. There was barely room for two horses abreast, and as it attempted to pass Mrs Blake she was nearly jostled out of the saddle. It was only her presence of mind in throwing her weight to the other side that saved her and the baby being bumped over the other side of the bridge". ...

## Red beech

The heartwood of **red beech** is light to medium red-brown in colour and the sapwood light brown to white and exhibits toning in greys, browns and greens. Heartwood is strong and durable. It has a tight, close grain appearance.

**Red beech** peels well and has good and steam-bending qualities, but can warp during seasoning. It has exceptional dimensional stability. The timber is moderately easy to split, and less likely to blunt cutting knives than other beech species.

Like all beeches, **red beech** timber often darkens and becomes richer after several months' exposure to natural light, and tonal variations even out. The timber has a lustre and natural sheen that tend to improve with age, meaning **red beech** remains lively and does not appear muddy like some contemporary timbers. The sapwood is light brown to white in colour and often generates unique sap stains because of the reaction of sugars in the protracted drying process. This 'colour' exhibits toning in greys, browns and greens, and is well suited to feature furniture making and select panelling where high character is required. Despite high shrinkage, once dry, the heartwood of **red beech** is the most stable timber available in New Zealand, extremely stable by world standards. The fine turning and routing properties of **red beech** mean that minimal sanding is required after machining to achieve a smooth finish, and it is suitable for veneer and decorative and special plywood manufacture. It has a reputation for corroding metal fastenings when used out of doors.

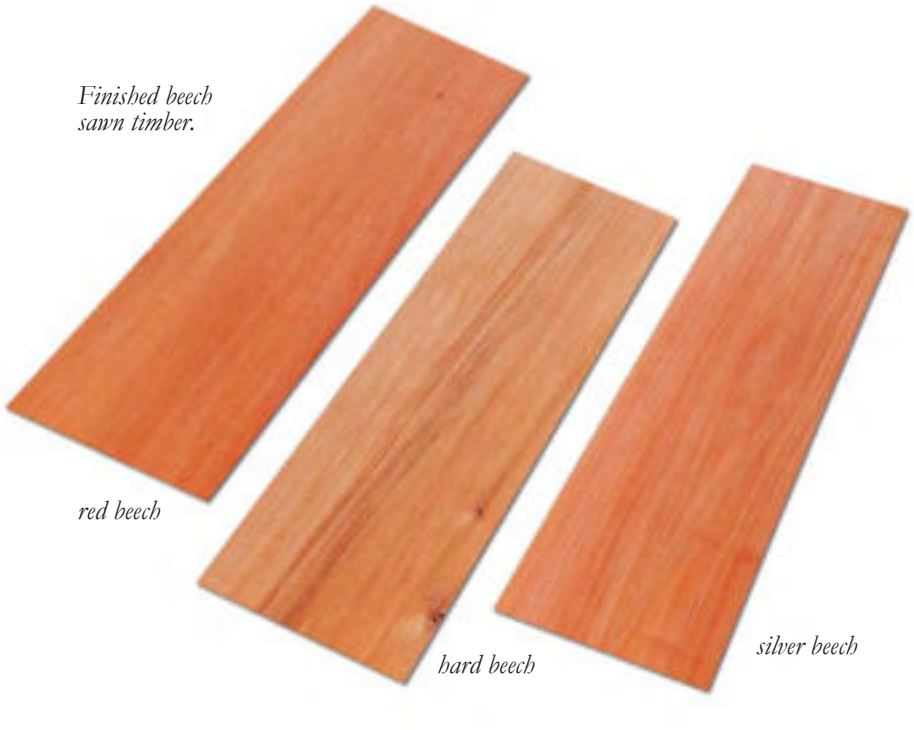
*The hard-wearing properties of red beech make it an excellent flooring timber.*

## Silver beech

**Silver beech** is the most popular beech timber. Because it does not hybridise, timber properties are more consistent than in the other beeches.

The colour of **silver beech** varies with location and age, and between the sapwood and heartwood. It always has a pinkish to red overtone. Lighter colouring resembles sugar maple (*Acer saccharum*), while darker tones resemble black cherry (*Prunus serotina*). The dry sapwood is a light pinkish grey, and the heartwood pinkish brown, slightly darker than heartwood totara (*Podocarpus totara*). The heartwood of some provenances is deep red.

The qualities of **silver beech** vary depending on location, with Southland beech being lighter and weaker than North Island timber. The moisture content of green timber ranges from 79 percent in the North Island to 97 percent in the South Island. Southland beech has higher shrinkage properties than the other beeches but like them, has good stability once dried.




*Finished beech sawn timber.*

applications without the need for treatment.

**Silver beech** is an attractive furniture timber and when French-polished, it can resemble mahogany. By steaming the timber for a longer period of time before kiln drying, a deep-pink colouring can be achieved.

**Silver beech** steam-bends easily. Compared with other native beeches, it is lighter and more easily worked, but less durable. Neither heartwood nor sapwood of **silver beech** is durable in high hazard situations, so it is unsuitable for outdoor applications. However, the timber can be used for interior and indoor furniture

Through careful selection and matching, individual boards and veneers can be chosen to give the desired end effect – either well matched or contrasting colour selections. The grain pattern and deep lustre when polished provide a contemporary elegance to furniture and finished interior fitouts.

*The contrasting colours of silver beech heartwood and sapwood.*

*Crenulations in the surface of the cambium are unique to hard beech.*

## Hard beech

**Hard beech** timber is light yellow-brown and durable. It has been sparsely milled in the past as it is abrasive to saws and tools. It is denser than that of the other New Zealand beeches. The timber tends to corrode uncoated steel fasteners, and the sapwood is prone to sapstaining unless treated with care during seasoning. **Hard beech** is probably the most difficult of the beeches to saw and season, and surface checks often develop during drying.

## PAST AND PRESENT USES

Native hardwoods such as beech and tawa are harder to saw and season than native and exotic softwoods, so they have not featured so prominently in New Zealand's timber industry. In the early days of European settlement, native softwoods such as kauri, rimu, matai, tōtara and kahikatea largely satisfied the nation's demand for timber. Since the 1950s, wood from exotic conifer plantations (mostly pine and some Douglas fir) has been readily available (Orwin 2009).

### Black beech

The potential for manufacturing and joinery of **black beech** has not been fully realized, and so has been mostly used either for utility purposes or where its heartwood's durability or strength properties have been relevant. Milling of **black beech** began in Canterbury in the second half of the 19th century and continued until the First World War. Native softwoods were relatively scarce in the region, so **black beech** was used in house construction for framing, exterior cladding, flooring, subflooring, piles and panelling, and also for fence posts, gates, rails, bridges, and boat-building. By 1915, most of Canterbury's lowland beech forests had been milled and the land converted to pasture. The limited quantities now available are used where the timber's stability, machining properties and appearance are paramount, such as tool handles, furniture, exposed floors, and interior joinery.

*Red beech used for stock yards and rails.*

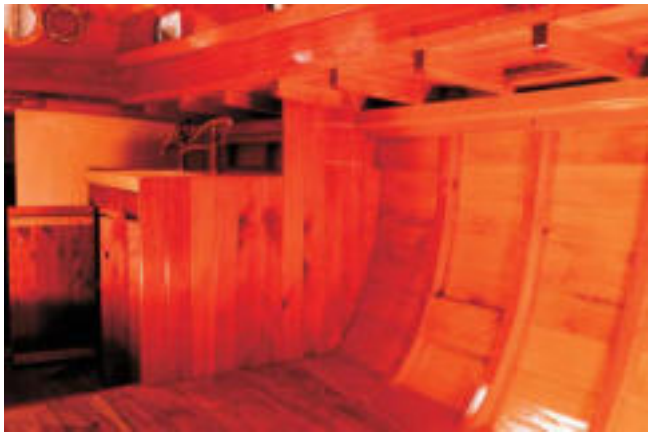
*Rough-sawn black beech from a second-growth stand shows attractive colouration.*

**Mountain beech** is relatively inaccessible and because it protects upper river catchments, has rarely been milled.

## Red beech

**Red beech** was used in the early mining industry and for land development purposes including mine props, bridges, wharf decking, fencing, railway sleepers, and boat-building. It was also used for framing, flooring, dowels, and handles. Since the 1970s, high-grade **red beech** has been used for furniture, flooring and decorative interior finishing. Its fine even texture makes it most suitable for turning into dowels and brushware. Being hard wearing, it is also suitable as stair treads and flooring. As a flooring timber, it has an attractive, figurative appeal and lustre, and is significantly harder and more resistant to impact than alternative softwood species such as rimu and matai.

*Beech timber was used extensively in both gold and coal mines as mine props as the timber was not only strong but "talked" (creaked) as it was compressed, providing a warning to miners of possible movement in the roof of the mine.*



*Red beech used for interior finishing in boats.*

**Red beech** can be used in exterior exposed situations, such as pergolas and outdoor decking, without the need for chemical treatment. Untreated sapwood is not durable, but treatment is unnecessary for uses such as indoor furniture where it is completely protected from moisture.

*The fine even texture of beeches make them excellent furniture timbers. Bookcases of silver beech (left) and red beech (right).*

*Sapwood and heartwood red beech panelling.*

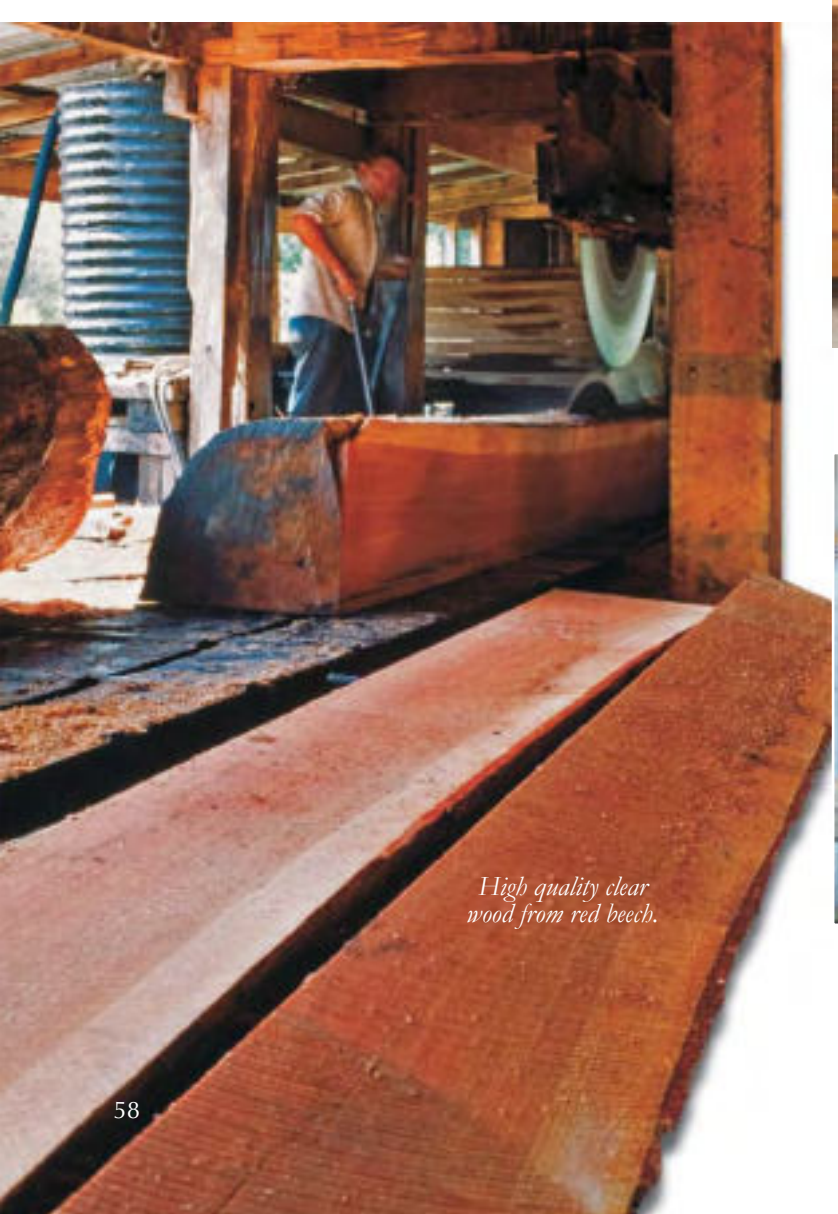
## Silver beech

In Southland, **silver beech** was, like rimu, a general utility wood, due to its abundance and favourable wood properties, and used for building, farm timbers and in mining. Since the 1920s, it has been the predominant beech timber, sourced mostly from Southland, and is set to replace rimu as the premier native species.

*Silver beech timber was commonly used in vehicle framing for its combined strength and steam-bending properties.*

Pinhole borer holes in **silver beech** wood can be used as a feature grade in 'antique' furniture, flooring and picture frames, and is most suitable for villa restoration where new, freshly sawn timbers with little defect might stand out adversely.

The lighter wood from Southland is the most suitable for furniture, turnery and brushware purposes, and also for flooring because it wears uniformly.



*High quality clear wood from red beech.*

Heartwood is resistant to preservative treatment, so is unsuitable for outdoor applications. Although classed as moderately durable (similar to macrocarpa and redwood), this is an average durability measure for the whole species resource. Suitability for exterior applications, such as weatherboards, cannot be guaranteed because of the highly variable nature of the timber properties, depending on the source. The wood can be used for interior and indoor furniture applications without the need for further treatment.

## Hard beech

**Hard beech** is used where strength and durability are important. It has mostly been used for bridge and wharf decking, bridge stringers, mine props, industrial flooring, stockyards, gates, posts and general building on farms. There is also potential for manufacturing brushware, mouldings, dowels, furniture, joinery and finger-jointed products.

*Silver beech from Southland provides superb interior joinery in the new Supreme Court in Wellington.*

*Silver beech, seen here been made into broom handles, has excellent machining properties.*

## LINDSAY & DIXON LTD.

Lindsay & Dixon Ltd, based in Tuatapere in western Southland, is currently the major producer of silver beech. Its forestry and processing operations are certified by the Forestry Stewardship Council.

Lindsay & Dixon own the cutting rights to and sustainably manage a forest estate of 11600 hectares of predominantly silver beech, providing an annual yield of up to 23628m$^3$ of sawlogs. Silvicultural management of the 75 – 80 year old second-crop forest is based on selectively harvesting single trees or small groups of trees, providing a quality, certified resource to meet market demand and conditions.

Silver beech is marketed as 'Maple Beech', the natural product, and 'Cherry Beech', which is steamed before kiln-drying to create an enhanced pink to red colour. Produced in four grades, these timbers make excellent flooring, interior joinery, furniture, turnery and veneer items. Increasingly, they are being recognized and sought after by architects and specifiers who want a legal and certified indigenous timber that complies with the requirements of the environmental 'green star' building programme.

*Selectively harvested silver beech forest in the Longwood Range, Southland.*

*Lindsay and Dixon's state-of-the-art mill at Tuatapere, Southland.*

*Hard-wearing silver beech flooring and a benchtop in this new home.*

*Silver beech used as sarking in the external entrance of Wanaka's new Holy Family Catholic Church.*

*Silver beech used for high-quality furniture.*

## Seed collection

- Fresh seed can be collected in many years. Beech trees are monoecious, so all trees can bear seed.
- Edge trees tend to bear more seed.
- Small amounts of seed can be picked from branchlets when ripe. For larger quantities, place seed trays under trees in March and April (and May at higher elevations). Litter under trees can be collected and sieved to separate mostly seed, which then requires drying.
- Check overall seed viability by cutting a sample with a knife to check the colour and thickness of the endosperm, which should be white and 2 mm thick.
- Seed can be stored for up to 8 years in airtight containers at 5-10°C and 6% moisture content. In preparation for seed sowing and after a long period of dry storage, seed will require 'stratifying', soaking and moist cool storage at 2-4°C for 3 months with free air circulation, before spring sowing.

## Seedling production

- Beech seedlings can be raised in containers or as bare-rooted stock.
- Sow stratified beech seed in spring in seed trays filled with moist, standard seed-raising mix. Cover with a 6-8 mm layer of coarse sand and place the trays in standard warm, humid germination facilities. Water as necessary.
- Germination usually occurs 2-4 weeks after sowing.
- When seedlings are 5-10 cm high, prick them out into small containers or open beds. Protect from frost.
- **Red beech** takes up to 2 years to raise to a 40-60 cm high seedling from sowing, whereas **silver beech** may take up to 3 years. Re-pot in larger containers when necessary.
- Current cost of 50 cm high 2 year old stock of beech raised in PB 3 polythene bags or similar size containers is around $4 per seedling.
- Polythene planter bags (PB3) are best for 2 year old stock. Seedlings raised in small root-trainers tend to be spindly and may need staking when transplanted.
- Large-scale bare-rooted seedling production was practised successfully in forest nurseries during the mid to late 1900s and could reduce seedling costs.

## Site preparation for grassland sites

- Fence planting areas to exclude livestock.
- If practical, graze pasture to a low height before final exclusion of livestock.
- Apply a pre-planting herbicide (glyphosate) at least a week before planting.

## Establishing beech plantations

- Select high-quality stock with a balanced root/shoot ratio. Inspect the root systems of a sample of stock and reject the whole batch if the root systems are distorted or container-bound.
- Regular releasing from other competing vegetation will be needed for up to 5 years after planting. Many establishment failures are due to lack of early weed control.
- Fertiliser addition will be needed on grossly infertile sites.

## Planting on open ungrazed sites

Density of planting on an open site will be influenced by requirements for intensive releasing from other vegetation at low stocking rates or by the need for thinning at high stocking rates.

Planting at lower rates (1000 stems/ha or less; 3 to 5 m spacing) will:

- reduce expenditure on seedlings and site preparation;
- delay canopy closure and therefore increase the cost of weed control;
- increase the need for form pruning to promote the development of single straight stems with light branching, and;
- increase diameter rates because of less competition.

Planting at high rates (more than 2500 stems/ha; 2 m spacing or more) will:

- increase expenditure on seedlings;
- promote relatively early canopy closure and reduce the cost of weed control;
- improve stem form and reduce branch size after canopy closure, and;
- reduce diameter growth rates later because of more competition, thus needing thinning.

## Use of nurse species

- Where possible, use existing woody vegetation cover less than 6 m high, e.g., *Coprosma* species, as a 'nurse' to improve survival, early growth rate, and stem form. Planting lines can be cut at regular spacing.
- On open sites, plant nurse species at wide (2 to 3 m) spacing to control weed growth and provide shelter. Plant beech 3-5 years later.
- Advantages of nurse species:
  - provide shelter on exposed sites;
  - can increase early height growth rate;
  - provide side shade which suppresses development of lateral shoots and reduces branch size;
  - decreases the incidence of multiple leaders, and;
  - reduces establishment costs, because nurse species are cheaper than beeches.
- Disadvantages of nurse species:
  - requires forward planning, because nurse establishment precedes beech establishment, and;
  - maintenance to ensure that the nurse doesn't smother beech.
  - additional establishment expense

## Tending

- Form pruning will be needed to remove double leaders and large branches.
- Smaller branches should also be removed to improve timber quality.
- Thinning may be needed.

## Establishment and early management of natural regeneration

Beech regenerates readily in many situations, and natural regeneration provides a much cheaper ready-made alternative to artificial establishment.

## Planting for a seed source

Small groves of beech can be established where they are absent and where a seed source is desired to allow natural regeneration to proceed in the very long term.

- Plant groups of seedlings on good sites in natural or cut gaps in existing vegetation. Trees will begin producing viable seed from about 20 years as open-grown trees, later within closed forest.

## Management of developing natural stands

'Pole stands' of beech commonly develop after major disturbance and are amenable to tending, depending on the stage of development.

- Low-density stands with widely spaced stems will benefit from form pruning.
- Denser stands can be left to self-thin naturally, a process that takes 100 years, or can be thinned to increase individual tree growth rates.
- Thinning down to 800 stems/ha or less should be done in several light operations, beginning by age 15 years.

## Animal and pest control

- Pest control may not be needed for the health of beech stands *per se*, but may be necessary if other values such as floral and faunal biodiversity are to be maintained or improved. Rabbits and hares eat seedlings and may need control in some situations. Possums and deer preferentially browse many broadleaved species associated with beech, reducing or even eliminating them.

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All photography is by Ian Platt (Woodend), except for the following: John Barran (p. 5 inset), David Bergin (p. 45 top), Michael Bergin (p. 38 inset, 42 top right, inset), Department of Conservation (p. 58 top left), Tomas Easdale (p. 38), Dag Guest (p.51), Bernie Lagan (p. 59: bottom row), Nick Ledgard (p. 43), Paul McCredie (p. 58 centre right), MAF (p. 57), Mark Smale (p. 36, p. 42 top left, top bottom, p. 58 bottom right, p. 59), Craig Smith (p. 49 top), and Kevin Platt (p. 9 centre, p. 21 top left).

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There is an extensive literature on the New Zealand beeches, only a fraction of which is quoted here. John Wardle's monograph *The New Zealand Beeches. Ecology, Utilisation and Management*, published by the New Zealand Forest Service in 1984, is still the major reference and contains a comprehensive bibliography which is partly updated below. The southern beeches are also described by John Wardle with Ian Platt as principal photographer in a recent comprehensive account of New Zealand trees - *Wardle's native trees of New Zealand and their story* (Wardle 2011). Earlier compilations, now largely of historical interest, are Leonard Cockayne's 1926 *Monograph on the New Zealand Beech Forests* in two parts, and the 1965 Forest Research Institute Symposium No. 5 on *Beech Forestry in New Zealand*. The ecology of the New Zealand beeches has been summarised more recently by John Ogden, Glenn Stewart and Robert Allen in a global overview of southern beech forests (Veblen et al. 1996). Timber properties have been summarised by Stan Reid (Reid 1953), the New Zealand Forest Service in *Timber Properties and Uses of the New Zealand Beeches* in 1974, and more recently by Norman Clifton (1990) in *New Zealand Timbers*.

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Tane's Tree Trust
Native Trees for the Future

Tane's Tree Trust was formed in 2001 to encourage New Zealand landowners to plant and sustainably manage native trees for multiple uses. The objectives of the Trust are: promotion of native forestry as an attractive land use option by consolidating and advancing the state of knowledge of native tree species; maximising economic incentives for establishing natives; resolving legal and political obstacles to the planting of natives; and encouragement of knowledge-sharing amongst stakeholders.

If you are interested in joining the network individual subscriptions are $45 with options for donations and corporate membership and sponsorship. For further information on the work of the Trust, contact:

office @tanestrees.org.nz
Phone: (07) 858 4404
P.O. Box 12094
Hamilton 3248

## INDIGENOUS TREE BULLETIN SERIES

*The New Zealand Beeches - Establishment, Growth and Management* is the sixth in this series of New Zealand Indigenous Tree Bulletins which summarise the latest information about management of planted and naturally regenerating native tree stands. The focus is on production as well as environmental and social objectives.

Bulletin No. 1 is *Totara Establishment, Growth, and Management*

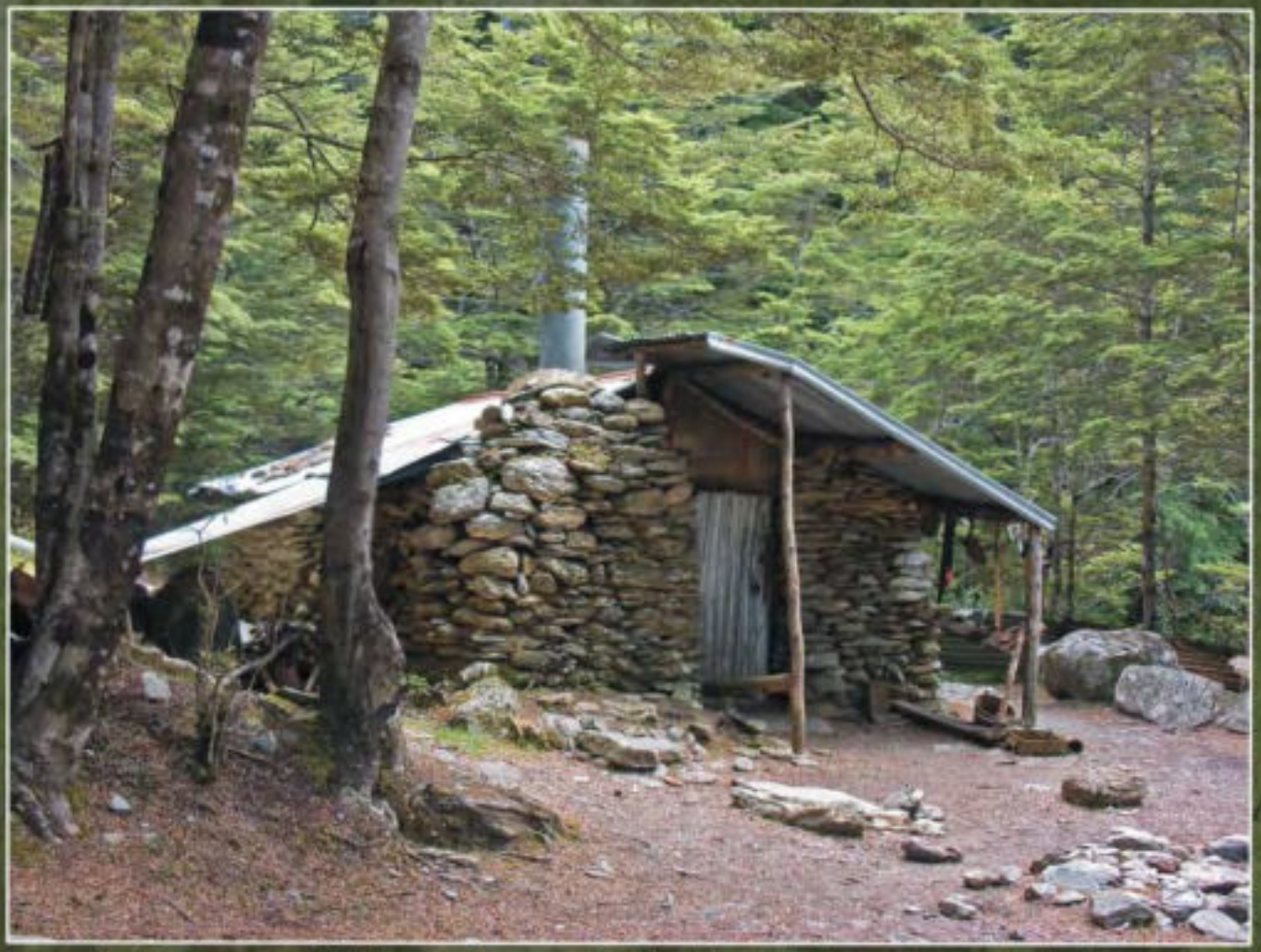
Bulletin No. 2 is *Kauri Ecology, Establishment, Growth, and Management*

Bulletin No. 3 is *Native Trees – Planting and Early Management for Wood Production*

Bulletin No. 4 is *Pohutukawa – Ecology, Establishment, Growth, and Management*

Bulletin No. 5 is *Farming with Native Trees*

Subjects for future Bulletins include: establishment of native hardwood species; and assessment and monitoring of native plantations.



*Beech forests have provided the context for many early industrial activities like mining. An old gold miners hut at Twelve Mile Gorge in Mt Crichton Scenic Reserve near Queenstown.*