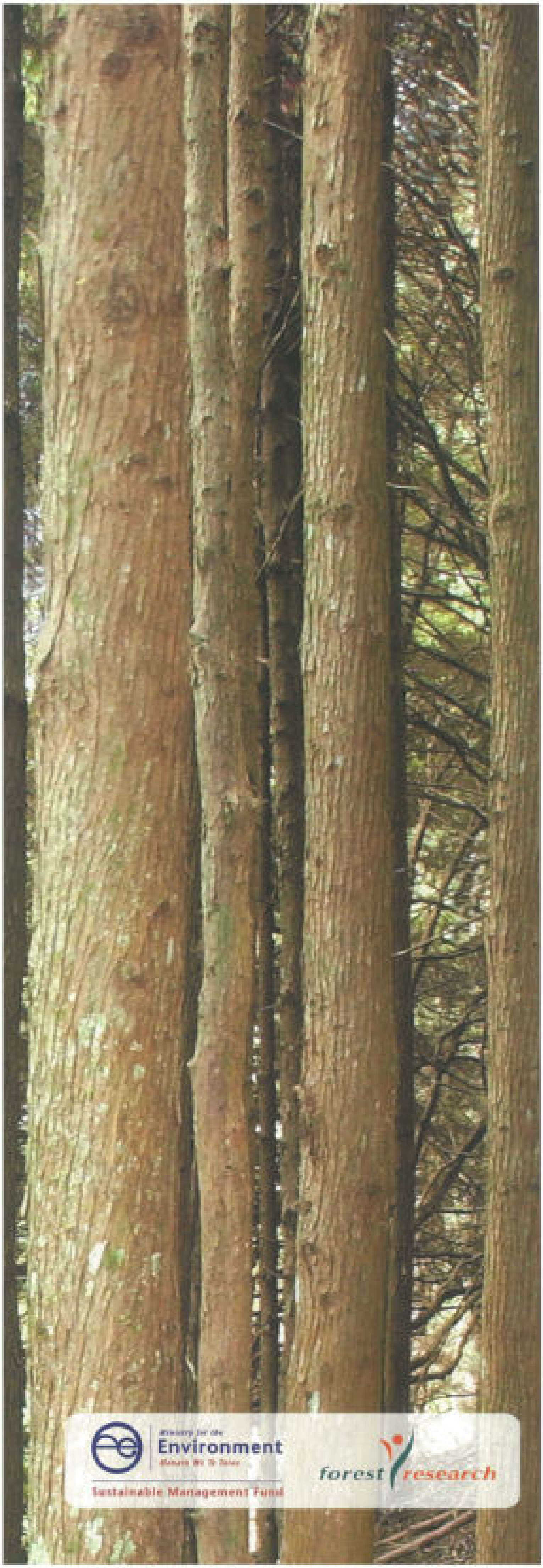
NATIVE TREES

PLANTING and EARLY MANAGEMENT for WOOD PRODUCTION

David Bergin
and Luis Gea



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Front cover: *Plantations of native trees and shrubs established for amenity and aesthetic values in the landscape, also provide the option of a future timber resource on appropriate sites.*

Back cover: *A dense planting of kahikatea in a Bay of Plenty park.*

NATIVE TREES —
Planting and Early Management for Wood Production

David Bergin and Luis Gea

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revised edition

New Zealand Forest Research Institute Ltd,
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INTRODUCTION

Millions of native trees and shrubs are being planted annually throughout New Zealand by various agencies, landowners, iwi, and community groups. Reasons for planting include enhancement of native plant and animal biodiversity for conservation; establishment of native cover on erosion-prone sites; improvement of water quality by careful revegetation of riparian areas; and management for production of high-quality timber. Evidence of large-scale planting of natives can be seen in urban and rural areas in many regions, supported by local authorities and community groups. Most visible are the large areas along roads and motorways planted in a wide range of native species. Other planting programmes are evident as travellers pass over rivers and streams where natives are planted in fenced-off riparian areas.

Many plantations of native trees established for timber production have not survived or have performed poorly. Planting has often been carried out in a casual way, with the expectation that native trees will either largely look after themselves or will respond to practices designed for exotic species. A small number of stands, some up to a century old, planted in various regions of the country have survived and indicate the potential that native trees have for producing valuable sawlogs. These and more recent trial plantings have provided information about establishment methods that are making planting programmes much more reliable.

There are many comprehensive guidelines written about establishment of native plants mainly for conservation in a range of ecosystems (e.g., Porteus 1983; Pollock 1986; Evans 1983; Ministry of Forestry 1988; Davis and Meurk 2001). These have provided valuable establishment information to land owners and managers, and community groups involved in revegetation using native species. This Bulletin does not set out to repeat these guidelines in detail. Rather, it focuses on planting native trees as a specialist timber resource for future generations. While there are a number of different sites available for planting native trees, including scrub, disturbed native forest, and sites with a cover of exotic forest, open sites are the most commonly planted areas. They are often the cleared sites within our productive landscapes that are fertile and easily accessible and therefore offer the greatest potential for good growth rates for native plantations.

This Bulletin begins by examining the range of objectives and site types where the planting of native tree species can be appropriate in our productive landscapes. The second chapter discusses practical options for establishing native trees and for enhancing existing areas of native vegetation, and the third is on matching species to site. A table lists the major native conifer and hardwood timber species, collating information from ecological requirements to wood properties and planting potential.

The next two sections provide guidelines for selection of planting stock and general information on planting techniques. Part 7 focuses on options for planting open sites, covering planting pattern, use of nurse crops and high-density *versus* low-density planting. Finally, we present some planting scenarios.

PART 1 – OBJECTIVES FOR PLANTING WITHIN OUR LANDSCAPE

Why Plant Native Trees?

Establishing a wood resource of native trees can often be achieved on the same site where stands will serve both environmental and production objectives. Most revegetation programmes use a wide range of native species and plant types (trees, shrubs, groundcover) to:

- extend forest remnants on farms and restore high forest;
- provide shelter on farms, around residential and horticultural blocks;
- provide aesthetic or landscape benefits;
- provide spiritual benefits;
- provide amenity and recreational facilities;
- enhance wildlife values and biodiversity;
- control erosion;
- improve water quality.

Many native trees can be planted for timber production. It is possible to select particular species and to construct plant communities in which the sustainable production of high-quality timber can be integrated with many of the conservation-based objectives. Planting of timber-producing trees can lead to other direct and indirect benefits such as:

- production of raw materials, e.g., bark, leaves, and oils used as medicines, herbs, food, and fibre;
- honey production;
- production of seed and cuttings used by the horticultural industry;
- provision of shade required for stream fisheries;
- provision of screens around buildings and unsightly areas;
- provision of physical shade on farms;
- enhancement of tourist areas.

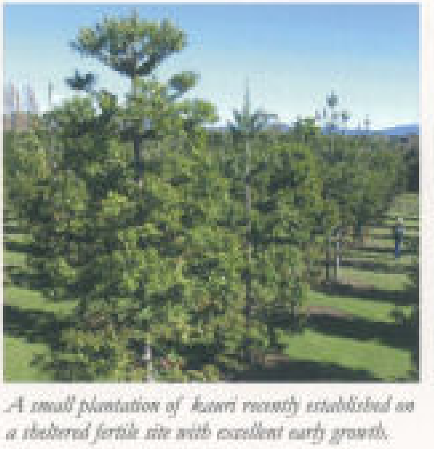
Planting of trees on bare land for carbon storage as part of the Kyoto Protocol (Horgan 2000) may provide a further economic opportunity and lead to increased interest in the planting of natives.

The planting of native trees has heritage and cultural appeal for those interested in growing them as well as those keen to use the timber for a range of practical and decorative purposes.

The supply of timber need not be a major reason for planting native trees. Acknowledgement of non-market benefits will reward owners and managers in many ways long before timber removal can be contemplated. As suggested by Meurk and Swaffield (2000), greater utilisation of native trees for sustainable woodlot timber will have significant biodiversity benefits in our production landscapes.

Revegetation of erosion-prone hill country with a range of native shrub hardwoods, harakeke, and cabbage tree.

Planted grove of native trees for amenity and recreation, Auckland Regional Botanical Gardens.



A small plantation of kauri recently established on a sheltered fertile site with excellent early growth.

Sites for Establishing Native Trees for Wood

Establishing native tree species should be considered in relation to several broad site types based on existing vegetation cover and landuse. The most common sites where natives are being planted are open grassed sites. Other sites where planting natives is feasible are within regenerating scrub, in partially logged native forest, and where direct replacement of exotic forest cover is required.

Planting open sites

Grassed sites retired from grazing are the most common areas for the planting of native trees and shrubs and are therefore the major focus in these guidelines. These usually ex-farm sites range from fertile sheltered sites, such as along retired riparian areas where good growth rates would be expected, to retired steep erosion-prone sites where revegetation to a native cover is preferable to continued grazing. Many urban or peri-urban areas being planted in natives are also open grass sites.

Mechanical clearing of a previous cover of exotic forest (e.g., pines) or woody brush weeds (e.g., gorse – *Ulex europaeus*) or other vigorous weeds (e.g., blackberry – *Rubus fruticosus*) also creates an open site for planting of natives. Unlike grass sites with a long history of grazing, recently cleared forest or scrubby sites, even if burnt over, will invariably have major ongoing weed problems which must be intensively managed to ensure successful establishment of natives.

A favoured method on more exposed sites is to establish a temporary nurse crop using hardy native or exotic species before interplanting of native timber tree species.

This line of planted totara has been regularly trimmed to form an effective shelterbelt in an orchard.

Recent research indicates favourable wood quality from fast-growing native woodlots

Current research being undertaken at Forest Research evaluating the growth and wood quality of selected native trees indicates that the timber from fast-growing planted trees can be as attractive as, and has many of the wood characteristics of, old-growth indigenous forest or locally grown and imported exotic species. With growth rates in excess of 50 cm in height and up to 1 cm in diameter per year on favourable sites, logs approaching 40 cm in diameter are achievable within 50 years of planting for kauri (*Agathis australis*) and totara (*Podocarpus totara*).

While development of heartwood is slow, particularly in native conifers, the sapwood of planted kauri and totara trees less than 50 years of age contains a range of colours and textures. A range of knot sizes in totara enhances its decorative potential. Basic density of the mainly sapwood from kauri in a 66-year-old plantation was lower than kauri heartwood but higher than that of radiata pine (*Pinus radiata*) (Bergin and Steward 2004). Wood shrinkage and stiffness testing showed plantation kauri was superior to that reported for old-growth kauri and commonly used exotic forestry species. Similar preliminary results are found with fast-grown planted totara.

The results suggest that relatively young plantation-grown native conifers have good potential as a solid wood resource. Preliminary investigations of some of the hardwood tree species in early plantations also indicate fast growth rates but probably faster development of heartwood than in young plantations of native conifers. Such research is providing encouragement to landowners planting native trees on good quality sites not only for environmental and social objectives but also for the option of timber production for future generations.

Other sites

Regenerating scrub — Many previously cleared or farmed areas have reverted to scrub cover. This usually consists of native pioneers, predominantly manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*), or other woody species including exotics such as gorse. For instance, large tracts of erosion-prone hill country on the East Coast of the North Island have reverted to manuka and kanuka after periodic downturns in the farming industry (Bergin *et al.* 1995). On some scrub sites, the natural regeneration of native tree species may be sufficient to obviate the need for planting but, in the absence of a local seed source, regeneration may be absent or scarce and the planting of desired native trees will be necessary.

Planting options will depend on height and density of scrub. Where possible, using natural canopy gaps will allow establishment of native tree species within the scrub cover to supplement or substitute for natural regeneration. Lanes cut through the vegetation using chainsaws or scrub-bars will allow planting at appropriate spacing. In trials established in the Wairarapa and on the East Coast of the North Island, lane widths exceeding 3 m in scrub up to 4 m high increased the risk of frost damage to planted native trees. Natural gaps in tall scrub (over 6 m) reduced the need for lane cutting. Spacing of trees at 3–6 m in lines 8 m apart will give an overall stocking rate of 200–400 stems/ha (Steward 2000).

In tall scrub it may be preferable to cut parallel access tracks through existing cover with circular gaps 4–6 m in diameter at regular intervals. Access lanes 10 m apart with gap centres at 15-m intervals and three to four trees planted in each gap will give an overall stocking rate of 180–240 stems/ha. Gaps exceeding 6 m in diameter are needed for the establishment of light-demanding species (e.g., totara) but may place frost-tender hardwood trees (e.g., puriri (*Vitex lucens*), kohekohe (*Dysoxylum spectabile*)) at risk (Steward 2000).

Hand-releasing with slashers is the most practical method for removing ferns and shrub hardwoods that have the potential to overtop planted trees. Releasing will be necessary for at least 2–5 years after planting or until trees reach about 2 m in height (Bergin and Pardy 1987). Unless this operation is carried out at least once each year, locating of planted seedlings may be impossible. Interplanting of natives in gaps or along cut lines in gorse or other exotic woody cover can be especially difficult in dense cover, and regrowth including coppicing from cut stumps will require regular maintenance to ensure planted natives are not smothered. It is essential that full overhead light is available for the planted native trees. If the surrounding canopy is closing over, branches or stems of adjacent shrubs and trees must be removed.

Where seed sources of native trees have been lost over large areas of reverting scrub, an alternative to intensive lane planting is planting of small groves of trees. These groves scattered throughout a scrub-covered landscape will eventually provide seed of native tree species for wind and bird dispersal and, along with browsing animal control, will encourage natural regeneration of hardwood and conifer trees.

Mixed scrub species dominated by manuka, typical of a regenerating site where enrichment of native trees involved planting in lines or gaps.

Forest sites — Native forests have often been degraded by partial logging, earlier attempts at clearing for farmland, or a long history of browsing by wild animals. Natural regeneration often occurs if sites are fenced off and animals are controlled. However, planting and management may be desired by landowners to increase the proportion of native timber tree species.

A survey of the existing plant community will indicate areas where tree species are non-existent or suppressed. Native conifers or hardwoods can be planted where there are natural or logging-induced gaps in the forest canopy. The recommended pattern consists of clusters of three to five plants at 1- to 1.5-m spacing. Distance between clusters can be varied to allow selection of suitable microsites where soil is disturbed, well-drained, and free from dense growth of tree ferns and large tree roots. Group plantings are easily relocated for regular releasing from ferns and shrubby species. The aim is to eventually achieve one good tree per cluster (Forest Research Institute 1980a; Pardy and Bergin 1992).

Site preparation in disturbed forest areas must include removal of ferns and shrub hardwoods that may suppress the young planted trees. A small tractor can be used to clear very dense ground cover such as toetoe (*Cortaderia fulvida*) and shrub hardwoods from canopy gaps in high forest (Forest Research Institute 1980a). Hand clearing with slashers may be adequate for the planting of small groups of trees. As for planted trees in regenerating scrub, annual releasing may be required for up to 5 years after planting or until trees reach about 2 m in height (Beveridge and Bergin 1999).

Gaps logged in native forest planted with native seedlings are vulnerable to vigorous regrowth of ferns and shrubs.

Poisoning of willows allows the development of underplanted and naturally regenerating native trees and shrubs.

Replacing exotic forest — There is increasing interest in returning stands of exotic trees to native vegetation. Clearfelling to allow removal of merchantable logs generally leaves a highly disturbed open site where regrowth of problem weeds can come to dominate. Regeneration of native plants is often present under exotic forest covers of pines and willow. On some sites it may be practical and desirable to remove low densities of canopy exotic trees by careful felling for removal of logs without damaging understorey natives.

Where timber is not recovered, directional felling to minimise damage to understorey native plants, or poisoning to waste in one operation or over several years, may be practical options for encouraging gradual development of native regeneration. Poisoning by drilling holes around the base of the trunks of exotic trees and inserting herbicide allows gradual disintegration of the tree crown. These options for removing an exotic overstorey may also be appropriate for underplanted native trees.

Planted Native Trees in our Productive Landscape

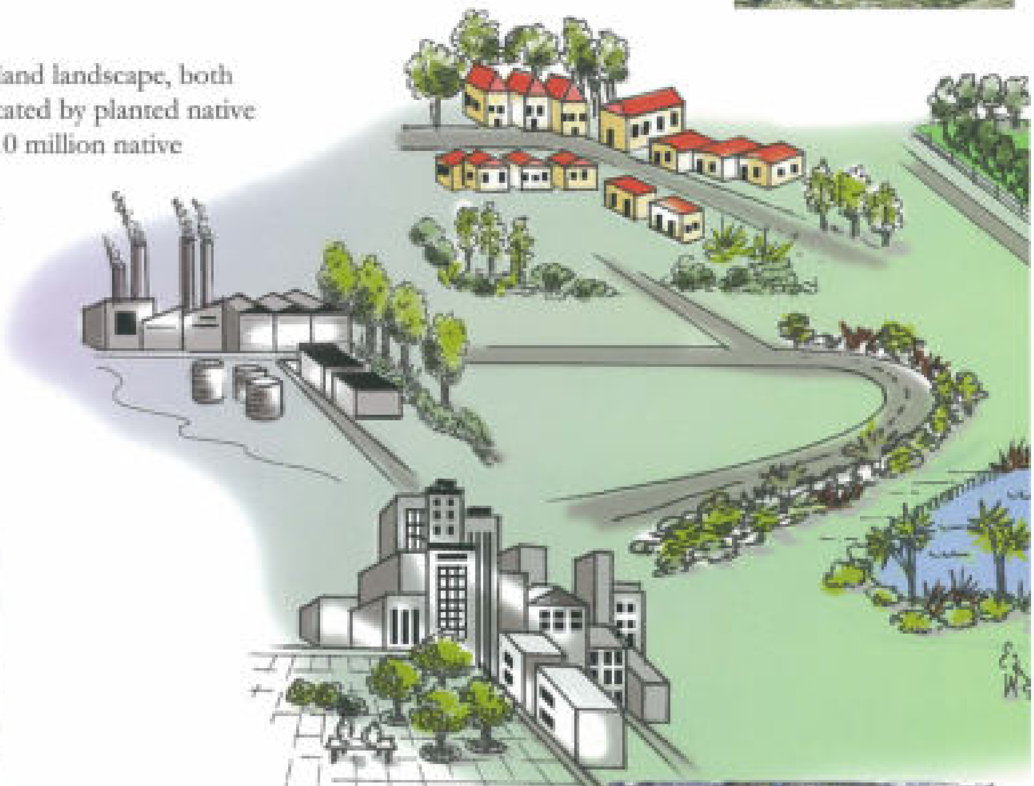
Concern is increasing about the ongoing decline in New Zealand's indigenous biodiversity and for the ecological sustainability of land uses that support our primary industries (Parliamentary Commissioner for the Environment 2002). While the Commissioner strongly supports ongoing preservation initiatives to restore our threatened ecosystems, there has not been adequate exploration of the potential beneficial roles that native plants can play in our productive landscapes dominated by exotic pastoral, horticultural, and forestry landuses. As part of a broad range of management opportunities for native plants on our working lands, there is excellent scope for the planting and management of native trees. In addition to the potential productive value of native tree plantations, the establishment of native forest in these productive landscapes will enhance indigenous biodiversity and will likely improve productivity of the existing primary sector.

Significant areas of the New Zealand landscape, both urban and rural, are being revegetated by planted native species. It is estimated that over 10 million native plants are produced annually in native plant nurseries throughout the country (Mark Dean, Naturally Native New Zealand Plants Ltd, pers. comm.). Significant proportions of these native plants are major timber species.

Unwittingly or by design, those planting native trees are establishing a resource which future generations will have the option to manage for extraction of high-quality, high-value specialty wood. Any long-term management plans will be designed to ensure that the non-wood values of planted areas will be preserved.

Replacing exotic forest

Options for reverting exotic forest to natives by regeneration or planting include careful felling and extraction or poisoning to waste.

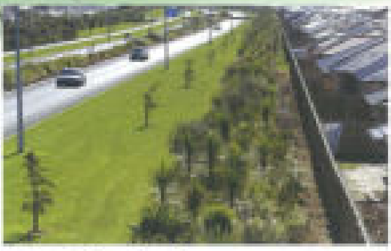


Urban planting

There is potential for utilising wood from native trees that have been planted in urban and peri-urban areas, along streets, and in gardens. Many are removed as they become too large and unsafe, or block views, or their roots damage buildings, roads, footpaths, and drains.

Screens

Establishment of screens along highways or adjacent to industrial sites could include a mix of native trees which will provide a resource of native timber.



Roadside planting

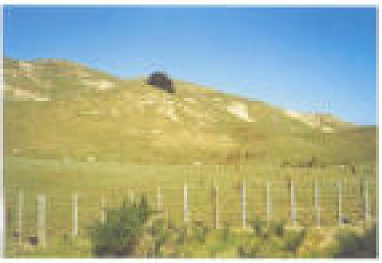
Stretches of the nation's highways are being planted in natives to provide attractive vistas for motorists, and screens for adjacent housing. They are another developing resource of native timber.

Shelterbelts

Some timber-producing native trees can be used to form single or multi-row shelterbelts, along with shrub hardwoods and flax onsome sites.

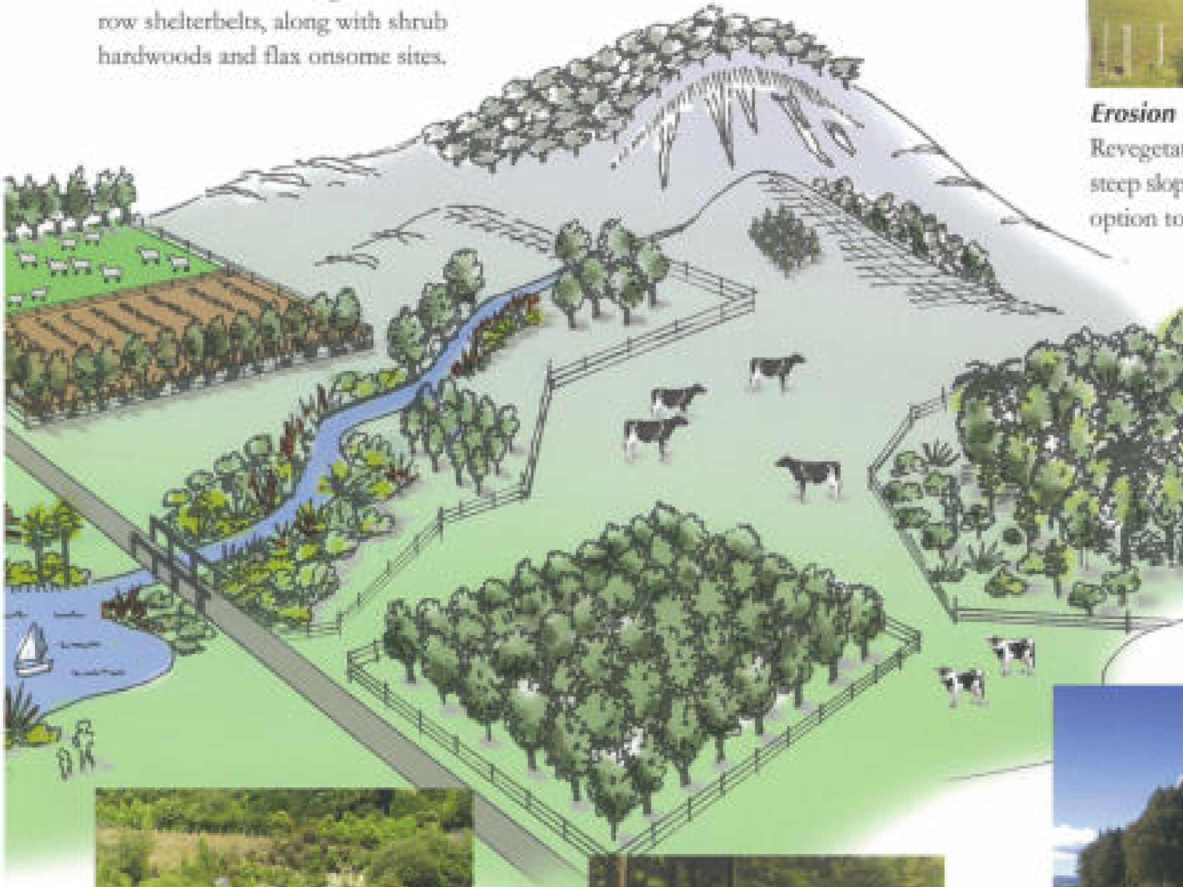
Enrichment of scrub

Enrichment planting in lines or gaps within any natural regeneration to reintroduce key timber species may be feasible. Planting scattered groups will provide a seed source.



Erosion -prone hill country

Revegetation of previously forested steep slopes may be the only practical option to reduce soil erosion.



Extension of forest remnants

Landowners may want to extend existing forest remnants on farmland by fencing off areas and planting with native trees with the option of supplying timber.

Woodlots in riparian zones

Riparian zones represent a significant land area for the planting of native trees and shrubs. Timber trees can be planted in groves or small groups along upper banks or on elevated terraces.

Establishing woodlots

Many native tree species show excellent potential for plantation management for timber. Small woodlots established on good sites will give optimum growth.

PART 2 – OPTIONS FOR ESTABLISHING NATIVE TREES

Planting of nursery-raised seedlings is the most commonly used method for establishing native trees and allows control of the species, and the density and pattern of the growing stand. Planting, however, can be a high-risk activity and very expensive and demanding to implement successfully, especially on a large scale. Direct seeding is an option that is of increasing interest but is likely to be very site-specific. Encouraging the growth of natural regeneration, while dependent on factors such as occurrence of local seed sources of the desired species and degree of weed competition, is a preferred option wherever possible.

Planting nursery-raised plants is the most common method of establishing native species.

Nursery-raised Seedlings

The usual method of establishing native species is to use plants raised from seed in containers (pots, planter bags, or rootrainers) in plant nurseries. Most native conifer and hardwood tree species can be grown from seed using standard nursery techniques. Seed production and germination rates vary and may affect the availability of some species from one year to the next. Seeding characteristics and appropriate nursery techniques have been published for kauri by Lloyd (1978) and Halkett (1983), for podocarps by the Forest Research Institute (1980b), and for hardwood trees and shrubs by the Forest Research Institute (1988) and Pardy and Bergin (1989).

Forest duff collected in winter beneath target trees contains seeds and can be used to produce seedlings of a range of native species including matai (Prumnopitys taxifolia) and miro (Prumnopitys ferruginea) which are slow to germinate (Herbert 1977). This method is best suited to small-scale operations.

Many native species have been successfully raised as bare-rooted seedlings and this method is especially suited to large-scale production and planting programmes where production costs can be reduced (e.g., Forest Research Institute 1980b; Beveridge et al. 1985). Container-grown and bare-rooted plants can be planted at appropriate spacings to encourage optimum growth rate or to fulfil requirements such as shading or screening.

Seedlings, depending on age and size, are each likely to cost between $2 and $5 for bulk orders from commercial nurseries, with faster-growing shrub hardwoods $2–3 and native trees particularly conifers $3–5.

Cuttings

Although some natives, particularly shrub hardwoods, are raised from cuttings, raising native timber species from cuttings is not practised on a large scale as most species are more easily raised from seed. Some native trees, such as rimu (Dacrydium cupressinum) (Dakin and Mearns 1974) and totara (Bergin 2003), can be raised from cuttings.

Transplanting of wildings

The removal of small seedlings from forest and scrub sites, often termed "wildings", is labour-intensive and mortality of transplants can be high. Transplanting wildings of species where seed is difficult to obtain each year and in which germination is poor such as matai and miro, has been successful on a small scale. Best survival and growth has been with wildings less than 15 cm tall.

Direct Seeding

Broadcasting seed as a method of establishing tree species has seldom been successful and it is rarely practised on a large scale. Laying of manuka brush containing ripe seed capsules on the ground has succeeded on a limited scale for the revegetation of recently disturbed forest and scrub areas (A.E. Beveridge, pers. comm.).

The Waipoua Forest Trust aims to extend kauri forest to the south of the Waipoua Forest Sanctuary and is using manuka seed to establish a shrub cover on grassed sites to shelter interplanted kauri (Bergin and Steward 2004).

Manuka seed is scattered by hand along furrows made 4–5 m apart by tractor-drawn discs. Ledgard and Davis (2004) found that mountain beech (Nothofagus solandri var. cliffortioides) and manuka can be established by seeding shortly after fire. The window for achieving good establishment may be no more than 2 years, after which exotic grass is likely to dominate.

Large-scale conversion of retired farmland to a cover of manuka by direct seeding undertaken by the Waipoua Forest Trust in Northland.

Successful direct seeding usually requires the removal of competing vegetation and/or exposure of mineral soil. Depending on site conditions and species, small newly germinated seedlings are more prone to mortality caused by desiccation, and by fungal and insect attack, than larger planted seedlings. Viability of seed can vary from one year to the next and between species. Collection of large amounts of seed for broadcast sowing on to prepared sites can be difficult and labour-intensive for some native species. High initial plant densities are required to allow for poor germination and early mortality.

In contrast to many native tree species, seeding of the readily available manuka is likely to give a rapid cover of woody native species on cleared sites that will enable later introduction of native trees.

Enhancement of Natural Regeneration

Native vegetation is regenerating naturally in many cleared or partially logged areas throughout the country. Meurk and Swaffield (2000) project that even in our largely exotic productive landscapes, native species (and hence biodiversity) are regenerating spontaneously in many sites such as within hedgerows, along roadsides, in shelterbelts, woodlots, gardens, and riparian areas. The pace at which this process occurs and the species composition of resulting communities will be influenced by many factors (Beveridge *et al.* 1985). These include:

- the characteristics of the original forest and the current landscape;
- site history, e.g., intensity of logging, burning, and clearance;
- the current condition and landuse of cleared areas;
- the presence, vigour, and persistence of weed species;
- distance from seed sources;
- presence and effectiveness of seed-dispersal agents;
- and the presence of browsing animals.

Reducing or eliminating factors that are inhibiting natural regeneration may be a more practical strategy than planting nursery-raised seedlings. A survey of sites in which natural regeneration is taking place may show that timber species are already present. Where regeneration is occurring, thinning, weed control, and releasing of target tree species from overtopping canopy may be required to improve survival and growth. Where natural regeneration is non-existent or insufficient, planting scattered groups of native timber trees that will become a seed source may be sufficient to restock such areas.

A survey of sites that are naturally regenerating will show whether native timber species are already present and whether supplementary planting is desirable.

PART 3 – PLANTING PATTERN AND ECOLOGICAL REQUIREMENTS

There is considerable variation in the ecological requirements and site preferences of native tree species. Some require shelter in early years on open sites to improve growth, while others tolerate exposure. Some species tolerate high levels of moisture while others are adapted to dry sites. Planting native species at random through an area is unlikely to match species to the most suitable sites and therefore will probably compromise overall performance.

Choice of species and planting pattern will also be influenced by the objectives of planting — e.g., timber production, shelter, soil conservation. Growth habit and performance of each species will determine suitability. For shelterbelts on farmland, native species that are suited to windy open sites, which have an erect form, and are amenable to trimming are likely to be more successful. For amenity and aesthetic purposes, the native tree species required are those that form attractive spreading crowns in parks or along avenues but which can be pruned to give straight lower boles for timber. For revegetation, scattered planting of native trees that benefit from interplanting in a shrubby cover may eventually yield good quality timber trees. Where the main aim is timber production, choosing the most valuable and productive species and planting on suitable sites will be the best option.

Matching Species to Site

Establishing groves of single or mixed species so that they resemble natural plant communities requires a knowledge of the ecological requirements of each species, as well as information on characteristics of the planting site, such as moisture and exposure. Planting of kahikatea (*Dacrycarpus dacrydioides*) in lower moist areas, siting of frost-prone hardwood tree species in relatively sheltered valley sites, or planting of manuka on exposed ridge sites to ameliorate the site for later planting of native timber trees are examples of species/site matching.

While natural distributions of native species will give an indication of site preferences, some tree species may actually grow faster on sites where they are not naturally dominant. Species occupy some sites in nature because they tolerate particular site factors better than other species. For example, kahikatea stands often occupy low-lying swampy sites that are occasionally flooded, though the largest kahikatea are found on better-drained ground. Similarly, kauri is often found as dense regenerating pole stands on exposed drought-prone ridge sites. It survives but grows slowly on these dry sites where there is less competition from other species that do not tolerate droughty conditions. The fastest growing kauri are, however, found on lower hill slopes where occasional trees have survived intense early competition from hardwood species.

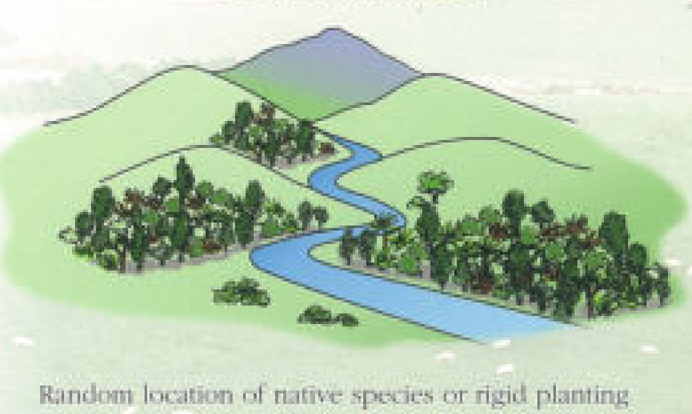
For native tree species, best plantation growth will occur on sheltered sites where soils are deep and fertile and there is adequate moisture.

The Dilemma in Establishing Native Plantations

Should those landowners wanting to establish a native woodlot match species to site based on natural regeneration patterns, or should they plant on the best sites to achieve optimum growth?

Locating species on sites matching their ecological requirements that mimic natural patterns of regeneration

Random Planting Pattern — not recommended

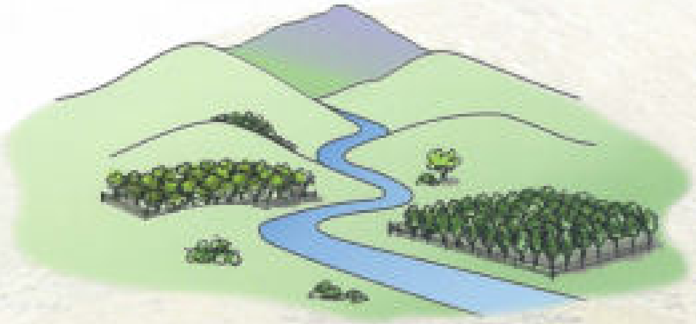


Random location of native species or rigid planting layout over a range of microsites without accounting for species/site preferences may result in a less natural appearance and sub-optimal survival and growth.

is likely to be the most appropriate approach where revegetation is the primary objective. Such sites will contain native timber species and, although growth rates are likely to be compromised by competition or other site factors, landowners still have the option of removing semi-mature or mature trees for future timber.

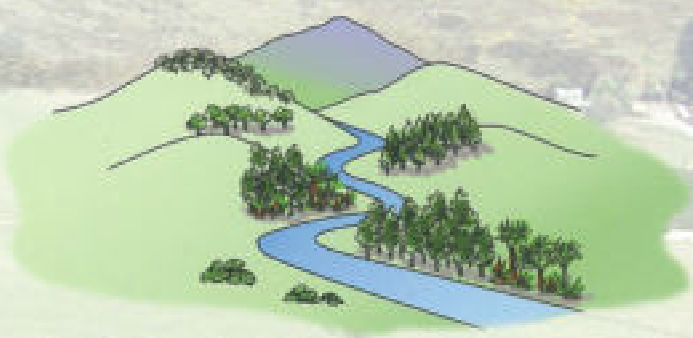
For those landowners whose major objective is to establish plantations of native trees for high-value timber production, using natural patterns of regeneration may play a lesser role in determining planting sites and patterns. To ensure optimum growth rates of native tree plantations targeting the best planting sites, in combination with good site management and silviculture practices, is the best strategy.

Choosing Optimum Sites for Native Tree Plantations



Establishing high-value native species in plantations on fertile sheltered sites, with optimal after-planting care and silviculture, provides the best opportunity of good growth rates and desired wood quality.

Mimicking Natural Regeneration Patterns — suitable for revegetation



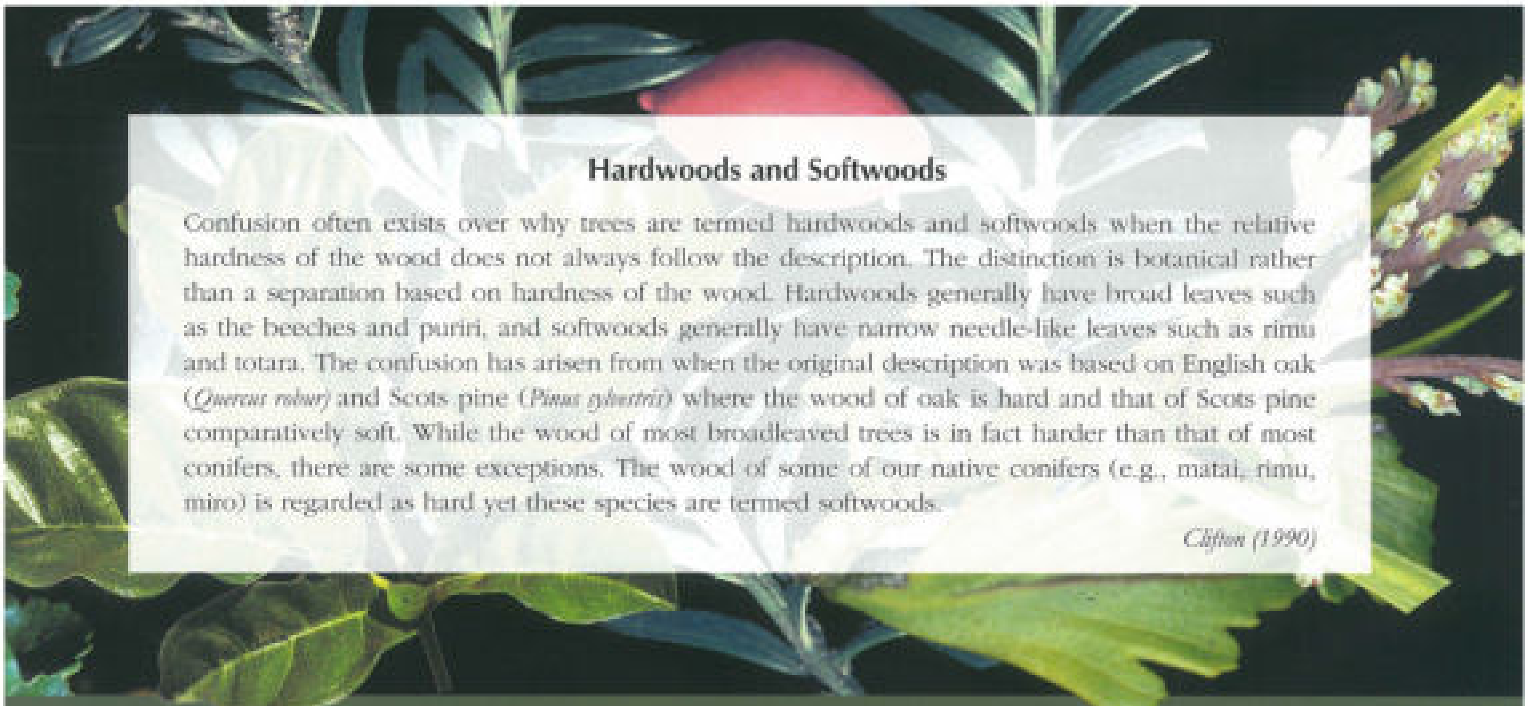
An understanding of ecological requirements of each of the native tree species will allow matching of each species to suitable sites to mimic natural regeneration. This planting pattern should give good survival and growth rates for most species, provided weed control and releasing are to a high standard.

PART 4 – CHOICE OF SPECIES FOR WOOD PRODUCTION

Choice of species is critical if native trees are being planted for timber production. Many native trees were used for a variety of purposes by both Maori and early European settlers. The tree species reviewed here have most of the following characteristics: desirable wood properties, reasonable growth rates, a relatively wide site tolerance, and can be raised as seedlings on a large scale. Information on their natural distribution, ecological requirements, wood quality and uses, and their propagation and plantation potential are given in the table below. This is summarised from the work of Hinds and Reid (1957), Forest Research Institute (1980a, 1980b, 1988, 1997), Wardle (1984), Bergin and Pardy (1987), Pardy and Bergin (1989), Clifton (1990), Pardy *et al.* (1992), Ecroyd *et al.* (1993), Ministry of Forestry (1998), Bergin (2003), and Bergin and Steward (2004).

Softwoods

Species	Natural distribution	Ecological requirements	Wood quality
Kauri (***Agathis australis***) 	Natural distribution from northern Northland southward to Kawhia in the west and Tauranga in the east. Grows up to 50 m. Massive ancient trees up to 3 m diameter.	Requires warm temperature and relatively high light conditions for optimum establishment and growth. Very tolerant of periodic dry conditions, hence survives on dry skeletal ridges where many other species cannot, often forming dense ricker or pole stands after clearance. Best growth on lower slopes where trees have survived competition from broadleaved species.	Heartwood light to rich reddish brown; sapwood very light brown. Straight even-grain wood with excellent strength, workability, and finishing properties. Has characteristic speckled appearance. Heartwood moderately durable. Regarded as one of the world's greatest timbers.
Totara (***Podocarpus totara***) 	Widely distributed in lowland and montane forests throughout the country; regenerating on farmland in many regions. Once scattered trees or stands on coastal, swamp margins, valleys and plains, volcanic and hill country sites.Up to 30 m tall. Ancient trees up to 2.5 m diameter.	Tolerant of a wide range of climates and sites. More tolerant of dry soils and seasonal droughts than other native conifers; intolerant of poorly drained soils. Most light-demanding of the conifers. Regeneration rare under canopy, more frequent under gradually opening scrub cover. Relatively unpalatable to domestic stock but is browsed by possums which are implicated in dieback of trees in some regions.	Timber considered to be unequalled in terms of its physical properties including ease of shaping, light weight, and durability. Heartwood amenable to all types of machining, easily brought to a smooth finish.
Rimu (***Dacrydium cupressinum***) 	Most widely occurring of the major conifer native trees; prominent in many forest types from North Cape to Stewart Island. Up to 50 m tall, usually 20–35 m. Can attain 1.5 m diameter.	Found on a wide range of soils throughout the country and over a wide climatic range. Dense stands on recent pumice soils in central North Island and moraines of Westland plains. Regeneration scattered or sparse in most forest types; regeneration on disturbed sites where mineral soil exposed and competition reduced. Seedlings need shelter from wind. Persists in shade but best growth is in well-lit forest gaps. Least palatable of the native conifers.	Heartwood highly decorative, even texture, hard, even wearing, durable above ground, paints well, and with excellent machining and finishing. Sapwood does not sapstain easily, seasons readily, machines and finishes well but is attacked by borer. Dry heartwood needs drilling before nailing.

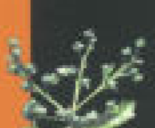
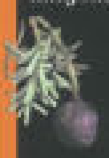
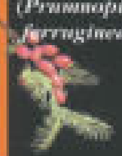


Hardwoods and Softwoods

Confusion often exists over why trees are termed hardwoods and softwoods when the relative hardness of the wood does not always follow the description. The distinction is botanical rather than a separation based on hardness of the wood. Hardwoods generally have broad leaves such as the beeches and puriri, and softwoods generally have narrow needle-like leaves such as rimu and totara. The confusion has arisen from when the original description was based on English oak (*Quercus robur*) and Scots pine (*Pinus sylvestris*) where the wood of oak is hard and that of Scots pine comparatively soft. While the wood of most broadleaved trees is in fact harder than that of most conifers, there are some exceptions. The wood of some of our native conifers (e.g., matai, rimu, miro) is regarded as hard yet these species are termed softwoods.

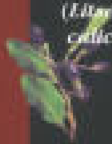
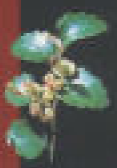
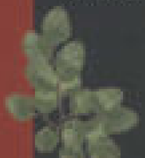
Clifton (1990)

Past and current uses	Propagation	Plantation potential
Maori in the north use it for waka taua (seagoing canoes) and construction of whare (buildings). Early settlers' uses included buildings, bridges, ships, vats, wooden machinery, and furniture. Today logs recovered from swamps after thousands of years of burial, and stump and head-log material recovered from earlier logging operations, are used for furniture, turnery, and crafts.	Collection of cones from crowns in February before cones break up and seed scatters. Germination from seed of northern stands may be better than from trees further south. Seedling root systems slow to develop. Successfully raised in northern nurseries, mostly in containers but taproots easily distorted and fibrous root development sometimes feeble.	Good growth rates on fertile sheltered sites, well beyond its natural range. Strong apical dominance usually resulting in tall, straight, single stems. Natural shedding of lower branches results in long, clear boles especially in stands. 50-cm-diameter achieved within 60 years on good sites with control of competition in early years. Heartwood formation slow. Preliminary evaluation of sapwood from fast-growing plantations indicates favourable wood qualities for furniture and high-value decorative uses.
Early Maori quickly appreciated its strength and carving potential. Used for joinery and furniture, and finishes well with a coating of oil or wax. Once widely used for joinery, fence posts, battens, buildings, bridges, railway sleepers, foundation piles, and shingles; sapwood used for building exteriors. In recent years only small amounts of wood, including recycled timber, available for crafts and turnery, and for rustic furniture.	Annual seeding but crop fluctuates in abundance. Some trees produce empty seed even when receptacles formed. Seed green when ripe, fallen seed turns brown but still may be viable. Germination often irregular and may occur in two phases. One-year-old nursery seedlings up to 30 cm high raised in lowland nurseries. Readily produces fibrous roots. Easily raised in containers or as bare-root seedlings. Can be raised from cuttings.	Most widely planted native tree during the twentieth century, reflecting the relative ease of seed collection and raising of seedlings, and adaptability to a wide range of sites when planted. Few plantations survived, most succumbing to poor weed control in early years. Easily established but single or wide-spaced trees multi-leadered and coarsely branched. Average annual height increment 55 cm and an annual diameter increment of 10 mm achieved on the best sites with good management.
Most commonly used native timber tree due to its abundance and wide distribution, its high quality and multiple uses. High grades used for flooring, weatherboarding, interior joinery, veneer, and furniture. Lower grades used for framing.	Infrequent and irregular seeding; good seeding once or twice per decade. Empty and undeveloped seed common. Seed highly palatable to finches in tree crowns. Seed collection therefore costly. Seedlings raised as bare-root or in containers; vigorous fibrous root systems can be difficult to achieve, especially in bare-root production. Can be raised from cuttings.	Tolerates wide range of forest sites; reliable performance. Currently not raised in large numbers, possibly due to difficulty in obtaining large quantities of seed every year, the need for sheltered planting sites, and only moderate growth rates compared to other major native conifers. Many trees in small established plantations have poor form stems. Slow initial height growth after planting; on good sites increases to up to 40 cm annual height growth once established.

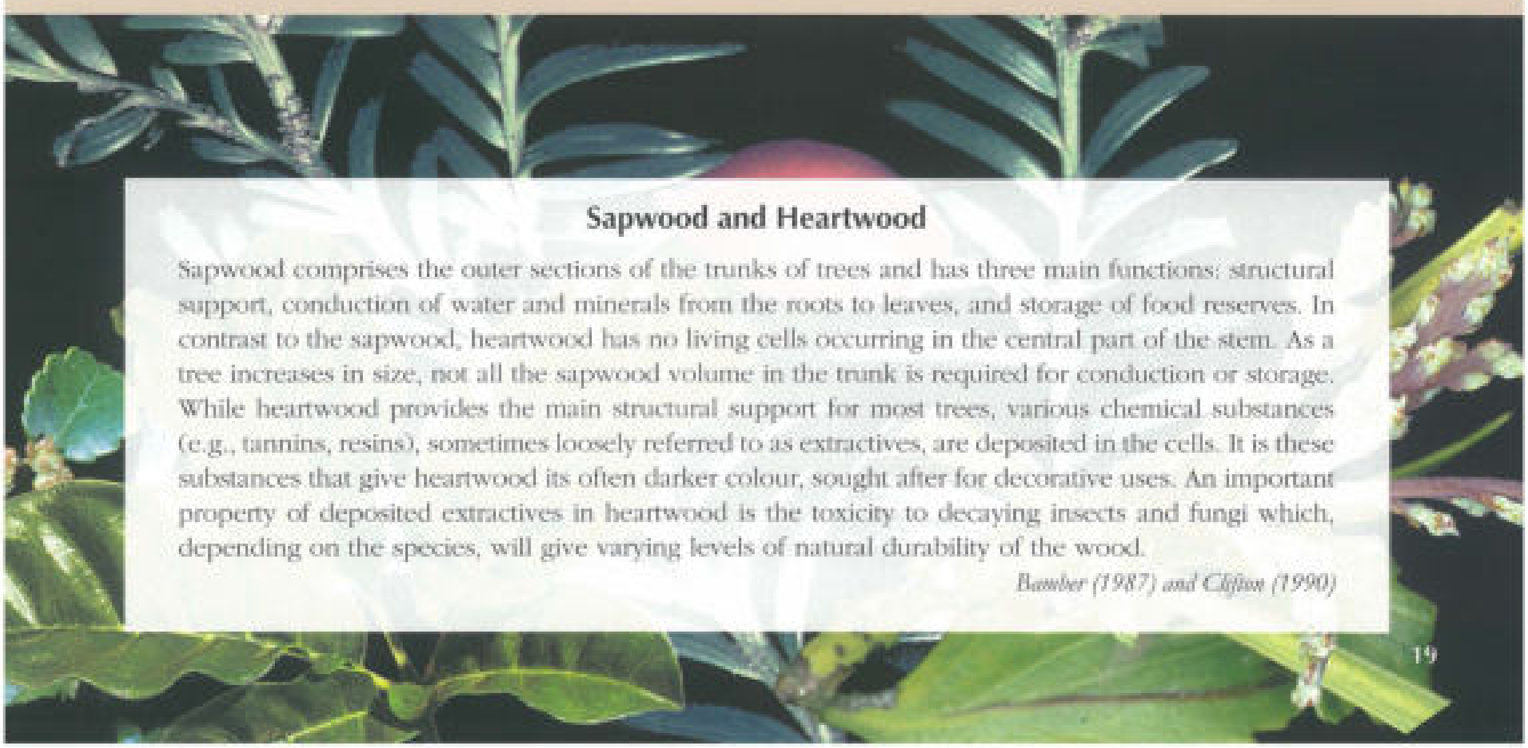
Species	Natural distribution	Ecological requirements	Wood quality
Softwoods			
Kahikatea (***Dacrycarpus dacrydioides***) 	Common throughout; dominant in lowland swamps. Tallest native tree at up to 60 m. Most trees 50–130 cm diameter.	Occupies a wide range of soils from heavy clays to pumice sands; densest stands found in lowland swamps as result of competition; largest trees on well-drained soils including pumice of the central North Island and deep river terraces. Natural regeneration abundant but, unless on open fresh soil surface, most fail within forest. More site-specific than rimu but almost as shade tolerant. Palatable to browsing animals.	Light, soft, white timber consisting mainly of perishable sapwood prone to sapstain and to attack by *Anobium* borer. Yellow resinous heartwood is durable. Known for ease of machining, turning, nailing, and freedom from tainting qualities.
Tanekaha (***Phyllocladus trichomanoides***) 	Sporadic in central, northern, and eastern regions of the North Island. Trees up to 20 m high, 50–80 cm diameter.	Found in many forest types, usually as single trees or in small groups. Optimum growth on well-drained lowland alluviums or pumice soils. Sometimes pioneer species forming pole and sapling stands along forest margins on steep dry terrain. In Northland often slowly establishing on ridges on dry sites with kauri where competition is less. New growth palatable. Regenerating seedlings common in many northern forests.	The strongest and most flexible NZ softwood, high density, straight-grained, and stable. Heartwood durable above ground, sapwood not durable. Not easily split. A fine even texture and lustrous figure. Saws, dresses, and turns well with a smooth finish.
Matai (***Prumnopitys taxifolia***) 	Throughout the country, most common in central North Island, locally abundant in South Island, rare on Stewart Island. Up to 25 m high; diameter in excess of 1 m.	Juvenile habit of pendulous branches and small red-brown leaves persists until tall sapling stage. Found on wide range of soil types, preference for well drained moist alluviums, abundant on pumice sands. Largest over-mature trees often hollow.	Dry heartwood darkens to deep red-brown, sapwood white similar to rimu but without intermediate zone. Heartwood durable above ground, hard and dimensionally stable. Straight grain with fine even texture. Easily machined and polishes well.
Miro (***Prumnopitys ferruginea***) 	Common throughout. Up to 25 m high. Usually smaller diameter than matai and rimu.	In association with most important timber trees, both conifer and hardwood. Often found in combination with rimu but not dominant. Occurs on wide range of soil types; good trees on deep pumice sands of central North Island.	Seasoned heartwood light brown, sapwood yellow-white. Heartwood durable above ground. Wood hard, grain moderately straight. Prone to warping. Easily machined.
Hardwoods			
Puriri (***Vitex lucens***) 	Sporadic in coastal and lowland forest from near south Taranaki in the west and North Cape to Mahia Peninsula in the east. Grows up to 20 m high with stem diameter up to 1.5 m, most less than 1 m diameter. Related to teak.	Prone to frosting and damage from possum browsing. Prefers lowland and coastal warm sites with fertile well-drained soil. Coppices readily; wind-fallen trees can form multiple stems along trunk.	Dark brown heartwood that is hard, heavy, ground durable, and strong. In early European times, reported to be difficult to work because of its interlocking grain. Timber is damaged by the larva of the Puriri moth (*Aenetus virescens*) that typically constructs tunnels. Callus forms over tunnel entrance where damage is not visible until the wood is sawn.
Rewarewa (***Knightia excelsa***) 	Scattered trees or small stands in lowland and hill forests of the North Island; rare in the north of the South Island. Large tree up to 30 m high and 1 m in diameter. Upright crown with erect branches.	A northern NZ species with best growth in warmer regions, moderately frost and drought resistant. A secondary species in many forest types, forming small colonies such as on exposed ridges and crests; long-lived pioneer in early seral forest, especially after clearance by fire. Seedlings will develop through shrub cover.	Timber with distinctive figure, tough, stiff, and hard wearing, with non-skid properties; machines well. When cut on the quarter, figure resembles oak. Can be peeled for veneer.
Kohekohe (***Dysoxylum spectabile***) 	Coastal forest from North Cape to the north of the South Island. Grows up to 17 m, and trunk diameter occasionally up to 1 m. Related to mahogany.	Temperate coastal forest tree. Successful in warm, frost-free moist environments. Shade-tolerant, regenerates under shade. Needs a covering of leaf litter during germination; seedlings can establish in shaded forest. Effective coloniser in forest rather than in open sites or early successional forest with poor litter.	Attractive, light reddish-brown wood with fine, even texture. Sapwood clear brownish white. Heartwood slightly lustrous and rather soft. Not durable for outside use. Easily worked and takes a high polish. Referred to as New Zealand mahogany.

Past and current uses	Propagation	Plantation potential
Early clearance of lowlands for dairying, and non-tainting qualities of this timber meant that large quantities were used for butter boxes, cheese crates, and dairy machinery. High grades used for weatherboarding, joinery, flooring, boat building, wooden ware, food-preparation equipment, and storage.	Seeds most years, with heavy crops of seed every 3–5 years. Pattern of seeding local. High proportion of viable seed when heavy crops produced. Seedlings easily raised in nurseries as bare-root and in containers. Dense fibrous root systems easily obtained.	High survival and moderate growth rates on most sites except dry ones. Tall flexible stems vulnerable to over-topping by dense regrowth of ferns and hardwoods soon after planting. Cicada damage can lead to breakage of stems within the first 3–5 years. 50% faster-growing than rimu on moist fertile sites with full overhead light. Generally good form and frost hardy.
Strong, so Maori used it for spears and for renewable parts of canoes and houses. Bark produces red dye to colour fibres for weaving. Early settlers used it for sleepers and props in mines, bridge and wharf decking, industrial flooring. Also used as exterior joinery, wooden machinery including sweeps and hay masts, boat framing, sporting goods, veneers. Saplings sought for fishing rods.	Light annual seed crops, infrequent good seed years. High incidence of empty seed in some localities, uneven seed ripening on small trees. Poor germination in cool upland Forest Research nursery; some success in northern nurseries. Seed in humus collected from beneath seed trees has produced seedlings. Can be raised from seed as bare-root or in containers.	Apically dominant, producing single straight leader. Nursery-raised seedlings have high survival and moderate growth, similar to kauri. No major plantations established. Requires full overhead light and side shelter. Drought resistant.
Maori used it for carving, canoes, some agricultural implements, adze shafts, pallisade construction. Used for exterior joinery and weatherboards and widely used for flooring due to hardness and stability. Minor current use for heavy duty flooring, craft furniture and turnery.	Seeding infrequent and irregular, heavy crops occasional. Seed damaged by insects and rodents. Difficult to germinate freshly collected seed, no response to range of seed treatments. Seed moist cool-stored for 2 or more years likely to give better germination. Slow growing in nursery, minimum 3 years to 50 cm high.	One of the slower growing native conifers. 13 m high and 19 cm diameter after 60 years for planted trees on a range of sites.
Notable for association with native wood pigeon as food source for Maori where berries used to attract birds for capture. In early settler times and up till recently, wood often used along with rimu but less attractive and stable. Used for flooring, weatherboards, interior finish.	Annual seed crop fluctuates in abundance. Seed very palatable to rodents. Most sound when red fleshy seed coat develops. Fresh seed does not germinate. Moist cool storage for a year or more improves germination.	As with matai, relatively slow growing native conifer. 12 m high and 26 cm diameter for 60-year planted trees.
Used extensively for house-blocks, piles, railway sleepers, culverts, and bridges. Also for machine-beds and bearings where great strength and durability were required. Where available, used for fence posts, stockyard rails. Current uses mainly for hand crafts where puriri moth damage and the interlocking grain used to good effect in turnery and other high-value products.	Seeds over many months but peaks in autumn. Large-crowned trees produce many seeds. Seedlings up to 1 m high can be raised within 1 year in nurseries in warm locations; easily raised as potted or bare-root plants with protection from frost. Can be cut back to two nodes to hold over in the nursery. One of the fastest-growing native tree species in the nursery and in early years after planting.	After the first year, annual height growth rates of up to 1 m on sheltered sites. Opening of canopy and pruning have induced some coppicing from base. Multiple stems can form, even at high density, suggesting damage to young seedlings. Prone to frosting. Many trees planted in a sheltered dense 40-year plantation formed tall straight branch-free lower stems, but wide spacing results in short boles and bushy crowns. Annual increments of the few plantations assessed were 40–50 cm height and 1 cm diameter. Often planted as specimen tree in parks and urban streets.
Early uses in bush tramways, brake blocks, non-skid floor strips, fence battens. Inlay and decorative work by early settlers continues today, particularly for small wood products for tourism market.	Annual seed crops variable. Moderate germination. Better raised as potted seedlings as root systems are woody and fibrous rooting can be feeble. Young seedlings require protection from frosts.	Minor planting as specimen trees in gardens and parks; the few plantations are small and indicate moderate growth rates. Erect crown form but multi-leaders can occur, even in closed stands.
Early Europeans used it widely as a furniture and cabinet-making wood because of its attractive colour.	Seeding irregular and local. Seed highly palatable to possums. Collect capsules as they begin to split as seed must be removed. Has high viability but cannot withstand drying out. Carefully cleaned seed has good germination. Seedlings frost-prone; easily raised in warm nursery conditions.	No significant plantations established. Planted trees on open sites form rounded crowns and a short single lower bole. Moderate growth rates. Possum damage to planted seedlings common.

Hardwoods

Species	Natural distribution	Ecological requirements	Wood quality
Mangaeo (*Litsea calicaris*) 	Northern half of the North Island from North Cape to near Mokau, Rotorua, and East Cape. Up to 12 m high; 80 cm diameter.	Not on poorly drained or drought-prone sites. More abundant to south of the range but avoiding the most frost-prone sites.	Medium-density wood with excellent strength and toughness, moderately fine and even texture. Sapwood non-durable; heartwood moderately durable above ground. Decorative striped figure.
Kanuka (*Kunzea ericoides*) 	Throughout New Zealand. Small tree up to 15 m high, 60 cm diameter.	Along with manuka, is a major pioneering species on open sites after major clearance. Regenerates on drought-prone ridge and upper slopes with less competition from hardwoods. Unpalatable to stock, so regenerates with manuka on grassed hill country sites. Unlike manuka, is a long-lived component of regenerating forest for over 100 years.	Hard, heavy, finely textured, pale-coloured wood. Prone to checking in drying and not durable in ground.
Pohutukawa (*Metrosideros excelsa*) 	Natural range in north of North Island to Poverty Bay in east and north Taranaki in west. Large spreading often multi-stemmed tree up to 20 m high.	Mainly coastal fringe species but occurs around some of the Rotorua lakes. Spectacular crimson flowering in December and January makes it popular. Grows on cliffs and banks of coastal headlands. Readily regenerates in open conditions.	Rich, reddish brown colour, heavy, strong, and durable. Characteristic gnarled and twisted trunks; straight trunks uncommon.
Silver beech (*Nothofagus menziesii*) 	At higher altitudes from East Cape to Wellington with northernmost stand in northern Kaimai Ranges; from Nelson through most of Westland to lowlands of Southland. Usually 20 m high but can grow to near 30 m.	Hardy tree tolerant of heavy frost and snowfall in moderate to high rainfall areas. Wide range of soil types. Frequently single species stands in high rainfall areas but also in mixture with other beeches, particularly mountain and red beech and podocarps such as rimu.	Sapwood light greyish pink, heart brownish pink. Fine even texture. Heartwood moderately durable above ground, sapwood non-durable. Saws and machines easily and takes good finish.
Red beech (*Nothofagus fusca*) 	In mountain forests from East Cape to Wellington and on central volcanic peaks. Northernmost stands on Mt Te Aroha and on Mamaku Plateau. Widely dominant in northwest South Island; scattered stands south West Coast and Southland, on Banks Peninsula, and Kaikoura. Tree up to 30 m tall.	Prefers well-drained moist soils of slopes and river terraces. Often in association with other beeches and wide range of species in North Island. Full light required for effective seedling regeneration in the south but overhead shade may be necessary in the north.	Heartwood light reddish brown, sapwood light brown to grey. Fine even texture, generally straight grained. Heartwood is durable. Saws, peels well; good machining, turning, finishing, and wearing qualities.

Past and current uses	Propagation	Plantation potential
Early high grade uses in specialised products; stocks for timber jacks, in railway jiggers, sporting goods, boat frames, and medium-duty handles. Small size but has been used for interior veneers and in vehicles. Lower grades used as framing and above-ground fencing.	Difficult to collect large quantities of seed. Some difficulties in producing good root systems in bare-root nursery production.	Minor planting only. Small group plantings in forest and scrub light-wells have good form.
As with manuka, used by Maori for a range of agricultural tools and for hand-held weapons. Widely used for firewood. Recent interest as hammer and other high-impact handles.	Seeds annually. Easily raised in large quantities as bare-root or containerised seedlings. Good fibrous root systems. Tall 60–70 cm seedlings in 1 year.	Transplants well as nursery-raised seedlings. Fast growth in full light on open sites; so widely used in revegetation programmes with manuka and other shrub hardwoods. Height growth can exceed 50 cm annually after the first year.
Used by Maori for beaters and other small items requiring weight and hardness. Carved trunks and branches highly prized by early settlers for boat stems and knees. Used in turnery and other crafts.	Prolific seeding each year, high germination rates, easily raised in nurseries. Seed from coastal stands less likely hybridised with northern rata (*Metrosideros robusta*). Can be transplanted easily as seedlings; large trees often successfully relocated.	Widely planted, especially through the efforts of local communities through the work of Project Crimson Trust. Good survival and growth on clay or ash banks. Some difficulties with survival of planted seedlings on coastal sand unless soil or rotting driftwood added.
In Southland was general utility wood like rimu due to abundance and favourable wood properties. Used for building, farm timbers, and in mining. Higher grade uses include furniture, implements, turnery, boat frames, flooring, interior finish and weatherboards.	Heavy seed crops at irregular intervals. Light crops most years. Rapid and even germination 2–4 weeks after sowing. Easily raised in nurseries as potted or bare-root transplants.	Main effort has been in management of regeneration after logging disturbance. Tall nursery-raised seedlings (minimum 40 cm) successfully established. Tolerates more shade than faster-growing red beech. Becomes bushy when planted on open sites; side shade required to improve form. Saplings attacked by ghost moth. Relatively fast growth in plantations, maintaining annual increments of up to 40 cm in height and nearly 1 cm diameter.
Used in early mining industry and for land settlement purposes where it was abundant, including bridges, wharf decking, fencing, railway sleepers, boat building. Also used for framing, flooring, dowels, handles. Recent use includes furniture.	Heavy seed crops at irregular intervals with light seeding in most years between. As for silver beech, rapid even germination after sowing. Seedlings easily raised in the nursery – potted or bare-root.	Nursery-raised seedlings generally have high survival and good growth in cooler climates; mortality can be high in warmer lowland regions. Regeneration in disturbed natural stands can usually be increased by screefing by tractor or by hand (moving humus layer to expose mineral soil). Planted seedlings on the West Coast on good sites averaged 2 m after 3 years – 60% faster than silver beech. Saplings attacked by ghost moth.



Sapwood and Heartwood

Sapwood comprises the outer sections of the trunks of trees and has three main functions: structural support, conduction of water and minerals from the roots to leaves, and storage of food reserves. In contrast to the sapwood, heartwood has no living cells occurring in the central part of the stem. As a tree increases in size, not all the sapwood volume in the trunk is required for conduction or storage. While heartwood provides the main structural support for most trees, various chemical substances (e.g., tannins, resins), sometimes loosely referred to as extractives, are deposited in the cells. It is these substances that give heartwood its often darker colour, sought after for decorative uses. An important property of deposited extractives in heartwood is the toxicity to decaying insects and fungi which, depending on the species, will give varying levels of natural durability of the wood.

Bamber (1987) and Clifton (1990)

PART 5 – CHOICE OF NURSERY STOCK

The use of strong, healthy planting stock is critical to the success of any planting programme. Seed must be collected from the best sources and nursery stock raised for the particular programme well ahead of the planting season. A variety of plant grades and container types is available. Forest Research experience in the evaluation of planting stock is described below, and other approaches used in operational-scale planting are discussed briefly. Most information is based on experience rather than on comparative experimental trials.

Factors that should be considered before planting include relative suitability of bare-rooted and container-grown stock; appropriate plant size and quality; and the type and size of containers.

Container Size

Light-weight containers filled with moist, nutrient-rich potting mix provide the ideal rooting environment for developing seedlings. Choice of containers for plants will depend on the scale of the project, species grown, and age and size of plants required. Native trees raised for large-scale revegetation programmes are grown in containers of four broad types:

- ***Planter bags*** made of flexible black polythene, usually PB2 or PB3 where grade corresponds to increasing size of the bag. Bag diameter ranges from approximately 10 to 15 cm and bag height is around 14 cm. Cost of seedlings raised in planter bags varies from $2 to $4 per seedling, depending on grade of bag and size of order;
- ***Solid pots*** 10–15 cm in diameter and 12 cm high, e.g., RX 90; average cost of seedlings raised in solid pots is similar to planter bags;

- ***Hillson Rootrainers*** are a smaller version of the Tinus. At 15 cm high with compartments 4 × 4 cm square, they are most suited for growing small seedlings

- ***Tinus Rootrainers*** approximately 20 cm high, each unit having four 5 × 5-cm square compartments in a hinged plastic unit or "booklet". Sides of each compartment are ribbed to encourage downward growth of roots. Rootrainers fit into a wire basket that keeps them upright and elevated off the ground, and so any roots that become exposed through a gap in the base are "air-pruned". They are easy to transport to the planting site using the baskets. The booklets open for easy removal of seedlings. Cost per seedling ranges from $1 to $2.

Larger bags or pots allow for greater development of plant shoots; this can be varied by spacing out of plant containers in the nursery, whereas in rootrainers plant growth is confined to the space available within the diameter of the growing compartment.

Use of rootrainers for raising trees and shrubs, particularly broadleaved species such as karamu (*Coprosma robusta*) and fivefinger (*Pseudopanax arboreus*), can result in tall "leggy" plants with little foliage on the lower stems.

Preliminary results from a collaborative Environment Bay of Plenty and Forest Research trial indicate that 1-year-old plants of broadleaved shrub hardwood species raised in PB3 bags survived and grew better during the first year on an open grassed site than plants raised in Tinus Rootrainers. The drought-prone area had been spot-sprayed with herbicide and regular weed control was carried out. Plants from bag-grown stock had bushier tops and a larger stem diameter than the rootrainer stock.

The small degree of rabbit damage that did occur in the trial was mostly confined to the smaller rootrainer stock; leaders with small diameter were browsed to near ground level, often resulting in mortality.

On the larger bushier planter bag stock, only side branches were browsed by rabbits.

Above and left: *Nearly all nurseries raise natives in containers. Most hardwood trees and shrubs can be raised to 50 cm height in 1 year; some of the conifer species may take up to 2 years.*

Below: *A diverse range of native trees and shrubs in the early stages of propagation, Taupo Native Plant Nursery.*

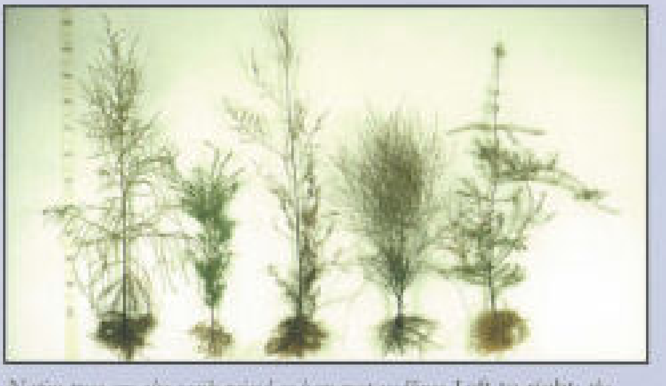
Size of Seedlings

The choice of seedling size is dependent on the species being planted; the characteristics of the site including degree of exposure, the weed species, and the animal pests present; the density and pattern of planting; and the resources and commitment to after-planting care. Large, well-conditioned plants at least 50 cm tall are likely to give the best results in large-scale programmes designed to produce low- to medium-density stands of trees. Smaller plants (approximately 30 cm high) will require more intensive weed control and site maintenance. Where rapid regrowth of fern and shrub hardwoods can be expected, tall seedlings (up to 80 cm) are less likely to be overtopped and suppressed between maintenance operations. On open sites, vigorous grass species such as kikuyu (*Pennisetum clandestinum*) can smother small plants within a short space of time. Larger plants have greater potential for recovery from browsing damage caused by rabbits, possums, and grazing stock. Smaller stock may be feasible for establishing large numbers of some of the faster-growing shrub hardwood species as a nurse crop, but taller older seedlings may be more desirable for establishing the slower-growing native conifer species.

Although larger plants are more expensive, their higher survival rate is likely to mean that smaller numbers are required. Comprehensive trials are required to determine relative performance and cost of large and small stock on a range of sites.

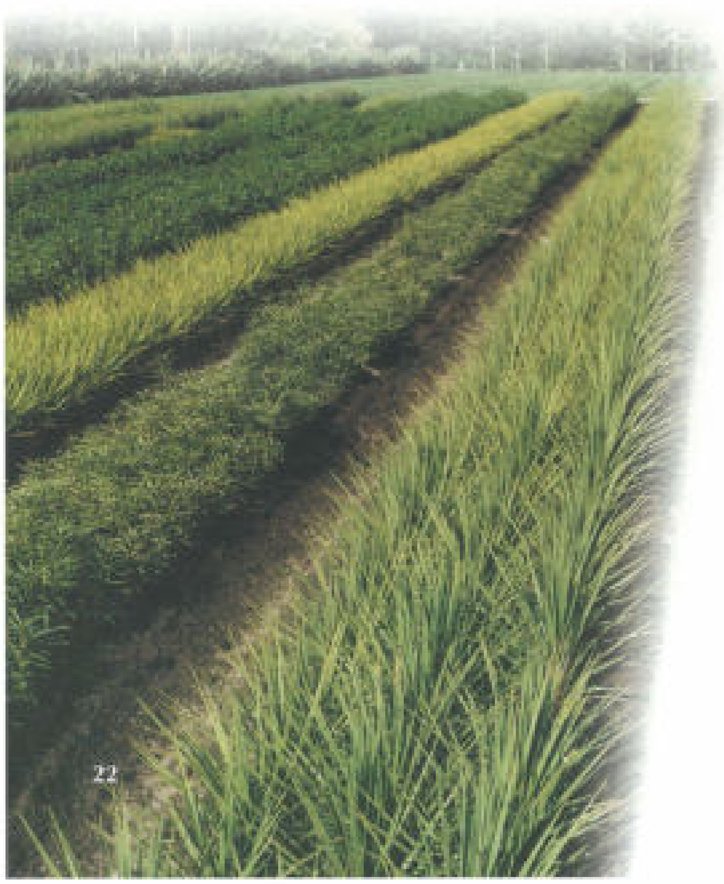
Left to right: *Pukatea, rewarewa, and titoki raised in PB3 planter bags.*

Five major native conifer tree species raised in PB3 planter bags. Left to right: *kahikatea, rimu, totara, tanekaha, kauri.*



Native trees are also easily raised as bare-root seedlings. Left to right: *the conifers rimu, miro, kahikatea, matai, totara.*

Left to right: *the hardwoods puriri, mangeao, kohekohe, rewarewa, pukatea.*



Seedling Quality

Plant tops are easily checked for vigour, height, spread, colour, and absence of fungus and insect damage. The development and health of root systems should be assessed for either container-grown or bare-root stock. Root distortion can occur at the base of the stem when seedlings are transferred to the propagation cells. This can be difficult to identify later and can lead to root strangulation or tree toppling (Jaap van Dorsser, formerly Forest Research Institute, pers. comm.). With container-grown stock, ideally plants will have been transferred to a larger bag or pot as soon as the roots have spread into the available potting mix in the first container. Any root distortion found during repotting must be rectified at the time to avoid later root strangulation and toppling.

Before planting, a random selection of seedlings, both container-grown and bare-root, should be inspected carefully. If plants are root-bound, taproots are distorted, or fibrous feeding roots are poorly developed the whole batch should be rejected. Bare-root systems should be trimmed to a compact root ball. At planting, root systems of container-grown seedlings should be sufficiently developed to bind all the potting mix into a cohesive mass that does not disintegrate when removed from the pot and placed in the planting pit. If the root systems have not had sufficient time to develop after repotting into larger containers, the compost will fall away and root exposure may increase transplanting stress.

Root-bound plants should ideally be rejected. If they have to be used, the root ball needs to be loosened, and any fibrous roots teased out or cut to encourage growth into the surrounding soil after planting. Seedlings with grossly distorted or under-developed root systems should be discarded.

It can be difficult to obtain a compact fibrous root system on some native species such as rewarewa (left) *and rimu* (right).

Container-grown or bare-rooted seedlings?

Although nearly all nurseries raise native trees and shrubs in containers, techniques for the production of bare-rooted plants in nursery beds have been developed for most native species. For bare-root production a well-developed seedling should have a dense, fibrous root system close to the base of the stem. This can be achieved by mechanical undercutting and wrenching at frequent intervals for at least 3 months prior to lifting (Forest Research Institute 1980b). Species such as rewarewa (*Knightia excelsa*) and kauri develop thick woody roots at an early stage and consistent production of a compact ball of fibrous roots can be difficult to achieve.

Once lifted, bare-rooted stock must be kept cool and planted within a few days. In contrast, container-grown plants can be reserved for use over an extended period and this flexibility is a major factor in the preference for raising natives in containers. They can be relocated easily in the nursery and transferred to larger pots if held over. Bare-rooted stock is easy to transport whereas plants in containers, being heavier and bulkier, require more planning for transport and care during on-site handling. Container-grown plants with intact roots surrounded by potting mix may have greater potential for survival and rapid early growth, especially on nutrient-poor sites but this has not been confirmed in comparative field trials. A major concern with container-grown seedlings is the difficulty of determining readily the quality of root systems (Jaap van Dorsser, pers. comm.).

"ECO-SOURCING" — the seed collector's dilemma

These rimu seedlings, raised in similar nursery conditions from seed collected from two widely separated regions, show clear differences in growth and foliage characteristics.

The need for eco-sourcing is often hotly debated. Eco-sourcing refers to the use of native plants that have been raised from seed or vegetative material collected from local natural populations. Plants of the same species, collected from different locations throughout the country, often show clear differences in growth and form. Differences in growth rates, tree form, foliage, or flowering have been shown in provenance studies for some native tree and shrub species including rimu (Norton *et al.* 1988), totara (Bergin & Kimberley 1992), the beeches (Wilcox & Ledgard 1983), and cabbage tree (*Cordyline australis*) (Harris *et al.* 2003).

Local provenances evolve in response to climatic and site conditions of that region and it is usually wise to exploit this through local seed collections. However, for tree plantations with an economic objective where experimental evidence from provenance trials is available, it would be sensible to use the best-performing provenances. Use of a local seed source may not always guarantee that its origin is local. Native trees have been planted throughout the country for decades without attention to their provenance and this continues, especially through urban garden centres. This is particularly likely with highly regarded plant varieties. Use of stock from distant populations may result in inter-provenance crosses with the local population. Inter-provenance hybrids may produce vigorous seedlings, and improved form and wood quality, with little or no detriment to the species genetic composition. Such provenance hybridisation could have occurred from natural processes, such as glaciation, tectonic change, and climate change.

There is a great deal of conjecture about the sourcing of native tree seedlings for plantations to be established for timber supply. Important cultural and ecological factors may also govern the use of plants raised from seed collected from local stands (Simpson 1991). However, strict adherence to the use of local seed raises difficulties where the definition of boundaries for seed-collecting zones is not clear or the supply of seed is inadequate. Should landowners be deprived of faster-growing provenances of timber species?

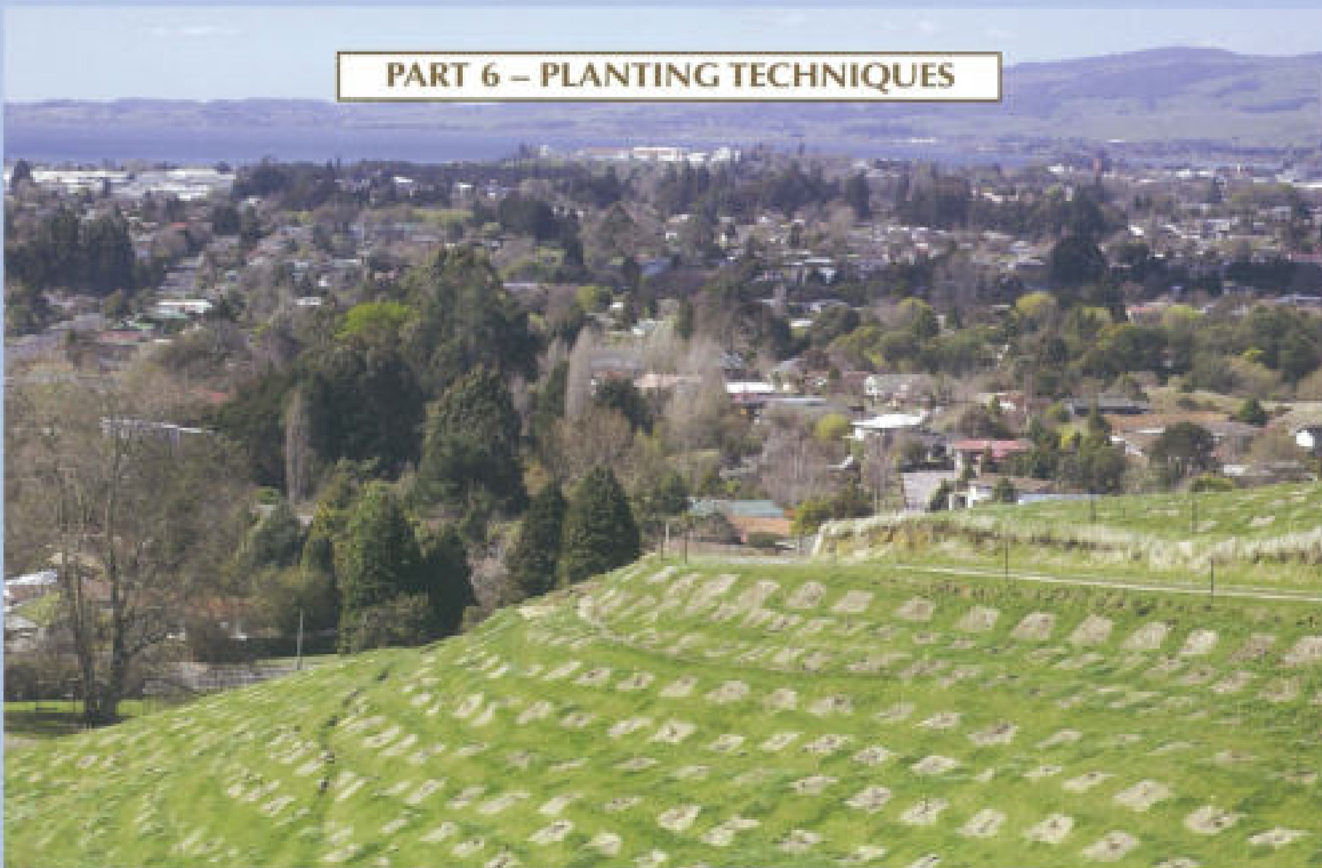
Experience with native species overseas has often shown that, due to evolutionary lag, local provenances may not perform best in plantations. Geneticists argue that isolation of local races can lead to inbreeding and may eventually reduce survival, health, and growth rates.

When located away from gene-conservation areas, the use of seed from the best-performing provenances that may give improved growth, tree form, and wood quality, may be a prudent option for landowners and investors in establishing native tree plantations.

It is critically important in both revegetation and timber plantations to collect seed from a sufficient number of parent trees (at least 10 per seedlot) to avoid excessive narrowing of the genetic base of stands, which would lead to further inbreeding.

Further research is required to determine patterns of variation among provenances of the major native timber species, the implications for maintaining local gene pools, and the benefits of using selected seed sources in plantations for wood production.

PART 6 – PLANTING TECHNIQUES



All planting programmes require careful pre-planning. Research results have shown that site characteristics need to be considered together with the establishment requirements of the chosen species. Site preparation, planting methods, quality of planting stock, and continuing maintenance, all contribute to survival, growth rate, and final form of the mature trees.

Site Preparation

Protection from animals

Fencing to exclude grazing stock and browsing animals such as deer and goats is essential. Possum eradication or reduction is also needed. Young native trees will not survive browsing or trampling. Later on, light grazing of grass between older, widely spaced trees may be feasible on some sites such as urban or regional parks, but careful stock management is needed to ensure that ring-barking does not occur. In small-scale projects, robust tree guards can be used to protect younger trees from grazing stock. Although a number of relatively unpalatable species (manuka, kanuka, totara) will grow in the presence of cattle, nursery-raised seedlings are likely to be vulnerable to browsing.

Browsing by rabbits, hares, possums, goats, and deer has resulted in the failure of many planting programmes. Where populations of rabbits, hares, and possums exist, poisoning is the most practical control option, while culling of deer and goats by shooters can be effective. Deer-proof or rabbit-proof fencing is possible on a small scale, but neither will exclude possums.

Animal protection for specimen trees planted on farm sites.

Grazing is recommended to remove top growth and give a short sward for spraying before planting of natives. Stock must then be excluded from the area. Where rabbits are present and cannot be completely controlled, there may be merit in allowing rank grass to develop in fenced areas to deter them before planting.

Alternative methods for controlling weed growth, such as weed matting and bark or chip mulches, are practical only for small-scale planting programmes. Large-scale programmes require timely knapsack spraying of herbicides.

Spraying grass cover

Pre-plant spraying with herbicide to eliminate grass and herbaceous weed competition is standard practice in planting programmes. Grazing to remove top growth, followed by stock exclusion is recommended before spraying to give a short sward of grass, although this may encourage rabbit browsing of newly planted seedlings. Spot-spraying is most practical where plants are established at 1.5 m or more apart; a minimum 1-m-diameter area of sprayed grass is required for each seedling to ensure rank grass does not overtop plants within the first year. Blanket spraying will be required for areas designated for high-density planting where seedlings will be planted less than 1.5 m apart. Glyphosate is applied at least 1 week before tree planting; a surfactant may be added to assist spread and uptake of herbicide, and a marker dye will show where spots have been sprayed. Recommended application rates are:

- Glyphosate – 10 ml/litre of water
- Surfactant – 5 ml/litre of water
- Marker dye – 1 ml/litre of water

A pre-emergent herbicide such as Gardoprim can be used to prevent subsequent germination of grass and weeds (Vanner 1998).

Weed-infested sites

Many previously cleared sites have become dominated by blackberry and other major exotic weed species such as gorse and willows. Such sites will require complete removal of this cover by spraying and mechanical methods before natives are planted. It may take up to 2 years to prepare for planting — the first year involving spraying and clearing the site of weed growth, the second year spraying vegetative regrowth or any regeneration from seed of problem weeds. Thorough site preparation and delaying planting of natives for at least 2 years until vigorous weed species have been largely controlled will improve the chances of successful establishment of native trees. Dense planting of natives to give a canopy cover as soon as possible after planting will shade out regrowth on potentially difficult weed-infested sites.

Knapsack spraying herbicide with a marker dye indicates where spots have been sprayed.

Two of the most aggressive weeds that are detrimental to newly planted native trees and shrubs are blackberry (left) *and gorse* (right).

Planting

Comprehensive guidelines for planting native trees have been produced by several authors including Evans (1983), Pollock (1986), Porteus (1993), Ministry of Forestry (1988), and Davis and Muerk (2001).

Cultivation

Loosening of soil around the planting position is likely to be beneficial on the most difficult substrates such as heavy clay soils or where compaction is evident. This will improve drainage and encourage early root penetration.

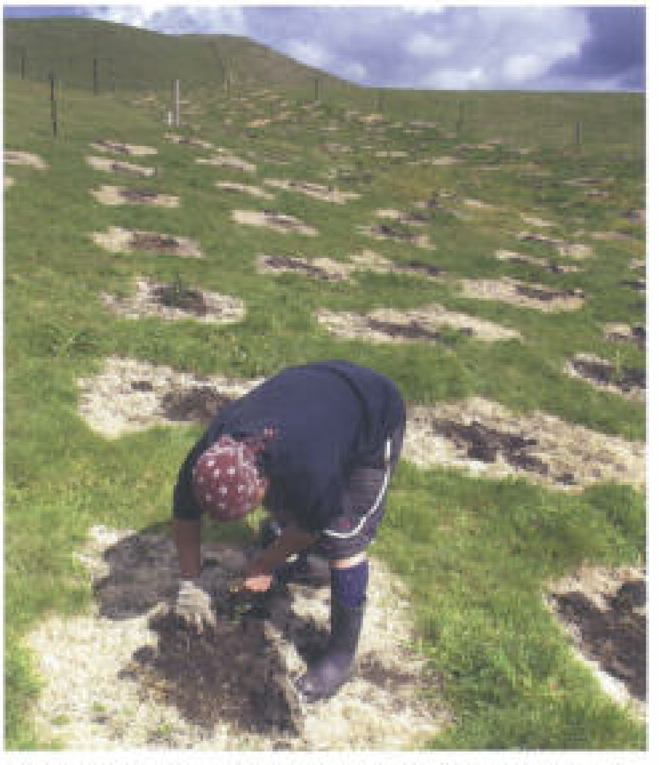
Planting time

Seasonal and annual climatic conditions influence the success of planting programmes. On cool upland sites, native trees are best planted in early spring when the heaviest frosts are over. On warmer lowland sites the optimum period for planting is between late autumn and early spring. Unexpected droughts in autumn or spring can cause mortality. In warmer districts, autumn planting may be preferred to ensure that seedlings are well-established before summer drought sets in (Bergin and Pardy 1987). Staggering of planting over several years may minimise overall losses in larger programmes.

Fertiliser application

Davis and Meurk (2001) considered that fertiliser is not normally needed for planted native species. On upland sites, the effects of fertiliser treatment at time of planting were often confounded by other factors such as degree of weed growth (Bergin & Pardy 1987). On grossly nutrient-deficient soils, fertiliser incorporated into the planting hole may stimulate growth. Broadcast application is likely to encourage weed growth.

Slow-release NPK fertiliser improved growth of kauri planted in gaps in 3- to 4-m-high scrub on nutrient-poor heavy clay soils on the Coromandel Peninsula (Bergin and Kimberley 1987). Height and diameter of 5-year-old trees had been increased by application of Magamp (50 g per seedling) at time of planting. Doubling the rate of Magamp appeared to be detrimental to growth and survival, and application 12 months after planting did not stimulate growth. Lloyd (1997) suggested that fertiliser applied in the early stages of establishment would improve plant vigour but not necessarily height growth.



Planting shrub and tree seedlings in sprayed spots. The area has been fenced to exclude animals.

Maintenance

A survey of native tree plantations has identified suppression by weeds, grasses, ground ferns, and woody shrubs as the main cause of poor survival and slow growth (Pardy *et al.* 1992). Regular manual and/or chemical releasing for up to 5 years after planting is required on most sites. Where vigorous blackberry and woody weeds are present, and depending on density and early performance of the planted trees, releasing may need to be extended for up to 10 years until canopy closure.

Careful spraying (during calm weather) with glyphosate around the base of each seedling is the most practical method for controlling grass and herbaceous weed regrowth. Use of a knapsack sprayer with a coarse jet at low pressure will prevent mist drift on to seedling foliage and green stems. Surrounding grass will require trampling before spraying to avoid spray contact with the foliage of planted trees. Spraying may be required every 6 months for about 2 years or until seedlings are at least 1 m high. Brush weeds or blackberry in any part of the planting area must be removed by hand or sprayed with an appropriate herbicide. Gorse, blackberry, and pampas grass (*Cortaderia selloana* and *C. jubata*) can easily overtop planted trees within 12 months and are extremely difficult to eradicate if they become dominant.

Modest beginnings — learning from local successes

Factors influencing the performance of planted trees vary from one site to another, and it is not always easy to predict which of these will be most important. For instance, particular weeds or animal pests may be a threat to establishment in one area but not in another. It may be wise to plant a small representative area in the first year, using a range of species and planting methods. This should help decide on appropriate procedures for a larger-scale programme.

It is best to avoid obviously difficult sites if failure is likely to reduce enthusiasm for continuing. Favourable sites provide opportunities for guiding establishment requirements before the more difficult sites are tackled.

Inspection of neighbouring areas of native bush often provides valuable information about species that might be used for initial vegetation cover. Identification of weed species can give advance warning of problems that can be expected on sites to be retired from current landuse. Previous planting of natives in the region may provide further insights into factors that need to be considered before too many resources are allocated.

Far left: *Blanket spraying is required for dense planting to keep planted seedlings free of competition (background). Careful spot-spraying of wider-spaced plants (foreground) is required to keep rank grass from overtopping planted trees.*

Left: *If surrounding grass has become tall, it will require trampling before spraying to prevent herbicide contact with planted trees.*

Right: *A well-maintained native seedling 9 months after planting on a vigorous grass site. In addition to the pre-plant herbicide application, timely and careful knapsack spraying of grass and weeds is required to keep the planted trees free of competition.*

Far right: *Hardwood seedlings approximately 50 cm high are swamped by regrowth of grass and herbaceous weeds within 6 months of planting. Careful herbicide spraying for at least 2 years is required to keep seedlings free of regrowth.*

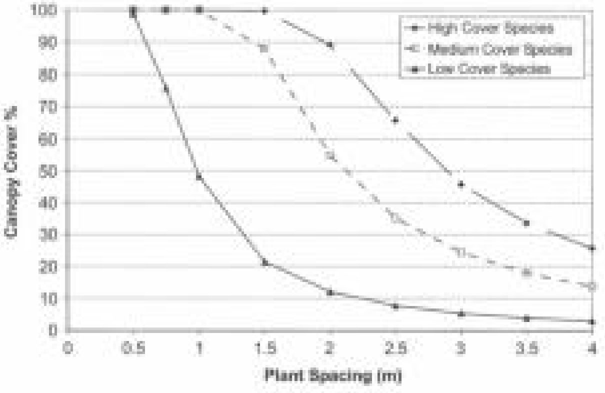
Canopy cover – a preliminary assessment

In an assessment of 15 revegetation sites planted for catchment protection in the Bay of Plenty, a linear relationship was found between plant stocking rate and canopy coverage 4–5 years after planting (Stace *et al.* 2003). For 12 native shrub and tree hardwood species sampled, there were clear differences in growth rate of plant crowns (Table 1).

Table 1. Mean crown spread of a range of native trees and shrubs 4.5 years after planting for catchment protection over 15 sites throughout the Bay of Plenty.

Species	Mean spread (m)
Black mapou	2.6
Akeake	2.5
Kohuhu	2.5
Manuka	2.1
Lemonwood	2.0
Kanuka	2.0
Karamu	1.8
Karo	1.6
Lacebark	1.6
Pohutukawa	1.5
Five finger	0.9
Rewarewa	0.6

Figure 1. Mean percentage canopy cover for the three categories of native species based on rate of crown spread that can be achieved 4.5 years after planting.



Three groups of species were idenified based on rate of crown spread:

(1) High percentage cover species — kohuhu (*Pittosporum tenuifolium*), black mapou (*P. colensoi*), akeake (*Dodonea viscosa*), lemonwood (*P. eugenioides*), manuka, kanuka.

(2) Medium percentage cover species — karamu, karo (*P. crassifolium*), lacebark (*Hoheria populnea*), pohutukawa.

(3) Low percentage cover species — fivefinger, rewarewa

Percentage canopy cover after 4–5 years for the three groups at different spacings is represented in Fig. 1. High cover species will give 90% canopy cover at 2 m spacing (2500 stems/ha), compared with 55% cover for medium cover species and only 10% site cover for species classed as low cover. Conversely, when plants are established at 3- to 4-m spacings, even the faster-growing high cover species will achieve only 30% cover.

While this assessment is only a snapshot of a limited range of native species from several operational plantings throughout the Bay of Plenty region, it does demonstrate clear differences in canopy spread between species over time. It confirms the need to choose species that have faster-growing crown canopies for rapid suppression of grass and weeds in revegetation programmes. Native trees, many of which have slower growth than shrub hardwoods, are likely to fall within the low percentage cover species group similar to the rewarewa sampled in this survey. Forest Research are currently undertaking collaborative trials on a range of sites to determine comparative rates of canopy cover growth for the major native tree and shrub species.

PART 7 – PLANTING OPEN SITES

Choice of Planting Pattern and Density

When revegetating an open site with native tree species, the aim is to quickly achieve canopy closure which is self-sustaining and requires little further intervention. Establishing plants at high density will give more rapid canopy closure, and hence suppression of weeds, than planting at wider spacing. The choice of planting density depends on the scale of planting, the species to be planted, the site conditions (particularly the degree of exposure), the resources available for purchase of stock, the degree of site preparation undertaken, the potential of vigorous weeds to colonise the site, and commitment to after-planting care, particularly weed control. Planting density will eventually affect the onset of between-tree competition in the developing stand.

Planting seedlings in lines on open sites ensures that even plant spacing and the desired density are achieved, particularly for large-scale operations. It also permits easier location of plants for releasing. Views of lines may detract from a natural appearance, but this effect is minimised with canopy closure and with subsequent effects of competition and thinning.

High-density planting

Where the objective is to establish a plantation and canopy cover is required as soon as possible, native trees can be planted as a dense stand on suitable sites. The stockings may have to be in excess of 5000 stems/ha (plant spacing less than 1.5 m apart), to achieve canopy closure within 5 years. Totara, kahikatea, kauri, and the beeches have been successfully planted on open sites at high stockings. At high density, trees form straight tall stems and branch-free lower boles due to intense inter-tree competition. A major disadvantage is the high cost of establishment, as tree seedlings are expensive. In addition, once canopy closure is achieved and within-stand competition intensifies, thinning will be needed or growth rates will reduce substantially. Depending on initial growth, this may need to be done within 1–2 decades of planting.

Low-density planting

On lowland sheltered sites, native trees can be planted in the open at wide spacings around 4 m or 600 stems/ha. This is particularly suited to establishing groves of native trees in urban or regional parks to provide recreational space and enhance aesthetic values. All site preparation, planting, and after-planting care should be carried out to a high standard and good-quality seedlings must be used as any mortality will leave large canopy gaps. Depending on resources and objectives of planting, trees will require removal of multiple leaders and lower branches if merchantable sawlogs are desired. Some species, such as kauri and kahikatea, will require less removal of double leaders and lower branches as they naturally form a largely erect monopodial habit, often but not always with a dominant leader. Other species such as totara and puriri will require repeat form-pruning to produce single stems.

Short boles and forking are inevitable if no form pruning is carried out where trees are planted at wide spacing.

Mixed planting of trees and shrubs

On less-exposed open sites, a mixture of shrubs and tree species can be planted concurrently. Planting stock of shrub hardwood species is likely to be cheaper than native tree species and can "bulk-out" a planting site to give early canopy cover and reduce the length of time for weed control from 5–10 years for widely spaced stands to about 2–3 years for dense plantings. The more expensive native conifer and hardwood timber tree species can be interplanted at near final spacing within the shrub crop, using a random pattern if a natural appearance is desired.

As well as shelter, shrub species provide side shading which encourages apical dominance of main leaders, smaller branch size, and a lower incidence of multiple leaders in early years. Regular inspection and maintenance will be required to ensure that light levels remain adequate for growth of the interplanted trees. Maintenance of a light-well above each interplanted tree is essential to encourage height growth but in time the shrub species will be suppressed.

Planting previously forested sites

These include sites that have been recently cleared of native forest, where a previous crop of exotic pines has been clearfelled or where there has been tractor clearing of dense scrub or blackberry. This can leave a bare site where topsoil has been removed to leave exposed less-fertile mineral soils and localised areas of compaction. Simcock and Ross (1995) recommended that, wherever possible, spreading of topsoil and debris from the previous forest cover over the site will provide a mosaic of microsites amongst stumps and logs in which to plant native trees and shrubs. Planting of natives that target suitable microsites within an irregular topography and amongst debris that provide some protection is likely to improve survival and early growth.

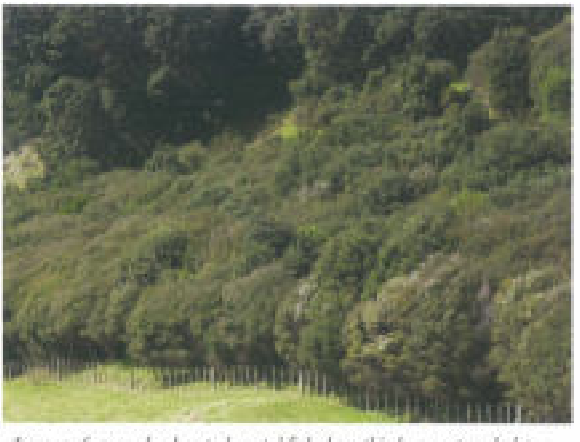
Manuka and other natives planted amongst the debris of stumps, logs, and branches.

The major concern with establishing natives on recently cleared forest or scrub sites compared to revegetating grassed sites is the greater potential for invasion of a wide variety of woody weeds and the need for extra vigilance in maintenance and pest control.

Use of nurse species

Native tree species establish naturally amongst pioneer vegetation, which provides protection from extremes of local climate. Planting of a hardy vegetation cover in advance of the chosen tree species can mimic this process of natural succession. The use of quick-growing, generally hardy, shrub hardwood species is a favoured method for providing shelter on an exposed site and a canopy cover to reduce the time needed for weed control. Such species are often termed "nurse species". Many native tree species favoured for timber production grow slowly in early years, but performance of some is improved when they are planted within shelter. A fast-growing nurse crop will give canopy closure quickly, suppressing weeds.

On severely exposed open sites, shelter must be provided for more sensitive tree species by advance planting of nurse species such as manuka, kanuka, kohuhu, and karamu. Once the nurse species is established, native trees can be interplanted according to the desired stocking rate and planting pattern. Depending on growth rate of the nurse species and severity of the site, target timber trees can be planted 1–5 years after the nurse crop. Gaps that occur naturally within the cover or are cut by hand can be used to plant target timber species.



A cover of manuka has to be established on this bare exposed slope before interplanting native timber trees.

Can exotics be planted as a nurse cover for natives?

Some exotic species can be planted to provide initial shelter on exposed sites and to reduce the need for weed control by establishing a quick cover. Tree lucerne (*Chamaecytisus palmensis*) is particularly suitable. It is short-lived and forms a light spreading crown of medium height but it does not establish well on heavy soils. Pines and eucalypts have been used, but are generally too fast-growing for most planted native species. If these fast-growing exotic nurse covers are left for more than about 5 years after planting, they can be difficult and costly to remove without damaging underplanted natives.

The tree lucerne nurse crop is dying out naturally as the planted natives beneath begin to dominate

It will be difficult to remove the large exotic pine nurse cover without damaging underplanted kauri.

It may be practical to utilise gorse or other woody exotic cover that may have regenerated on exposed sites. However, gaps or lines will need to be cut to provide planting sites for native timber trees. Careful monitoring and regular releasing will be essential to ensure the natives are not suppressed by vigorous regrowth of the exotic species.

Which plant spacing?

The costs for planting natives at a range of densities are given in Table 2, taken from a number of sources (Lawrie Donald, Environment Bay of Plenty, pers. comm.; Mike Dodd, AgResearch, pers. comm.). The cost of $2.00 per seedling for shrubs and $4.00 per seedling for trees is based on PB3 stock provided at bulk rates. Estimates for site preparation and releasing, largely involving knapsack spraying of herbicides, are based on a recently retired farm site in grass. The costs for fencing, animal pest control, blanking, and clearing of dense exotic woody vegetation are not included. The time to canopy closure is estimated for each spacing, using growth rates expected of shrub hardwood species planted as nurse crops; for native trees, growth to achieve canopy closure is likely to be slower. For instance, totara planted at 2500 stems/ha took at least 8 years to achieve canopy closure on a south Auckland site (Bergin 2003), whereas manuka planted as a nurse crop at the same density on a similar site took only half this time (Steward 2000).

Table 2. Approximate cost per hectare of planting and early management of nursery-raised native seedlings on a grass site at five different plant densities.

	High density →				Low density
Plant spacing	1 × 1 m	1.5 × 1.5 m	2 × 2 m	3 × 3 m	4 × 4 m
Stocking (stems/ha)	10 000	4 444	2 500	1 100	625
Expected time to canopy closure					
for shrubs	2 years	3 years	4 years	6 years	8 years
for trees	4 years	6 years	8 years	12 years	16 years
Site preparation (includes herbicide spraying of grass, some woody weed vegetation clearance) @ $0.50 per plant	$5,000	$2,222	$1,250	$550	$313
Seedling cost					
shrubs @ $2.00 per plant	$20,000	$8,888	$5,000	$2,200	$1,250
trees @ $4.00 per plant	$40,000	$17,776	$10,000	$4,400	$2,500
Planting cost @ $1.00 per plant	$10,000	$4,444	$2,500	$1,100	$625
Grass control for up to 2 years* @ $0.50 per plant annually for shrubs and trees	$10,000	$4,444	$2,500	$1,100	$625
Woody weed inspection/control annually @ $300 until canopy closure or up to 5 years					
for shrubs	$600	$900	$1,200	$1,500	$1,500
for trees	$1,200	$1,500	$1,500	$1,500	$1,500
Total †					
for shrubs	**$45,600**	**$20,898**	**$12,450**	**$6,450**	**$4,313**
for trees	**$66,200**	**$30,386**	**$17,750**	**$8,650**	**$5,563**

* This allows for a minimum of two spray releasings per year; low density options should consider extra years of weed control.
† Dollar values are not converted to NPV.

The level of stocking clearly has the greatest impact on cost of establishing natives. At 10,000 stems/ha costs are $45,000 to $66,000 compared to $4,300 to $5,500 at 625 stems/ha.

Estimating annual weed and pest control is difficult and may be grossly under-estimated for some sites. Weed control costs increase with lower-density planting due to greater time to canopy closure. An annual cost of $300 has been estimated for inspection and timely control of regrowth of any woody weed species. Many planting programmes at low stocking fail as weed control is not carried out when required, so it is essential that planting sites are inspected at least annually and problem weeds controlled until canopy closure.

In practice, for difficult weedy sites, planting at high density to achieve rapid native canopy cover, particularly using a greater proportion of faster-growing shrub hardwoods than trees, is a more practical option.

Two options for the establishment of native timber species on open grass sites

Year 1 – Site preparation for low and high density options

- Erect stock-proof fences
- Graze grass where practical
- Remove stock
- Control wild animals

LOW DENSITY OPTION

Year 1 – Spraying

- Spot-spray at the required spacing (>1.5 m apart) using knapsack sprayer 2 weeks prior to planting

Year 1 – Planting

- Plant large seedlings in sprayed spots
- For exposed sites, use hardy shrub species initially before interplanting tree species
- Aim to get <2500 stems/ha (plant spacing minimum 2 m)

Year 1 – Blanking

- Inspect site every 3–6 months
- Determine and remedy any causes of mortality
- At wide spacing any losses will leave large gaps, so replant with large seedlings during the next planting season

Years 1–2 – Weed control

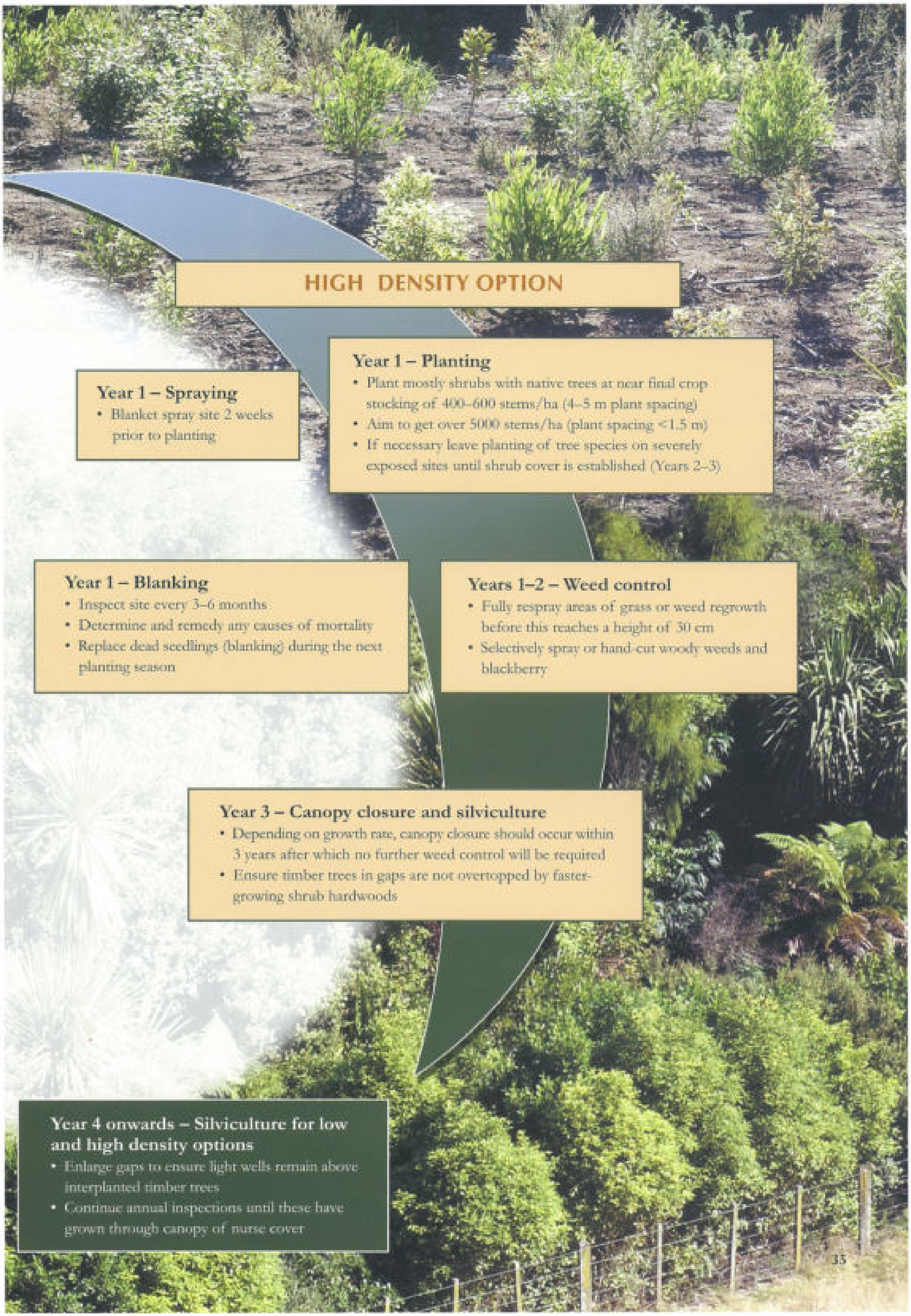
- Spray weeds around base of each seedling before they reach a height of 30 cm
- Trample tall weeds if necesssary before spraying
- Selectively spray or hand cut woody weeds and blackberry

Years 3- 5 – Supplementary planting of trees

- If not planted in Year 1, plant native timber species in gaps at near-final spacing of 4–5 m apart

Years 3-10 – Continuing weed control and canopy closure

- Grass control becomes less important once trees are 1–2 m in height
- Inspect sites and continue to remove vigorous weeds and blackberry



HIGH DENSITY OPTION

Year 1 – Spraying

- Blanket spray site 2 weeks prior to planting

Year 1 – Planting

- Plant mostly shrubs with native trees at near final crop stocking of 400–600 stems/ha (4–5 m plant spacing)
- Aim to get over 5000 stems/ha (plant spacing <1.5 m)
- If necessary leave planting of tree species on severely exposed sites until shrub cover is established (Years 2–3)

Year 1 – Blanking

- Inspect site every 3–6 months
- Determine and remedy any causes of mortality
- Replace dead seedlings (blanking) during the next planting season

Years 1–2 – Weed control

- Fully respray areas of grass or weed regrowth before this reaches a height of 30 cm
- Selectively spray or hand-cut woody weeds and blackberry

Year 3 – Canopy closure and silviculture

- Depending on growth rate, canopy closure should occur within 3 years after which no further weed control will be required
- Ensure timber trees in gaps are not overtopped by faster-growing shrub hardwoods

Year 4 onwards – Silviculture for low and high density options

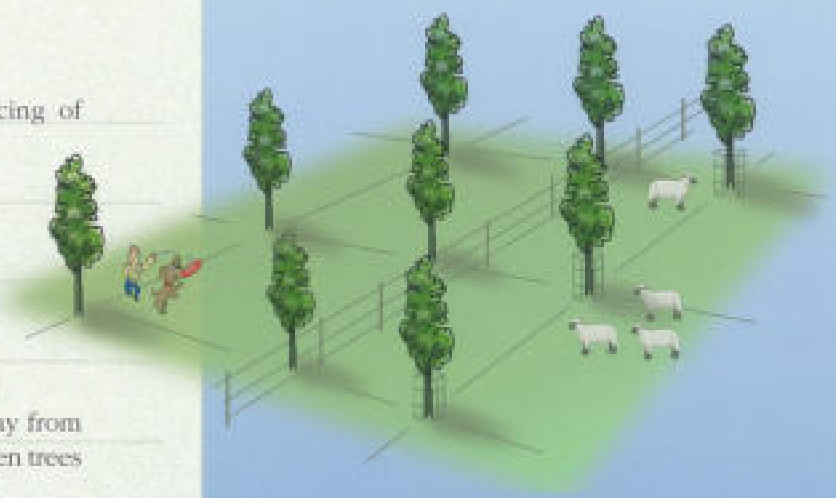
- Enlarge gaps to ensure light wells remain above interplanted timber trees
- Continue annual inspections until these have grown through canopy of nurse cover

Recommendations for Establishing Plantations

Five scenarios below demonstrate different planting patterns, densities, and timing for establishing a stand of native timber trees on open sites. Choice of scenario will depend on the site and species to be planted, the degree and type of weed growth expected, resources available for planting and management, and the objectives for establishing the stand.

1. Planting native trees at low density

- Plant native tree species at near final spacing of 4–5 m.
- Appropriate for sheltered lowland grassed sites where side shelter is not necessary and problem weeds are unlikely to occur.
- Pre-plant spot-spraying with Glyphosate.
- Use knapsack sprayer to keep rank grass away from seedlings for at least 2 years; large areas between trees can be left to develop into rank grass.
- On flat or rolling sites, wide spacing allows for tractor mowing as for urban parks.
- Alternatively, grazing will keep grass under control with tree protection, particularly at early stages.
- Intensive form-pruning required to ensure development of straight, single, branch-free lower stems for wood production.
- Kauri, tanekaha, and kahikatea form single stems. Large lower branches need to be removed. Hardwoods, totara, and rimu often multi-leadered with coarse branching; require early removal of double leaders and steep-angle branches.
- Canopy closure unlikely to occur for at least 2 decades, hence suited to well-managed open park scapes.

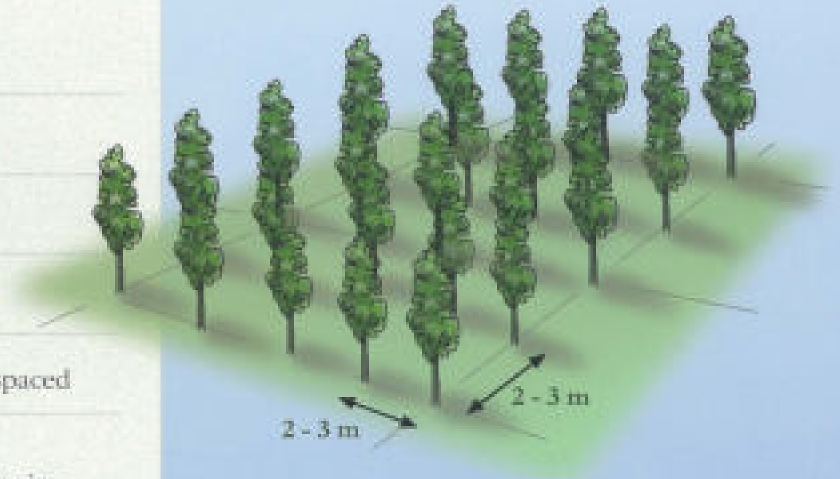


Low density (about 500 stems/ha)

- Intensive silviculture to give good form
- Grazing with tree protectors in early years, or mowing between trees in urban parks.

Open-planted rewarewa at 5 m spacing in Cornwall Park, Auckland.

2. Planting native trees at medium density

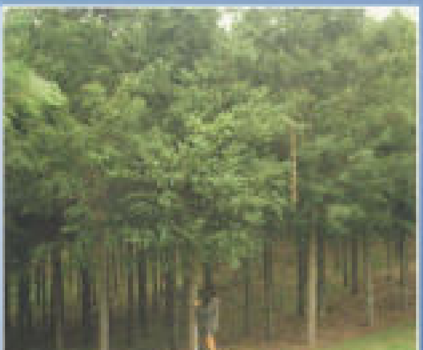


- Ideal for retired grassed areas where it is the most practical option over relatively large areas.
- Plant native trees at 1000–2500 stems/ha (trees spaced 2–3 m apart).
- Lower stocking similar density to a Douglas fir regime of around 1000-1500 stems/ha (Miller and Knowles 1994).
- As with low density planting, this option is not suited to sites where problem woody or scrambling weeds are present or expected to develop without vigilant weed inspection and timely control for many years until canopy closure.
- Initial establishment cost considerably reduced with lower number of seedlings required and less planting
- Pre-plant spot spray grass and keep rank grass from seedlings for at least 2 years.
- Depending on tree species planted and early growth, canopy closure will take at least 10 years.
- Remove multiple leaders and large lower steep-angle branches from sapling stage for crop trees.
- Selectively thin up to half of the trees probably within 20 years of planting; timing depends on speed of canopy closure.

Medium density (1000–2500 stems/ha)

- Only native trees planted on grassed site.
- No major weed problems expected.
- Form pruning required and delayed thinning.

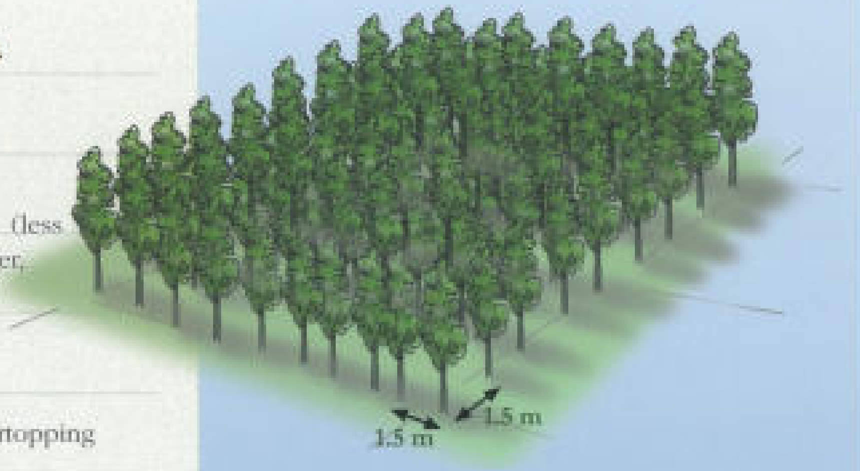
A 25-year-old kahikatea stand, planted at medium density on a previously grazed site, will require thinning to maintain good growth.



Totara planted at 3 m spacing 30 years ago on a Hawke's Bay site have been pruned regularly to form clear lower boles.

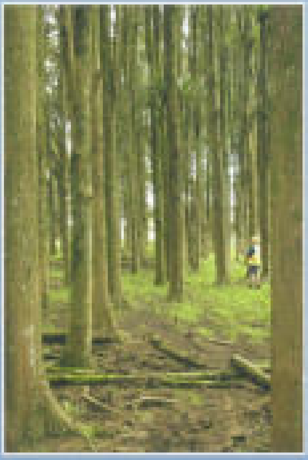
3. Planting native trees at high density

- Plant at very high density >6000 stems/ha (less than 1.5 × 1.5 m) to give quick canopy cover, but at considerable increase in seedling and planting costs.
- Minimum of 2 years' spray releasing required after planting to prevent grass overtopping seedlings.
- Canopy closure should occur in about 5 years.
- It is inevitable that most trees will need to be thinned out; dense planting will encourage excellent stem form and small or no branching on lower part of the bole for most trees.
- Thin selectively and progressively starting within 1–2 decades.
- Aim to achieve a final stocking of around 400 stems/ha, depending on species planted and growth rate.
- Scope to remove trees with poor form during thinning.
- Only practical on a small scale due to the cost for the large number of seedlings required per hectare.



High density (>6000 stems/ha)

- Only timber tree species planted as woodlot.
- Most trees will require thinning out.

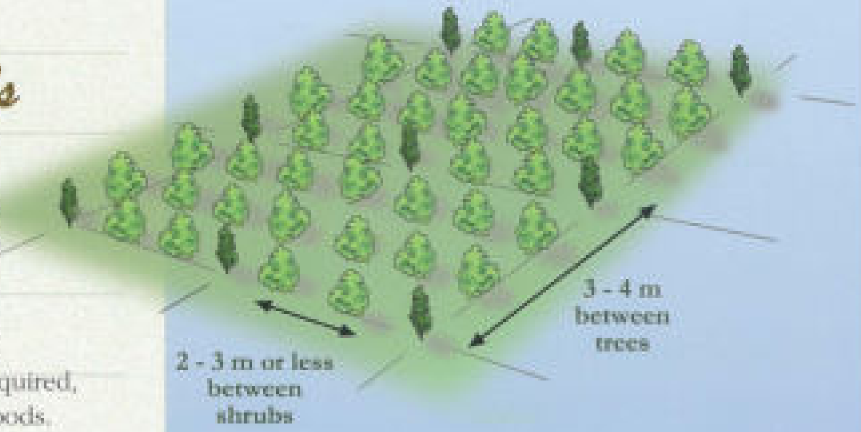


Dense planting of this 90-year-old totara stand at 1.2 × 1.5 m spacing in Northland has resulted in excellent stem form although competition has reduced growth. Progressive thinning from early years would have maintained good growth rates of crop trees.

Dense planting of native trees in large groups throughout difficult weed-infested sites may be a practical option for establishing a seed source. This group of 25-year-old rimu poles planted in the central North Island will require thinning to maintain good growth.

4. Planting a mixture of native trees and shrubs

- Involves planting concurrently a mix of native timber species at near final stocking, with shrub hardwood species planted as a filler.
- Plant native trees at 600–1000 stems/ha and, depending on how quickly canopy cover is required, plant 1500 stems/ha or more of shrub hardwoods.
- Will reduce period of weed control and improve establishment and form of timber species.
- Total cost of planting cheaper shrub species (@ $2–3 each) plus timber species ($3–5) will be less than dense planting of timber species alone.
- Shrub species will develop large crowns faster than timber species and thus accelerate canopy closure.
- This medium-density option is essential for sites where major weed species are expected; typical sites will be those where dense woody weed species and blackberry have been cleared.



Mixed species

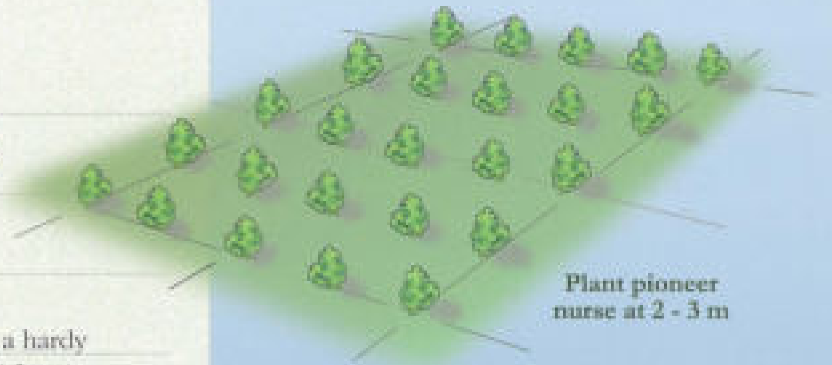
- Trees planted with higher proportion of faster-growing shrubs at same time
- Major weed problems expected

The more costly kohekohe seedlings have been recently planted on this warm sheltered slope along with less costly manuka to "fill out" the site.

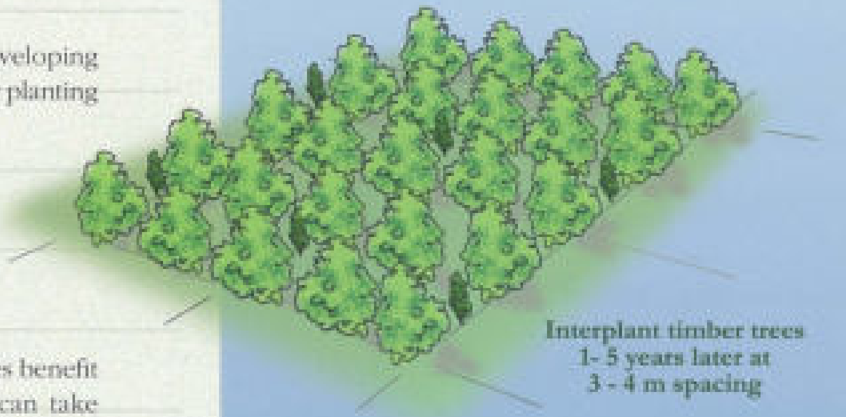
Planting a mixture of natives that includes a high proportion of fast-growing shrub hardwood species to give early canopy cover is essential for sites where major woody weed species are expected.

5. Interplanting native trees into an established nurse crop

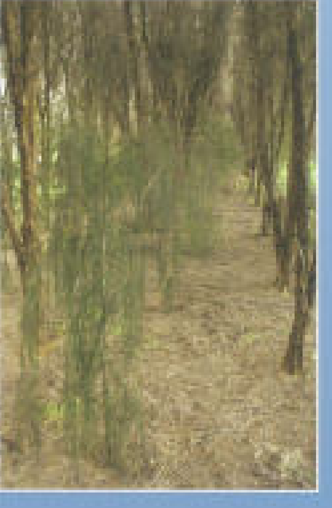
- This option essential for exposed sites where a hardy pioneer cover is required to protect later establishment of timber species.
- Tree species to be interplanted within a developing nurse of hardy pioneer species 1–5 years after planting of nurse crop.
- Plant nurse cover at 2–3 m spacing (1000–2500 stems/ha); plant tree species at near final spacing of 3–4 m (600–1000 stems/ha).
- Time interplanting of tree species so that trees benefit from shelter provided by nurse crop and can take advantage of canopy gaps to encourage height growth and good form.
- Existing regenerating scrub can be used as pioneer cover for interplanting of native trees in lines or gaps.
- Timely removal of overtopping nurse canopy is essential to maintain "light-wells" for developing interplanted native trees.



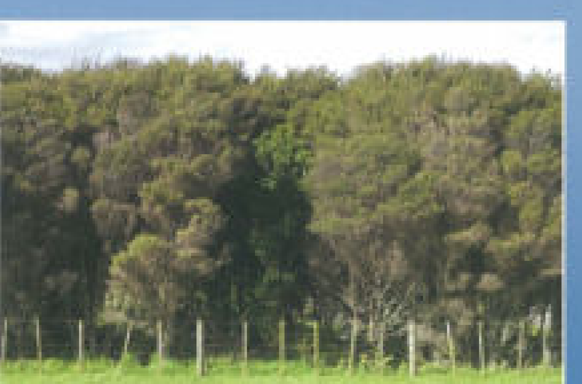
Plant pioneer nurse at 2 - 3 m



Interplant timber trees 1- 5 years later at 3 - 4 m spacing



A line of 4-year-old rimu planted under a nurse cover of manuka established 10 years ago on an exposed ex-farm site. The manuka provided initial shelter and is encouraging good height growth and small side branching on rimu.



A 10-year-old nurse crop of manuka with puriri planted within a gap about 4 years ago.

CONCLUDING REMARKS

For a period of more than a century, hundreds of thousands of native tree seedlings have been planted with the aim of re-establishing a native forest resource. Only a fraction of the planted stands have survived to the present day. Surviving stands often bear evidence of poor site selection and poor management and most do not reflect their true potential in terms of survival and growth rates. Historically, the most productive sites have been used for pasture, horticulture, and exotic forestry. Native trees were often planted on poorer sites and were then neglected. Failure of many planting programmes has resulted in a widely-held perception that native trees are difficult to establish, and grow very slowly. The establishment of native trees using planting practices developed for exotic pine forestry may have also contributed to the relatively poor performance of early plantings.

The adoption of natural ecological processes to encourage regeneration of native tree species may be feasible on many sites and may be the only option for revegetation on a large scale. However, natural regeneration of native timber species on recently fenced open sites is likely to take many decades and this timeframe could be extended significantly if there are no local seed sources, and if aggressive and persistent weed species are present. Planting does offer the opportunity of a faster route to establishing native trees. Despite many early failures, there are some excellent examples of small native tree plantations with exceptional early growth rates, planted on sheltered fertile sites, that had been well managed.

A comparison of estimated costs per hectare for establishing native trees or shrubs at different plant densities shows that the major contributor is the cost of nursery-raised seedlings (Table 2). The estimated bulk rates of $2–4 per plant may even be an under-estimate for some planting programmes (Mike Dodd, pers. comm.). Unless methods for using cheaper and generally smaller stock raised in rootrainers can be demonstrated as feasible on a large scale, planting of seedlings raised in PB2 or PB3 planter bags at a spacing of around 2 × 2 m (2500 stems/ha) is likely to be a preferred choice on many sites. Bulking out the site with a high proportion of the faster-growing shrub hardwoods will reduce time to canopy closure. However, the lower planting densities require a long-term commitment by landowners to ensure that inspection of sites is carried out regularly until canopy closure and problem weeds are controlled before they overtop any planted seedlings.

As the cost of planting programmes using native trees is high and the commitment to managing planted areas easily under-estimated, it is recommended that only a small proportion of the site is fenced and planted in the first year to assess the key local factors influencing early performance. Problem weed and animal pests may become apparent only after planting. A modest approach will avoid possible large-scale failure and provide an opportunity to determine optimum species, stock types, and management requirements to ensure long-term success of establishment on a particular site.

While a substantial degree of experience and expertise has accumulated over recent years, there is a lack of comparative data on the range of planting options for natives. This includes the need for quantitative evaluation of the range of seedling types, sizes, and qualities, as well as options for planting techniques, fertilisers, stocking rates, and silvicultural management appropriate for various sites. Existing nursery and planting trials are aimed at improving current practices that will lead to improved performance and give those involved in the planting and management of natives greater confidence in achieving their vision of a sustainable resource of native trees for future generations.

Today, landowners and investors have the opportunity to utilise the developing experience and expertise in the establishment and management of native trees. Good early planning is required to ensure that appropriate species are selected and that site management meets their ecological requirements. A 2-year lead time will be needed for most species if plants are to be raised from seed. Resources must cover the cost of site preparation, seedling production, transplanting, and a long period of post-planting care, with emphasis on weed control until near-canopy-cover is attained. Planning for use as a timber resource in the long term need not detract from other benefits to be gained from the planting of individuals, groves, and stands of native tree species throughout our productive landscapes.

Tane's Tree Trust Information Database

Tane's Tree Trust was launched in 2001 with the aim of promoting the successful planting and sustainable management of native trees for productive, aesthetic and biodiversity purposes. In addition to consolidating and advancing the state of knowledge of an increasing range of native tree species, the Trust is actively involved in supporting research and building a network of knowledge sharing. With the millions of native trees being planted each year, many in small plantations specifically as a long-term future timber resource, one initiative is the development of an on-line register of these plantations. The aim is to record detailed establishment and management information for the major plantations and monitor long-term performance. By providing guidelines to landowners on how stands can be monitored using Permanent Sample Plots, data will be collated into a centralised interactive network that can be used to provide the latest information for improved establishment and management practices.

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forest research

Forest Research is a Crown Research Institute based in Rotorua and Christchurch. Under its Native Species Research Programme, the planting and management of a range of native tree species are being evaluated for timber production as well as from environmental and social standpoints.

For information on management of native species, contact Dr David Bergin or Greg Steward
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Email: david.bergin@ensisjv.com ; greg.steward@ensisjv.com

Tāne'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 use. 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 (subscriptions range from $30 for individual members to $110 for corporate members), or require further information, contact the Chairman: Ian Barton, P. O.Box 1169, Pukekohe. Phone (09) 239 2049; Email ibtrees@wc.net.nz.

INDIGENOUS TREE BULLETIN SERIES

Native Trees — Planting and Early Management for Wood Production is the third in this series of New Zealand Indigenous Tree Bulletins which summarise the latest information about 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.*
No.2 is *Kauri Ecology, Establishment, Growth, and Management.*

Subjects for future Bulletins include:
Guidelines for planting and managing native hardwood trees;
Monitoring performance of planted native forest stands.

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