PLANTING PODOCARPS IN DISTURBED INDIGENOUS FORESTS OF THE CENTRAL NORTH ISLAND

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ABSTRACT

An outline is given of the objectives and methods used in recent years to establish nursery-raised podocarps on forest, scrub and open sites of the central North Island Volcanic Plateau. Rimu (Dacrydium cupressinum) *has been the species most widely used because of its persistence and ability to grow on a range of sites in competition with shrubby regrowth and in the presence of introduced mammals. The technique recommended for logged forest is planting of small clusters of large seedlings in light wells at intervals which allow selection of the most suitable microsites. A major aim has been to replace trees removed by logging, so the intensity of planting depends on the degree of logging disturbance. A similar group planting technique is recommended for those scrub sites where the prospects for natural regeneration are poor. On more open sites planting pioneer indigenous or exotic species as a first step is recommended to provide some shelter.*

If good quality nursery stock is used and unfavourable microsites are avoided, high survival of several species can be obtained on sheltered sites. Early growth is slow on these upland sites; without releasing some planted trees have reached heights of 4-7 m in 15-20 years but with releasing to provide more light better growth has been obtained.

INTRODUCTION

Experimental raising and field planting of a number of native conifers, mainly the "podocarps" (species of *Dacrydium* and *Podocarpus*) and *Phyllocladus*,† was started at the Forest Research Institute, Rotorua, about 25 years ago. Programmes for

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† *Phyllocladus* is not a genus of the Podocarpaceae but for convenience it is included in the term "podocarps" used in this paper to refer to the native conifers (other than kauri, *Agathis australis*).

operational planting in some districts have been developed by the New Zealand Forest Service since 1975. Techniques are still evolving and require refinement but the major problems can now be recognised and general guidelines provided.

This paper describes planting of podocarp seedlings in the central North Island State Forests. Recently some 50 000 seedlings have been planted out annually by the New Zealand Forest Service in Pureora State Forest Park, West Taupo (N.Z. Forest Service, 1984), and in Whirinaki State Forest Park in the Urewera region (N.Z. Forest Service, 1981). Most plantings have been in forests partly logged during the past 10 years under the revised Management Policy for New Zealand's Indigenous State Forests (N.Z. Forest Service, 1977). However, attention has also been given to more difficult sites severely disturbed by earlier uncontrolled logging operations and sites cleared of forest by the activities of man and browsing animals.

Further management-scale plantings of rimu have been made during the past few years in small clearfelled coupes in State Forests of South Westland; this work has relevance to rimu plantings in higher rainfall areas of the North Island (Forest Research Institute, 1984).

Some work has been done by the New Zealand Forest Service on raising and planting out a range of broadleaved and shrub species for amenity, restoration of degraded sites, or to provide shelter for the establishment of podocarps. A strong interest in restoration planting has also been shown by other government departments, local bodies, conservation organisations, landowners and the general public.

Two recent accounts providing guidelines for revegetation with native plants are those by Evans (1983) and Pollock (in press).

REASONS FOR PLANTING

The broad objective of planting podocarps on forest and scrub sites of the central North Island is to restore a high forest canopy, using species present in the original forest. In those forests zoned for management, planting provides the option of further timber production.

Planting in selectively logged forests can be regarded as an insurance against inadequate or poorly distributed regeneration; seedlings can be placed where they are most likely to survive and grow well without damage from further logging.

On more severely disturbed sites indigenous species may be planted to improve aesthetic, recreation and wildlife habitat values.

In scrub and on degraded sites, where seed sources have been lost and natural regeneration of the desired tree species is sparse or lacking, planting can help restore high forest and replace lost or depleted species.

RANGE OF PLANTING SITES

Method and intensity of planting vary according to the forest type, its history, degree of disturbance and the abundance, distribution and development of natural regeneration. Broad management categories are:

1. High Forest Sites

Unlogged forest types in the central North Island vary from dense podocarp forest containing up to 130 mature podocarps/ha to medium and low density podocarp forest with a lower limit of about five podocarps/ha in a matrix of broadleaved trees and shrubs. Controlled logging during the past ten years in these forests has produced canopy gaps from a few metres to 40 metres across where individual trees or groups of 3-10 trees have been removed. Planting is easiest in freshly logged forest with disturbed ground in canopy gaps.

Substantial areas of intensively logged forest remain from earlier periods when logging was not controlled, resulting in considerable canopy disruption, lack of sound seed trees, and vigorous regrowth of shrubs, ferns, grasses and introduced weeds. In the older logged forest regrowth occupies much of the disturbed ground so that there are few canopy gaps providing suitable planting sites; this type of "reverted cutover" forest makes site preparation more difficult than in freshly-logged forest.

Forest Service plantings in the central North Island have been most extensive within modified high forest.

2. Scrub Sites

Scrub sites comprise seral communities dominated by manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides* var. *ericoides*) (=*Leptospermum ericoides*), kamahi (*Weinmannia racemosa*) or a variety of shrub hardwoods, commonly including wineberry (*Aristotelia serrata*), *Fuchsia excorticata*, pate (*Schefflera digitata*), broadleaf (*Griselinia littoralis*), and species of

Pseudopanax, Melicytus, Pittosporum and *Coprosma.* These have resulted from land clearing, burning, or intensive logging, and tend to be small and scattered. They may be "at risk" through fire, stock trespass, or further clearance, especially on privately owned land. Scrub sites are the natural nurseries for forest tree species where the seed source is adequate and they sometimes have excellent natural regeneration. Where such regeneration is scarce and animal control is adequate they can provide the best sites for enrichment planting throughout the North Island.

3. *Open and Degraded Sites*

These include grassland, recently cleared forest, ground denuded by dam or pipeline construction, roadsides, burned scrub, log landings (skids), and clearings induced by heavy animal browsing in high forest. This category includes sites with sparse or low vegetation as well as sites occupied by unproductive stands of exotic species such as *Pinus nigra* and *P. ponderosa.*

In general, podocarps are most easily established within existing vegetation that provides shelter. Where shelter is insufficient, some form of preparatory planting with pioneer indigenous or exotic species assists establishment, survival and stem form of the podocarps.

CHOICE OF SPECIES

The native conifers planted in the central North Island in approximate order of importance are:

rimu (*Dacrydium cupressinum*)
kahikatea (*Dacrycarpus dacrydioides*)
totara (*Podocarpus totara*)
tanekaha (*Phyllocladus trichomanoides*)
matai (*Prumnopitys taxifolia*) (=*Podocarpus spicatus*)
miro (*Prumnopitys ferruginea*) (=*Podocarpus ferrugineus*)

Matching the ecological requirements of a planted species to current site conditions in a changing forest, and other difficulties, may preclude planting to achieve a composition similar to that of the original forest. However, the principle of planting species occurring naturally on the site appears to be sound. The ecological characteristics of the species listed above and their site tolerances have been outlined in two papers (N.Z. Forest Service, 1980; Beveridge, 1983).

Rimu is the most important species, being the most widespread native conifer, showing the greatest site tolerance, and having a relatively low susceptibility to damage by defoliating insects and browsing animals.

COLLECTION OF SEED AND WILDINGS

Most seedlings are raised from seed collected in autumn beneath forest trees of good form. However, the periodicity of seeding of the podocarps poses problems in seed collection, especially for rimu. Seed crops of rimu tend to be irregular, light and local except for occasional years in which good seed crops are widespread — the last such year in the North Island was 1978. In general, seeding of the other podocarps is also irregular. Kahikatea produces heavy crops in some years and negligible crops in others but the pattern of seeding is localised so some seed is generally available. Matai is even more erratic; miro regularly produces moderate seed crops (Beveridge and Smale, 1981).

The most effective method for collecting large quantities of seed in high forest is to place sheets of hessian beneath trees during periods of maximum seedfall, usually in autumn (March to May). These sheets need to be cleared of seed regularly to minimise damage or loss by birds, insects, rodents and possums. On open-growing pole-sized trees seed can often be picked by hand from lower branches. No reliable methods have yet been found for storing podocarp seed for more than two years. Consequently the irregular seedfalls of some podocarps can result in shortfalls of stock in some years.

An alternative to collecting fresh seed is to rake up forest humus containing seed on the completion of seed fall in early winter. This technique (Herbert, 1977) is useful for tanekaha, matai and miro since seed of these species collected in autumn directly from the trees generally fails to germinate within six months. Some broadleaved species can also be raised by use of forest duff from selected sites.

When seed is unavailable or germination is poor, nursery stock can be raised by carefully uprooting 10-20 cm high wildings from well-lit forest or scrub and transplanting them to nursery beds where they need to be grown on for two or three years. Wildings are likely to grow unevenly in nursery beds, especially when root damage is sustained on lifting.

Rimu has been successfully propagated from cuttings (Dakin and Mearns, 1974). However, raising seedlings from seed appears to be the cheapest and most suitable method for large-scale production.

The few investigations that have been made into genetic variation of indigenous tree species have shown that there are provenance differences in seedling growth rate and form — *e.g.*, in the beeches (Wilcox and Ledgard, 1983) and in rimu (McEwen, 1983). Whenever practicable, local, well-adapted provenances should be chosen for planting. Using local seed sources also ensures that the genetic integrity of populations is preserved and is especially important when planting trees near Ecological Areas and other reserves.

RAISING SEEDLINGS

Germinative capacity of the podocarps varies. For rimu, kahikatea and totara, freshly fallen seed is kept under moist cool storage for 3-6 months before sowing in spring. Kahikatea germinates readily and evenly in spring and is the most easily raised species. Germination of spring-sown rimu seed is generally good (up to 70%) but may continue for several months. Some totara seed can remain dormant for up to two years. Problems exist with germinating tanekaha, matai and miro although germination of the two latter species can be improved by cool, moist storage of seed for two years. Tanekaha is best germinated from forest duff containing seed.

Podocarp seedlings can be grown to a planting height of 50-80 cm in 3-5 years from seed. Seedlings can be raised either in open beds as barerooted stock or in containers. Seed is broadcast on to nursery beds and kept under 50% shade cloth. Similarly, for germinating seed in forest duff, finely sieved humus containing seed can be spread on to moist seedbeds. With bare-rooted seedling production, lining out is at a final spacing of 15×15 cm after seedlings have been in seedbeds for one year (two years for rimu). The lined-out seedlings are kept under shade cloth for 12 months. In colder regions seedlings require a further two years to reach a minimum planting height of 50 cm but in warmer districts only one year. Larger planting stock, useful for some sites with vigorous growth of ferns and hardwoods, can be obtained by leaving seedlings in the nursery for a further year.

Undercutting during early autumn of the year in which seedlings are to be planted, followed by wrenching at monthly inter-

vals until lifting, ensures a compact fibrous root system on lined-out seedlings.

When containers are used, the newly germinated seedlings are pricked into small plastic containers and then repotted into final larger containers (polythene bags) when one or two years old. However, if seedlings are not repotted annually and roots trimmed, root distortion can occur. Container-grown seedlings are more expensive to produce than bare-rooted seedlings and are more difficult to condition. They are also more costly and difficult to transport to the planting site. In general, bare-rooted podocarp seedlings perform consistently well on a range of sites, probably as a result of conditioning in the nursery; such stock has been preferred for large-scale plantings by the New Zealand Forest Service.

PLANTING PATTERNS

Podocarp seedlings grow best in sheltered well-lit conditions when planted on the cool upland sites of the central North Island. Growth is also better on well-drained ground with lightly disturbed topsoil. These requirements are important when considering planting patterns which include: (1) group planting, (2) line planting, and (3) "blanket planting", *i.e.,* establishment of regular plantations.

Group Planting

This method has been most commonly used in central North Island high forest, and to a lesser extent in scrub and on open sites. In forest and scrub, group planting involves (i) selection of the most suitable microsites within natural or man-made canopy gaps, and (ii) planting of separate groups of seedlings. In earlier experimental interplantings of old logged forest, relatively large groups of 13 or more seedlings were used with no subsequent releasing. More recently, small clusters of three seedlings which are regularly released in the early years from competing vegetation have been preferred. Within clusters seedlings are spaced 1 to 1.5 m apart. Clusters are spaced at least 5 m apart but spacing is kept flexible to ensure only the better microsites are planted. Places to avoid are those already stocked with natural seedlings and those with poor drainage, compacted ground, or dense fern and grass. The aim is to obtain one well-established seedling per cluster.

In scrub where enrichment planting of podocarps is desirable because natural regeneration is scarce or poorly distributed, parallel cut lines spaced 5-10 m apart provide access for planting. Along these lines small gaps to accommodate groups of seedlings can be cut at 5-10 m intervals. Again, flexible spacing allows selection of the best microsites.

Group planting in forest or scrub not only retains shelter and makes use of the most favourable microsites available but costs are lower than in mass planting as fewer seedlings are used. Small planted groups with some irregularity within a matrix of other vegetation are more attractive and natural than regular line-planting; through minimum site disturbance a greater diversity of species can be maintained to benefit wildlife.

Line Planting

Line planting has been used mainly in scrub. Seedlings are planted singly at regular (2-3 m) spacing. Planting and subsequent location of seedlings is easy. However, regular spacing may lead to planting on unsuitable microsites, or excessive planting near natural seedlings.

Blanket Planting

Blanket planting has not been widely used for establishment of indigenous conifers. Some larger logged gaps in high forest and animal-induced clearings in Whirinaki Forest have been planted at 2×2 m spacing, requiring large numbers of seedlings. Since all microsites are planted, even those which are unfavourable, survival and growth have been variable. Small plantations of rimu, totara, kahikatea and kauri have been established on open sites in favourable lowland localities but costs have been high, weed control difficult, and the form of open grown rimu and totara poor.

On open sites of the central North Island it is recommended that "nurse" species be established before podocarps are planted. Limited experimental work has been done but it is known that most species survive and grow better with some shelter and that newly-planted rimu is prone to have shoot tips damaged where exposed to wind.

An established nurse of hardy pioneer indigenous or exotic species provides shelter and helps to suppress weed growth. These nurses should be relatively fast-growing and browse-

resistant if animals are present and cannot be adequately controlled. In the central North Island *Pittosporum* species have been most useful in providing an indigenous cover. *Coprosma* spp., *Griselinia littoralis, Melicytus lanceolatus,* and *Hebe stricta* var. *stricta* have also been effective.

Trials with *Eucalyptus regnans* as a nurse species are promising. Sites with unwanted, unthrifty or slow growing exotic conifers have also been used. However, with faster growing exotic species, consideration must be given to methods required to remove the nurse crop when it is no longer needed, without damaging the established podocarps. This can best be achieved by choosing a planting pattern suitable for both exotic nurse species and indigenous conifers.

SITE PREPARATION AND PLANTING

In selectively logged forests the method of site preparation required for planting depends on time elapsed since logging. In recently logged forest only minimal site preparation is required since regrowth on disturbed areas will not be well established. For group planting a 3-4 m diameter gap to accommodate a compact cluster of three podocarp seedlings can be cut by slasher. A minimum one-metre-wide cleared buffer around the centrally planted seedlings prevents vigorous regrowth from overtopping seedlings for up to 12 months.

In reverted or second growth forest, where logging gaps are often occupied by dense wineberry or other fast-growing and short-lived successional species, small clearings must be made. Hand cutting in heavier regrowth is expensive. Machines may be preferred to cultivate small patches in order to remove or reduce troublesome fern and coppice growth. Care must be taken to prevent excessive compaction or removal of topsoil since poor drainage can be induced with resulting poor seedling growth.

In scrub with no access, narrow lines can be cut at 5-10 m intervals. For minimum impact in tall scrub this may involve removing only the understorey. A flexible spacing of groups along lines enables natural gaps to be used where they occur and these can be enlarged if necessary; otherwise gaps can be cut at suitable microsites. A 3-4 m diameter gap is recommended for scrub up to 10 m high; for taller scrub the gap will need to be correspondingly larger. With single seedlings planted at regular intervals along lines, the cut line needs to be wide enough to allow sufficient light through the overstorey.

On open sites a major problem is competition from grasses and ferns. Spot spraying of a herbicide 3-4 months before planting should clear vegetation sufficiently to plant a nurse species. Further spraying may be required when podocarps are interplanted some years later. The alternative to herbicides is to screef ground vegetation from the planting spot immediately before planting.

On upland sites seedlings are best planted from mid-winter to early spring although in warmer districts planting in autumn may have the advantage of getting seedlings better established before summer droughts. Trials have shown that application of fertiliser at time of planting or one year later has not resulted in a worthwhile response.

RELEASING

The greatest hazard after planting is competition from ferns, grasses, sedges and shrub hardwoods. Trials have shown that, if frequent early releasing is not carried out, many planted seedlings become smothered by regrowth, adversely affecting vigour and form and reducing survivals to less than half on some sites.

Most releasing is done by slashing regrowth within a 1-2 m radius of planted seedlings. With group planting, as seedlings are usually within 1.5 m of each other, the objective is to release the cluster as a unit. Where regrowth is vigorous, annual releasing is recommended for the first four or five years to ensure easy relocation of planted seedlings. In other areas releasing may be needed less frequently.

Five years after planting, seedlings on good sites should be about 2 m high and beyond competing ground vegetation. One or two further releasings may be required at 3-5 yearly intervals to allow leaders to penetrate overtopping regrowth.

Herbicides have not been used widely for releasing planted seedlings in forest or scrub. This is due to the range of ferns, grasses and shrub hardwoods that need to be controlled and the difficulty of using a herbicide that will not damage planted seedlings.

Current trials are testing the effectiveness of herbicides for long-term control of regrowth in forest and scrub. This method may have advantages over hand releasing.

On open sites control of grass by carefully spraying herbicide around protected seedlings is generally more practical than releasing by hand.

COST OF PLANTING

Site preparation, planting and releasing costs vary depending on intensity of planting, time elapsed since logging on forest sites, and degree of nurse planting required to provide shelter on open sites. An indication of costs can be given for interplanting an area of 50 ha of freshly logged low volume podocarp/tawa forest in Horohoro Forest, Mamaku Plateau. Replacement of 200 logged rimu involved planting 500 seedling clusters of 3-5 seedlings, totalling 1700 seedlings. Planting was done at the rate of 1 man-hour/ha to establish 38 seedlings/ha. Cost of raising podocarp seedlings is high, currently (1985) $1 per seedling.

There is no prospect of a monetary return from such interplanting. Establishment practices which favour planting a minimum number of seedlings on good microsites followed by tending as required is therefore recommended to keep costs down.

DAMAGING AGENTS

Suppression by tree ferns, ground ferns, or shrub hardwood regrowth is the main cause of mortality of planted seedlings on forest sites; grass and bracken (*Pteridium aquilinum* var. *esculentum*) can be troublesome on scrub and open sites. In forests, smothering by falling trees, debris or collapsing climber tangles can cause some later mortality. Podocarps, and rimu in particular, can persist for some time with unfavourable light but can respond to releasing after periods of suppression or slow growth.

Damage by biological agents rarely kills planted seedlings directly but may reduce their vigour and result in loss of height with subsequent smothering by competing vegetation. Damage to newly planted seedlings by trespassing or feral livestock is often more severe than that caused by browsing deer or possums but all such animals can severely retard growth where more palatable plants have been depleted. Local problems with animals include uprooting of seedlings by pigs on moist sites, severing stems of newly planted seedlings by rabbits and hares on open or grassy sites, and killing of tanekaha and kahikatea saplings by antler-rubbing of deer on stems.

Insects can severely damage young planted seedlings on some sites, frequently causing malformation of totara and loss of leaders on well-established rimu and kahikatea. Such damage is often local and is less apparent in some seasons. Insect damage typically causes some loss of shoot tips and there are few years in which leaders escape minor damage. The damage caused by

insects is less important when planted trees have reached about 4 m in height.

Caterpillars of several species (tortricids and geometrids) can badly defoliate totara. Egg laying by cicadas can cause severe scarring of stems 5-10 mm in diameter, sometimes resulting in weakening or breakage; this damage occurs most often on rimu and kahikatea.

When sapling stems are damaged by larvae of longhorn borers (*Navomorpha* spp.) death of leading shoots up to a metre in length can result. Stick insects (Phasmidae) periodically cause substantial defoliation of kahikatea and totara and some damage on rimu. Miro and matai are not eaten by stick insects (J. Innes, pers. comm.) and suffer little damage from other defoliating insects.

Rimu often suffers dead shoot tips for unknown reasons, even when planted in more sheltered forest sites. On exposed sites more severe shoot death or death of the seedlings has occurred and both drought and desiccating winds appear to be involved.

In general, frost does not appear to cause direct damage to open-grown seedlings of rimu, kahikatea and matai in forest clearings but new growth of totara and tanekaha can be damaged by unseasonal frost. However, shoot tips of all species can be damaged by desiccating winds following frosts.

Fungal attack on seedlings has not been recorded as a problem with field plantings of podocarps.

SURVIVAL, GROWTH AND DEVELOPMENT

Survival of planted seedlings in sheltered forest clearings is high, usually over 90% after five years. Greater mortality can be expected on open sites, particularly in hot, dry or windy summers.

In general, bare-rooted podocarps planted on central North Island sites grow only a few centimetres in height during the first year. Best first year growth of rimu (30-45 cm) has been obtained with 5-year-old planting stock potted in the fifth year in the nursery and planted in logged gaps on weedfree, disturbed ground at Pureora.

Trials in reverted logged forest at Mamaku in 1961 showed that without releasing the podocarps continued to grow slowly in competition with weed growth for 10 years with some 40% stagnating or succumbing to smothering. A proportion survived this phase of intensive competition and sustained a more rapid

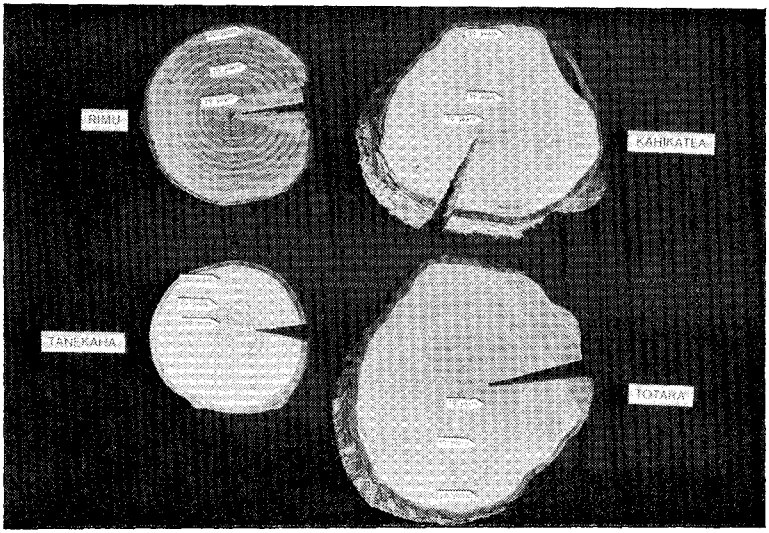

FIG. 1: *Stem sections of four native conifers planted on upland sites of the central Volcanic Plateau. Note slow growth in the first 7-10 years after planting when competition from regrowth is most vigorous. Diameter of the rimu disc is approximately 11 cm.*

growth in height and diameter during the ensuing 10-year period. This capacity to persist under unfavourable light in early years and to respond to better light conditions later is demonstrated by illustrations of stem sections of rimu, totara, kahikatea and tanekaha in Fig. 1. The first three species were grown in the Mamaku trial and the tanekaha was grown in secondary kamahi forest in Pureora State Forest Park. The altitude of both sites was 550 m. Planted podocarps and tanekaha on these sites have attained heights of 4-7 m in 20 years from planting. Growth rings on stem sections indicate that rate of diameter growth increased approximately four-fold at about 7-10 years after planting when leaders grew through the overtopping competing vegetation.

If planted seedlings are kept free from competition in early years, survival is substantially improved and consequently fewer seedlings need to be planted. A degree of side shelter must be maintained to prevent bushy form of rimu and totara. Annual height growth of released rimu, kahikatea and totara on favourable sites has accelerated after the second year and has averaged

about 20 cm if leaders have not been badly damaged (commonly the case with totara). Kahikatea and totara planted as tall seedlings (60-80 cm) on good sites have reached 2 m in height within five years; from this height seedlings have usually continued to develop, even if slightly overtopped by other vegetation. Rimu is slower growing in early years and miro is the slowest and most site specific of all species tried.

Exhibiting extremes in site tolerance, matai, which is shade tolerant, has persisted beneath regrowth at little more than planting height for 20 years in the Mamaku trial, while the light-demanding tanekaha has reached 8 m in height over the same period on the Pureora scrub site.

CONCLUSIONS

The techniques described and the results achieved are based on plantings in soils derived from volcanic ash (tephra) at altitudes of 500-600 m. Further work is required to test these techniques on warmer sites at lower altitudes. Results to date, together with the performance of small plantations of kahikatea rimu and totara established up to 50 years ago, indicate that growth rates may be better than those recorded for the central Volcanic Plateau. On warmer sites there is also scope for raising and planting out such attractive but frost-sensitive broadleaved tree species as mangeao (*Litsea calicaris*), puriri (*Vitex lucens*), and kohekohe (*Dysoxylum spectabile*) which also have the potential to produce valuable timber. Experimental work with these species and with rewarewa (*Knightia excelsa*) and hinau (*Elaeocarpus dentatus*) is at an early stage.

It is envisaged that the current enthusiasm for planting a wide range of indigenous species will be maintained. Although planting for future timber production is likely to have a less important role and cannot be justified on economic grounds, the objectives of improving aesthetic, recreation and wildlife habitat values are becoming increasingly more important. A landscape improved by retaining areas of healthy and diverse indigenous vegetation may not only increase value of the land but will also give pleasure to those who are appreciative of New Zealand's heritage.

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