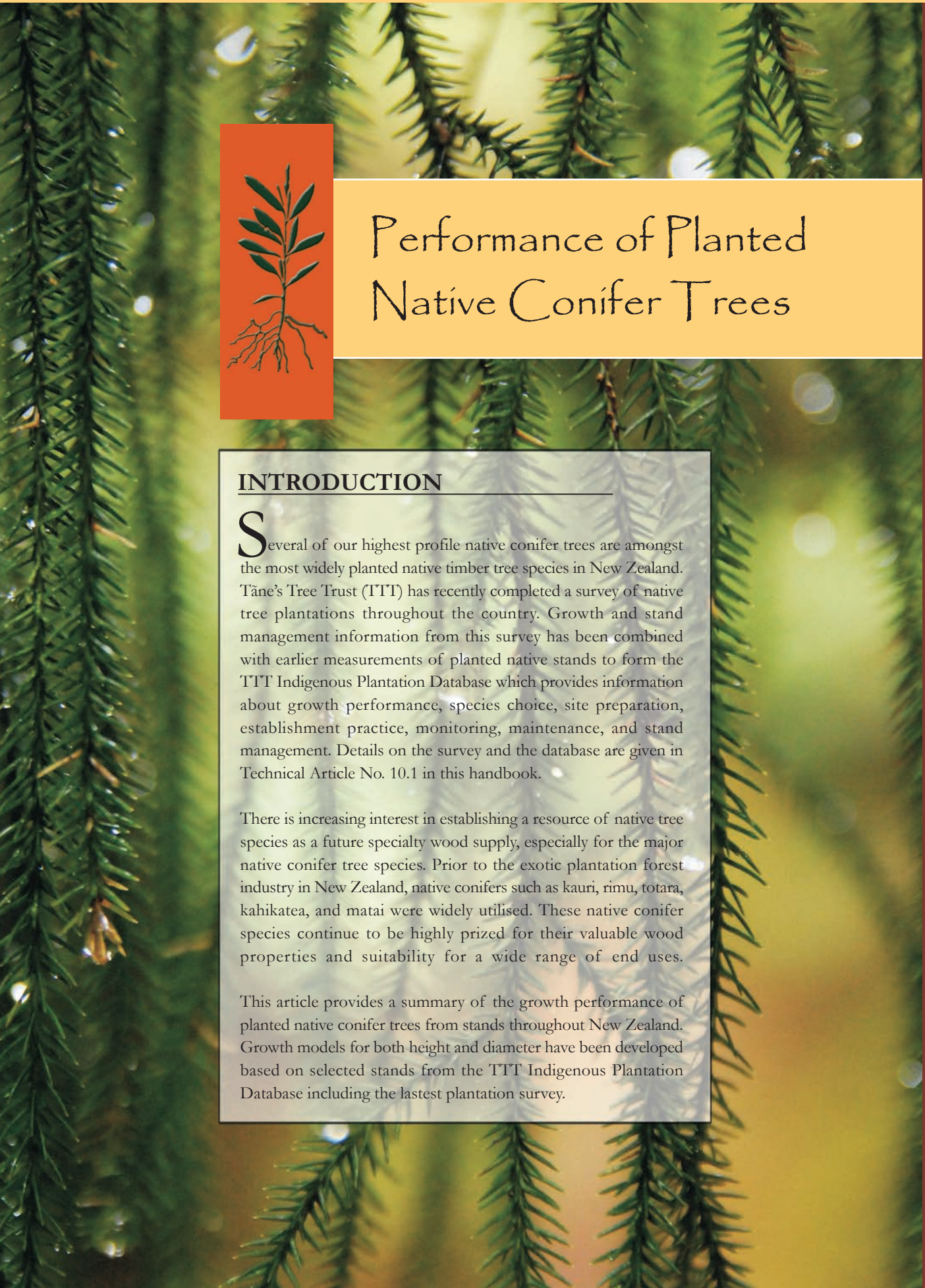


Performance of Planted Native Conifer Trees

INTRODUCTION

Several of our highest profile native conifer trees are amongst the most widely planted native timber tree species in New Zealand. Tāne's Tree Trust (TTT) has recently completed a survey of native tree plantations throughout the country. Growth and stand management information from this survey has been combined with earlier measurements of planted native stands to form the TTT Indigenous Plantation Database which provides information about growth performance, species choice, site preparation, establishment practice, monitoring, maintenance, and stand management. Details on the survey and the database are given in Technical Article No. 10.1 in this handbook.

There is increasing interest in establishing a resource of native tree species as a future specialty wood supply, especially for the major native conifer tree species. Prior to the exotic plantation forest industry in New Zealand, native conifers such as kauri, rimu, totara, kahikatea, and matai were widely utilised. These native conifer species continue to be highly prized for their valuable wood properties and suitability for a wide range of end uses.

This article provides a summary of the growth performance of planted native conifer trees from stands throughout New Zealand. Growth models for both height and diameter have been developed based on selected stands from the TTT Indigenous Plantation Database including the lastest plantation survey.

MEASUREMENT OF STANDS

Most of the plantations identified in the TTT plantation survey were inspected and trees assessed for growth. Permanent Sample Plots (PSPs) or inventory growth plots were established within representative areas of most planted stands with known age and management history. The methods for establishing PSPs followed those of Ellis and Hayes (1997). This data has been added to other datasets, including a survey by the Forest Research Institute in the mid-1980s (Pardy et al. 1992).

DBH (diameter at breast height - 1.4 m above ground) measurements of all planted trees within PSPs were recorded and heights measured for a minimum sample of 12 trees per plot using a Vertex Hypsometer. Inventory growth plots were used for newly planted stands where trees were too small for measurement of DBH. Stand stocking was calculated from bounded plots of known area and estimates of stem density of non-bounded inventory plots was calculated using a minimum of 30 intra-tree distances within stands.

Site factors and the history of site and stand management were collated from owners and managers, or from early archives of plots established by the former New Zealand Forest Service or the Forest Research Institute. Datasets from both the earlier plantation survey and the recent TTT survey were combined. The combined dataset includes a small number of stands that were remeasured during both surveys and where individual trees could be relocated.

Stands of 48-year-old rimu (above) and totara (below), Holt Forest Trust, northern Hawkes Bay.

Measuring the diameter at breast height of a 32-year-old planted kauri in one of many kauri plantations assessed in the upper North Island.

SPECIES AND NUMBERS PLANTED

Conifers make up the bulk of the planted native tree species measured, comprising over 5,000 of the more than 7,000 trees measured for DBH in the TTT Indigenous Plantation Database. These are spread over nearly 300 plots established in either single-species stands, mixed species stands, scattered trees such as in established gardens, or as single or multi-row shelterbelts. Not all trees in the database such as stand edge trees, shelterbelts and newly planted stands were used in the development of growth models.

Stands are located in virtually every region of New Zealand from Northland to Southland and from lowland coastal sites to inland sites over 500 m above sea level. Stand density averaged 2200 stems per ha and ranged from only 200 stems per ha to over 5000 stems per ha. Very few plantations had been pruned or thinned, with the most common treatment being only a low pruning for improved access.

The species most commonly planted included:

- Totara – *Podocarpus totara*
- Kauri – *Agathis australis*
- Rimu – *Dacrydium cupressinum*
- Kahikatea – *Dacrycarpus dacrydioides*

Smaller numbers of other species included:

- Tanekaha – *Phyllocladus trichomanoides*
- Matai – *Prumnopitys taxifolia*
- Miro – *Prumnopitys ferruginea*
- Kawaka – *Libocedrus plumosa*

Small numbers of three other conifer species measured during the plantation survey were toatoa (*Phyllocladus toatoa*), Halls totara (*Podocarpus cunninghamii*) and kaikawaka (*Libocedrus bidwillii*).

GROWTH MODELS

Stand selection for modelling

Growth models were derived from the database for each of the major planted conifer species. These models predict mean height and DBH by age for each species. One of the difficulties in using data from native plantings is that many stands are small with edge trees, while others are scattered plantings with trees in fairly open conditions. Conversely, many stands are at very highly stockings, and would most likely to have been thinned if under a more active management regime. Inter-tree competition affects both height and diameter growth. At low stockings, height growth tends to be slower and diameter growth faster compared with more tightly stocked stands.

A summary of the data used to develop the models is shown in Table 1. When modelling height, only stands identified as being shelterbelts along with several clearly atypical stands were excluded from the analysis. However, when modelling DBH, plots identified as being in scattered stands such as in gardens or urban parks or small stands likely to have significant edge effects were excluded from the analysis.

Several stands with stockings less than 400 stems/ha were also excluded as being atypical compared with the remaining stands in the database. Because of this, stocking density of stands used to develop the DBH model was high, averaging 1720 stems/ha and ranging from 400 to over 4000 stems/ha. Because of the high stockings in the stands used to develop the DBH models presented in this article, they may also be somewhat conservative if applied to trees grown at recommended plantation stocking densities.

Mean age across all eight conifer species used for modelling growth was 33 years and varied from 9 years to over 100 years. The youngest stands were excluded from the analysis.

Table 1: Summary of the number of plots and trees used for developing height and diameter growth models for the more commonly measured planted native conifer species including stand age and stocking.

Species name	No. stands		No. trees measured		Age (years)			Stocking (stems/ha)
	Height	DBH	Height	DBH	Mean	Min	Max	Mean
Totara	68	45	1191	1743	42	9	102	1740
Kauri	80	47	2190	1286	31	9	82	1290
Rimu	33	20	420	339	32	9	69	1800
Kahikatea	39	25	444	549	28	9	78	1810
Tanekaha	14	6	75	49	35	12	64	2300
Kawaka	8	7	34	48	21	9	50	2260
Miro	8	3	22	26	38	9	55	1950
Matai	13	2	38	7	34	13	55	1360

Data analysis

Sigmoidal growth curves of the Bertalanfy-Chapman form were fitted using nonlinear regression. Fits of models using either separate slope or asymptote parameters for each species were tested. For both height and DBH, models with separate asymptote parameters for each species performed best. For the height model, an intercept of 0.5 m representing height at planting was used. For the DBH models, a zero intercept at age 4 years was used, this being the average age at which breast height is achieved by native conifers.

Models for predicting height

Plot mean heights along with fitted height/age regression curves for the eight conifer species are given in Figure 1 for the individual species. Predicted mean heights from these growth curves for specific ages are shown in Table 2. The modelled age range varied from 60-100 years of age for the different species depending on data available in the TTT Indigenous Plantation Database.

The conifers showing the most rapid height growth were kauri and kahikatea which averaged over 23 m 80 years after planting. These were followed by rimu with a mean height of 21 m at age 80 years while totara averaged 19 m, similar to that observed by Bergin and Kimberley (2003). Of the minor conifer species, kawaka and tanekaha showed average height growth rates slightly slower than totara, while miro and matai had the slowest height growth rates.

At age 40 years, height mean annual increments (MAI) for the four most common conifers ranged from 29 cm/year for totara to 36 cm/year for kauri and kahikatea while the slowest growing conifers miro and matai averaged only 19-23 cm/year. At age 60 years, height MAI had decreased slightly to 26-32 cm/year for the four most common species.

Models for predicting DBH

Plot mean DBHs along with DBH/age curves are shown for the conifers in Figure 2, and predicted diameters from these curves for specific ages are shown in Table 2. Kauri, kahikatea and totara all showed very similar average DBH growth, averaging over 30 cm at age 60 years with rimu marginally slower averaging 29 cm.

The limited data for kawaka and tanekaha suggest their DBH growth rates were comparable to the more commonly planted conifers, while miro and especially matai were considerably slower. DBH MAI at age 40 years averaged more than 6-7 mm/year for kauri, totara and kahikatea, slightly under 6 mm/year for rimu, and less than 4 mm/year for miro and matai. These had decreased slightly by age 60 years, averaging more than 5 mm/year for kauri, totara and kahikatea, slightly under 5 mm/year for rimu, and only 2-3 mm/year for miro and matai.

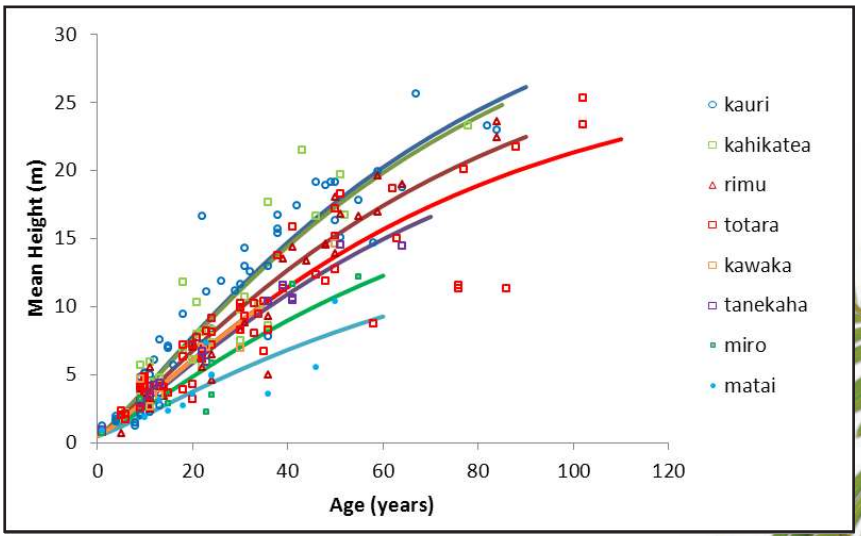
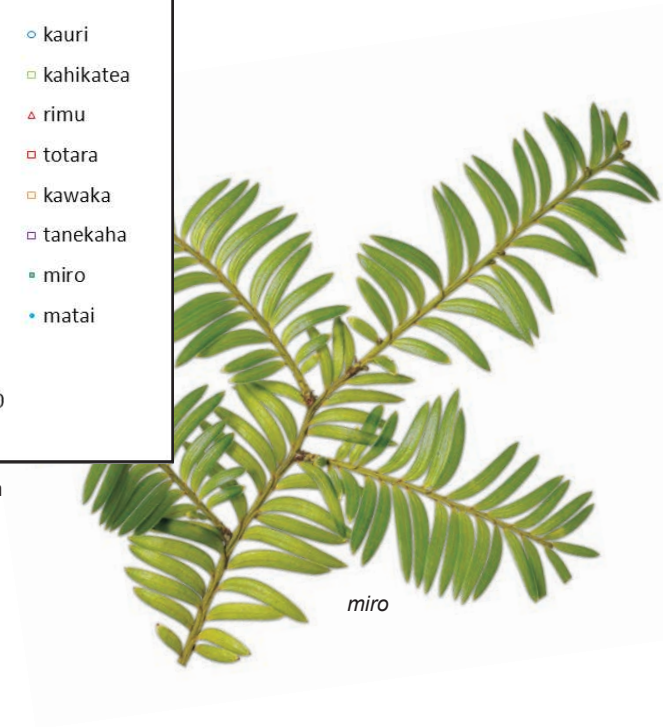


Figure 1: Height/age regression curves for conifers derived from data in the TTT Indigenous Plantation Database.


miro

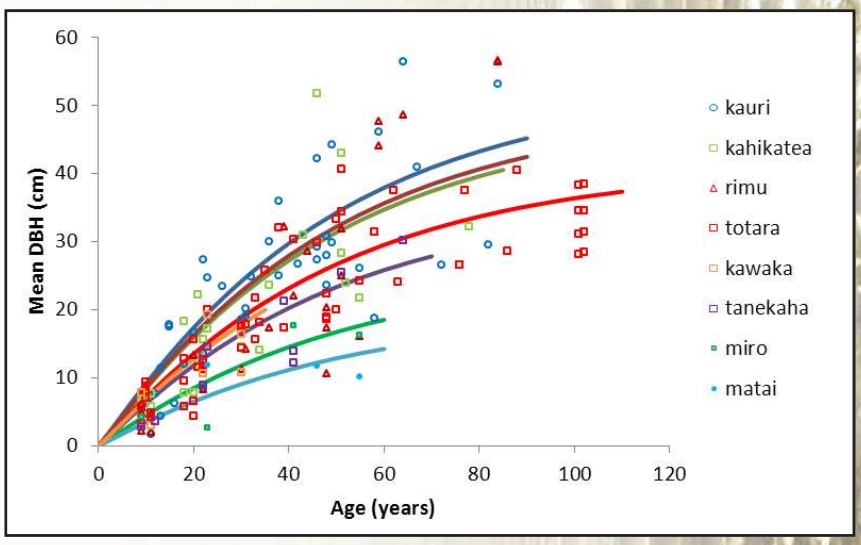


Figure 2: DBH/age regression curves for conifers derived from data in the TTT Indigenous Plantation Database.

Table 2: Predicted average height (m) and DBH (cm) for eight native conifer species.

Age (years)	Kauri	Rimu	Kahikatea	Totara	Tanekaha	Miro	Matai	Kawaka
Height (m)								
10	3.8	3.4	3.8	3.1	3.0	2.6	2.1	3.1
20	7.5	6.8	7.5	6.1	6.0	4.9	4.1	6.0
40	14.2	12.8	14.3	11.6	11.2	9.2	7.5	11.4
60	19.4	17.4	19.5	15.7	15.2	12.5	10.1	
80	23.3	20.8	23.4	18.8				
DBH (cm)								
10	8.8	7.9	8.6	8.5	7.0	5.0	3.4	6.6
20	15.9	14.3	15.6	15.3	12.6	9.0	6.2	11.9
40	25.8	23.2	25.3	24.9	20.5	14.6	10.0	19.3
60	31.8	28.6	31.1	30.7	25.3	18.0	12.4	
80	35.3	31.8	34.6	34.1				

Factors affecting growth in individual stands

The growth rates of these conifer plantations are for sites of average productivity. Individual stands show considerably faster or slower growth rates as can be seen by individual points in Figures 1 and 2. This variation is due both to differences in site productivity and to variable stand management. Many of the stands in the survey had not been well maintained after planting compromising their growth performance. In particular, because of their slow initial growth, good early growth of native trees depends on suitable weed control for some years after planting while timely thinning of over-stocked stands in later years will also improve growth performance. Consequently, these average growth rates do not necessarily reflect the true potentials of each species.

Competition between trees in highly stocked stands will slow diameter growth at older ages. Average stocking of the stands used to develop the DBH model was over 1700 stems/ha, reducing somewhat to 1140 stems/ha in those stands over 40 years of age. There are a number of plantings of rimu and kauri in Cornwell Park, Auckland, at wide spacings averaging about 400 stems/ha which were not included in the DBH model dataset as they were not typical of the other stands in the survey. However, these stands give some idea of the growth rate that might be achievable at somewhat lower stockings. Average MAI DBH in these trees at age 60-80 years is about 8 mm/year.

VOLUME GROWTH

A widely used measure of forest productivity is stem volume MAI. This is calculated by dividing the per hectare summed stem volumes of the stems in a stand by the stand age. Under-bark stem volume can be estimated from tree height and DBH using a volume function such as the pole kauri function of Ellis (1979). It is important when estimating per hectare stand parameters such as volume MAI to use data from large plots with minimal edge effects. This is often difficult to achieve for stands of planted New Zealand natives, many of which are small.

However, by restricting the analysis to stands with stockings of 400 stems/ha or more and with 10 or more trees measured for DBH, and by excluding scattered plantings and plots with significant numbers of edge trees, it was possible to obtain realistic estimates of volume MAI. There were 64 plot measurements in conifer stands in the database satisfying these criteria, including 26 predominantly totara and 24 kauri, with the remainder being either rimu or kahikatea (Figure 3). Stem volume was estimated using the Ellis (1979) volume function.

Unlike a growth function (e.g. as used for DBH and height), a MAI curve reaches a maximum and then declines. The age of maximum MAI is the rotation length that gives the greatest average annual volume production. For fast growing exotic species this occurs at a relatively young age. However for native conifers average volume MAI increases gradually with age, peaking at about age 80 years at an average of about 10 m^3/ha/year (Figure 3), although there is considerable variation between sites with volume MAI ranging between 4 and 16 m^3/ha/year for stands greater than 30 years in age. These values are comparable to the average of 8 m^3/ha/year found for totara by Bergin and Kimberley (2003) and values of 9-13 m^3/ha/year for two stands of kauri (Bergin and Steward 2004).

The flat form of the volume MAI curve for native conifers implies that rotation lengths between 50 and 100 years will produce similar volume MAIs averaging about 10 m^3/ha/year. However, other factors such as mean tree size and heartwood formation are also important when evaluating rotation length.

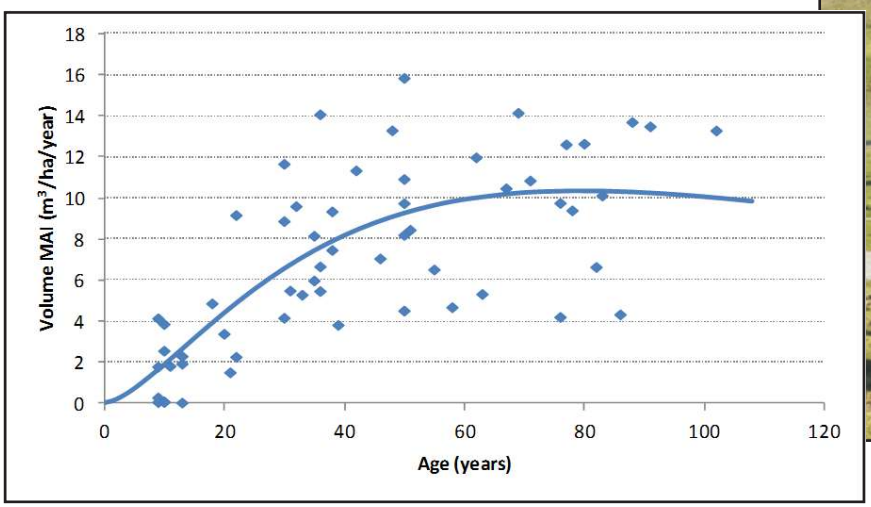


Figure 3: Volume MAI for planted native conifer stands with fitted regression line.

Mixed conifers, Awhitu, Auckland

Rimu and tanekaha, Cornwall Park, Auckland

Mixed conifers, Whatawhata, Waikato

Pruned totara, Northland

CONCLUSIONS

The most commonly grown New Zealand native conifer tree species used in plantations are totara, kauri, rimu, and kahikatea. This is particularly the case where the objective is to provide a sustainably managed native forest with potential as a long-term timber resource.

Mean annual growth rates at age 40 years were 6-7 mm/year for DBH and 36 cm/year for height for the faster growing conifer species, similar to those reported in an earlier native plantation survey (Pardy et al. 1992). Volume MAI increased with age over the first 50 years, but was fairly stable between ages 50-100 years averaging about 10 m^3/ha/year.

There was considerable variation in growth between plots with volume MAI in older stands ranging between 4 and 16 m^3/ha/year. This was considered to be due to differences in site productivity and management practices. Stands had often not been well managed compromising their growth performance. Consequently, these average growth rates do not necessarily reflect the true potentials of each species.

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A 67-year-old plantation of kauri established at approximately 500 stems per ha in Mair Park, Whangarei, has a mean height of 26 m and mean DBH of 41 cm.

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Tãne's Tree Trust promotes the successful planting and sustainable management of New Zealand native trees and shrubs for multiple uses.

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