Performance of Planted Native Hardwood Trees

INTRODUCTION

A number of native hardwood tree species including the beeches (*Nothofagus* spp.) have been planted over many decades throughout New Zealand. Some have the potential for fast growth and rapid heartwood development if planted on good quality sites. However, not many plantations of native hardwoods have been established and managed well as a potential specialty wood resource. Consequently little is known of their growth characteristics across a range of species and sites.

A nationwide survey of native tree plantations was recently completed by Tāne's Tree Trust (TTT) aimed at locating planted stand and assessing their performance. Data from this survey including that of native hardwood tree species has been included in the TTT Indigenous Plantation Database. Details on both the survey and the database are given in Technical Article No. 10.1 in this handbook

This article provides a summary of the growth performance of planted native hardwood trees based on selected stands within the TTT Indigenous Plantation Database. Growth models for both height and diameter have also been developed.

The performance of the other native species groups assessed during the TTT plantation survey – conifers and shrub hardwoods – are given in other Technical Articles within Section 10 of this handbook.

MEASUREMENT OF STANDS

Responses to a questionnaire sent to forestry and farming networks nationwide identified a number of planted stands of native hardwood trees most of which were inspected and trees assessed for growth. Permanent Sample Plots (PSPs) or inventory growth plots were established within representative areas of these stands of known age and management history. The methods for establishing PSPs are described be Ellis and Hayes (1997). Data was also included from an earlier survey carried out by the Forest Research Institute in the mid-1980s (Pardy et al. 1992).

DBH (diameter at breast height – 1.4 m above ground) of all planted trees within plots was recorded and height measured for a minimum sample of 12 trees per plot using a Vertex Hypsometer. Stand stocking was calculated for bounded plots of known area and estimates of stem density in non-bounded inventory plots was calculated using a minimum of 30 intra-tree distances.

SPECIES AND NUMBERS PLANTED

Hardwood trees made up only a small fraction of the planted native tree and shrub species measured, comprising about 700 of the nearly 10,000 measurements in the TTT Indigenous Plantation Database. These trees were located in numerous stands established in either single-species plantings, mixed species stands, scattered trees such as in established gardens, or as single or multi-row shelterbelts. Stands were located from Northland to Southland on mostly lowland sites. Very few stands had been pruned or thinned after planting.

The hardwood trees most commonly planted were:

- Red beech – *Nothofagus fusca*
- Black beech – *Nothofagus solandri*
- Puriri – *Vitex lucens*

Smaller numbers of other hardwood trees planted included:

- Silver beech – *Nothofagus menziesii*
- Rewarewa – *Knightia excelsa*
- Karaka – *Corynocarpus laevigatus*
- Kohekohe – *Dysoxylum spectabile*

The only other hardwood tree species encountered in the plantation survey and measured in small numbers were taraire (*Beilschmiedia tarairi*) and pohutukawa (*Metrosideros excelsa*). A number of other hardwood species which grow to a smaller stature and are often used in revegetation programmes are included with native shrubs covered in Technical Article 10.4.

GROWTH MODELS

Stand selection for modelling

Growth models were derived from the database for each of the major hardwood tree species. These models predict mean height and DBH by age for each species.

A summary of the data used to develop the hardwood tree models is shown in Table 1. Trees planted in the open or on stand edges may have significantly faster diameter growth due to less competition compared to trees growing within stands. Therefore, trees identified in the database as being in the open, in shelterbelts, or in scattered stands such as in gardens or urban parks were excluded from the data used to develop the growth models.

Stands with stocking less than 400 stems/ha were also excluded when developing the DBH model although they were considered suitable for modelling height growth. Stands less than 6 years old were also excluded.

Scattered stands of planted native hardwood trees such as in gardens or urban parks were excluded from the data used to develop the growth models.

Stocking density of stands used to develop the DBH model was high, averaging nearly 1500 stems/ha with different species averaging from 1200 to over 2000 stems/ha. Because of these high stockings, the DBH models developed for hardwood trees in this article are likely to be conservative if applied to trees grown at recommended lower plantation densities.

Mean age across all eight conifer species used for modelling growth was 37 years and individual stands varied from 9 years to over 110 years. The oldest hardwood tree stands assessed in the survey were red beech and black beech and these were located in Otago.

Table 1: Summary of plots used for developing height and diameter growth models for native hardwood tree species.

Species name	No. plots		No. trees measured		Age (years)			Stocking (stems/ha)
	Height	DBH	Height	DBH	Mean	Min	Max	Mean
Red beech	27	22	256	483	36	11	110	1440
Black beech	20	16	138	252	45	11	110	1270
Silver beech	8	6	62	16	32	16	50	1170
Puriri	26	19	171	289	36	9	69	1440
Rewarewa	10	9	69	26	31	9	50	2110
Karaka	11	7	49	55	38	11	64	1200
Kohekohe	5	3	38	6	42	12	59	1820

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 2 years was used, this being the average age at which breast height is achieved by native hardwood trees.

Model predictions of height and DBH

Plot means of height and DBH along with fitted mean height and DBH growth curves for the four most commonly planted hardwood tree species are shown in Figures 1 and 2.

There were marked differences between species in height growth rates. The species showing the most rapid height growth were red beech and black beech which averaged 16-17 m 40 years after planting. These were followed by rewarewa, puriri and silver beech with mean heights of 14-15 m at age 40 years, while kohekohe and karaka werethe slowest growing averaging about 10 m at age 40 years. Height mean annual increment (MAI) at age 40 years was over 40 cm/year for red beech and black beech, about 35 cm/year for silver beech, puriri and rewarewa, and around 25 cm/year for kohekohe and karaka.

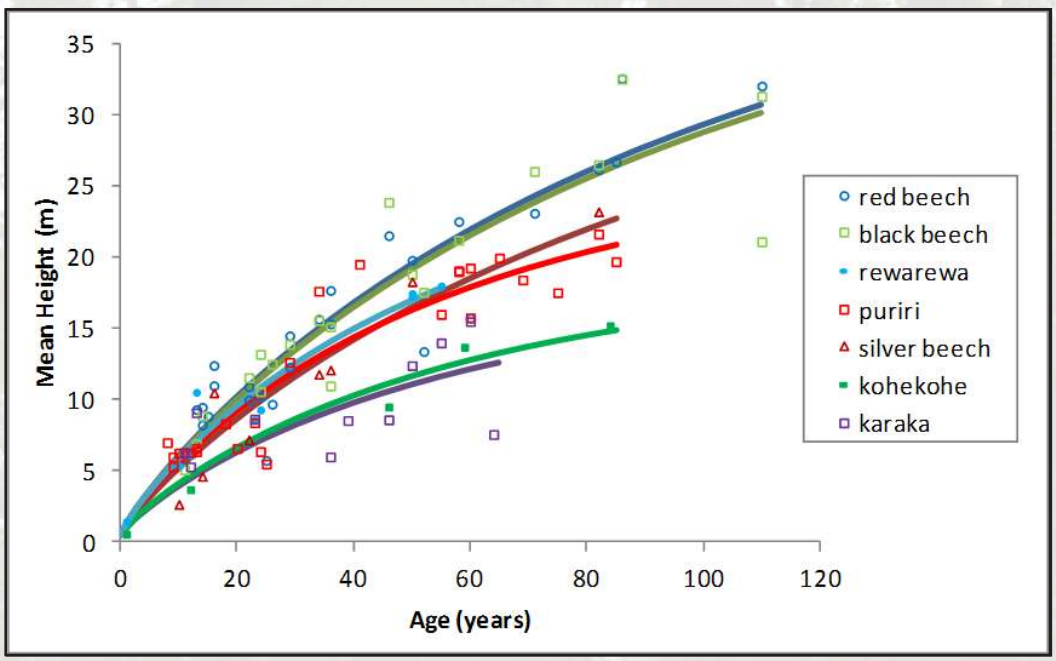

Figure 1: Height growth curves for the seven most commonly planted native hardwood tree species.

The three beech species showed similar DBH growth rates, averaging about 35 cm at age 40 years, while puriri and rewarewa averaged 30 cm, with karaka and kohekohe approaching 25 cm. DBH MAI at age 40 years averaged about 9 mm/year for the beech species and 6-8 mm/year for the other species.

Predictions of average height and DBH for all eight hardwood tree species are shown in Table 2. Predictions in this table are restricted to the age range in the data. By 60 years, most of the beech species have exceeded 20 m in predicted average height with puriri and rewarewa averaging 18 m and and karaka and kohekohe only 12 m. All the beeches and puriri are predicted to average 40-46 cm in DBH at 60 years whereas the remaining species rewarewa, karaka and kohekohe average 28-36 cm.

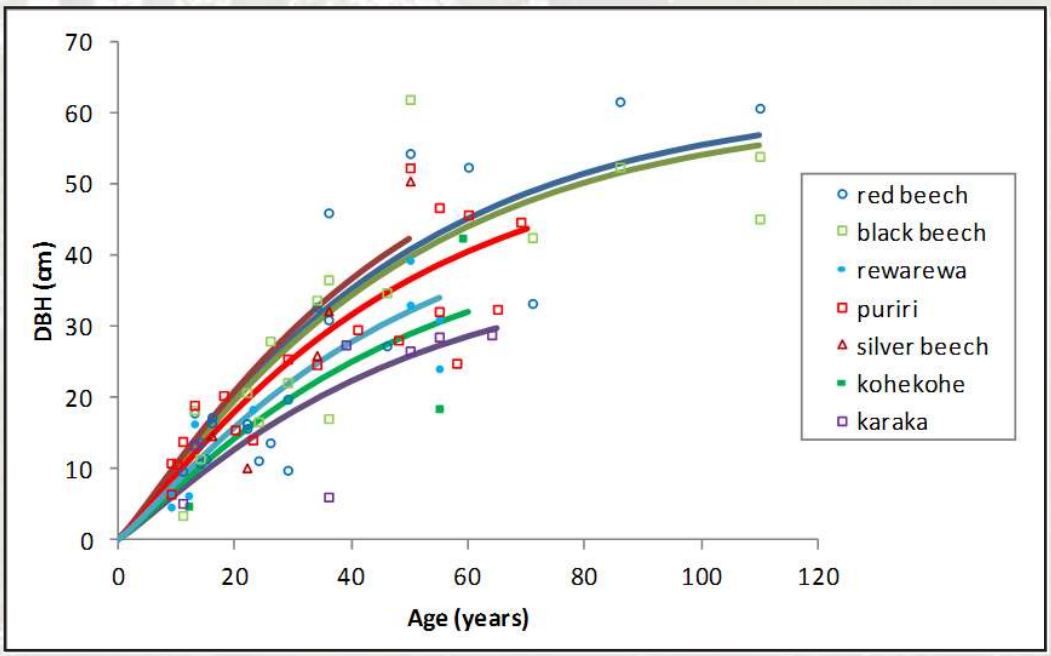

Figure 2: Diameter growth curves for the seven most commonly planted native hardwood tree species.

Table 2: Predicted average height (m) and DBH (cm) for seven native hardwood tree species

Age (years)	Red beech	Black beech	Silver beech	Puriri	Rewarewa	Karaka	Kohekohe
Height (m)							
10	6.0	5.2	6.0	5.6	5.8	3.9	4.1
20	10.2	8.7	10.0	9.2	9.6	6.3	6.6
40	16.7	14.2	16.5	14.4	15.0	9.8	10.3
60	21.8	18.6	21.5	17.9	18.6	12.2	12.7
80	25.9	22.0	25.5	20.4			14.5
Diameter (cm)							
10	10.2	10.6	9.9	9.1	8.0	6.4	7.2
20	20.0	20.8	19.5	18.0	15.8	12.6	14.2
40	35.2	36.5	34.2	31.6	27.8	22.2	24.9
60	45.1	46.8	43.9	40.5	35.7	28.4	31.9
80	51.5		50.0	46.2			

Beech planted at 1800 stems/ha have required pruning of lower brances and removal of occasional multiple leaders, Southland.

A scattered open 20-year-old planting of puriri pruned to 2.5 m, Opononi, Northland.

A 30-year old plantation of black beech established at 3 m spacing (1100 stems per ha) with poor form at Banks Peninsula, Canterbury.

A 16-year-old red beech stand that has been low pruned, Waikato.

VOLUME GROWTH

A widely used measure of forest productivity is stem volume MAI. This is calculated by dividing the per hectare summed stem volumes 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.

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 only 16 plot measurements in predominantly hardwood stands in the database satisfying these criteria, including 7 beech, 6 puriri, with the remainder being either karaka or rewarewa (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. Based on the limited number of available stands, it appears that volume MAI for native hardwoods typically averages about 10 m^3/ha/year in mature stands (Figure 3). This is similar to the average growth rate for native conifers (see Technical Article No. 10.2).

The analysis also suggests that as with native conifers, maximum volume MAI occurs after age 50 years. However when compared with native conifers, the precise nature of the volume MAI relationship with stand age is less clear due to the limited number of available stands.

Native hardwood trees planted at wide spacing, such as these karaka in an urban park in Auckland, were used in the development of diameter and height models but were not used in calculating volume growth which was restricted to stands with stockings of 400 stems/ha or more.

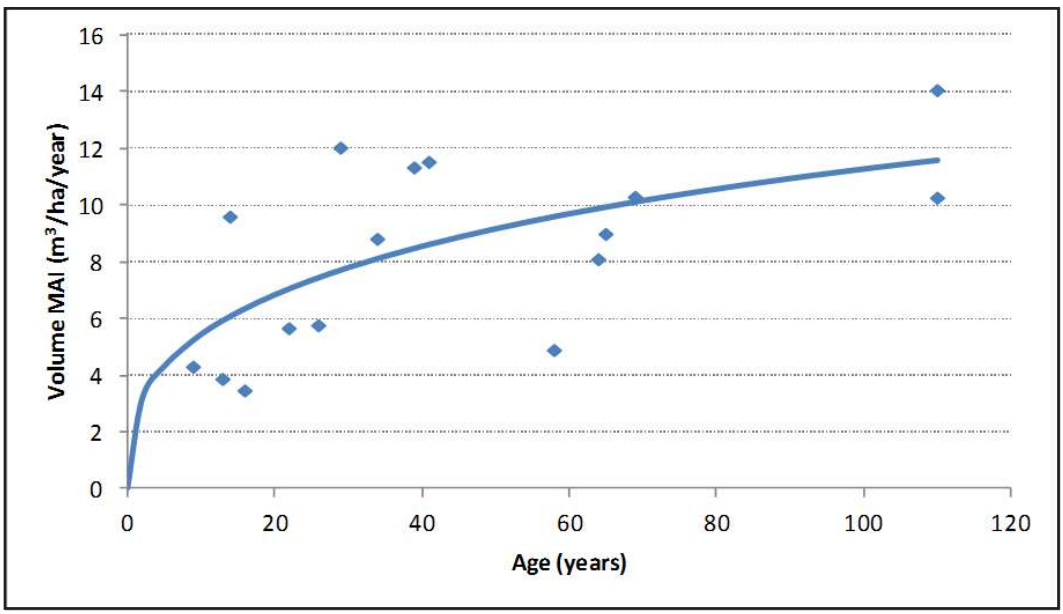

Figure 3: Volume MAI for planted native hardwood stands with a fitted regression line.

CONCLUSIONS

Although far less commonly planted than the native conifer species, there are sufficient stands of planted native hardwood trees to allow for some assessment of growth rates to be made. The most commonly planted New Zealand native hardwood tree species are red beech, black beech and puriri, and there are minor plantings of silver beech, rewarewa, karaka and kohekohe.

The beech species had average mean annual DBH growth rates at age 40 years of 9 mm/year while the other hardwood species average 6-8 mm/year. Height growth was fastest for red and black beech with average height MAI at age 40 years of 40 cm/year. Volume MAI in mature stands averaged about 10 m^3/ha/year.

There is clearly a need for establishment of native hardwood trees as plantations at densities of 500-1000 stems/ha to determine their growth potential for timber production. Other than for some of the beeches, the TTT plantation survey has also illustrated a lack of well-established stands of planted hardwood trees to determine effect of different planting densities on stem form and lower branching, and hence the silvicultural requirements for a range of species.

Native hardwood tree species planted at wide spacing often develop multiple leaders with large branching to low levels on stems. These rewarewa and other native hardwood trees established as low density stands in Cornwall Park, Auckland, required tree protectors in early years to prevent damage where grazing stock have been used to maintain grass growth.

References:

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Pardy, G. F.; Bergin, D. O.; Kimberley, M. O. 1992: Survey of native tree plantations. *Forest Research Institute Bulletin No. 175*. 24p.

Wardle, J. 1984: *The New Zealand beeches. Ecology, utilisation and management*. New Zealand Forest Service. The Caxton Press. 447p.

An unmanaged stand of red beech planted around 1900 in North Taieri near Mosgiel, Otago. This highly variable stand had an average diameter of 57 cm and mean height of 33 cm approximately 110 years after planting.

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Tãne's Tree Trust
Native Trees for the Future

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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