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INTRODUCTION

Millions of seedlings of hardy pioneer native shrub and small tree species are raised in nurseries throughout New Zealand each year. These are used for many purposes including revegetation of riparian areas in pastoral landscapes and on erosion-prone steep hill country. Shrubs species, together with the monocots harakeke (*Phormium* species), ti kouka or cabbage tree (*Cordyline australis*) and toetoe (*Austroderia* species), are the most commonly planted native plants currently used in large scale revegetation projects in New Zealand (Bergin and Gea 2007).

Fast-growing, hardy shrub species are favoured for providing shelter on exposed sites and canopy cover on cleared sites which would otherwise be susceptible to invasion by weeds. When such a cover is established rapidly, the time needed for weed control is reduced. Hardy, early successional species also tend to be less expensive to raise as seedlings compared to most native tree species. Consequently, many native revegetation programmes throughout New Zealand initially focus on establishing a cover of vegetation using hardy shrub species.

When suitable seed sources are available, native conifer and hardwood tree species will establish naturally within pioneer vegetation which provides shelter and protection from extremes of climate (Bergin and Gea 2007). Therefore, planting a cover of hardy shrub species in advance of establishing the native high forest tree species can mimic this process of natural succession. Many native tree species favoured for timber production grow slowly in their early years, but their performance can be improved when they are planted within the shelter provided by a shrub nurse crop.

In a recent survey of native plantations by Tāne's Tree Trust, a number of stands of known age consisting of early successional native shrub and small tree species were assessed for growth. This article summarises the growth rates of these sampled stands and includes predictions from a generic growth model applicable to the more commonly planted native shrub species.

SPECIES AND NUMBERS PLANTED

Of the 10,000 plant measurements in the Tāne's Tree Trust Indigenous Plantation Database, 20% are for planted native shrub and small tree species used widely in revegetation programmes. The selection of species used in revegetation programmes varies from site to site depending on the objectives of the programme, the species which are naturally most common in the local area, and characteristics of the site such as degree of exposure, level of fertility or moisture availability.

Some 42 different shrub and small tree species were measured in 54 plots from 39 different locations nationwide. Details of the 16 most commonly planted species are shown in Table 1. These species were:

- *native shrubs* – manuka, kohuhu, tarata, akeake, makomako or wineberry, karamu, rautaawhiri, akiraho, mapou;
- *monocot* – ti kouka or cabbage tree;
- *small native trees* – kanuka, mahoe, whauwhaupaku or five finger, houhere species, kapuka, manatu.

Table 1: Summary of the number of plots and plants used for assessing height and root collar diameter (RCD) growth for native shrubs and small trees assessed in the nationwide survey of native plantations.

Common name	Botanical name	No. plots	No. plants measured		Age (years)		
			Height	RCD	Mean	Min	Max
Kohuhu	*Pittosporum tenuifolium*	27	311	247	16	6	59
Kanuka	*Kunzea ericoides*	22	246	232	15	5	36
Tarata	*Pittosporum eugenioides*	27	213	168	18	6	59
Ti kouka	*Cordyline australis*	25	216	50	17	6	50
Manuka	*Leptospermum scoparium*	12	132	114	12	5	23
Manatu	*Plagianthus regius*	17	159	91	17	6	46
Karamu	*Coprosma robusta*	15	103	94	12	6	20
Kapuka	*Griselinia littoralis*	14	84	73	17	9	36
Houhere	*Hoheria populnea*, *H. sextylosa*	14	81	47	14	6	29
Whauwhaupaku	*Pseudopanax arboreus*	11	57	46	14	6	36
Makomako	*Aristotelia serratus*	11	56	42	14	9	36
Akeake	*Dodonea viscosa*	9	49	38	22	11	55
Mahoe	*Melicytus ramiflorus*	12	49	43	13	6	30
Akiraho	*Olearia paniculata*	6	38	40	14	14	14
Rautaawhiri	*Pittosporum colensoi*	6	36	34	12	6	24
Mapou	*Myrsine australis*	6	17	15	21	9	60

Red mapou was not widely planted and had the slowest growth rate in mixed-species revegetation programmes.

Karamu was commonly planted in mixture with other native shrub hardwoods where it produces large crops of fruit in early years, attracting birds.

Invariably the shrub and small tree plantings assessed in the survey consisted of mixed species assemblages rather than single species plantings. They were mostly planted in riparian areas although a small number were on retired hill country or had been planted for amenity or aesthetic reasons in gardens and urban parks. Few had been planted specifically as a nurse crop for the later inter-planting of conifer or hardwood trees. Ages of these shrub and small tree plantings averaged 19 years and ranged from 5 to 60 years.

The average stocking was 2,560 plants/ha which corresponds to a mean spacing of approximately 2 m. However, stocking decreased with increasing age, reflecting the effect of mortality over time, and possibly also the use of closer planting in more recently established stands. The stands aged less than 10 years old averaged 3,900 plants/ha corresponding to a mean spacing of approximately 1.6 m.

MEASURMENT OF STANDS

Site factors and the history of site and stand management was collated from owners and managers. For sites dominated by shrub hardwoods of known age since planting, a representative sample of up 30 plants for each of the major species was measured. As many of the shrubby species are multi-leadered from near ground level and often heavily branched, especially when young, measuring diameter at breast height is often impractical.

Consequently, root collar diameter (RCD) was measured using large callipers or diameter tapes to measure the one or more stems at approximately 10 cm above ground level. For multi-stemmed plants, the RCD of a single-stemmed plant of equivalent stem cross-sectional area was calculated. All plants in the sample were measured for height using an extendable height pole.

Stand stocking was calculated using a minimum of 30 representative intra-tree distances within stands taking care to avoid stands edges. Stand stocking was variable from less than 1000 stems/ha to several thousand stems/ha.

GROWTH RATES OF NATIVE SHRUBS

Data analysis

A sigmoidal growth curve of the Bertalanfy-Chapman form for predicting mean height of mixed species shrub plantings as a function of age was fitted using nonlinear regression. An intercept of 0.5 m representing height at planting was used in this model. Relative height and RCD growth by species was obtained using analyses of covariance which included terms for plot, species and age. From these, mean heights and RCDs of each species were produced adjusted to a common age and adjusting for differences between sites.

Height growth of mixed species plantings

Mean heights of the 54 shrub plots in the database along with a fitted regression growth curve are shown in Figure 1. This also shows growth curves for low and high productivity sites, corresponding to the 10th and 90th percentiles. Predicted mean heights for low, average and high productivity sites from these growth curves are given in Table 2. In a typical mixed-species shrub planting a mean height of 4.5 m is achieved at age 10 years, and 7 m at age 20 years. Shrub species tend to reach a maximum height of about 9-10 m at about age 30-40 years.

Growth rates vary between stands by up to ±40% depending on the climatic and soil properties of the site as well as management practices carried out at each site. A mean height of 4 m will be achieved at about age 9 years on an average site, but will take 6 years on a good site and 15 years on a poor site.

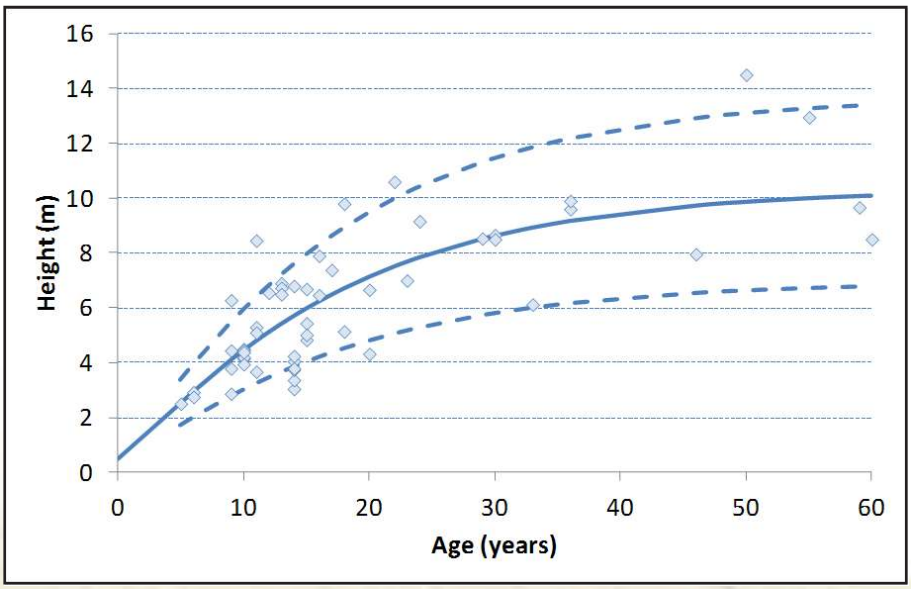

Figure 1: Mean height versus age of 54 plots containing mixed-species plantings of native shrubs and small trees. Solid regression line shows average growth while dashed lines indicate growth for high and low productivity sites.

Time taken to achieve canopy closure

Canopy closure occurs when the crowns of neighbouring plants merge to form a continuous canopy cover. The time taken to achieve this is an important factor when deciding on the spacing to use at planting. Until the canopy closes, the site will be susceptible to invasion by weed species, and regular weed control may therefore be required to ensure the successful establishment of a relatively weed-free stand of native shrubs. Canopy cover will be achieved earlier if a closer plant spacing is used, but the higher number of seedlings required will incur correspondingly greater establishment costs.

Canopy breadth of shrub species was not generally assessed in the Tāne's Tree Trust Indigenous Plantation survey. However, in a survey of 5 year-old native shrub plantings carried out for the Bay of Plenty Regional Council, the ratio of crown height to crown breadth was found to average 1.5, although varying between species (Bergin and Gea 2007). This mean ratio of 1.5 suggests that crown closure begins to occur in a mixed species shrub planting when the mean height is about 50% greater than the plant spacing.

Therefore, at a spacing of 1.5 m, canopy closure will occur at a mean height of about 2.25 m. Based on the growth curves shown in Figure 1, this height will be achieved after 3 years on a good site and 4 years on an average site but will take 7 years on a poor site (Table 3). At a closer spacing of 1 m the height at crown closure is estimated to be 1.5 m. For good, average and poor sites, this will be achieved at about ages 2, 3 and 4 years respectively. However, at a wider spacing of 2 m the height at crown closure is about 3 m which will be achieved for good, average and poor sites at about 4, 6 and 10 years respectively.

Table 2: Predicted mean height by age for mixed-species plantings of native shrubs and small trees for slow growing, average, and fast growing sites.

Age (years)	Mean height (m)		
	Slow growing site	Average site	Fast growing site
5	0.3	2.5	0.7
10	1.7	4.5	3.4
15	3.0	6.0	5.9
20	4.0	7.1	7.9
25	4.8	8.0	9.5
30	5.4	8.6	10.6
35	5.8	9.1	11.4
40	6.1	9.4	12.1

Growth rates of individual species

Relative growth rates of individual species are summarized for all 16 species in Table 4. More detailed predictions for the 8 most common species are shown for mean heights at ages 10, 20 and 30 years in Figure 2, and mean RCD at ages 10 and 20 in Figure 3 (there was insufficient data beyond age 20 to obtain good estimates of RCD). Growth rates are similar for most species especially up to age 10 years. However, manatu and houhere show somewhat faster height growth than most other species, while kapuka and mapou are the slowest.

Table 3: Time in years for mixed-species plantings of native shrubs and small trees to achieve canopy closure target heights for a range of plant spacings on slow growing, average, and fast growing sites.

Plant spacing (m)	Time in years to reach canopy closure		
	Slow growing site	Average site	Fast growing site
1	4.3	2.6	1.7
1.5	7.0	4.3	3.1
2.0	10.0	6.1	4.4

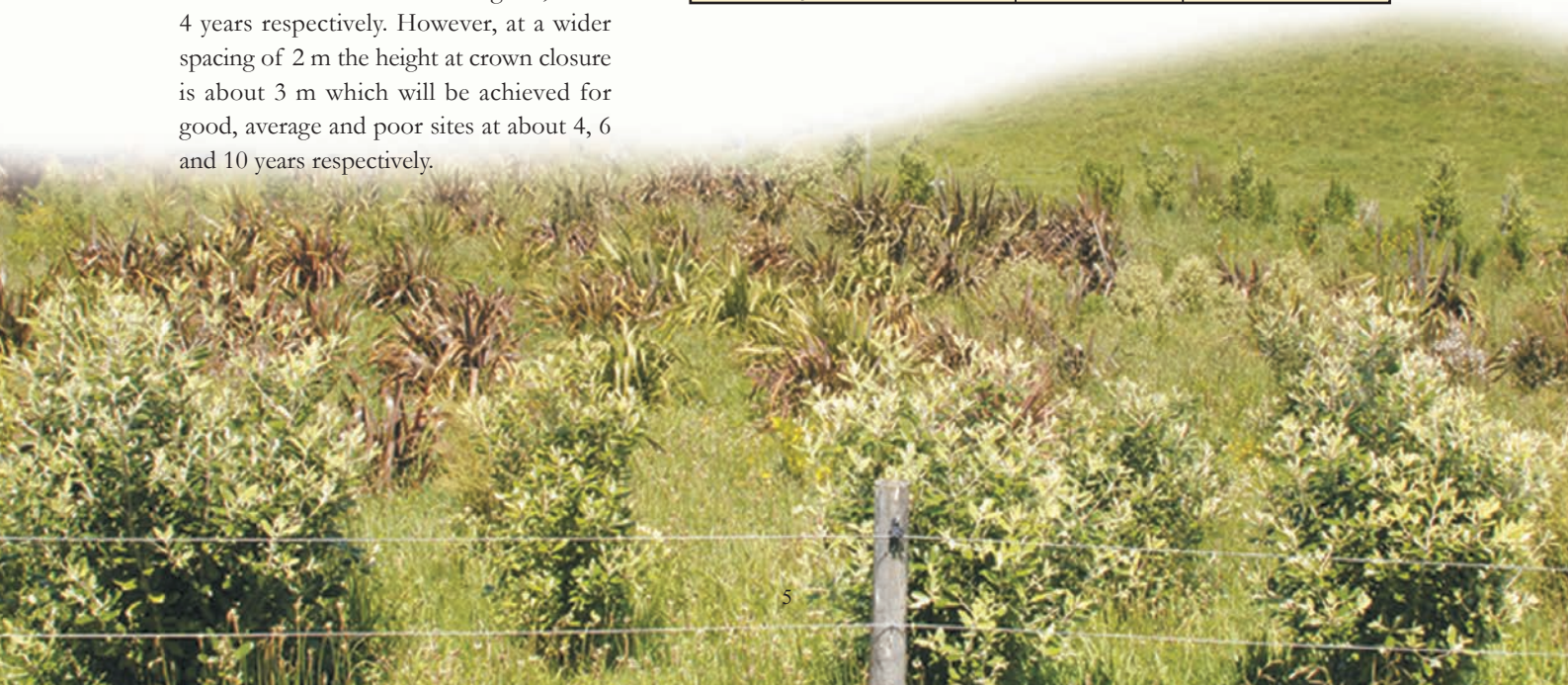

Table 4: Relative height and RCD growth rates by species. Relative growth rates are expressed as ratios with an average species having a ratio of 1.0, faster growing species being greater than 1.0, and slower growing species less than 1.0. Values within a column followed by the same letter do not differ significantly (least significant difference test, p=0.05).

Species	Relative height growth rate		Relative RCD growth rate	
Manatu	1.26	a	0.81	d
Houhere	1.25	ab	0.90	cd
Tarata	1.13	bc	1.14	abc
Kanuka	1.06	c	0.78	d
Akeake	1.03	cd	0.98	bcd
Makomako	1.01	cd	1.25	ab
Kohuhu	1.01	cd	1.03	bcd
Ti kouka	0.99	cd	1.24	ab
Manuka	0.98	cd	0.80	d
Mahoe	0.97	cde	1.06	abcd
Whauwhaupaku	0.96	cde	0.99	bcd
Akiraho	0.95	cdef	0.97	bcd
Rautaawhiri	0.95	cdef	1.05	abcd
Karamu	0.93	def	0.94	bcd
Kapuka	0.83	ef	1.38	a
Mapou	0.69	f	0.69	d

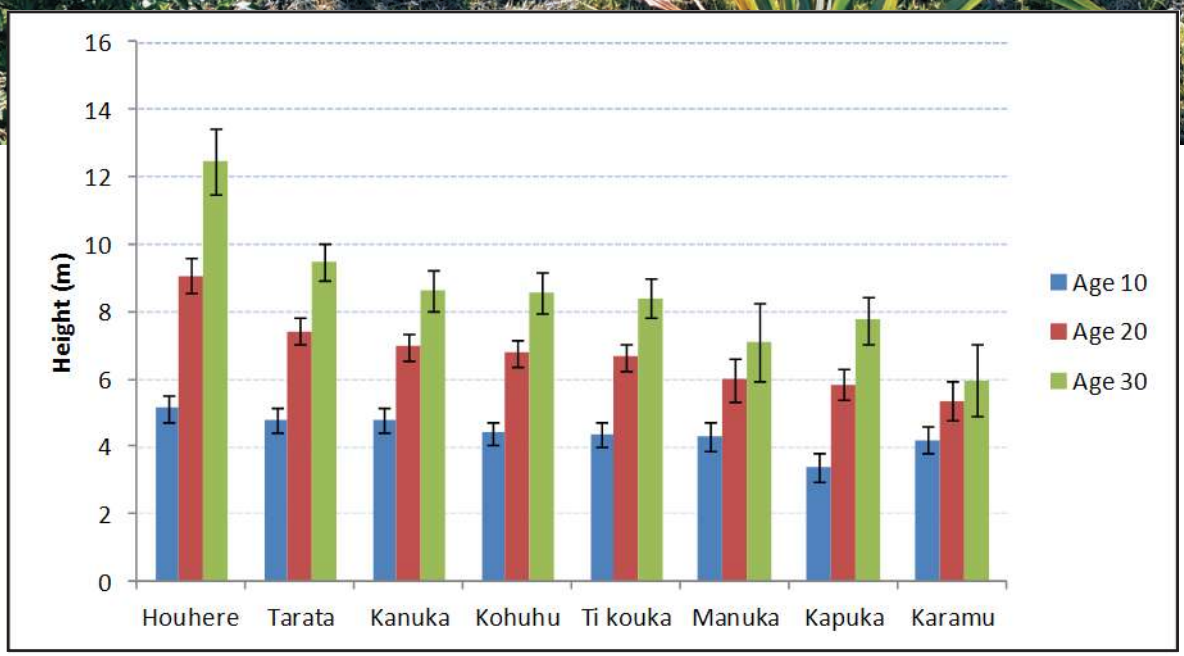

Figure 2: Mean heights of the more commonly planted native shrub and small tree species at ages 10, 20 and 30 years. Error bars show standard errors.

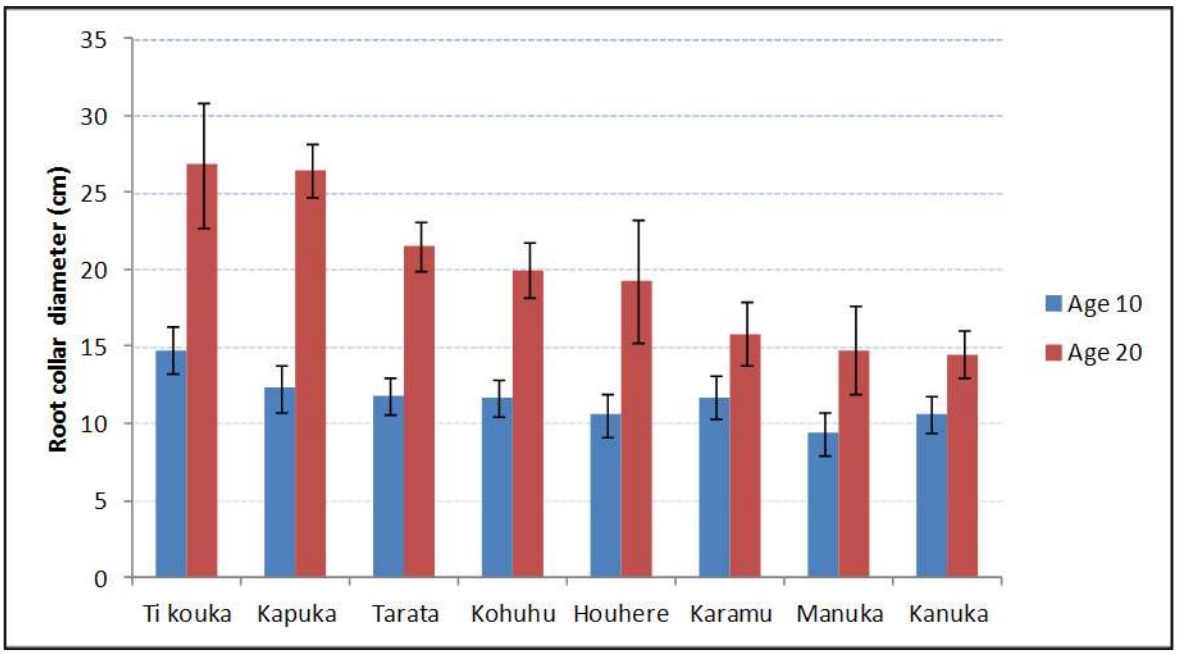

Figure 3: Mean root collar diameter of the more commonly planted native shrub and small tree species at ages 10 and 20 years. Error bars show standard errors.

Overall, the early growth rate of most of the native shrub species assessed in the survey averaged over 40 cm per year for height and over 1 cm per year for diameter. These are substantially faster than growth rates of both native conifer and native hardwood tree species (refer to Handbook Articles No. 10.2 and 10.3). This is also reflected in nursery production where most shrub hardwood species take less than a year to reach a planting height of 50 cm compared to tree species which typically take at least two years (Bergin and Gea 2007).

CONCLUSIONS

The results of this survey show that the early growth rate of selected native hardy shrub and small tree species planted on open sites average over 40 cm per year for height and over 1 cm per year for diameter. These are substantially faster than growth rates of both native conifer and native hardwood tree species.

Planting of early successional pioneer species is therefore a practical method for establishing a woody cover of native vegetation and this mimics natural regeneration strategies for most sites. Not only are seedlings of most of the shrub species cheaper to obtain than the slower growing high forest native species, but they can provide a cover of native vegetation on exposed open sites where performance of most conifer and hardwood tree species would be poor. In addition, faster growing pioneers will have a greater chance of outcompeting invasive weeds.

While some of the small native species listed above will grow for a century and more (e.g. kanuka, kapuka), most are shrubby species that will only form low canopies and understorey tiers in high forest. However, their role as 'nurse cover' in providing sheltered microsites for the establishment by natural regeneration or by inter-planting of conifers and hardwood trees species, is essential.

A 2-year-old mixed-species planting of native shrub hardwoods established at 1.5 m spacing on steep hill country retired from grazing, Bay of Plenty.

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The Ministry of Agriculture and Forestry does not necessarily endorse or support the content of the publication in any way.

Authors: David Bergin and Mark Kimberley, Scion

Contact: Tãne's Tree Trust
Website: www.tanestrees.org.nz

Tãne's Tree Trust
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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.

ISSN 2230-3014 October 2011. Revised May 2012.

Printed by Scion Digital Print Centre, Rotorua