COMPARISON OF TAPER, VOLUME AND BARK THICKNESS OF 26 YEAR OLD SEEDLINGS AND CUTTINGS FROM MAMAKU FOREST

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EXECUTIVE SUMMARY

COMPARISON OF TAPER, VOLUME AND BARK THICKNESS OF 26 YEAR OLD SEEDLINGS AND CUTTINGS FROM MAMAKU FOREST

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A trial comparing *Pinus radiata* cuttings and seedlings was established in 1970 on an indigenous cutover site in Mamaku Forest near Rotorua. Both plant types were genetically unimproved. The cuttings were collected from seven year-old parents. The harvesting of this trial at age 26 years provided an opportunity to compare taper, volume and bark thickness of the two plant types. Sectional measurements were taken on a matched sample of 59 trees (29 cuttings and 30 seedlings) in February 1997. The mean diameter at breast height (*Dbh*) for the cuttings was 53.96 cm and 53.64 cm for the seedlings with the cuttings having 9.8% more volume under-bark than the seedlings. For a tree with the same *Dbh* and height, the sectional volume showed 9% more volume under-bark in cuttings than seedlings from stump height to 6 m. For a stand of cuttings and seedlings with the same *Dbh* and height this would result in the cuttings having a 13.43% more total volume under-bark. Bark thickness was less in cuttings. The seedlings had 20% thicker bark than the cuttings at breast height.. These results validate an earlier study carried out by Penman (1988) when the trees were 16 years of age.

Keywords: *Pinus radiata*; seedlings; cuttings; volume; taper; bark thickness

CONTENTS

Introduction

Numerous studies comparing *Pinus radiata* seedlings and cuttings carried out over 20 years are summarised by Bolstad & Libby (1982). In 1985 Klomp & Hong published results of a trial comparing cuttings and seedlings on a cleared indigenous forest site located at Mamaku forest near Rotorua and reported that "seedlings have thicker bark, and are more tapered . . ..". Subsequently Penman carried out an assessment and analysis of the same trial aged 16 years which showed the mean diameter at breast height and total stem volume under bark were lower in cuttings. However, there were significant differences in tree form and taper, which resulted in 8% more total stem volume under bark in cuttings for trees of the same diameter over bark at breast height (*Dbh*) and total height (*H*). Bark thickness was shown to be less in cuttings.

In February 1997 the same trial was scheduled for harvest which provided an opportunity to validate the above study for 26 year old trees.

Stand Details

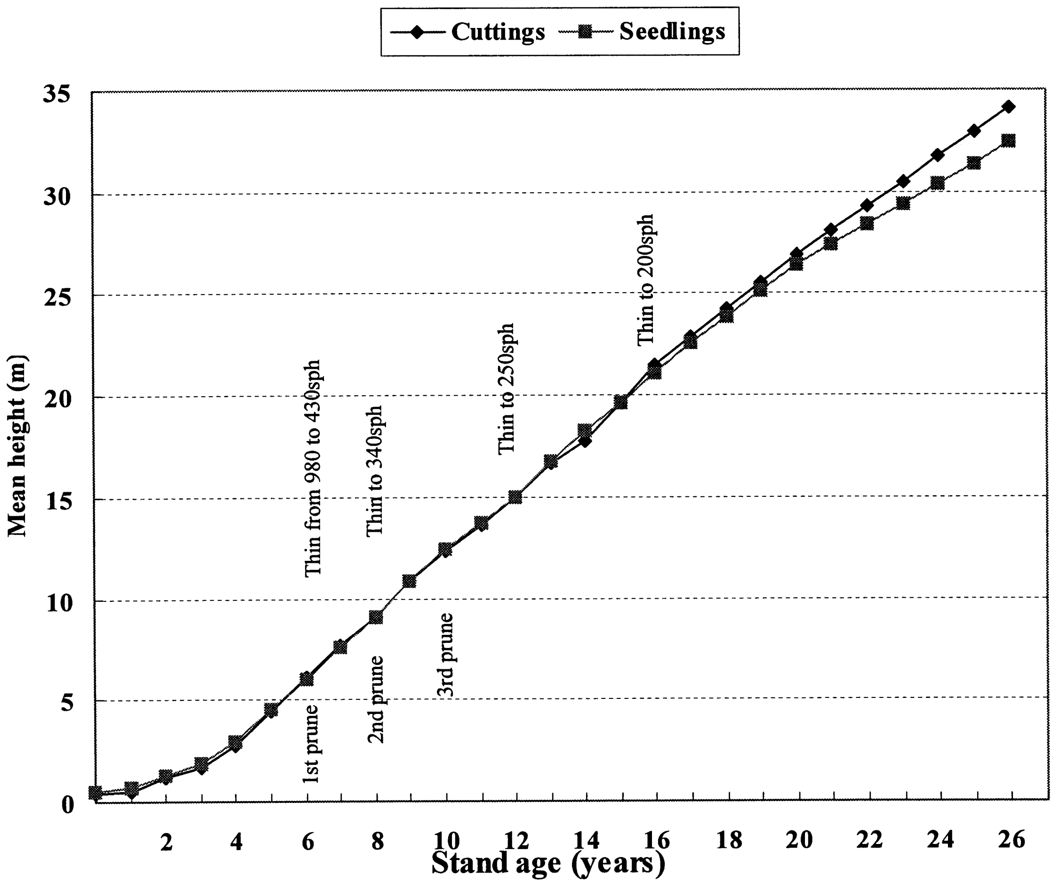
Both the seedlings and cuttings came from bulk collected (genetically unimproved) sources. The cuttings were collected from seven year old trees. The trial was established at Mamaku Forest near Rotorua in winter 1970 at an actual stocking of 1420 stems/ha. Trees were planted in a two hectare block. Cuttings and seedlings were planted in alternate rows, 3.6m apart between rows and 1.8m apart within rows At age six years the trial was thinned to approximately 500 stems/ha and pruned to a height of 2.0m. At the medium and high pruning lifts (approx. 6 m), further thinnings were done. At age 12 years the trial was thinned to 250 stems/ha. In November 1985 the trial, now aged 14 years, was thinned to a final crop stocking of 200 stems/ha.

Klomp *et al* (1997) took an independent sample from the same trial. *Dbh* and *H* measurements were taken between the age of 1 and 26 to monitor the stand growth as shown in figures 1 and 2.

Height growth

Figure 1 shows the mean height of seedlings and cuttings. Klomp found no significant differences between the two groups at any age.

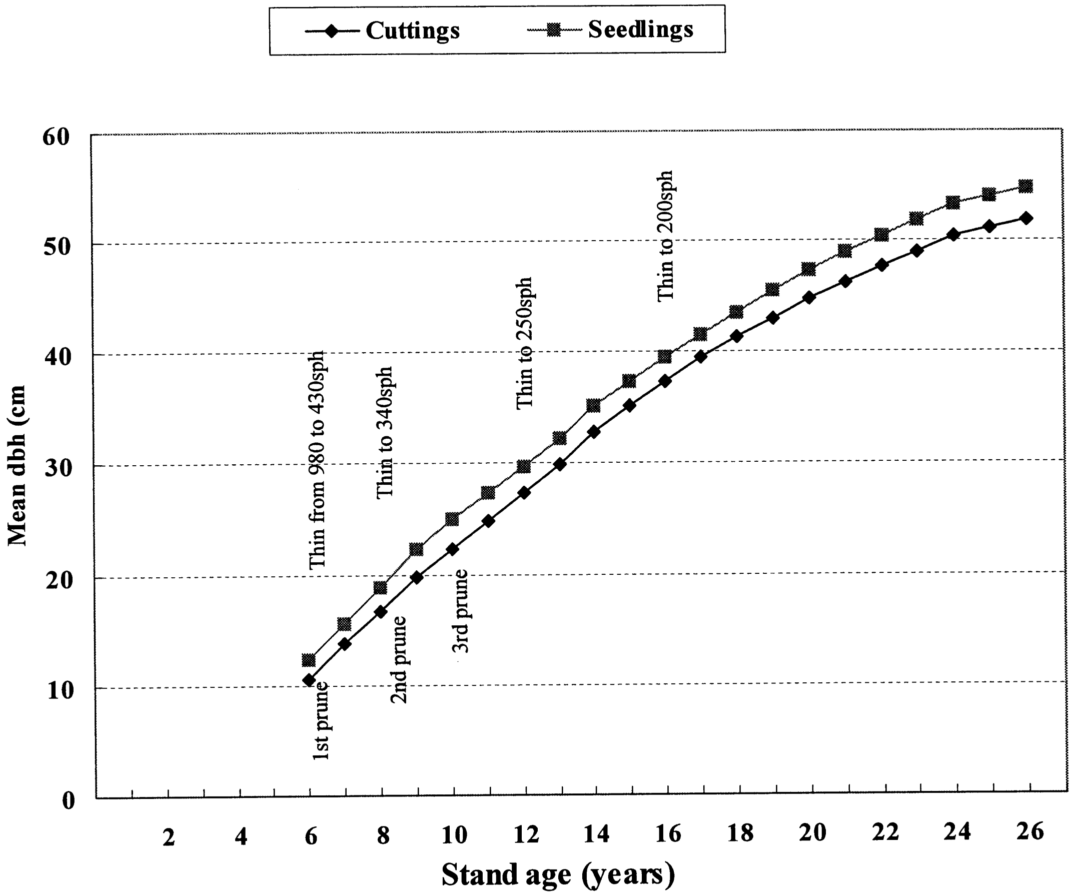
Figure 1. Comparison of mean height growth between seedlings and cuttings



Diameter Growth

Dbh was first measured at the first pruning lift at stand age 6 years. At this time cuttings were significantly smaller in diameter (10.6cm) than seedlings (12.4cm). Although annual increments were generally not significantly different, at harvesting in 1997 Klomp *et al* (1997) measurements showed the seedlings still had a significantly larger *Dbh* (54.7cm) compared with the cuttings (51.8cm) (Fig.2).

Figure 2. Comparison of mean diameter growth between seedlings and cuttings



Methodology

59 trees (29 cuttings and 30 seedlings) were selected and sectionally measured in February 1997 following the procedures described in Gordon and Penman (1987). In brief, over-bark measurements of stem diameter using a diameter tape were taken at levels above ground (h) = 0.3 m, 0.7 m and 1.4 m.

- The tree was then felled and over-bark measurements of stem diameter (*Dob*) were taken at 3m intervals starting at $h = 3$ m, until the length to the tip of the tree was less than 4.5m.
- Total tree height was not measured in the field hence the estimates of tree heights were made based on the taper of the last measured section (linear extrapolation).
- The bark was measured at fixed heights after *Dob* was measured, and a direct measurement of under-bark diameter (*Dub*) was recorded.

- All sectional measurements were run through a comprehensive set of computer edits to screen out possible measurement and recording errors. Trees were checked for extreme or inconsistent measurements. Graphical displays of tree profiles were compared with sample averages to select outliers and atypical trees for more detailed checking. The range of tree sizes is shown in Table 2.
- A taper equation was fitted to the sample data in order to predict the change in $\left(\frac{Dub}{Dbh}\right)^2$ with proportion of total height. An ANOVA test was performed to check the significance of differences in taper between cuttings and seedling.
- The taper equation was then integrated to find volume under bark between specified levels to compare differences in volume.
- The bark thickness between cuttings and seedlings was also compared.

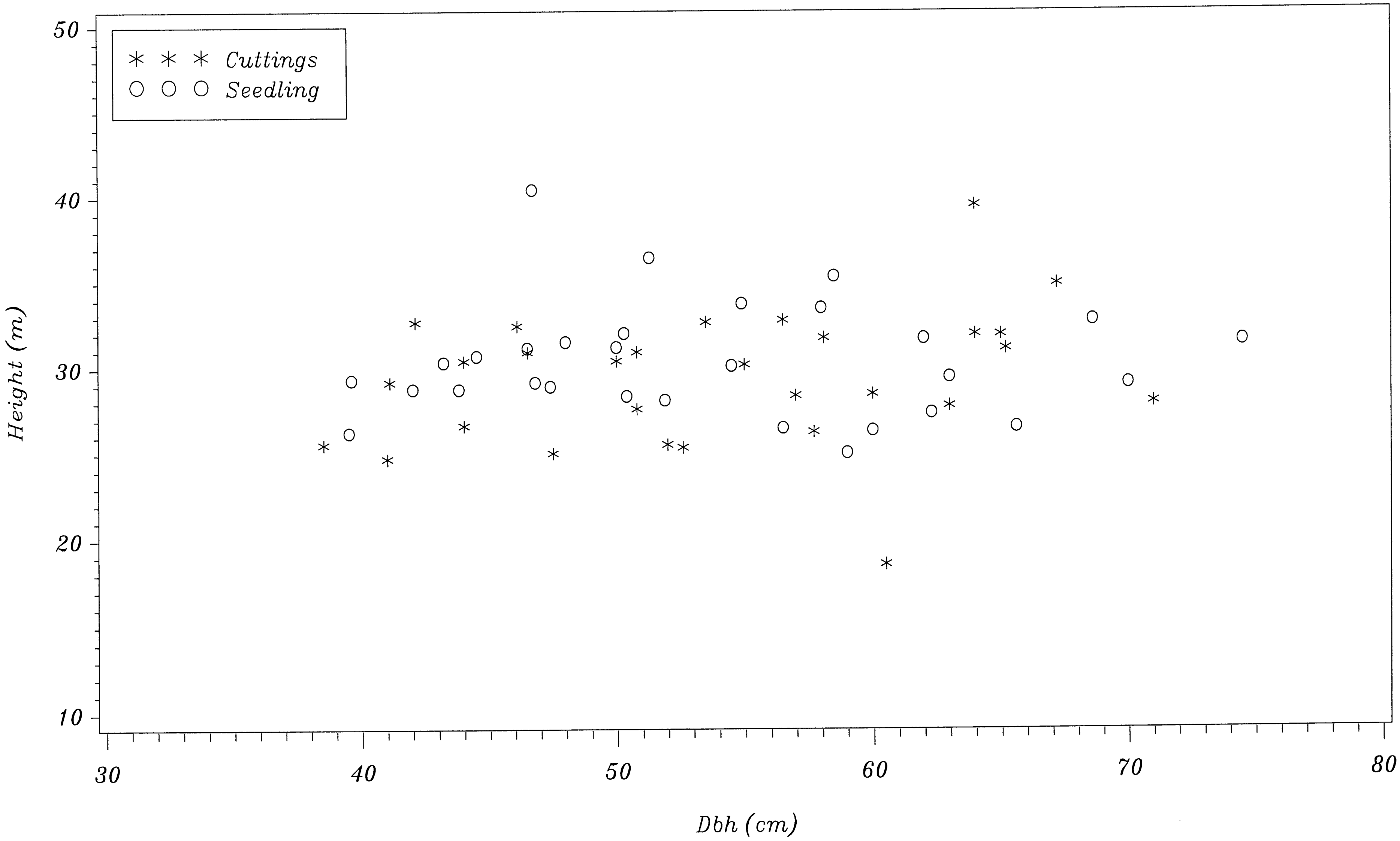
Table 1. Tree Size Statistics of Sample data (59 trees).

	Variable	Minimum	Mean	Maximum	Std. Deviation
Cuttings	Breast Height Diameter over bark (*Dbh)* (cm)	38.50	53.96	71.00	8.9373
	Tree Height (*H*) (m)	18.60	29.40	39.50	3.9375
	Tree Volume U. B. (*TSVub*) (m^3)	1.2489	2.8134	4.3801	0.9425
Seedlings	Breast Height Diameter over bark (*Dbh*) (cm)	39.50	53.64	74.50	9.2967
	Tree Height (*H*) (m)	25.10	30.40	40.50	3.3278
	Tree Volume U. B. (*TSVub*) (m^3)	1.0982	2.5436	4.5549	0.8991

Figure 3 shows the relationship between Dbh and H for the sample data.

Figure 3. Tree Height and DBH Relationship

Mamaku forest



Analysis

Taper Equation

A polynomial taper equation was fitted to the sample. "All-subset" regressions were calculated to determine the best polynomial model. A 3-term model with power terms greater than 5 was selected as giving the best fit and being free from systematic bias (Gordon 1983).

The taper equation was of the form:

$$\left(\frac{Dub}{Dbh}\right)^2 = \beta_1\left(\tfrac{L}{H}\right)^2 + \beta_2\left(\tfrac{L}{H}\right)^3 + \beta_3\left(\tfrac{L}{H}\right)^7 \quad (1)$$

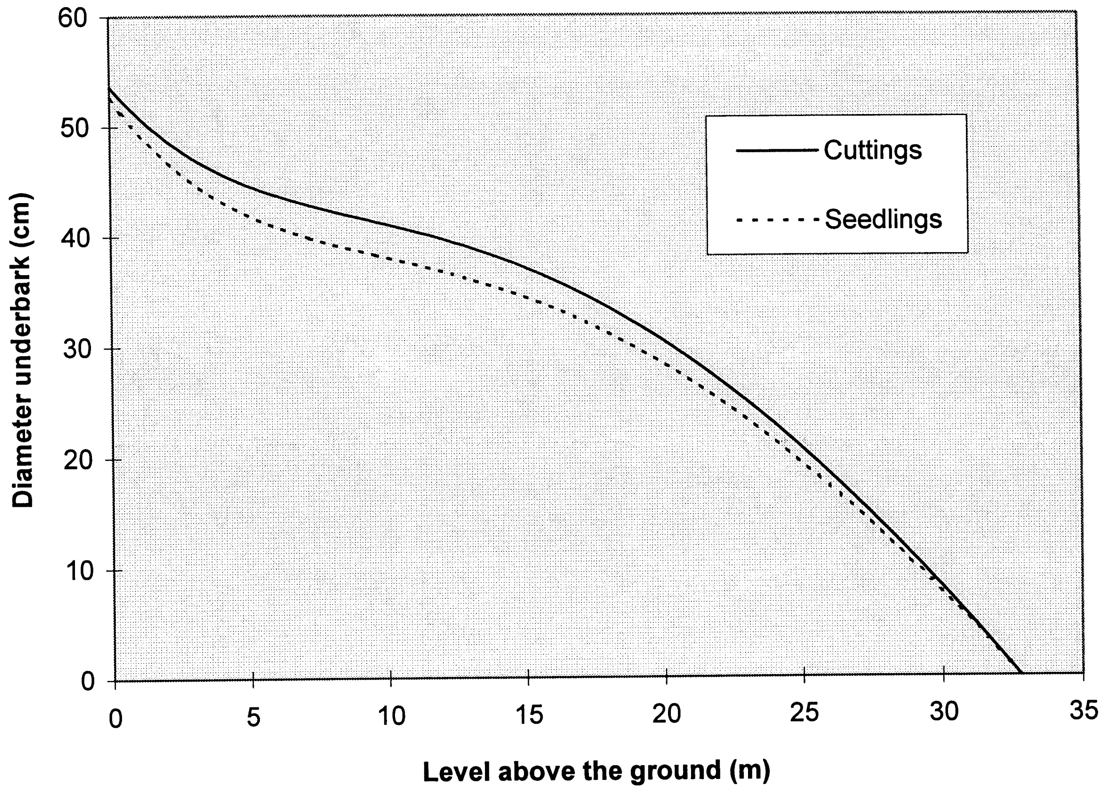
An analysis of variance of the residual sums of squares showed that there was a significant difference between the two groups hence Equation 2 is fitted separately to find the best-fitting equation.

Table 2 The coefficients of Equation 2 :

	Cuttings		Seedlings	
	Coefficients	**Standard errors**	**Coefficients**	**Standard errors**
β_1	3.418339	0.121170	3.018725	0.105485
β_2	-3.421578	0.191937	-3.102678	0.166887
β_3	0.995667	0.082846	1.036612	0.071585

Mean *Dbh* of the combined sample was calculated and the height was derived using the Petterson height curve of 12 trees. Figure 4 shows the taper equations derived for each group using the coefficients contained in Table 2.

Figure 4. Under-bark taper curves for tree with *Dbh* = 53.8 cm and *H* = 32.8 m.



Estimating Sectional Volume

$$V_l = \frac{\pi * Dbh^2}{40000}\left\{\frac{B_1}{3H^2}\times\left(L_1^3 - L_2^3\right) + \frac{B_2}{4H^3}\times\left(L_1^4 - L_2^4\right) + \frac{B_3}{8H^7}\times\left(L_1^8 - L_2^8\right)\right\}$$

where:

V_l : estimated stem volume under bark between L_1 *and* L_2 metres (m^3).

H : total tree height (m).

L_1 : distance from tip to specified upper level (m).

L_2 : distance from tip to specified lower level (m).

β_i : coefficients as given in table 2.

Table 3. The estimated sectional volume between specified levels for a tree with $Dbh = 53.8$ cm and $H = 32.8$ m.

Log	Volume (m^3)			Difference as percentage of
	Cuttings	Seedlings	Difference	Seedling volume
0.3 - 6 m	1.0032829	0.91478554	0.088497	9.67
6 - 9 m	0.4270364	0.36950743	0.057529	15.57
9 - 12 m	0.3896172	0.33404541	0.055572	16.64
12 - 15 m	0.3478062	0.29854371	0.049263	16.50
15 - 18 m	0.2939353	0.25357975	0.010356	15.91
0 - 32.8m	3.046009	2.685407	0.360602	13.43

It can be seen that the volume equations are predicting larger volumes for the cuttings.

Bark thickness

Initially the bark thickness was analysed to derive a relationship for determining the ratio of under-bark and over-bark diameters of the whole sample. Plots of *Dub*/*Dob* over the length down from the tip (*L*) as a proportion of *H* showed that the ratio of *Dub* to *Dob* followed a normal pattern for *Pinus radiata*, being fairly constant over the central section of each stem but lower towards the base and top (Gordon 1983b). An analysis of variance of the residual sum of squares showed that there was a significant difference in the equations between the seedling and cutting. The following equation was fitted to each group:

$$\left(\frac{Dub}{Dob}\right)^2 = \alpha_0 + \alpha_1\left(\frac{L}{H}\right)^{\beta_1} + \alpha_2\left(\frac{L}{H}\right)^{\beta_2} \qquad (3)$$

where: ***Dub*** : diameter under-bark (cm).

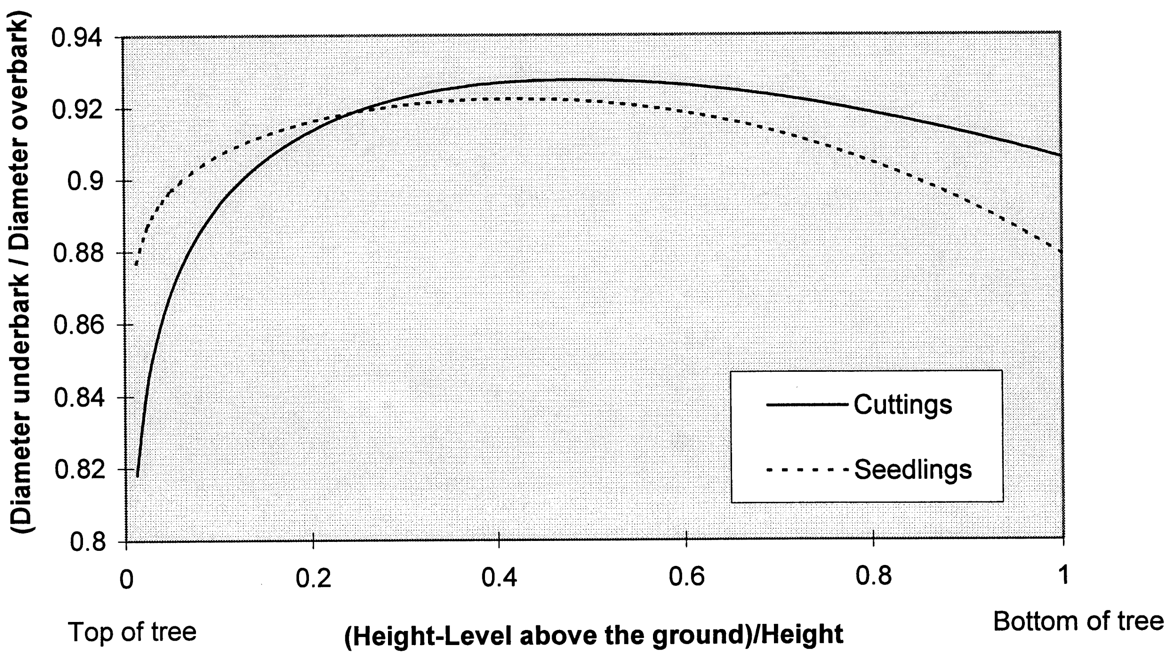
Dob : diameter over-bark (cm).

Table 4. Coefficients of Equation 3

	Cuttings		Seedlings	
	Coefficients	**Standard errors**	**Coefficients**	**Standard errors**
α_0	-0.465775	0.000000	-0.115977	0.022203
α_1	-0.142631	0.061880	-0.111881	0.020991
β_1	1.451626	0.652274	2.825909	0.858808
α_2	1.428905	0.063468	1.000000	0.000000
β_2	0.052216	0.016936	0.027794	0.013473

Figure 5 shows the ratio of diameter under-bark (*Dub*) to diameter over bark (*Dob*) with proportion of tree height for an average tree at 26 years of age.

Figure 5. Ratio of $\left(\frac{Dub}{Dob}\right)$ for a tree with $Dbh = 53.8$ cm and $H = 32.8$ m.



There was clearly more bark in seedlings than in cuttings below 75% of tree height

Fielding (1970) also found in his older plantation that the bark of cuttings was significantly different than of the seedlings. The cuttings tend to have a thinner bark at the lower section of the tree stem. The mean $\left(\frac{Dub}{Dob}\right)$ ratio from the tree sample at breast height is given in table 5. Table 6 shows the bark thickness ratio $\left(\frac{2bt}{Dob}\right)$ of the two groups at different level above the ground.

Table 5. Mean $\left(\frac{Dub}{Dob}\right)$ of two groups from the 59 trees sample at the breast height.

	Cuttings	Seedlings	Significant of difference
Mean	0.9092441	0.8859559	P < 0.001
Std. Deviation	0.0004959	0.0007050	

The results show that the mean $\left(\frac{Dub}{Dob}\right)$ for cuttings at 1.4m was significantly greater than for seedlings based on $\alpha = 1\%$.

Table 6. Comparison on the mean ratio of bark thickness (*2bt*) to *Dob* or $\left(\frac{2bt}{Dob} = 1 - \frac{Dub}{Dob}\right)$

Level (m)	Cuttings	Seedlings	% difference
1.4	0.090756	0.114044	-20.42%
3	0.087166	0.106855	-18.43%
6	0.081184	0.095525	-15.01%
9	0.076885	0.086943	-11.57%
12	0.073914	0.081510	-9.32%
18	0.074446	0.078267	-4.88%

Note: The difference is as a percentage of seedlings.

Discussion

Stand level

Klomp *et al* (1997) provided the different age measurements at the stand level for the same trial. Table 7 describes the average tree sizes of each group.

Table 7. Average tree sizes from the Mamaku trial at 16 years old and 26 years old period.

	Dbh (cm)		*H* (cm)	
	16 yrs old	26 yrs old	16 yrs old	26 yrs old
Seedlings	39.50	54.80	21.10	32.40
Cuttings	37.40	51.80	21.50	34.10

Using their stand level data, we calculated the tree size variables of cuttings as a percentage of seedlings at two ages (16 and 26 years old).

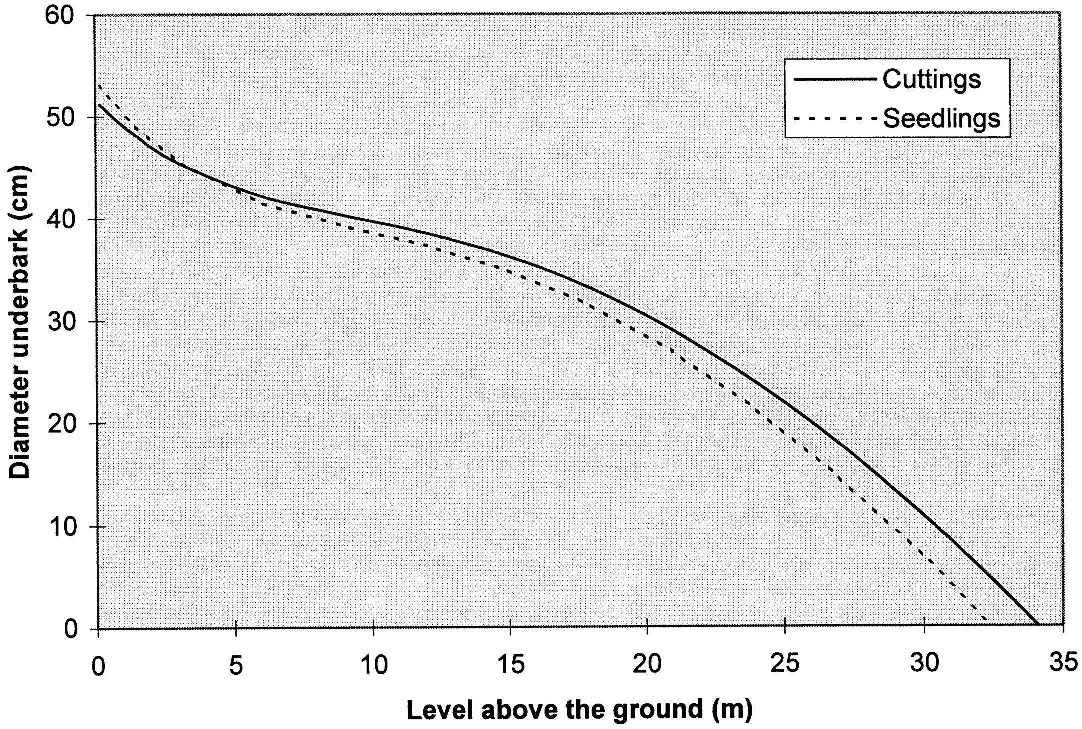
Table 8. Comparison table of cuttings as percentage of seedlings

	Age	
	16 yrs old	**26 yrs old**
Dbh	-5.32%	-5.47%
H	1.9%	5.25%
Sectional Volume (0.3m-18m)	-0.78%	3.33%

Note: Penman (1988) equations were used to predict the sectional volume at the age of 16 years old.

Table 8 shows that mean *Dbh* of seedlings is 5% fatter than the cuttings in general but the mean sectional volume of cuttings is 3.33% more than of seedlings for the 26 years old plantation. The difference was mainly explained by the better tree form of cuttings than seedlings. Figure 6 illustrates the change in *Dub* for the given tree sizes in the 26 years old plantation.

Figure 6. Comparison of Diameter under-bark for the average trees at the stand level (age=26 years old). *Dbh* = 51.8 cm and *H* = 34.1 m for the cuttings and *Dbh* = 54.8 cm and *H* = 32.4 m for the seedlings.



General

The mean *Dbh* of seedlings in 1985 was significantly larger than cuttings, resulting in a 13.8% higher mean total stem volume under bark (*TSVub*). The latest sample taken in May 1997 (stand age 26 years) showed a similar mean *Dbh* for the two groups with 9.8% higher mean *TSVub* in cuttings than seedlings.

Dub was lower in seedlings than cuttings for a tree with the same *Dbh* and total height. The bark of cuttings in this plantation tends to be thinner than that of seedlings up to 75% of total height as shown in Figure 5. This effect explains the different form of tree taper between the two groups.

To check the difference in the sample of 59 trees, bark thickness was compared at fixed heights and the result showed the mean ratio of $\left(\frac{Dub}{Dob}\right)$ was significantly different at breast height.

Conclusion

Although the cuttings and seedlings sampled in this study had a similar *Dbh*, there were significant differences between the two groups in taper and bark thickness. An independent sample taken by Klomp at the harvesting time showed that mean *Dbh* and *H* for the average tree size of the cuttings were -5.5% and 5.27% than the seedlings respectively. However the sectional volume between 0.3 and 18 m for the cuttings was 3.33% more than the seedlings. Cuttings appeared to have a better stem form than seedlings.

For a tree with the same *Dbh* and *H*, the sectional volume showed 9% more volume under-bark in cuttings than seedlings for the pruned log, and 13.43% more for total volume under-bark. Bark thickness was less in cuttings. At the breast height the difference in mean $\left(\frac{Dub}{Dob}\right)$ ratio was around 2.8% less in seedlings than cuttings and the mean bark thickness ratio $\left(\frac{2bt}{Dob}\right)$ was approximately 20% more in seedlings. This difference partly explains why the total volume under bark for cuttings was higher in the sample.

Acknowledgment

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