VOLUME, TAPER, AND BARK THICKNESS IN SEEDLINGS AND CUTTINGS FROM MAMAKU FOREST, NEW ZEALAND

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ABSTRACT

A row-by-row comparison of "bulk collected" **Pinus radiata** D. Don cuttings and seedlings was planted out in 1970 on a cleared indigenous cutover site in Mamaku Forest. The cuttings came from 7-year-old parents. The area had been marked for a final thinning to a stocking of 200 stems/ha in 1985.

Sectional measurements were taken on 38 thinned trees (19 seedlings and 19 cuttings) in January 1986. The mean diameter at breast height (dbh) 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 dbh and height. Bark thickness was less in cuttings.

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

INTRODUCTION

Results of previous research comparing *P. radiata* seedlings with cuttings carried out in Australia, New Zealand, and California over the last 20 years have been summarised by Bolstad & Libby (1982). The performance of *P. radiata* cuttings has been reported by Fielding (1964, 1970), Thulin & Faulds (1986), Pawsey (1971), Libby *et al.* (1972), Shelbourne & Thulin (1974), and Wilcox *et al.* (1976). Klomp & Hong (1985), comparing seedlings and cuttings on a cleared indigenous forest site, reported that "seedlings have thicker bark, are more tapered . . .".

This report documents the comparison of volume, taper, and bark thickness between seedlings and cuttings from the same trial.

Both seedlings and cuttings came from bulk-collected (non-seed-orchard) sources. The cuttings were from ortets of age 7. Ortets used at present are much younger, and the quality of planting stock has improved considerably since 1970 when this trial was established. However, the results given here are important as an early indication of the performance of rooted cuttings compared with seedlings.

The trial in Mamaku Forest was planted at a stocking of 1420 stems/ha in 1970. At age 6, it was thinned to approximately 500 stems/ha, and pruned to 2.0 m. At the medium and high pruning lifts, further thinnings were done. At age 12, the trial was thinned to 250 stems/ha. In November 1985, the area was marked for a final thinning to a stocking of 200 stems/ha.

PROCEDURE

Seventy trees were available for destructive sampling from the trees to be thinned. Trees were selected in clusters of dbh classes, e.g., 25–30 cm, 30–35 cm. Badly malformed and diseased trees were eliminated, leaving 19 seedlings and 19 cuttings to sample.

The trees were sectionally measured as described by Gordon & Penman (1987). Briefly the procedure was:

- Trees were marked at 0.15, 0.7, and 1.4 m above ground, then felled.
- Total height was measured.
- 3-cm-thick discs were taken at 0.15, 0.7, 1.4, and 3 m and at 3-m intervals until a 5-cm diameter was reached.
- The diameter over bark of each disc was measured by diameter tape.
- The bark was removed, and diameter inside bark was measured.

RESULTS

The mean dbh of the whole trial in June 1985 was 37.1 cm for seedlings and 34.5 cm for cuttings (Klomp & Hong 1985). The mean dbh of the samples in January 1986 was 37.6 cm for seedlings and 33.8 cm for cuttings (Table 1). A t-test showed that there was no significant difference between the June 1985 and January 1986 means for both sets of data, indicating these samples were representative of the population.

Taper equation fitting for combined data

The all-possible regression method was used to find an equation to predict the change in $(d/dbh)^2$ with proportion of total height. As a large proportion of the total variation in $(d/dbh)^2$ is in the lowest section (butt swell), a polynomial equation with a high power term was found to fit significantly better than a cubic or quartic equation. This equation can be integrated to find volume under bark for any section of the tree.

The equation that showed the best fit (highest r^2, all terms significantly different from zero) on the combined data was of the form:

$$Y = b_1X^2 + b_2X^5 + b_3X^{10} + b_4X^{90} \quad (1)$$

where:

X = h/H
Y = $(d/dbh)^2$
dbh = diameter over bark at breast height (cm)
d = diameter inside bark (cm)
H = total tree height (m)
h = distance from tip (m)
b_1 etc. = coefficients

This equation was then fitted to the cuttings and seedlings separately.

Equation fitting for separate groups

An analysis of variance of the residual sums of squares showed that there was a significant difference in the equations between the two sets of data (Table 2).

TABLE 1–Summary of measurements in January 1986

	dbh (cm)			Height (m)			Total stem volume under bark (m^3)		
	min.	mean	max.	min.	mean	max.	min.	mean	max.
Seedlings	28.5	37.6	44.9	18.0	21.2	22.8	0.496	0.819	0.975
Cuttings	28.5	33.8	41.9	18.4	20.9	24.7	0.492	0.706	1.169

TABLE 2–Analysis of variance: Equation 1

Source	Residual sums of squares	Residual d.f.	Residual mean square	F	Approximate probability of obtaining F value
Combined	1.391	335	0.004154		
Two groups	1.2162	331	0.007345	5.95	< 0.001
Difference	0.1748	4	0.0437		

where: F = (difference mean square / two groups mean square)

The all-possible regression method was then used on the separate data sets to find the best-fitting equation. The above equation was found to be the best four-term equation for both the data sets. However, a comparison of the residual mean squares, between this equation and the best three-term equation, showed little difference. Plots of the residuals for both sets, from both equations, were examined and found to be virtually indistinguishable.

The same three-term model was found to be best for both data sets, and is of the form:

$$Y = b_1X^2 + b_2X^3 + b_3X^{90} \qquad (2)$$

The coefficients of Equation 2 are given in Table 3. An analysis of variance of the residual sums of squares showed that there was a significant difference in the equations between the two groups.

TABLE 3–Coefficients of Equation 2

Coefficients	b_1	b_2	b_3
Seedlings	1.3648	–0.4712	0.4930
Cuttings	1.6314	–0.7088	0.3271

Both equations (Fig. 1) were calculated using the mean dbh for cuttings and for seedlings. The equation for cuttings resulted in a greater percentage of volume over the length of the stem from stump height to about 80% of tree height. The integral of the equations to enable the volume under bark to be estimated for any section of a tree (seedling or cutting) is of the form:

$$V = \frac{Pi\, dbh^2}{40\,000}\left[\frac{b_1}{3H^2} \times (L_1^3 - L_2^3) + \frac{b_2}{4H^3} \times (L_1^4 - L_2^4) + \frac{b_3}{91H^{90}} \times (L_2^{91} - L_1^{91})\right] \quad (3)$$

where:

V = estimated volume between specified levels under bark (m^3)
H = total tree height (m)
Pi = 3.141593
L_1 = distance from tip to specified upper level (m)
L_2 = distance from tip to specified lower level (m)
b_1 etc. = coefficients as given previously

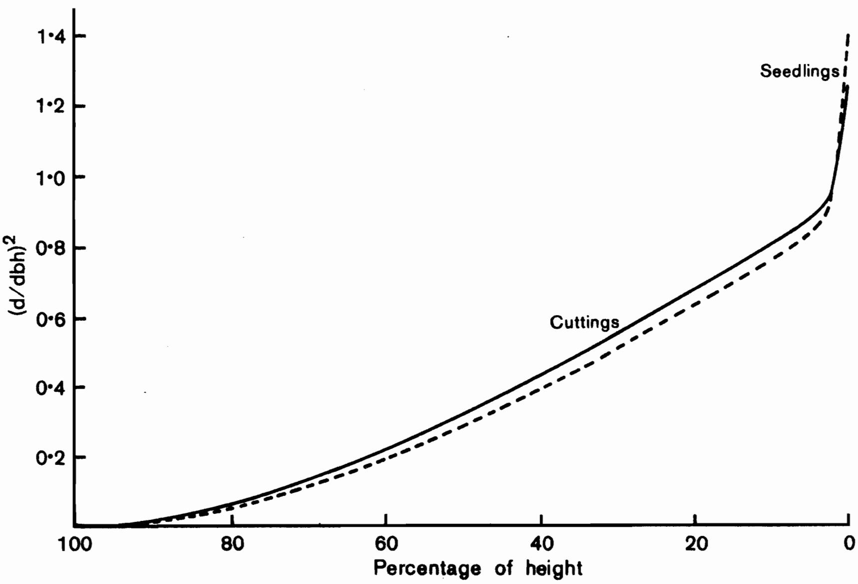

FIG. 1—Taper curves.

From the combined sample, the diameter of the tree of mean basal area was calculated. The height of this tree was estimated using the Petterson height curve. These two values (dbh 36.0 cm and height 21.1 m) were used in the taper equations derived for each group to estimate volume under bark between specified levels (Table 4).

BARK THICKNESS

Bark equations were fitted to the data as described by Gordon (1983), where the variables X and 1–X were shown to predict a large proportion of the variation in

TABLE 4—Volume (under bark) for a tree 36 cm dbh, 21.1 m height

Log	Volume (dm^3)			Percentage volume greater in cutting than seedlings
	Seedlings	Cuttings	Difference	
0.3– 6 m	408	433	25	6.1
6– 9 m	135	149	14	10.4
9–12 m	87	99	12	13.8
12–15 m	48	55	7	14.6
15–18 m	19	22	3	15.8
Total stem volume	736	795	59	8.0

ln (1–d/D). An analysis of variance of the residual sums of squares showed that there was a significant difference in bark equations between the two groups.

The ratio of diameter under bark (d) to diameter over bark (D) with proportion of tree height is shown in Fig. 2. There was approximately 2% more bark in seedlings than in cuttings below 50% of tree height. The equation was of the form:

$$\text{Ln}\,(1-d/D) = b_0 + b_1\,(1-X)^{b_2} + b_3X^{(b_4H)} \qquad (4)$$

where: D = diameter over bark (cm)

The coefficients of Equation 4 are given in Table 5.

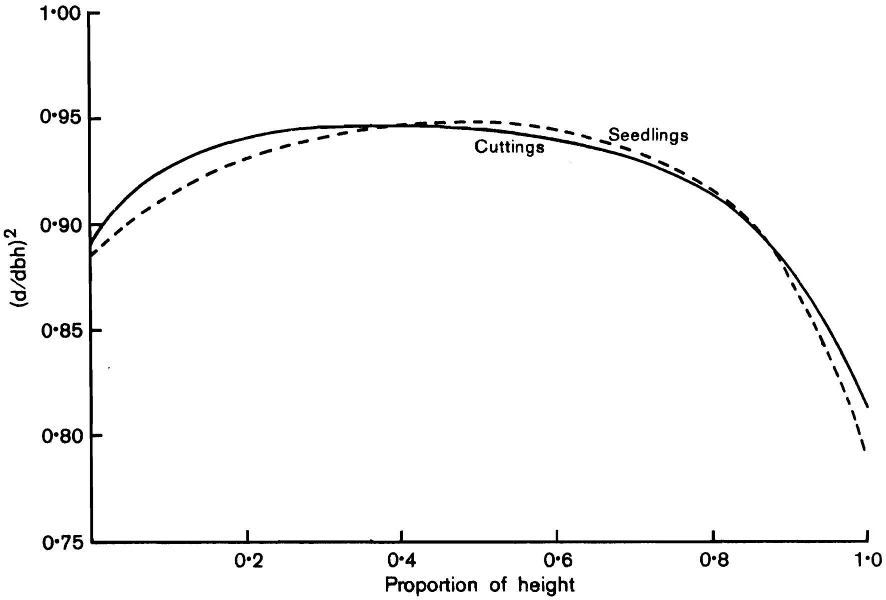

FIG. 2—Bark thickness.

TABLE 5—Coefficients of Equation 4

Coefficients	b_0	b_1	b_2	b_3	b_4
Seedlings	–3.20785	1.04642	2.99228	1.66044	0.17539
Cuttings	–2.97243	0.76095	7.15660	1.30155	0.19155

DISCUSSION

There were significant differences in tree taper which resulted in 8% more total stem volume under bark in cuttings for trees of the same dbh and height at 15 years after planting. However, the mean dbh of the population seedlings in 1985 was significantly larger than that of cuttings. The sample mean total stem volume (under bark) of the seedlings was 13.8% higher than that of cuttings. If this was true of the population this difference could offset any increase in total stem volume (under bark) due to the taper of the cuttings.

For a tree of the same dbh and height, the ratio of diameter inside bark^2 to dbh^2 was higher in cuttings. The difference in this ratio decreased with level above the ground, until at 80% of tree height the ratio was very similar. The main reason for the difference in taper was thinner bark in the lower 50% portion of the cuttings.

The main conclusion that can be drawn from this study is that different tree volume and taper equations are needed for seedlings and cuttings. Further work is required on the present seed orchard stock to establish what differences if any occur in these planting stocks.

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