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TITLE: PERFORMANCE OF RADIATA PINE SEEDLINGS AND CUTTINGS ON A FARM SITE, VALLEY ROAD, ROTORUA

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ABSTRACT*

The advantages of using physiologically aged radiata pine cuttings (from 3-year-old donor trees) in place of seedlings were demonstrated in a spacing trial planted on farmland near Rotorua. The stand was grown and managed on a direct sawlog regime. Growth and form differences at age seven years included the cuttings being taller but slimmer with a more cylindrical butt log compared to seedlings. Closer spacing at planting enhanced height but not dbh growth for both stock types. The most pronounced contrast between the two stock types was the better resistance to toppling and superior form, particularly straightness, of the cuttings. This trend had a marked effect on crop selection ratios, resulting in seedlings needing at least double the numbers planted to approach the crop quality of the cuttings. The superior shape and form of the butt log of the cuttings resulted in a substantially higher recoverable volume of clear grade timber compared with the seedlings in STANDPAK analyses. Consequently, the value of pruned logs per hectare for the cuttings was 20% higher than that for the seedlings.

Note: This material is unpublished and must not be cited as a literature reference.

PERFORMANCE OF RADIATA PINE SEEDLINGS AND CUTTINGS ON A FARM SITE, VALLEY ROAD, ROTORUA

INTRODUCTION

Earlier field trials with radiata pine cuttings in New Zealand were established to evaluate the potential of clonal forestry. The concept failed because of problems with physiological aging and the lack of a system that produced sufficient material to plant large areas. These early trials showed that rooted cuttings could be advantageous because of their uniformity of growth, improved stem straightness and relative freedom from malformation compared with seedlings. However, the cuttings used in these early trials were taken from donor trees aged from 5-25 years and showed a comparative growth loss which was unacceptable to forest managers (Menzies and Klomp, 1988).

More recently, cuttings taken from donor trees of a younger age, 1-5 years, were compared with seedlings in two series of field trials established in 1983 and 1984. These later trials have shown that considerable improvement in form can often be achieved without loss of growth, by planting rooted cuttings rather than seedlings (Klomp and Menzies, 1988; Forest Research Institute, 1991).

The trial described in this report is a spacing trial comparing cuttings with seedlings at three initial spacings, 200, 400 and 600 stems/ha, planted on farmland near Rotorua, in 1984. Trial results on early performance, including survival, growth and form for the first 5 years were published earlier (Menzies *et al.*, 1991).

The updated information in this report includes growth data, selection ratios and form assessments to age 7 years. The latter includes sweep and taper measurements of the pruned (5.5 m) butt log. These data were used to derive yields for the pruned butt logs using PC-STANDPAK, an integrated computer-based modelling system. Log variables including value (in $/ha) were obtained for both cuttings and seedlings.

METHODS

Site, trial design and materials

The 14 ha trial was planted on farmland at Valley Road, Rotorua, in July 1984. It is situated on the lower slopes of Mt Ngongotaha (Appendix I) and can be viewed from Highway 5. The site has a NNW aspect on slopes of 5-30° and the soil is a yellow-brown loam. The experimental design is of a randomised complete block with two stock types and three planting densities (Table 1), replicated in five blocks. The complete trial layout is shown in Appendix II. Each sub-plot is 0.21 ha in area with a one-row buffer inside the plot boundary, resulting in an inner plot size of 0.1 ha for measurement purposes.

TABLE 1 - Stock type, genetic origin and spacing

Stock type	Genetic origin	GF rating
1/0 seedlings	Special 268 collection	15
0/1 cuttings (from 3-year-old donor trees)	268 x 875 ESSO	16
Stocking (stems/ha)	**Spacing (m)**	**No. trees/Inner plot**
200	7.15 x 7	20
400	5 x 5	42
600	4.08 x 4.08	72

Establishment

After short-grazing of the pasture, circular planting spots of 1.5 m in diameter were sprayed with a Gramoxone/simazine mixture, one month before planting. Planting was done by hand using a planting spade and applying a wedge technique with cultivation if necessary.

Grazing management

The trial was grazed for the first time after planting in September 1986, two years after establishment. Two thirds of the trial was mobstocked with ewes, which were left in over a long weekend and some damage occurred, particularly stem debarking. Subsequent grazing with fewer sheep proved to be more successful and a combination of sheep and beef cattle has caused no further problems. Long term effects of the early damage was negligible.

Silvicultural management

First lift pruning was carried out as a variable lift to half height, at age 3.5 years after planting. This operation was immediately followed by a thinning down to 300 stems/ha in the 400 and 600 stems/ha initial stockings. The plots planted at 200 stems/ha were cull-thinned for unprunable stems only.

Subsequent pruning lifts, specified to leave 3-3.5 m of green crown were carried out at age 4.5, 5.5 and 6.5 years. No further thinnings were scheduled, although small numbers of unprunable trees were removed following the second and third lift pruning operations. This resulted in the nominated 200 stems/ha stocking being somewhat less and many of the 400 and some of the 600 stems/ha stockings did not achieve the nominated target of 300 stems/ha, seven years after planting. Table 2 shows the actual stocking rates at age seven years.

TABLE 2 - Stocking rates (stems/ha)

	Cuttings			Seedlings		
Initial, at planting	200	400	600	200	400	600
Nominated, at thinning	200	300	300	200	300	300
Current, at 7 years	162	273	289	117	196	270
Range, at 7 years	120-190	230-300	270-300	80-170	120-280	230-300

Butt log form factors

In addition to dbh, height and pruned height, sweep and taper measurements were carried out after the fourth pruning lift.

Diameter over stubs (DOS) and maximum branch measurements were not collected but predicted values were similar to actual values from two trials in the 1984 series, Tikitere and Kanui Station, where identical stock types were grown on similar sites.

Sweep was measured in the 5.5 m pruned butt log, using an aluminium straightedge. The deviation from straightness was measured on the outside edge of the tree allowing for a stump height of 0.3 m. The total number of trees measured for sweep was 713.

Taper was calculated from the diameters measured at 1.4 m (dbh) and 5.0 m and expressed in mm/m of log. The total number of trees measured for taper was 678.

STANDPAK evaluation

STANDPAK was used to produce butt log yield and values for both cuttings and seedlings. Standard assumptions (Appendix III) were used for both stock types, except where actual measurements were available. The latter included height, dbh, pruning and stocking regimes in GROSTAND; juvenile sweep values in LOGASORT and mature sweep values in SAWMOD (Appendix III).

The EARLY growth model was used up to mean stand height of approximately 18 m, after which growth model NAPIRAD was used to derive predicted stand height and basal area (BA) at age 28 years.

Site index was calculated from the last height and age available and the basal area level set at "high + 20%" (the maximum available) for both stock types.

Preliminary runs indicated that the predicted basal area level was still below the actual BA level and so an adjustment was required.

An adjustment was made to the initial BA value (age 4 yrs) rather than a later value to better reflect the diameter influence on DOS and Max. Branch and thus the defect core size. The percentage error for height and basal area (following adjustment) are shown in Table 3.

TABLE 3 - Errors in height and BA as % of predicted values

Age	*Seedlings*						*Cuttings*					
	Act ht	Pred ht	% error	Act BA	Pred BA	% error	Act ht	Pred ht	% error	Act BA	Pred BA	% error
4	5.3	5.3	0	2.55	3.12	-18.3	5.6	5.6	0	2.17	2.36	-8.0
4.5	5.6	5.6	0	4.29	4.42	-2.9	5.9	5.9	0	3.80	3.55	7.0
5	6.9	7.0	-1.4	7.83	7.85	-0.2	7.5	7.4	1.3	7.05	6.66	5.8
6	8.7	8.6	1.2	9.94	9.74	2.0	9.3	9.0	3.3	9.08	8.50	6.8
7	10.1	10.2	-1.0	11.41	11.40	0.1	10.7	10.7	0	10.46	10.46	0

STANDPAK was run through to SAWMOD to derive log yields, timber grade outturn and value, and to evaluate the superior straightness of the cuttings compared with the seedlings.

RESULTS

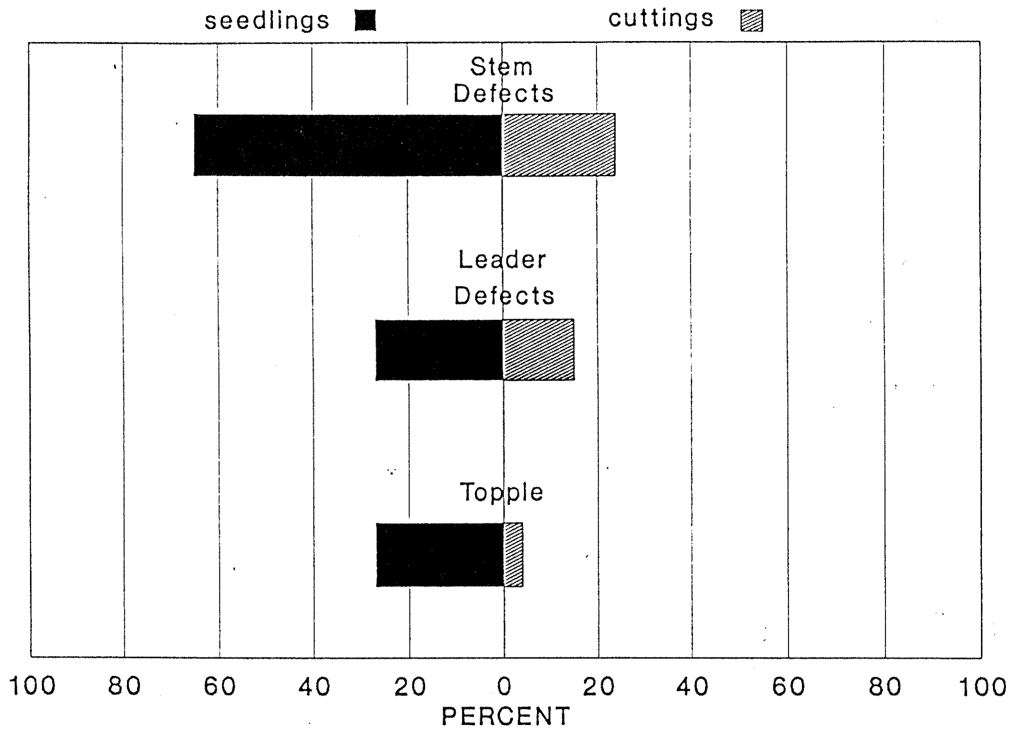
Earlier results, up to age 5 years after planting, were published previously (Menzies *et al.*, 1991) but a brief summary of this information is warranted.

Early malformation traits

Early form advantages of the cuttings were evident during the first growing season in the field. The incidence of speed wobble, one year after planting, was significantly higher amongst the seedlings (45%) compared with cuttings (16%) ($P = 0.05$). The occurrence of toppling was also higher amongst seedlings.

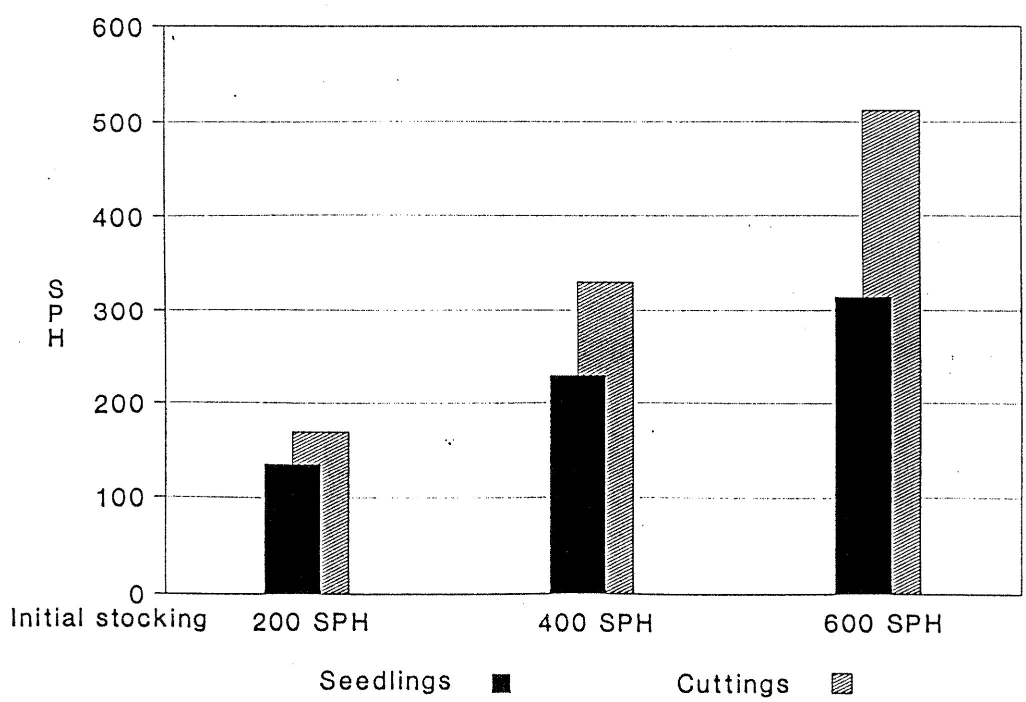
All trees were visually assessed for malformation at age 4 years, prior to first crop selection and thinning operations. A comparison of these early malformation traits is shown in Fig. 1.

FIG. 1 - Percentage malformed trees before thinning (age 4 years)



The cuttings had significantly less stem defects (25% cf 65%) and leader defects (15% cf 27%) and had also toppled less (4% cf 27%) than seedlings (P = 0.05). This had a profound effect on selection of the potential crop element, as it was much easier to choose crop trees of good quality among cuttings than it was for seedlings. The cuttings had a significantly higher proportion of potential crop trees compared with seedlings, before thinning (P = 0.05) (Fig. 2).

FIG. 2 - Potential crop trees - before thinning (age 4 years)



Growth comparisons

Growth comparisons, at age 7 years, are shown in Table 4.

TABLE 4 - Mean height, pruned height and dbh at age 7 years

	Height (m)	Pruned height (m)	DBH (cm)
Stock type			
Seedlings	10.1 a	5.6 b	25.7 a
Cuttings	10.7 a	6.0 a	24.6 b
Spacing/sph			
600 (300)	10.8 a	6.0 a	25.5)
400 (300)	10.5 b	5.9 a	25.1) ns
200	10.0 c	5.5 b	25.0)

Means followed by the same alphabetical letter are not significantly different (LSD test, P = 0.05)

The cuttings were significantly taller than the seedlings but had a significantly smaller dbh. Trees were significantly taller in plots at higher initial stockings but there was no significant difference in dbh between the three spacings. There were no significant interactions between stock type and initial spacings. Because cuttings were taller, they were pruned higher.

Quality comparisons

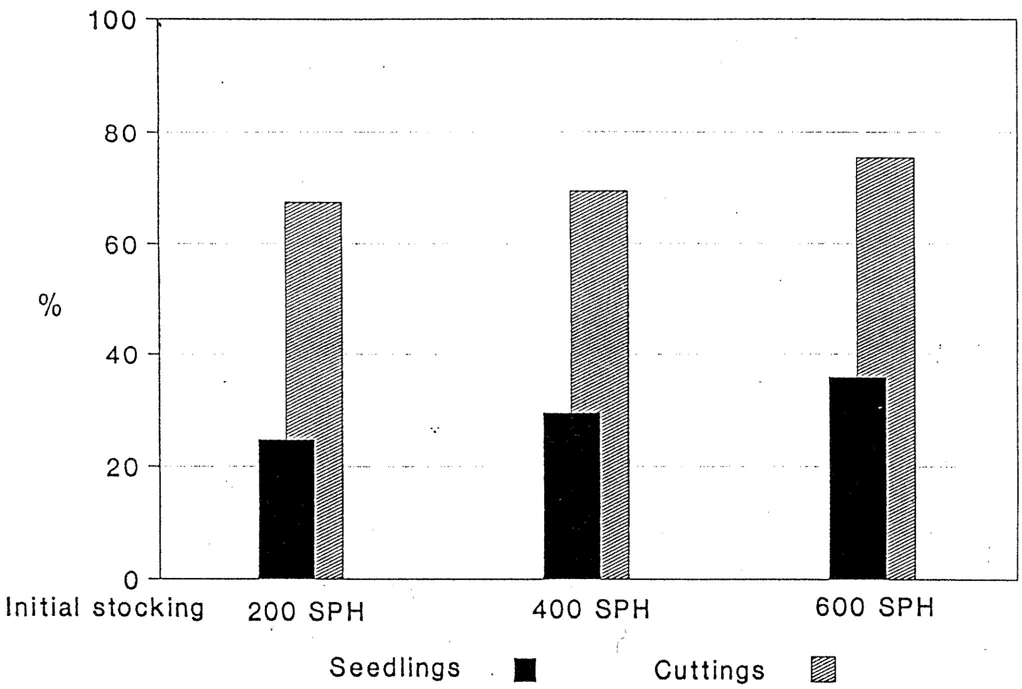
Sweep and taper were the quality factors measured on the 5.5 m pruned butt logs, following the fourth pruning lift and 7 years since planting. A total of 713 trees were measured for sweep and 678 trees were measured for taper.

Sweep

For analysis, the juvenile sweep values were converted to mature logs sweep values using a relationship derived from sawing study data (J. Tombleson and N. Woods, pers. comm.). It relates deviation in the pith and defect core to outside sweep deviation in mature logs.

In the data analysis, all butt logs with a converted (mature) sweep measurement of 0-6 mm/m of log were included in the 'straight' category. The percentage of straight butt logs was significantly higher for cuttings (71% overall) compared with seedlings (30% overall) for all three initial stockings (P = 0.05) (Fig. 3).

FIG. 3 - Percentage of straight butt logs
(Swept 0-6 mm/m)



The mean sweep (in mm/m) in the 5.5 m butt logs of seedlings and cuttings for the respective, initial stockings is presented in Table 5.

The cuttings had a significantly lower mean sweep value compared with seedlings. The trend was consistent over all three initial stockings.

TABLE 5 - Mean sweep in 5.5 m butt logs (mm/m)

Stock type	*Initial stocking (stems/ha)* 200	400	600	Mean
Seedlings	10.0	9.2	8.2	9.2**
Cuttings	3.8	4.2	3.1	3.7

** Significantly higher than that of cuttings at p = 0.01

Crop selection

The initial stockings of 400 and 600 stems/ha were thinned down to 300 stems/ha, 4 years after planting. The basic criteria was selection on firstly form then size and espacement. The superior form of the cuttings was evident at that first selection and consequently crop selection ratios for cuttings were significantly better than that for seedlings (Menzies *et al.*, 1991).

When further simulated thinnings down to 200, 150 and 100 stems/ha are done at age 7 years, it presents an opportunity to look at the effects of thinning criteria on: 1) butt log straightness; 2) mean tree height and 3) mean dbh (Figs 4, 5, 6). More details of these effects are tabled in Appendix IV.

Effect of selection criteria on straightness

If straightness of the butt log is used as a selection criterium, almost 100% of the cuttings have a straight (<6 mm/m of sweep) butt log for selection ratios of 6:1, down to 2.7:1 (400 to 150 stems/ha). The selection ratio of 2:1 (400 to 200 stems;ha) still returns 89% of the cuttings with a straight butt log. In contrast, seedlings with a selection ratio of 6:1 do best at 76% with straight butt logs, but lower ratios are well down. The 2:1 selection ratio (400 to 200 stems/ha) resulting in only 31% of butt logs in the straight category.

If crop trees are selected on height, the percentage of straight butt logs is consistently higher among cuttings (74-76%) than among seedlings (29-42%) over the range of selection ratios.

If crop trees are selected on dbh, the percentage of straight butt logs is again consistently higher for cuttings (69-74%) compared with seedlings (26-40%) over the range of selection ratios.

Effect of selection criteria on mean height

If selecting the crop on straightness of the butt log, the effect on mean height is minimal over the range of selection ratios within each initial stocking. Cuttings are consistently taller than seedlings, 11 m compared with 10.5 m for the 400 stems/ha and 11.4 m compared with 10.7 m for the 600 stems/ha. The extra 200 stems/ha at planting therefore results in a slight increase in mean height.

If crop trees are selected on height, the mean height for cuttings increases by 1.1 m (11.2 to 12.3 m), and seedling height increases by 0.9 m (10.5 m to 11.4 m), comparing the lowest (2:1) with the highest (6:1) selection ratio.

If crop trees are selected on dbh, the mean height of the cuttings increases by 0.7 m (11.0 to 11.7 m), whilst seedling height increases by 0.3 m (10.5 to 10.8 m), comparing the lowest (2:1 with the highest (6:1) selection ratio.

Effect of selection criteria on mean dbh

When selecting for straightness the mean dbh increases only slightly for both cuttings (24.4 to 25.3 cm) and seedlings (25.2 to 25.9 cm), comparing the 2:1 with the 6:1 selection ratio.

If crop trees are selected on height, the increase in mean dbh is also relative to selection ratio but is more pronounced. The mean dbh of cuttings increases by 2.0 cm (24.9 to 26.9 cm) whilst the mean dbh of seedlings increases by 1.0 cm (25.3 to 26.3 cm), comparing the 2:1 with the 6:1 selection ratio.

Selecting crop trees on dbh consistently increases the mean dbh relative to the increase in selection ratios for both cuttings and seedlings. However, for selection ratios higher than 2:1, the mean dbh for cuttings is generally equal to or bigger than that for seedlings.

The 200 stems/ha initial stocking was not included in this exercise as even in the reduction to 100 stems/ha, only minimal selection was available because of tree losses due to mortality and unacceptable form.

Taper

Taper was calculated from the diameters measured at 1.4 m (dbh) and 5.0 metres and expressed in mm/ metre.

The cuttings had significantly less taper (23 mm/m) than the seedlings (29 mm/m). This trend was consistent at all three initial stockings (Fig. 7).

FIG. 4 - Effect of crop selection on butt log straightness

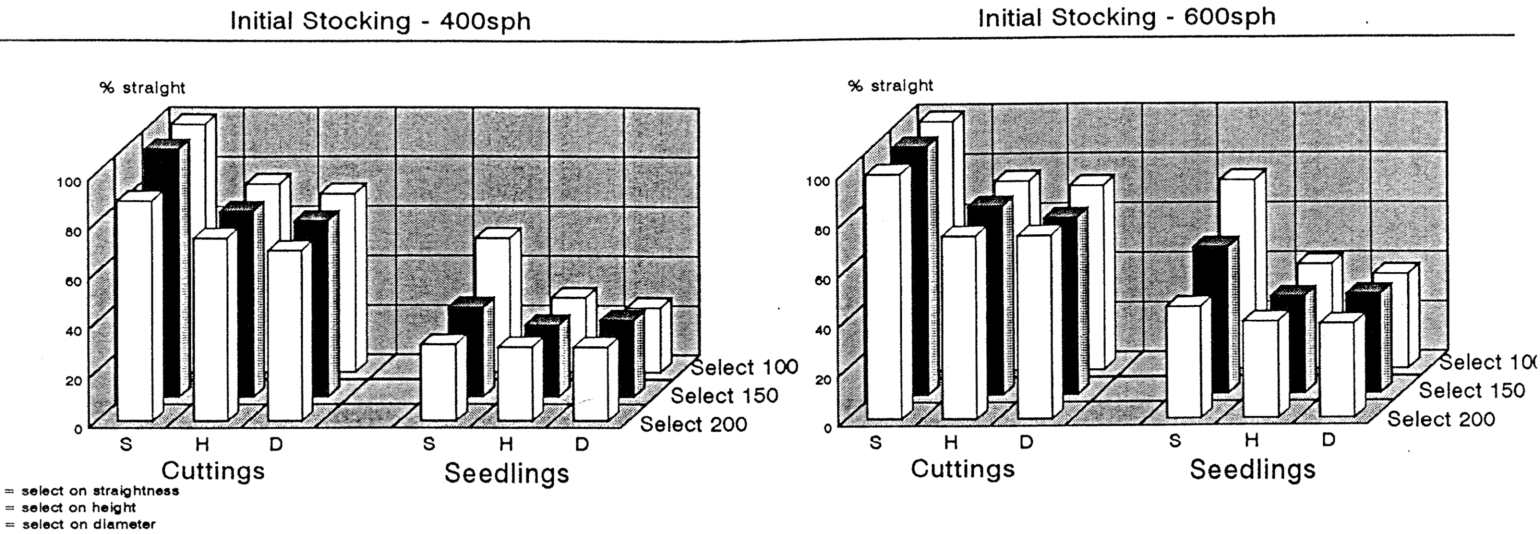


FIG. 5 - Effect of crop selection on tree height

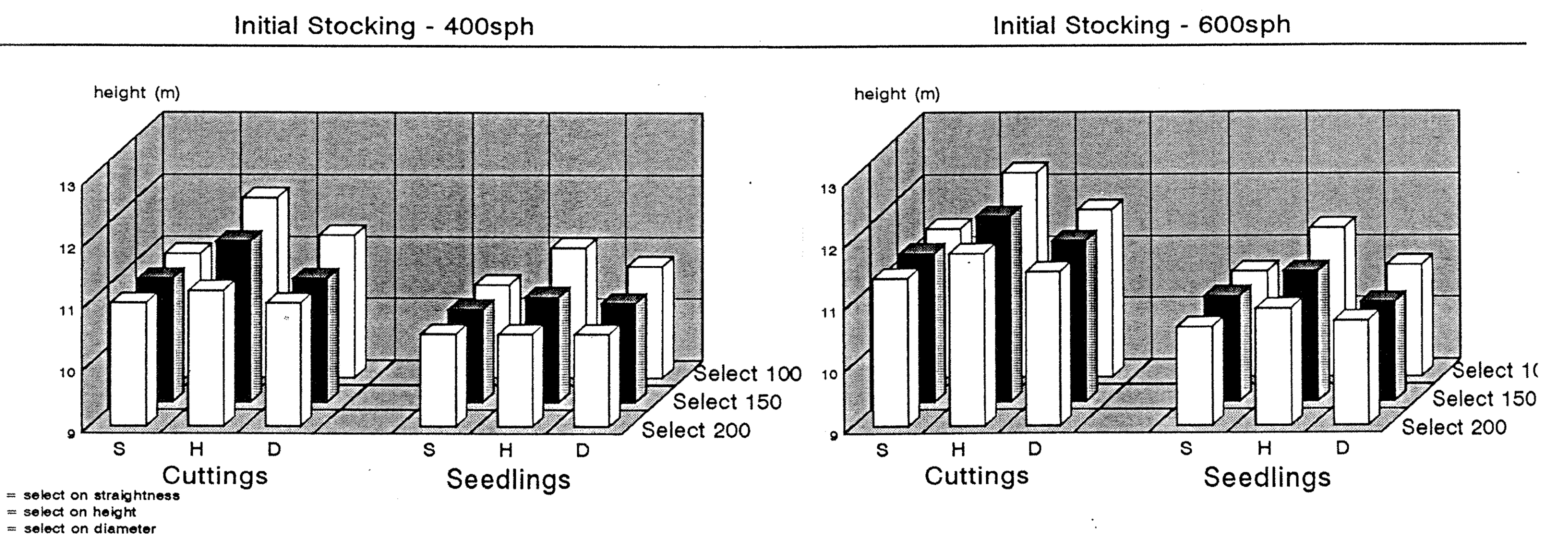


FIG. 6 - Effect of crop selection on tree diameter

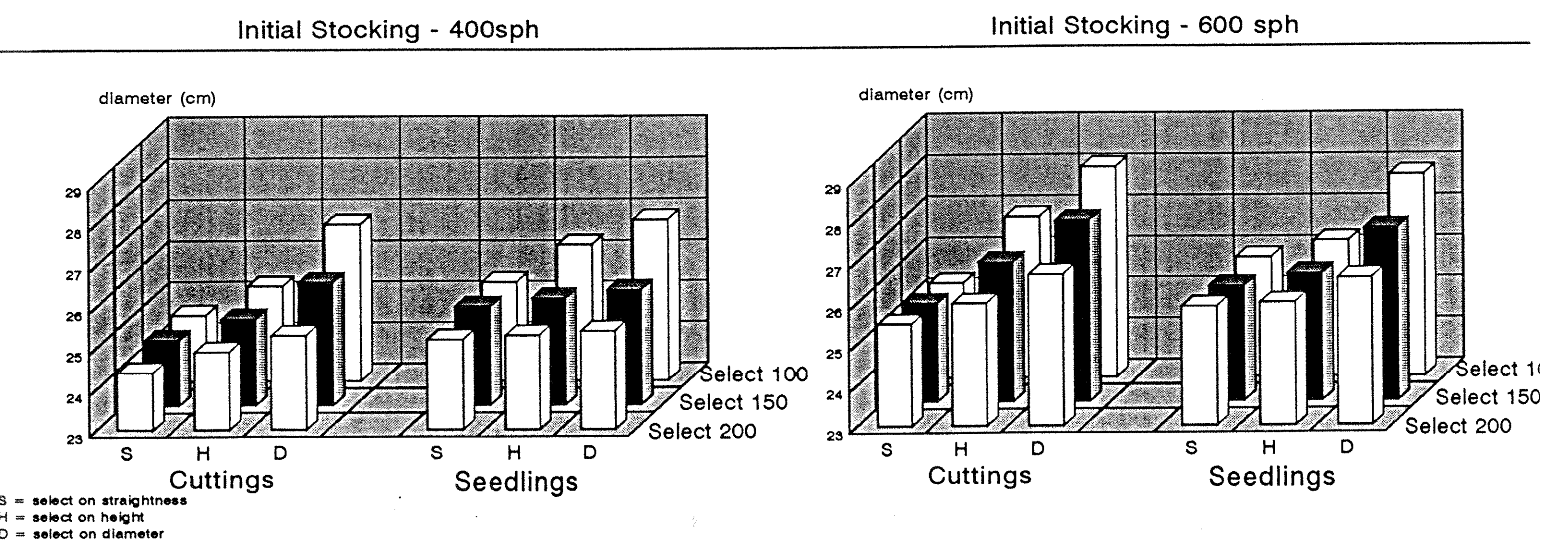
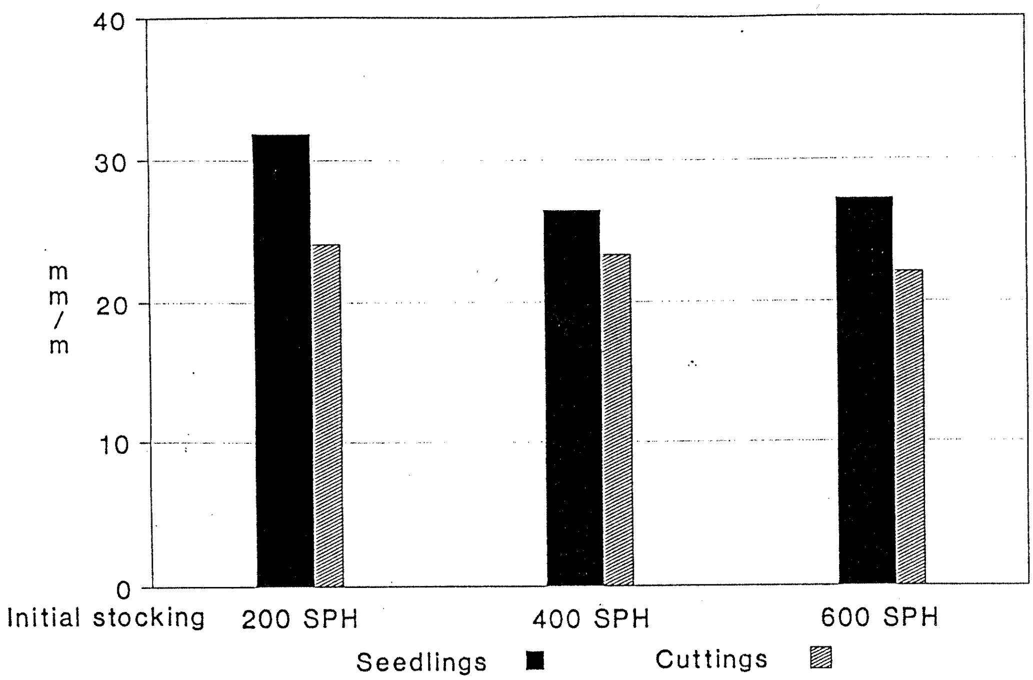


FIG. 7 - Taper of 5.5 m butt logs at age 7 years (mm/m)



Growth, quality and yield predictions using STANDPAK

Growth and pruned log outputs at age 28 years are shown in Table 6 and Appendices V and VI.

TABLE 6 - Growth and pruned log outputs

	Seedlings	Cuttings
(a) Growth		
Stocking (sph)	206	206
Height (m)	40.3	41.2
Dbh (cm)	61.1	60.9
BA (m^3/ha)	60.3	59.9
Volume (m^3/ha)	794	805
(b) Log (pruned)		
Log length (m)	5.5	5.5
Recoverable volume (m^3/ha)	209.3	223.3
Mean small end diameter (mm)	475	474
Taper (mm/m)	16.3	16.1
Max DOS (mm)	212	206
Max branch (mm)	63	58
Max defect core (mm)	289	273
Mean defect core (mm)	247	221

Predicted growth is similar for both seedlings and cuttings although cuttings are taller and have a slightly larger total volume.

The smaller DOS and Max. branch, combined with less sweep, results in a smaller defect core (DC) in the cuttings and produces a higher recoverable volume for cuttings (223.3 m^3/ha) compared with seedlings (209.3 m^3/ha).

Pruned log timber grade outturn is shown in Table 7.

TABLE 7 - Log timber grade outturn

Grade	Seedlings Percentage	Seedlings m^3 sawn/ha	Cuttings Percentage	Cuttings m3 sawn/ha
No. 1 & 2 clears	53.0	59.8	57.0	71.5
No. 1 cuttings and Fact.	4.0	4.5	3.9	4.9
No. 1 & 2 Framing	33.1	37.3	31.5	39.5
Box	9.9	11.2	7.7	9.6
Total recovery	53.9	112.8	56.2	125.5

Cuttings have a higher percentage (57%) of No. 1 and 2 clears compared with seedlings (53%). Percentages of all other grades are slightly higher in the seedlings.

Total sawn volume is higher for cuttings (125.5 m^3/ha) compared with seedlings (112.8 m^3/ha) and most of the extra volume in the cuttings was sawn as No. 1 and 2 clears grade timber.

Pruned log value

The residual log value is shown in Table 8.

TABLE 8 - Pruned log value

	Seedlings	Cuttings
Residual value ($/m^3 log) at mill	133	150
Residual value ($/ha) at mill	27,837	33,495

On a pruned log basis the cuttings have a higher residual value ($150/m^3) compared with the seedlings ($133/m^3). The higher recoverable volume per hectare for cuttings compared with seedlings contributes to a total residual value per hectare of $33,495 for cuttings compared with $27,837 for seedlings. These residual values are not stumpage values and should be used for comparative purposes only, not for defining absolute levels of profitability.

DISCUSSION

Early form advantages of the cuttings were largely due to a greater resistance to speed wobble and topple and stronger apical dominance, compared with seedlings.

These traits of physiologically aged (field-collected) cuttings have been reported on from other trials (Menzies and Klomp, 1988; Klomp and Menzies, 1988; FRI, 1991; Menzies *et al.*,1991).

In the Valley Road trial the cuttings grew significantly taller than the seedlings and this was the same as reported for height growth on two other farm sites (Table 9). In general these cuttings (from 3-year-old donor trees) have grown as tall as or taller than the seedlings on all 11 sites of the 1984 cuttings/seedlings trial series.

The cuttings had a significantly smaller dbh at Valley Road and this occurred at only one other site, a forest (sand-dune) site at Pouto. On all (9) other sites cuttings showed no significant loss in dbh growth.

TABLE 9 - Growth comparisons at age 7 years

Sites	*Height (m)* S	C	Sign.	*Dbh (cm)* S	C	Sign.	*Survival (%)* S	C	Sign.
Farm									
Valley Road	10.3	10.7	*	25.7	24.4	*	47	65	*
Whangarei	9.8	10.7	*	17.9	18.0	n.s.	58	82	n.s.
Tikitere	9.1	9.5	n.s.	23.2	22.4	n.s.	20	62	*
Reporoa	9.3	9.6	n.s.	21.0	20.6	n.s.	56	67	n.s.
Kanui Station	8.3	8.7	*	21.8	21.5	n.s.	52	65	n.s.
Oroua Downs	7.9	8.0	n.s.	17.7	17.8	n.s.	79	81	n.s.
Forest									
Otangaroa	8.8	9.0	n.s.	15.0	14.3	n.s.	41	55	n.s.
Pouto	9.5	9.4	n.s..	17.8	16.8	*	90	88	n.s.
Rerewhakaaitu	8.0	8.3	n.s.	17.0	16.3	n.s.	60	81	*
Taupo	9.6	9.9	n.s.	20.6	20.3	n.s.	61	75	n.s.
Tahorakuri	9.6	9.7	n.s.	19.7	19.2	n.s.	75	71	n.s.

* Significant at $p = 0.05$
S = Seedlings, special '268', GF15
C = Cuttings, from 3-year-old donor trees, '875 x 268', GF16
Note : Survival was affected by a scheduled thinning at Valley Road. All sites experienced periodic cull thinnings for topples, runts and blown tops.

The reason for the slight loss in dbh growth for the cuttings at Valley Road is most likely due to their superior survival rate and form resulting in a higher proportion of the smaller trees being retained compared with the seedlings. This is supported by the simulated thinnings exercise (Appendix IV) where the difference in dbh disappeared when the crop element is selected on height or dbh.

Both cuttings and seedlings were significantly taller in plots at higher initial stockings but there was no significant difference in dbh between the three spacings. This suggests that both stock types benefitted from mutual protection and this was expressed in improved height growth.

The cuttings had a significantly higher survival rate at Valley Road, Whangarei and Kanui Station, whilst on all other (8) sites the difference was not significant.

The superior straightness of the cuttings was obvious at the early visual assessments following pruning lifts and this result was verified by the actual measurements of butt log sweep after the fourth lift. Visual assessments of form carried out at the other 10 sites revealed a similar trend, although actual sweep measurements have not yet been carried out on those sites.

Regardless of whether crop selections were based on height, dbh or straightness, the cuttings consistently showed a significantly higher percentage of straight logs. Crop selection ratios at Valley Road indicate that to achieve a crop quality similar to cuttings at least double the number of seedlings need to be planted. This trend was also evident in seedling/cutting comparisons on other sites (Forest Research Institute, 1991).

The cuttings had a more cylindrical shape of the butt log compared to the seedlings, seven years after planting. The effect of this reduced taper is difficult to evaluate as little is known of the relationship between juvenile and mature log taper. Adjusted taper values were tested as inputs into SAWMOD but had little effect on either grade outturn or log value at age 28 years.

Generally, the model predicted early growth equally well for seedlings and cuttings. However, the basal area growth on this site was higher than the maximum level available in EARLY and there is a need for modification of the model to cater for these high fertility sites. After an adjustment to the initial basal area there is reasonable confidence that the predicted log volume at age 28 years is accurate.

Although there is a slightly higher recoverable volume in the cuttings compared with the seedlings, this has had little or no effect on the sawn timber output. The major factors responsible for the higher outturn of clear grade timber in the cuttings are the straightness of the pruned log and the smaller defect core. The overall impact of the better recovery of high grade timber results in a 20% greater return per hectare for cuttings compared with seedlings.

CONCLUSION

The planting of physiologically-aged cuttings from 3-year-old donor trees in place of seedlings can result in a substantial increase in the quality of sawlogs grown on a farm site. The predicted value of clear grade timber from pruned logs of the cuttings was 20% higher than that of seedlings.

RECOMMENDATION

Currently, quality comparisons between these cuttings and seedlings are solely based on the 5.5 m butt logs. It is already apparent that the improved form of the cuttings continues further up the tree (Figure 8). It is recommended that a MARVL or similar type of assessment be done at mean stand height 18-20 m to compare second and third logs and also evaluate the effect of attrition of both stock types in all three initial stockings.

FIGURE 8 - Seedling/Cutting Spacing Trial, Rotorua

Seedlings		**Cuttings**
200 sph	Initial stocking	200 sph
110 sph	Current stocking (1992)	170 sph

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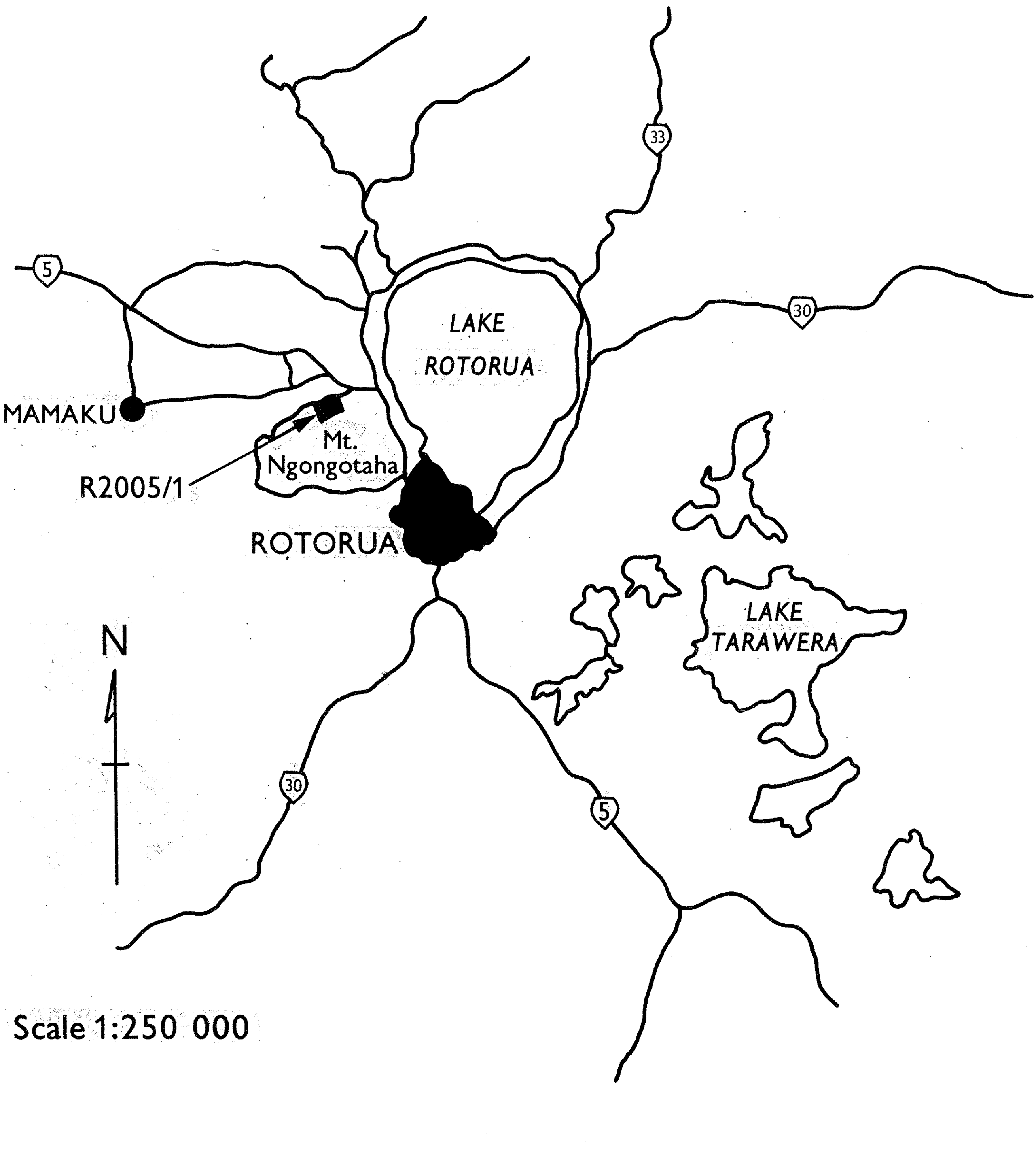
APPENDIX I

LOCALITY PLAN
R2005/1
Valley Road
NGONGOTAHA



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APPENDIX II.

1984 VALLEY ROAD SPACING TRIAL
SEEDLINGS AND CUTTINGS

BLOCK 1	400 S	400 C	400 S	400 S	600 S	200 C	600 C	200 S	200 C	600 C	
	200 S	400 C	600 C	200 C	200 S	400 C	400 S	200 C	600 S	200 S	BLOCK 4
BLOCK 2	200 S	200 C	600 S	400 C	600 C	600 S	400 C	400 C	400 C	400 S	
	600 C	400 C	400 C	400 S	400 S	600 C	400 C	400 C	400 S	600 S	
BLOCK 3	600 S	400 C	400 S	200 S	200 C	600 S	600 C	200 C	400 S	200 S	
	200 C	600 S	200 C	200 S	400 C	400 S	400 S	600 S	600 S	400 C	BLOCK 5
	400 S	200 S	400 S	400 C	600 C	600 C	600 C	400 S	200 S	200 C	

PLOT AREA = 0.1 HA
PLOT + BUFFER = 0.2 HA
TOTAL AREA = 14 HA

200 = 200SPH

400 = 400SPH

600 = 600SPH

APPENDIX III - STANDPAK inputs used in the economic evaluation of cuttings and seedlings

	Seedlings / Cuttings
Growth model	EARLY / NAPIRAD
Height model	KGM3 (34)
Stand volume table	KGM3 (29)
Basal area level	High + 20%
Weibull equation	Rotorua Conservancy
Taper equation	Kang Young Crop
Breakage equation	Kang Young Crop
Density class	Medium
Sweep class	See below
Internode levels	Medium
Clearfelling age	28 years
Sawmill type	Carriage Bandmill A
Conversion standard	2
Sawmill uptime	90%
Timber price list	Domestic (1988)

Mean sweep in pruned log

	Seedlings	Cuttings
Juvenile sweep (mm/m) (for LOGASORT (mm)	13.9	5.3
Mature sweep (for SAWMOD)		
Mean sweep 0-6 mm/m	3.4	1.6
Mean sweep > 6 mm.m	11.6	8.7
Percentage swept 0-6 mm/m	30.0	70.7
Percentage swept > 6 mm/m	70.0	29.3

Effect of selection criteria on straightness, height and dbh.

400 SPH Select best	200 sph		150 sph		100 sph	
Select on straightness	S	C	S	C	S	C
STRAIGHT (%)	31	89	36	100	54	100
MEAN HT (m)	10.5	11	10.5	11	10.5	11
MEAN DBH (cm)	25.2	24.4	25.4	24.6	25.4	24.6
Select on height						
STRAIGHT (%)	30	74	29	75	30	76
MEAN HT (m)	10.5	11.2	10.7	11.6	11.1	11.9
MEAN DBH (cm)	25.3	24.9	25.6	25.1	26.3	25.3
Select on diameter						
STRAIGHT (%)	30	69	31	71	26	72
MEAN HT (m)	10.5	11	10.6	11	10.8	11.3
MEAN DBH (cm)	25.4	25.3	25.8	26	26.9	26.8
600 SPH Select best	**200 sph**		**150 sph**		**100 sph**	
Select on straightness	S	C	S	C	S	C
STRAIGHT (%)	45	99	59	100	76	100
MEAN HT (m)	10.6	11.4	10.7	11.4	10.7	11.4
MEAN DBH (cm)	25.9	25.5	25.8	25.4	25.9	25.3
Select on height						
STRAIGHT (%)	39	74	39	76	42	76
MEAN HT (m)	10.9	11.8	11.1	12	11.4	12.3
MEAN DBH (cm)	26	26	26.1	26.4	26.3	26.9
Select on diameter						
STRAIGHT (%)	38	74	40	71	38	74
MEAN HT (m)	10.7	11.5	10.6	11.6	10.8	11.7
MEAN DBH (cm)	26.6	26.7	27.2	27.4	27.9	28.1

For each selection level * selection criteria ,values with the same shading are not significantly different (LSD test ,p=0.05).

APPENDIX V.
GROSTAND SIMULATION.

```
Growth Model    : 23 EARLY   Run Name        : CUTTINGS
High fert.  Pumice Plateau crn.fn.  BA adj 20.0%
Height Model    : 34         Site Index      : 31.7
Stand Volume    : 29         Start Date      : 1988 Jan
Monthly Growth :  3          Mean Top Height :  5.8

Growth Model    :  9 NAPIRAD Run Name        : CUTTINGS
Height Model    : 26         Site Index      : 31.7
Stand Volume    : 29         Start Date      : 1988 Jan
Monthly Growth :  3          Mean Top Height :  5.8
```

STANDING YIELD

Age yrs	MeanTopHt m	MeanHt m	Stocking stems/ha	BasalArea sq.m/ha	MeanDBH cm	Volume cu.m/ha
3.8	5.8	5.6	300	2.36	10.0	6
PRUNED (Date) 300 stems/ha to 40.0% of stem height.						
3.8	5.8	5.6	300	2.36	10.0	6
4.0	6.2	5.9	300	3.55	12.3	9
4.8	7.5	7.0	300	5.51	15.3	16
PRUNED (Date) 300 stems/ha to leave 3.5 m. of crown						
4.8	7.5	7.0	300	5.51	15.3	16
5.0	7.9	7.4	300	6.66	16.8	21
5.9	9.5	8.7	300	9.71	20.3	34
PRUNED (Date) 250 stems/ha to 4.7 m.						
5.9	9.5	8.7	300	9.71	20.3	34
THINNED stand (least prnd) to waste leaving 250 stems/ha						
5.9	9.5	8.7	250	8.09	20.3	29
6.0	9.7	9.0	250	8.50	20.8	31
6.9	11.4	10.5	250	11.63	24.3	48
PRUNED (Date) 220 stems/ha to 6.0 m.						
6.9	11.4	10.5	250	11.63	24.3	48
THINNED stand (least prnd) to waste leaving 220 stems/ha						
6.9	11.4	10.5	220	10.23	24.3	42
7.0	11.5	10.7	220	10.45	24.6	43
10.6	17.8	16.5	220	24.61	37.7	149
SWITCHED to later model set from G23 H34 V29 M3						

Age yrs	MeanTopHt m	MeanHt m	Stocking stems/ha	BasalArea sq.m/ha	MeanDBH cm	Volume cu.m/ha
10.6	17.8	17.3	220	24.61	37.7	149
28.0	41.7	41.2	206	59.90	60.9	805
END Rotation						

APPENDIX V1.
GROSTAND SIMULATION

```
Growth Model    : 23 EARLY    Run Name          : SEEDLINGS
High fert.  Pumice Plateau crn.fn.  BA adj 20.0%
Height Model    : 34          Site Index        : 30.9
Stand Volume    : 29          Start Date        : 1988 Jan
Monthly Growth  :  3          Mean Top Height   :  5.5

Growth Model    :  9 NAPIRAD Run Name           : SEEDLING
Height Model    : 26          Site Index        : 30.9
Stand Volume    : 29          Start Date        : 1988 Jan
Monthly Growth  :  3          Mean Top Height   :  5.5
```

STANDING YIELD

```
Age   MeanTopHt MeanHt Stocking BasalArea MeanDBH  Volume
 yrs      m          m   stems/ha  sq.m/ha     cm    cu.m/ha
 3.8      5.5     5.3      300       3.12     11.5        8
  PRUNED (Date) 300 stems/ha to 40.0% of stem height.
 3.8      5.5     5.3      300       3.12     11.5        8
 4.0      5.9     5.6      300       4.42     13.7       11
 4.8      7.2     6.7      300       6.48     16.6       18
  PRUNED (Date) 300 stems/ha to leave  3.5 m. of crown
 4.8      7.2     6.7      300       6.48     16.6       18
 5.0      7.5     7.0      300       7.85     18.3       23
 5.9      9.0     8.3      300      11.22     21.8       38
  PRUNED (Date) 250 stems/ha to  4.7 m.
 5.9      9.0     8.3      300      11.22     21.8       38
  THINNED stand (least prnd) to waste leaving 250 stems/ha
 5.9      9.0     8.3      250       9.35     21.8       32
 6.0      9.2     8.6      250       9.74     22.3       34
 6.9     10.9    10.0      250      12.74     25.5       50
  PRUNED (Date) 220 stems/ha to  6.0 m.
 6.9     10.9    10.0      250      12.74     25.5       50
  THINNED stand (least prnd) to waste leaving 220 stems/ha
 6.9     10.9    10.0      220      11.21     25.5       44
 7.0     11.0    10.2      220      11.40     25.7       45
10.6     17.2    15.8      220      24.85     37.9      146
  SWITCHED to later model set from G23 H34 V29 M3

Age   MeanTopHt MeanHt Stocking BasalArea MeanDBH  Volume
 yrs      m          m   stems/ha  sq.m/ha     cm    cu.m/ha
10.6     17.2    16.7      220      24.85     37.9      146
28.0     40.9    40.3      206      60.32     61.1      794
  END Rotation
```

APPENDIX V11.
GROSTAND PRUNING DETAILS.

CUTTINGS

Date 1988 Jan Age 3.8 Pruning (Date) to 40.0% of stem height

PrunHt 2.2 m	MeanTopHt 5.8 m	Stocking 300 stems/ha
CrownHt 2.2 m	MeanHt 5.6 m	
DOSHt 0.8 m	MaxBr 3.4 cm	
DOS 15.5 cm	Crop DOS 15.5 cm	Calip 8.7 cm

Date 1989 Jan Age 4.8 Pruning (Date) to 3.5 m of crown remaining

PrunHt 3.5 m	MeanTopHt 7.5 m	Stocking 300 stems/ha
CrownHt 3.5 m	MeanHt 7.0 m	
DOSHt 2.4 m	MaxBr 4.7 cm	
DOS 17.3 cm	Crop DOS 17.4 cm	Calip 10.3 cm

Date 1990 Mar Age 5.9 Pruning (Date) to 4.7 m

PrunHt 4.7 m	MeanTopHt 9.5 m	Stocking 250 stems/ha
CrownHt 4.7 m	MeanHt 8.9 m	
DOSHt 3.7 m	MaxBr 5.4 cm	
DOS 19.1 cm	Crop DOS 19.2 cm	Calip 12.1 cm

Date 1991 Apr Age 6.9 Pruning (Date) to 6.0 m

PrunHt 6.0 m	MeanTopHt 11.4 m	Stocking 220 stems/ha
CrownHt 6.0 m	MeanHt 10.6 m	
DOSHt 4.9 m	MaxBr 5.8 cm	
DOS 20.6 cm	Crop DOS 20.6 cm	Calip 13.0 cm

APPENDIX V111.
GROSTAND PRUNING DETAILS.

SEEDLINGS

Date 1988 Jan Age 3.8 Pruning (Date) to 40.0% of stem height

PrunHt	2.1 m	MeanTopHt	5.5 m	Stocking	300 stems/ha
CrownHt	2.1 m	MeanHt	5.3 m		
DOSHt	0.8 m	MaxBr	4.5 cm		
DOS	18.1 cm	Crop DOS	18.1 cm	Calip	10.3 cm

Date 1989 Jan Age 4.8 Pruning (Date) to 3.5 m of crown remaining

PrunHt	3.2 m	MeanTopHt	7.2 m	Stocking	300 stems/ha
CrownHt	3.2 m	MeanHt	6.7 m		
DOSHt	2.3 m	MaxBr	5.5 cm		
DOS	18.9 cm	Crop DOS	19.1 cm	Calip	11.9 cm

Date 1990 Mar Age 5.9 Pruning (Date) to 4.7 m

PrunHt	4.7 m	MeanTopHt	9.0 m	Stocking	250 stems/ha
CrownHt	4.7 m	MeanHt	8.4 m		
DOSHt	3.4 m	MaxBr	6.3 cm		
DOS	21.2 cm	Crop DOS	21.3 cm	Calip	12.5 cm

Date 1991 Apr Age 6.9 Pruning (Date) to 6.0 m

PrunHt	6.0 m	MeanTopHt	10.9 m	Stocking	220 stems/ha
CrownHt	6.0 m	MeanHt	10.1 m		
DOSHt	4.9 m	MaxBr	6.3 cm		
DOS	21.0 cm	Crop DOS	21.0 cm	Calip	12.9 cm