Final assessment of 21 to 22 year-old cuttings trials

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Plantation Management Cooperative

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EXECUTIVE SUMMARY

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THE PROBLEM
Early results from field trials of seedlings and cuttings of different physiological ages, planted in 1983 and 1984, showed that while cuttings were generally taller than seedlings, cuttings with a physiological age of more than three years generally had a smaller DBH than seedlings. These results had led to a recommendation that physiological age should be kept to three years or less if early diameter growth losses were to be avoided. It was not known if these trends would continue as the trials approached rotation age.

COOP INITIATIVES
The Plantation Management Cooperative funded a re-measurement of these trials.

THIS PROJECT
Five trials planted in 1983 and eight trials planted in 1984 were assessed for growth and form in 2006/07. The 1983 trials included seedlings and cuttings with a physiological age of 1- to 5-years, all of GF14. The 1984 trials included cuttings up to a physiological age of six years. There were different levels of genetic improvement in the different cutting stock types from GF12-17, and these were matched with seedling controls.

RESULTS
The variables assessed included DBHOB (over bark), bark thickness, DBHIB (inside bark), stem malformation, and stem acceptability. Bark thickness decreased significantly with increasing physiological age, and therefore DBHIB was used to compare results across different physiological ages. For the 1983 trials, overall average DBHIB over the five sites showed that cuttings from 4- and 5-year-old parents were significantly slimmer than the seedlings. However, for the eight 1984 trials, while overall the seedling controls had a larger DBHIB than the cuttings from 3- and 4-year-old parents, these differences were not significant. Interestingly, none of the cutting stock types at any of the eight sites was significantly smaller than their seedling controls (DBHIB), and at four of the eight sites, the cuttings from four-year-old parents, with a physiological age of six years, were larger than their seedling controls. There were no significant or consistent differences in stem malformation or stem acceptability between seedlings and cuttings.

IMPLICATIONS FOR THE COOP

Early field trial results indicated that physiological age of cuttings should be kept to three years or less if early diameter growth losses were to be avoided. The final assessment at age 22-23 years showed that diameter growth (DBHIB) was not consistently significantly worse in cuttings older than a physiological age of three years. While in the 1983 trials, DBHIB was significantly less for 4- and five-year-old cuttings, compared with seedlings, in the 1984 trials, none of the cutting stock types at any of the eight sites was significantly smaller than their seedling controls. At four of the eight sites planted in 1984, the cuttings from four-year-old parents, with a physiological age of six years, were larger than their seedling controls. Thus, there was not a consistent loss of early diameter growth with increasing physiological age across all sites. Nursery plant quality of cuttings is probably more important than physiological age.

For stem form, earlier results had shown that cuttings with a physiological age of two years or more were less prone to toppling and had more defect-free trees. Cuttings with a physiological age of three years or more had significantly more defect-free trees on farm sites and some forest sites. Therefore, cuttings with a physiological age of three years or more could be expected to have a comparatively smaller defect core in the butt log.

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INTRODUCTION

Successful introduction of clonal forestry with radiata pine has been hampered by problems, particularly understanding the implications of physiological aging (or maturation) of propagated material during the clonal testing phase. There are both advantages and disadvantages associated with physiological aging. Early trial results with radiata pine indicated that there is an optimum physiological age of 3-4 years, when there are advantages of improved stem form with some aging, but not the disadvantages of poorer rooting of cuttings or early loss of diameter growth associated with older physiological ages. Aging results in mature plants being difficult and expensive to propagate, multiplication rates being low, and subsequent vegetative propagules having poor early field performance compared with more juvenile plants.

In 1983-84, field trials were established on both forest and farm sites in the North Island to investigate the long-term growth and form effects of cuttings of different physiological ages of up to five years. Five sites were established in 1983 using GF14 genetic material, and in 1984, 10 sites were established using GF12-17 genetic material.

Early results from these trials were reported in FRI Bulletins 135, 160, and 203 (Menzies *et al.* 1988, Miller 1991, and Burdon and Moore 1997), What's New No. 212 (Menzies *et al.* 1991a), in various conference papers, and in Management of Improved Breeds Cooperative Report No. 3 (Holden 1988), Management of Improved Radiata Breeds Cooperative Report No. 10 (Klomp and Holden 1988), and Stand Management Cooperative Report Nos. 29 (Klomp *et al.* 1992), and 34 (Holden *et al.* 1993).

These trials are now over 20 years old, and approaching rotation age. A final assessment of diameter growth and form on the surviving trials has been done to determine if these early growth and form effects continued throughout the rotation.

METHODS

The 1983 trials were planted in Tairua Forest (A973/1), Poutu Forest (A973/2), Kaingaroa Forest (R1887/1), Lake Taupo Forest (R1887/2), and Tikitere Forest (R1887/3). These trials had been last measured for DBH in 1991.

The surviving 1984 trials were planted in Poutu Forest (AK840/1), Hosking's farm near Whangarei (AK840/2), Tikitere Forest (RO2004/1), Rerewhakaaitu Forest (RO2004/2), Tahorakuri Forest (RO2004/4), Lake Taupo Forest (RO2004/5), and Kanui Station in the Hawkes Bay (WN287/1). These trials had also been last measured for DBH in 1991.
The five 1983 trials had 8 stock types, including climbing select and seed orchard seedlings, cuttings from 1- to 5-year-old trees, and tissue-culture plantlets (Table 1). All stock types were of "850" seed orchard origin, GF14.

Table 1: Stock types and codes

Stock Type	Code
Climbing select seed origin seedlings	CS
Seed orchard origin seedlings	OS
Cuttings from 1-year-old trees	C1
Cuttings from 2-year-old trees	C2
Cuttings from 3-year-old trees	C3
Cuttings from 4-year-old trees	C4
Cuttings from 5-year-old trees	C5
Tissue-culture plantlets	TC

The eight 1984 trials had 11 stock types, including four seedling types, cuttings from 1- to 4-year-old trees, and tissue-culture plantlets (Table 2). There were four ex-farm sites and four forest sites. The ex-farm sites were at Hosking's farm, near Whangarei, Tikitere, Reporoa, and Kanui Station in the Hawkes Bay. The forest sites were at Pouto, Rerewhakaaitu, Tahorakuri, and Lake Taupo Forests.

Table 2: Stock types and codes for the 1984 trials

Stock Type	GF Ranking	Code
Bulked "880" op seedlings	12	S880
Bulked "875" cross seedlings	17	S875
Special collection "268" seedlings	15	S268
Gwavas "850" seedlings	14	S850
Cuttings from 1-year-old trees, "880" op progeny test	12	C880/1
Cuttings from 2-year-old trees, "850" seed orchard	14	C850/2
Cuttings from 3-year-old trees, "880" op progeny test	12	C880/3
Cuttings from 3-year-old trees, "875"x"268" ESSO	16	C875/3
Cuttings from 4-year-old trees, "875" progeny test, Cpt. 327, Kaingaroa	17	C875/4K
Cuttings from 4-year-old trees, "875" progeny test, Onepu, Tasman	17	C875/4O
Tissue-culture plantlets, Gwavas "850"	14	T/C

The trial designs for all trials were row-plots of 8 trees per treatment, randomly placed in 12 blocks (96 trees per treatment), established at 400 stems per hectare. The trials have since been thinned to 200 stems/ha (four trees per row plot).

The trials were visited during winter 2006 and all remaining trees measured or assessed for DBHOB (outside bark), bark thickness at breast height, form, and acceptability as a crop tree. Tree form was scored on a 1-9 scale (where 1 = crooked and/or multiple forks, and 9 = perfectly straight with no malformation. Acceptability was scored as 0 = unacceptable as a crop tree, and 1 = acceptable as a crop tree. DBHIB (inside bark) was estimated from DBHOB – (2 x bark thickness). Trees were recorded as toppled if the stems were estimated to be 15º or more from vertical.

Analysis of results

The field design was a randomised complete block design. Stock types were considered to be fixed effects and all other effects were considered to be random effects. The equation for the model of analysis of variance for such a design on a single location was as follows:

$$Y_{ij} = \mu + R_i + S_j + R_i * S_j + E_{ij}$$

Where:

Y_{ij}	=	the observation on a tree of the jth entry in the ith replicate
μ	=	the overall mean
R_i	=	the effect of the ith replicate
S_j	=	the effect of the jth stock type
$R_i * S_j$	=	the interaction effect of the ith replicate with the jth stock type
E_{ij}	=	the random error associated with each tree of the jth stock type in the ith replicate

The equation for the analysis of variance model on several locations has more effects than the single location model as it contains a term for locations and a term for the interaction of stock type with location. Stock types were considered to be fixed effects and all other effects were considered to be random effects. The following model was used:

$$Y_{ijk} = \mu + L_i + R_j : L_i + S_k + S_k * L_i + E_{ijk}$$

Where:

Y_{ijk}	=	the observation on the tree of the kth stock type in the jth replicate of the ith location
μ	=	the overall mean
L_i	=	the effect of the ith location
$R_j : L_i$	=	the effect of the jth replicate within the ith location
S_k	=	the effect of the kth stock type
$S_k * L_i$	=	the interaction effect of the kth stock type with the ith location
E_{ijk}	=	the random error associated with each tree of the kth stock type in the jth replicate of the ith location

RESULTS

Summary of early results from 1983 trials

Two of the sites had significant toppling (Table 3), and at Lake Taupo, C2-C5 cuttings had significantly less toppling than the seedlings and C1 cuttings.

At Tairua, the C2-C5 cuttings had significantly less toppling than the seedlings (CS and OS).

Table 3: Percent toppling three years after planting on two of the five sites planted in 1983

Site	Age (years)	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	3	54 c[1]	42 bc	29 ab	16 a	22 a	21 a	20 a	22 a
Forest									
Lake Taupo	3	11 c	8 bc	9 c	1 a	1 a	0 a	1 a	2 ab

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

For early height growth, trees were taller on the two farm sites, compared with the three forest sites. Cuttings were generally taller at both four and six years after planting, while tissue-culture plantlets were often shorter (Tables 4, 5). All age groups of cuttings were taller on three sites at both four and six years after planting (Tairua, Tikitere and Kaingaroa). C1-C4 cuttings were taller at Lake Taupo at four years after planting, and C1, C3, and C4 cuttings at six years after planting. Seedlings were generally taller than cuttings at Pouto, although the differences were not significant. The tissue-culture plantlets were generally shorter than the OS seedlings and cuttings, although the differences were not always significant.

Table 4: Height (m) four years after planting for the five sites planted in 1983

Site	Site mean (m)	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	5.9	5.39 e[1]	5.71 cd	5.96 abc	6.09 a	5.90 abc	6.06 ab	5.81 bcd	5.62 de
Tikitere	6.2	5.85 c	5.86 c	6.41 ab	6.31 ab	6.53 a	6.19 abc	5.94 c	6.08 bc
Forest									
Pouto	4.9	4.58 bc	4.94 a	4.81 ab	4.75 ab	4.78 ab	4.97 a	4.87 a	4.35 c
Kaingaroa	4.3	4.11 cde	4.05 de	4.19 bcd	4.32 bc	4.41 ab	4.60 a	4.16 cde	3.94 e
Lake Taupo	4.7	4.53 c	4.63 bc	4.88 a	4.72 abc	4.80 ab	4.81 ab	4.58 c	4.58 c

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 5: Height (m) six years after planting for the five sites planted in 1983

Site	Site mean (m)	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	8.65	8.06 e[1]	8.49 cd	8.79 abc	8.95 ab	8.66 bcd	9.08 a	8.75 abc	8.39 de
Tikitere	9.72	9.28 b	9.30 b	9.82 a	9.95 a	10.06 a	9.97 a	9.61 ab	9.72 ab
Forest									
Pouto	8.02	7.64 c	8.13 ab	8.08 ab	8.11 ab	8.16 ab	8.37 a	8.05 b	7.62 c
Kaingaroa	7.50	7.30 cd	7.39 bcd	7.40 bcd	7.50 bc	7.62 b	8.03 a	7.60 b	7.17 d
Lake Taupo	7.61	7.34 cd	7.64 abc	7.92 a	7.61 abcd	7.78 ab	7.83 a	7.46 bcd	7.26 d

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

For early diameter growth, there was a general trend of smaller diameters with increasing age of cuttings. At both ex-farm sites, Tairua and Tikitere, both C4 and C5 cuttings had a significantly smaller diameter than SO seedlings four years after planting (Table 6), although six years after planting, it was only the C5 cuttings at Tairua that had a significantly smaller diameter than SO seedlings (Table 7). At Pouto Forest in Northland, C2-C5 cuttings had a significantly smaller diameter than SO seedlings (Tables 6+7). At the other two forest sites of Kaingaroa and Lake Taupo, C5 cuttings had a significantly

Table 6: DBH (cm) four years after planting for the five sites planted in 1983

Site	Site mean (m)	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	12.1	11.5 cd[1]	12.6 a	13.0 a	12.9 a	12.5 ab	11.9 bc	11.4 d	11.0 e
Tikitere	12.8	12.5 cd	13.2 bc	14.0 a	13.3 abc	13.6 ab	12.1 d	11.4 e	12.0 de
Forest									
Pouto	11.0	11.2 ab	11.7 a	11.7 a	10.7 bc	11.0 b	10.9 b	10.8 bc	10.2 c
Kaingaroa	7.8	7.9 a	8.1 a	8.3 a	7.8 a	8.0 a	8.0 a	7.2 b	7.0 b
Lake Taupo	8.6	8.8 bc	9.0 ab	9.4 a	8.5 cd	8.8 bc	8.5 bcd	7.9 e	8.1 de

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 7: DBH (cm) six years after planting for the five sites planted in 1983

Site	Site mean	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	19.2m	18.3 d[1]	20.0 ab	20.4 a	20.6 a	19.9 ab	19.2 bc	18.5 cd	17.0 e
Tikitere	21.8m	21.9 b	22.9 ab	23.2 a	23.2 a	23.0 a	20.7 c	20.2 cd	19.6 d
Forest									
Pouto	17.4m	17.5 b	18.4 a	18.5 a	17.2 b	17.2 b	17.1 b	17.0 b	16.1 c
Kaingaroa	16.3m	16.7 ab	17.1 a	17.1 a	16.7 ab	16.6 ab	16.3 b	15.5 c	14.4 d
Lake Taupo	15.7m	16.3 ab	16.5 ab	17.0 a	15.9 bc	16.1 bc	15.6 c	14.3 d	14.1 d

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Smaller diameter than SO seedlings at four years after planting, and C2 cuttings at Lake Taupo (Table 6). Six years after planting, C4-C5 cuttings had a significantly smaller diameter than SO seedlings (Table 7). Thus overall, C4 and C5 cuttings were significantly smaller in DBH six years after planting on four out of give sites, and C2+C3 cuttings were significantly smaller in DBH six years after planting at Pouto (one out of five sites) (Table 7). The tissue-culture plantlets performed similarly to the C5 cuttings, showing slower growth than should be expected from juvenile material (Tables 6 and 7).

Following first-lift pruning, all trees in the trials were assessed for leader malformation (double leaders, multileaders, or basket whorls) and stem defects (kinked, swept or wobbled). The average percentage of trees at each site with no defects ranged from 48% at Tikitere to 78% at Pouto (Table 8). C2-C5 cuttings consistently had more defect-free trees than the OS seedling control, and C3-C5 were significantly better on the two ex-farm sites.

Table 8: Percentage of defect-free trees four years after planting

Site	Site mean	CS	OS	C1	C2	C3	C4	C5	TC
Farm									
Tairua	59%	40 c[1]	47 bc	62 a	59 ab	62 a	67 a	69 a	65 a
Tikitere	48%	17 c	35 b	50 ab	55 a	56 a	55 a	58 a	60 a
Forest									
Pouto	78%	63 c	77 b	75 bc	82 ab	84 ab	90 a	85 ab	66 c
Kaingaroa	50%	30 c	46 b	45 b	53 b	54 b	66 a	60 ab	49 b
Lake Taupo	73%	50 c	61 bc	72 ab	73 ab	83 a	77 ab	84 a	81 a

[1] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Summary of early results from 1984 trials

There was some tree toppling on all eight sites in the first four years (Table 9). Generally, cuttings had less topple than seedlings for cuttings from two-year-old trees or older, and these differences were often significant. This is the same trend that was found with the 1983 trials (Table 3).

Survival on the farm sites was affected to a varying extent by the re-introduction of sheep and/or cattle. At Hosking's, near Whangarei, sheep were re-introduced in the second year, and there was some damage to the four-year-old cuttings. Cattle were re-introduced in the third year, but there was only very slight damage. At Tikitere, there was severe damage to the trial by sheep and cattle in the second year, with bark stripping and toppling. At Reporoa, sheep in the second year caused some toppling and browsing, while at Kanui Station, there was some sheep browsing in the second year.

Table 9: Tree toppling in the first four years, comparing the seedlings and cuttings for each level of genetic improvement (GF ranking). C is used to indicate where the cuttings in a given comparison were better than the comparable seedling control, and S where control seedlings were better than the cuttings. An * is used to indicate that the difference was significant at $P \leq 0.05$.

Site	Age (years)	Site mean (%)	C880/1	C850/2	C880/3	C875/3	C875/4K	C875/4O
Farm sites								
Hosking's	2	16	C	C*	C	S	C	S
Tikitere	4	18	C*	S/C	C*	C*	C	C*
Reporoa	2	43	S	C*	C*	C	C*	C
Kanui	2	20	C*	C*	C*	C*	C*	C*
Forest sites								
Pouto	2	25	C	C*	C*	C*	C*	C*
Rerewhakaaitu	4	13	S	C	C*	C*	C*	C*
Tahorakuri	2	5	S	C	C	C*	C*	C*
Lake Taupo	2	<2	-	-	-	-	-	-

In 1988, Cyclone Bola affected the Hosking's, Tikitere, Rerewhakaaitu, and Lake Taupo trials, and seriously toppled trees or those with tops broken out were cull thinned.

Overall survival at age seven years is given in Table 10. Generally, cuttings were better than seedlings, but this varied by site, and was often not significant. On the farm sites, the 2- to 4-year-old cuttings were better than seedlings (often significantly better) except for the four-year-old cuttings at Hosking's. On the forest sites, all cuttings were better than seedlings at Rerewhakaaitu, but the differences were variable at the other three sites, although these differences were not significant except for C875/4K cuttings at Lake Taupo being significantly worse than their seedling controls (Table 10).

Table 10: Survival at age seven years, comparing the seedlings and cuttings for each level of genetic improvement (GF ranking). C is used to indicate where the cuttings in a given comparison were better than the comparable seedlings, and S where seedlings were better than the cuttings. An * is used to indicate that the difference was significant at P≤0.05.

Site	Site mean (%)	C880/1	C850/2	C880/3	C875/3	C875/4K	C875/4O
Farm							
Hosking's	70	C	C	C	C	S	S
Tikitere	49	S	C*	C*	C*	C*	C
Reporoa	60	S	C	C	C	C	C
Kanui	58	C	C*	C*	C*	C*	C*
Forest							
Pouto	91	S/C	S	C	S	S/C	C
Rerewhakaaitu	75	C	C	C	C*	C	C
Tahorakuri	71	C	S	C	S	S	S
Lake Taupo	61	S	C	S	C	S*	S

Height growth at Age seven years is summarised in Table 11. The heights were similar for both farm and forest sites. One to four-year-old cuttings were generally taller than their seedling controls, except for the C3(875) cuttings at Pouto and Rerewhakaaitu Forests, where the seedlings were taller.

Table 11: Height at age seven years, comparing the seedlings and cuttings for each level of genetic improvement (GF ranking). C is used to indicate where the cuttings in a given comparison were better than the comparable seedlings, and S where seedlings were better than the cuttings. An * is used to indicate that the difference was significant at P≤0.05.

Site	Site mean (m)	C880/1	C850/2	C880/3	C875/3	C875/4K	C875/4O
Farm							
Hosking's	10.4	C	C	C	C	C*	C
Tikitere	9.6	C*	C*	C	C	C	C*
Reporoa	9.4	C*	C*	C	C	C*	C*
Kanui	8.5	C	C*	C*	C*	C*	C*
Forest							
Pouto	9.6	C*	C	C	S	C	C
Rerewhakaaitu	8.5	C	C	C	S	C	C
Tahorakuri	9.7	C	C	C	C	C	C*
Lake Taupo	9.8	C	C	C	C*	C	C*

Table 12: DBH at age seven years, comparing the seedlings and cuttings for each level of genetic improvement (GF ranking). C is used to indicate where the cuttings in a given comparison were better than the comparable seedlings, and S where seedlings were better than the cuttings. An * is used to indicate that the difference was significant at P≤0.05.

Site	Site mean (cm)	C880/1	C850/2	C880/3	C875/3	C875/4K	C875/4O
Farm							
Hosking's	18.4	C	S	C	S	C	C
Tikitere	23.6	C	C	S	S	S	S
Reporoa	20.9	C*	C	S	S	S	S*
Kanui	21.1	C*	C*	S	C*	S	S*
Forest							
Pouto	18.1	C	C*	S*	S*	S	S
Rerewhakaaitu	17.1	C*	C	S	S*	S	S*
Tahorakuri	19.2	C	S	S*	S/C	S*	S*
Lake Taupo	20.2	C	S	S	C	S	S*

DBH at Age seven years is summarised in Table 12. Diameter (DBH) growth was greatest on the ex-farm sites, except at Hosking's, where the intensive pruning regime probably affected tree growth. While DBH growth of 1- and 2-year-old cuttings was generally better than the seedling controls, the 3- and 4-year-old cuttings were generally slimmer. For the three-year-old cuttings, these differences were significant on two of the eight sites for each of the two different three-year-old stock types, while for the C875/4K cuttings, the difference was significant on only one site (Tahorakuri Forest). For the C875/4O cuttings, the difference was significant at five out of the eight sites. The C875/4O cuttings were collected from a warmer site than the C875/4K cuttings, and the estimated physiological age of the C875/4O cuttings was six years, compared with four years for the C875/4K cuttings.

Results at age 23 years for the 1983 trials

The average survival percentage for the eight stock types over five sites is given in Table 13. There were no significant differences in percentage survival between stock types at any of the sites. The Tikitere trial was thinned to 50% of initial stocking (from 400 sph down to 200 sph), and hence the current lower survival of 44%. Also, any trees that could not be pruned because of poor form at Tikitere were thinned out, and this resulted in fewer seedlings remaining.

Table 13: Survival (%) at 23 years of age for the five sites planted in 1983

Site	Site mean (%)	Mean stems/ha	CS[1]	OS	C1	C2	C3	C4	C5	TC
Farm										
Tairua	68	272	47	44	69	72	68	75	81	86
Tikitere	44	176	38	36	45	41	46	49	50	44
Forest										
Pouto	81	324	74	81	82	84	83	93	86	67
Kaingaroa	63	252	66	58	56	63	64	61	64	71
Lake Taupo	67	268	59	59	66	74	75	57	77	66

[1] See Table 1 for description of stock types

Diameter growth (over bark) was greatest on the two ex-farm sites, compared with the three forest sites (Table 14). While OS seedlings were generally larger diameter than cuttings, C3 cuttings were larger than OS seedlings on three sites (although not significantly larger), and C1-C4 cuttings were not significantly smaller than the OS seedlings (except C3 cuttings at Pouto Forest). C5 cuttings were significantly smaller than OS seedlings on four out of five sites (except at Tikitere). Overall, the OS seedlings were larger than the cuttings, and significantly larger than the C2, C4, and C5 cuttings (Tables 14 and 21). The tissue-culture plantlets were consistently poor.

Table 14: DBHOB (mm) at 23 years of age for the five sites planted in 1983

Site	Site mean (m)	CS	OS	C1	C2	C3	C4	C5	TC	Signif.[1]
Farm										
Tairua	553	525 bc[2]	616 a	581 ab	560 ab	568 ab	568 ab	530 bc	473 c	***
Tikitere	561	550 ab	566 ab	565 ab	553 ab	619 a	559 ab	557 ab	522 b	**
Forest										
Pouto	415	387 cd	452 a	448 a	429 ab	411 bc	423 ab	401 bcd	369 d	***
Kaingaroa	479	449 c	502 ab	509 ab	516 a	512 a	467 bc	448 c	425 c	***
Lake Taupo	470	456 bc	496 ab	505 a	486 ab	515 a	479 ab	428 cd	394 d	***
Overall mean[3]	498	477	529	523	511	526	502	474	439	***

[1] ** Significant at P≤0.01, *** Significant at P≤0.001
[2] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)
[3] Least squares overall mean (adjusted for numbers of trees remaining on each site)

Bark thickness at breast height is known to decrease with increasing maturation (Menzies *et al*. 1988), and so bark thickness was measured on all trees. There was a general trend for bark thickness to decrease with increasing maturation, and C4-C5 cuttings had significantly thinner bark at four of the five sites, compared with OS seedlings (Table 15). Overall, the OS seedlings had thicker bark than all the cuttings, and significantly thicker than C2-C5 cuttings (Tables 15 and 21). The tissue-culture plantlets generally had the thinnest bark, indicating that they were showing signs of maturation.

Diameter growth under bark (DBHIB) was calculated from DBHOB and bark thickness (Table 16). The trends for DBHIB were very similar to the trends for DBHOB. While OS seedlings were generally of larger diameter than cuttings, C3 cuttings were larger than OS seedlings on three sites, and C4 cuttings were larger than OS seedlings at Tikitere. Again, C1-C4 cuttings were not significantly smaller than the OS seedlings, except for C3 cuttings at Pouto Forest, and C5 cuttings were not significantly smaller than OS seedlings on two sites (Tikitere and Kaingaroa Forests). Overall, the OS seedlings were larger than all the cuttings, except C3, and significantly, larger than C4 and C5 cuttings (Tables 16 and 21). The tissue-culture plantlets were consistently the smallest.

Table 15: Bark thickness (mm) at 23 years of age for the five sites planted in 1983

Site	Site mean (mm)	CS	OS	C1	C2	C3	C4	C5	TC	Signif.[1]
Farm										
Tairua	26.9	27.2 abc[2]	30.3 a	28.7 ab	28.0 ab	26.9 bc	26.6 bc	24.1 cd	23.2 d	***
Tikitere	32.9	36.6 a	34.1 ab	32.5 ab	32.7 ab	34.6 ab	30.9 b	31.3 b	30.5 b	**
Forest										
Pouto	20.8	21.3 b	24.7 a	24.0 a	21.0 b	21.0 b	19.7 bc	17.7 c	17.2 c	***
Kaingaroa	29.9	30.8 abc	33.3 a	32.7 a	31.5 ab	32.5 a	27.5 bcd	24.5 d	26.7 cd	***
Lake Taupo	28.5	30.6 ab	31.5 a	31.2 ab	29.3 ab	30.7 ab	28.0 b	23.0 c	23.2 c	***
Overall mean[3]	27.9	29.5	30.9	29.8	28.7	29.1	26.6	24.2	24.2	***

[1] ** Significant at P≤0.01, *** Significant at P≤0.001
[2] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)
[3] Least squares overall mean (adjusted for numbers of trees remaining on each site)

Table 16: DBHIB (mm) at 23 years of age for the five sites planted in 1983

Site	Site mean (mm)	CS	OS	C1	C2	C3	C4	C5	TC	Signif.[1]
Farm										
Tairua	499	470 bc[2]	555 a	524 ab	504 ab	514 ab	515 ab	482 bc	427 c	***
Tikitere	495	477 b	497 ab	500 ab	487 ab	550 a	497 ab	495 ab	459 b	**
Forest										
Pouto	373	345 de	402 a	400 ab	387 abc	369 bcd	384 abc	366 cd	334 e	***
Kaingaroa	419	387 de	435 abc	444 ab	453 a	448 ab	412 bcd	399 cde	372 e	***
Lake Taupo	413	395 bc	433 ab	442 a	427 ab	454 a	423 ab	382 cd	348 d	***
Overall mean[3]	442	418	468	463	453	468	449	426	390	***

[1] ** Significant at P≤0.01, *** Significant at P≤0.001
[2] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≤0.05)
[3] Least squares overall mean (adjusted for numbers of trees remaining on each site)

For stem malformation, there was a significant effect only at Pouto Forest, where C1 cuttings were significantly better than CS seedlings and TC plantlets (Table 17); there was no significant difference between OS seedlings and C1- C5 cuttings. There were some slight trends at other sites, which were not significant. At Tikitere, C1-C5 cuttings were better than OS seedlings, while at Kaingaroa, C2- C5 cuttings were slightly better than OS seedlings, and at Lake Taupo, C1- C5 cuttings were slightly better than OS seedlings. Overall, stem malformation was not significant (Table 17), but the cuttings were the same or better than the OS seedlings (Tables 17 and 21). CS seedlings were consistently poor.

Table 17: Malformation at 23 years of age for the five sites planted in 1983, where tree form was scored on a 1-9 scale (where 1 = crooked and/or multiple forks, and 9 = perfectly straight with no malformation)

Site	Site mean	CS	OS	C1	C2	C3	C4	C5	TC	Signif.[1]
Farm										
Tairua	5.4	4.8	5.7	5.9	5.4	4.9	5.8	5.1	5.9	ns
Tikitere	5.6	4.6	4.8	5.6	6.2	5.6	6.0	5.9	6.0	ns
Forest										
Pouto	6.7	6.0 b[2]	7.3 ab	7.5 a	6.9 ab	6.5 ab	6.5 ab	6.8 ab	6.0 b	*
Kaingaroa	5.8	5.8	5.7	5.7	6.0	6.0	5.8	6.0	5.6	ns
Lake Taupo	7.3	6.9	7.0	7.4	7.5	7.8	7.6	7.3	7.1	ns
Overall mean[3]	6.1	5.6	6.1	6.4	6.3	6.1	6.3	6.2	6.1	ns

[1] ns= Not significant at $P \leq 0.05$, * Significant at $P \leq 0.05$
[2] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, $P \geq 0.05$)
[3] Least squares overall mean (adjusted for numbers of trees remaining on each site)

For stem acceptability, the range in site means was from 37% at Tairua up to 68% at Lake Taupo (Table 18). The forest sites had higher acceptability than the ex-farm sites. Based on survival and initial stocking of 400 sph, the number of acceptable stems/ha was estimated. Again, the forest sites were better than the ex-farm sites, with 182-185 acceptable stems/ha at Pouto and Lake Taupo Forests (a selection ratio of about 1: 1.2), while at Tikitere, there were only 70 acceptable stems/ha (a selection ratio of about 1: 5.7). There was a significant stock type effect only at Pouto Forest, where OS seedlings and C1- C5 cuttings were significantly better than CS seedlings and TC plantlets (Table 18). There were some slight trends at other sites, which were not significant. At Tikitere, C1-C5 cuttings were better than OS seedlings, while at Lake Taupo, C1- C4 cuttings were slightly better than OS seedlings. Overall, there was a significant difference in Acceptability, with the tissue-culture plantlets significantly worse than the OS seedlings (Table 21).

Table 18: Acceptability percentage at 23 years of age for the five sites planted in 1983, where acceptability was scored as 0= unacceptable as a crop tree, and 1= acceptable as a crop tree

Site	Site mean (%)	No. accept. stems/ ha	CS	OS	C1	C2	C3	C4	C5	TC	Sig.[1]
Farm											
Tairua	37	101	36	36	44	39	31	42	32	35	ns
Tikitere	40	70	22	34	37	54	39	47	40	45	ns
Forest											
Pouto	57	185	34 b[2]	69 a	78 a	63 a	60 a	57 a	58 a	33 b	*
Kaingaroa	41	103	29	46	46	47	49	44	44	24	ns
Lake Taupo	68	182	60	67	75	75	75	71	65	56	ns
Overall mean[3]	49	127	36	51	56	55	51	52	48	39	*

[1] ns= Not significant at P≤0.05, * Significant at P≤0.05
[2] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)
[3] Least squares overall mean (adjusted for numbers of trees remaining on each site)

An overall analysis was done to compare the five sites and eight stock types (Table 19). Site and replication were significant for all variables, and stock type was significant for all variables except malformation. The interaction between site and stock type was significant for DBHOB, bark thickness, and DBHIB. For DBHOB, the significant interaction was caused mainly by changes in the ranking of the C2 and C3 cuttings at the five sites. The C3 cuttings had a comparatively low DBHOB and DBHIB at Poutu, while the C2 cuttings were comparatively high at Kaingaroa. For bark thickness, the CS seedlings had comparatively thick bark at Tikitere, while the C1 cuttings had comparatively thin bark at Tikitere.

Table 19: Analysis of variance table for the five sites and eight stock types, planted in 1983

Source	df	DBHOB	Bark Thickness	DBHIB	Malformation	Acceptability
Site	4	61.23 ***[1]	56.72 ***	57.07 ***	20.92 ***	19.70 ***
Rep	55	2.84 ***	3.56 ***	3.02 ***	1.47 *	1.36 *
Stock type	7	16.82 ***	21.12 ***	16.09 ***	1.61 ns	4.63 **
Site x stock type	28	2.74 ***	2.75 ***	2.56 ***	1.04 ns	1.45 ns
Error	2376					

[1] ns= Not significant at P≤0.05, * Significant at P≤0.05,
** Significant at P≤0.01, *** Significant at P≤0.001

The overall means and standard errors for DBHOB, bark thickness, and DBHIB for the eight stock types over five sites are given in Table 20, and for stem malformation and stem acceptability in Table 21. These data are summarised in Table 22, where the means for the C1-C5 cuttings are compared with the OS seedling means, with C being used to indicate that the cuttings in a given comparison were better than the OS seedlings, and an S being used to indicate that the OS seedlings were better than the cuttings. An * is used to indicate that the difference was significant, based on the standard errors. The OS seedlings were consistently larger than the cuttings for DBHOB (significant except for C1 and C3 cuttings), with thicker bark (significant for the C2-C5 cuttings). For DBHIB, OS seedlings were significantly larger than C4 and C5 cuttings.

Overall, there was no significant difference between OS seedlings and the cuttings for stem malformation and stem acceptability (Table 22). CS seedlings were the worst, followed by the tissue-culture plantlets.

Interestingly, for all the variables, the means for the cuttings and tissue-culture plantlet stock types had smaller standard errors than the means for the two seedling stock types, meaning that the cuttings and tissue-culture plantlet stock types were more uniform (less variable) than the seedling stock types.

Table 20: Means for assessed variables averaged over the five sites for the eight treatments at 23 years of age, planted in 1983

Stock type[1]	**DBHOB (mm)**		**Bark thickness (mm)**		**DBHIB (mm)**	
	Mean	Std. error	Mean	Std. error	Mean	Std. error
CS	477	8.5	29.5	0.61	418	7.6
OS	529	8.6	30.9	0.62	468	7.7
C1	523	7.9	29.8	0.57	463	7.1
C2	511	7.8	28.7	0.57	453	7.0
C3	526	7.7	29.1	0.56	468	6.9
C4	502	7.7	26.6	0.56	449	6.9
C5	474	7.4	24.2	0.54	426	6.6
TC	439	7.7	24.2	0.56	390	6.9
Overall mean[2]	498		27.9		442	
Signif.[3]	***		***		***	

[1] Where CS=Climbing select seedlings, OS=seed orchard seedlings, C1= cuttings from one-year-old trees, C2= cuttings from two-year-old trees, C3= cuttings from three-year-old trees, C4= cuttings from four-year-old trees, C5= cuttings from five-year-old trees, and TC=tissue-culture plantlets.
[2] Least squares overall mean (adjusted for numbers of trees remaining on each site)
[3] ns not significant at P≤0.05, * Significant at P≤0.05, *** Significant at P≤0.001

Table 21: Means for assessed variables averaged over the five sites for the eight treatments at 23 years of age, planted in 1983

Stock type[1]	Survival (%)	Malformation		Acceptability (%)	
		Mean	Std. error	Mean	Std. error
CS	57	5.6	0.19	36	3.0
OS	56	6.1	0.19	51	3.0
C1	64	6.4	0.17	56	2.8
C2	67	6.3	0.17	55	2.8
C3	67	6.1	0.17	51	2.7
C4	67	6.3	0.17	52	2.7
C5	72	6.2	0.16	48	2.6
TC	66	6.1	0.17	39	2.7
Overall mean[2]	65	6.1		49	
Signif.[3]	ns	ns		*	

[1] Where CS=Climbing select seedlings, OS=seed orchard seedlings, C1= cuttings from one-year-old trees, C2= cuttings from two-year-old trees, C3= cuttings from three-year-old trees, C4= cuttings from four-year-old trees, C5= cuttings from five-year-old trees, and TC=tissue-culture plantlets.
[2] Least squares overall mean (adjusted for numbers of trees remaining on each site)
[3] ns not significant at P≤0.05, * Significant at P≤0.05, *** Significant at P≤0.001

Table 22: Assessed variables at Age 23 years, comparing the seedlings and cuttings over the five sites. C is used to indicate where the cuttings in a given comparison were better than the comparable seedlings, and S where seedlings were better than the cuttings. An * is used to indicate that the difference was significant, based on the standard errors.

Stock type	DBHOB	Bark thickness	DBHIB	Malformation	Acceptability
C1	S	S	S	C	C
C2	S*	S*	S	C	C
C3	S	S*	C	S	C
C4	S*	S*	S*	C	C
C5	S*	S*	S*	C	S
TC	S*	S*	S*	S	S*

Results at age 22 years for the 1984 trials

The average survival for the 11 stock types over 8 sites is given in Table 23. There were no significant differences between stock types at any of the sites. Survival was higher on the forest sites, compared with the farm sites. In 1991, the trial at Hosking's was thinned to 50% of initial stocking by selecting the best four trees per row of eight to retain in each block (from 400 sph down to 200 sph), and hence the current lower survival of 45%, compared with the survival before thinning of 70%. The survival at all other sites was similar to that at Age seven years, but 1-7 % lower.

Diameter growth (over bark) was greatest on the ex-farm sites, compared with the forest sites (Table 24). While 1- and 2-year-old cuttings were generally larger in diameter than their seedling controls, 3- and 4-year-old cuttings were generally smaller than their seedling controls. However, none of these differences were significant (except for C880/3 cuttings at Pouto Forest). Surprisingly, C875/4O cuttings were larger than their seedling controls at Hosking's and Kanui Station, despite their physiological age of around six years, although again, this difference was not significant. The tissue-culture plantlets were worst on four of the eight sites, but also the best on one site (Rerewhakaaitu, Table 24).

There was a general trend for bark thickness to decrease with increasing maturation, and C875/4O cuttings had significantly thinner bark than their seedling control at seven of the eight sites, while C875/4K cuttings had significantly thinner bark than their seedling control at five of the eight sites (Table 25). The bark thickness for the tissue-culture plantlets was not ranked consistently across sites, compared with the different-aged cuttings.

The trends for DBHIB were very similar to the trends for DBHOB (Table 26). While 1- and 2-year-old cuttings were generally larger in diameter than their seedling controls, 3- and 4-year-old cuttings were generally smaller than their seedling controls. However, none of these differences were significant. The C875/4K cuttings were larger than their seedling controls on three of the eight sites (Hosking's, Rerewhakaaitu and Kanui Station), while C875/4O cuttings were larger than their seedling controls on four of the eight sites (Hosking's, Pouto, Tahorakuri and Kanui Station). The performance of the tissue-culture plantlets was not consistent, and tended to follow the trends of bark thickness, with poorer growth associated with thinner bark.

For stem malformation, site means were higher on the forest sites (6.90- 7.27), compared with the ex-farm sites (4.84- 6.65), although the Hosking's site had a mean value close to the forest sites at 6.65 (Table 27). There was a significant effect only at Pouto Forest and Hosking's, although at Hosking's, the LSD test did not show any of the treatment means significantly different from each other. At Pouto, none of the cuttings were significantly different from their seedling controls.

For stem acceptability, the range in site means was from 28% at Reporoa up to 65% at Tahorakuri (Table 28). The forest sites had a higher acceptability than the ex-farm sites. Based on survival and initial stocking of 400 sph, the number of acceptable stems/ha was estimated. Again, the forest sites were better than the ex-farm sites, with 130- 191 acceptable stems/ha at the forest sites (a selection ratio of about 1: 2.1-3.1), while on the ex-farm sites, there were only 59- 100 acceptable stems/ha (a selection ratio of about 1: 4.0-6.8). There was a significant stock type effect only at Pouto Forest and Hosking's, although at Reporoa, the ANOVA did not show a significant stock type effect, but the LSD test did show some significant differences. At these three sites, there were no significant differences between any of the cutting types and their seedling controls.

An overall analysis was done to compare the eight sites and eleven stock types (Table 29). Site, replication, stock type, and the interaction between site and stock type were significant for all variables. For DBHOB, the significant interaction was caused mainly by changes in the ranking of the S880 seedlings, the C880/3 and C875/4O cuttings, and the tissue-culture plantlets over the sites. The S880 seedlings had a comparatively low DBHOB at Hosking's, while the C880/3 and C875/4O cuttings were comparatively high at Hosking's. The tissue-culture plantlets had a comparatively high DBHOB at Reporoa and Rerewhakaaitu. For bark thickness, the S850 seedlings had comparatively thin bark at Tikitere, while the C880/3 cuttings and tissue-culture plantlets had comparatively thick bark at Kanui Station and Tikitere, respectively. The S880 seedlings, the C880/3 cuttings, and the tissue-culture plantlets caused the main interactions for DBHIB. The S880 seedlings had a comparatively small DBHIB at Hosking's, but a large DBHIB at Tikitere and Kanui Station. The C880/3 cuttings had a comparatively small DBHIB at Tikitere and Pouto, but a large DBHIB at Hosking's and Tahorakuri, while the tissue-culture plantlets a comparatively large DBHIB at Reporoa and Rerewhakaaitu. There was no clear pattern for the interactions between site and stock type for malformation and acceptability.

The overall means and standard errors for DBHOB, bark thickness, and DBHIB for the 11 stock types over eight sites are given in Table 30, and for stem malformation and stem acceptability in Table 31. These data are summarised in Table 32, where the means for the cuttings are compared with their seedling control means, with C being used to indicate that the cuttings in a given comparison were better than the seedling control, and an S being used to indicate that the control seedlings were better than the cuttings. An * is used to indicate that the difference was significant, based on the standard errors. For DBHOB, the 1- and 2-year-old cuttings were larger than their seedling controls, but the control seedlings were consistently larger than the 3- and 4-year-old cuttings (significant only for C4(O) cuttings). The seedling controls had consistently thicker bark for the 3- and 4-year-old cutting types, but the 1- and 2-year-old stock types were not significantly different from the equivalent seedling controls. For DBHIB, again the 1- and 2-year-old cuttings were larger than their seedling controls, but the control seedlings were consistently larger than the 3- and 4-year-old cuttings, although none of these differences were significant. Overall, there were no significant differences between the different cutting types and their seedling controls for stem malformation and stem acceptability (Table 32). The tissue-culture plantlets consistently performed worse than the seedling control for all variables, although not significant for malformation.

Table 23: Survival (%) at 22 years of age for the eight sites planted in 1984

Stock type[1]	Farm sites				Forest sites			
	Hosking's	Tikitere	Reporoa	Kanui Stn	Pouto	Rerewhakaaitu	Tahorakuri	L. Taupo
S880	43	36	50	42	88	66	58	57
S875	46	39	51	45	89	73	71	64
S268	44	20	50	50	90	58	72	56
S850	46	40	57	43	94	65	73	63
C880/1	40	34	47	51	88	76	71	45
C850/2	47	54	57	60	91	76	58	59
C880/3	44	49	48	65	92	71	71	55
C875/3	47	63	59	63	86	79	68	70
C875/4K	48	60	58	73	90	77	65	43
C875/4O	42	50	45	59	94	78	70	59
T/C	44	54	60	74	89	72	77	47
Site mean	44	45	53	57	90	72	68	56

[1] See Table 2 for explanation of codes for stock types

Table 24: DBHOB (mm) at 22 years of age for the eight sites planted in 1984

Stock type[1]	Farm sites				Forest sites			
	Hosking's	**Tikitere**	**Reporoa**	**Kanui Stn**	**Pouto**	**Rerewhakaaitu**	**Tahorakuri**	**L. Taupo**
S880	506 b[3]	603 a	530 ab	609 a	382 cd	452 bc	465 abcd	502 abc
S875	531 ab	569 ab	522 ab	552 bc	382 cd	451 bc	437 cde	471 bcde
S268	509 b	572 ab	531 ab	583 ab	381 cd	457 abc	450 bcde	481 abcd
S850	553 ab	583 ab	567 a	611 a	424 ab	479 ab	482 ab	494 abcd
C880/1	519 ab	599 a	538 ab	588 ab	396 bc	455 bc	454 bcde	505 ab
C850/2	576 a	587 ab	570 a	602 ab	433 a	483 ab	496 a	524 a
C880/3	561ab	534 ab	527 ab	589 ab	349 e	453 bc	467 abc	484 abcd
C875/3	510 b	525 b	496 b	590 ab	374 cde	437 c	449 bcde	473 bcd
C875/4K	526 ab	544 ab	491 b	554 bc	357 de	455 bc	428 ef	453 cde
C875/4O	535 ab	554 ab	487 b	572 abc	368 cde	417 c	429 def	447 de
T/C	519 ab	586 ab	548 ab	528 c	313 f	497 a	399 f	422 e
Site mean	532	565	528	577	378	457	449	479
Sig. (F-test)[2]	***	*	***	***	***	***	***	***

[1] See Table 2 for explanation of codes for stock types

[2] * Significant at P≤0.05, *** Significant at P≤0.001,

[3] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 25: Bark thickness (mm) at 22 years of age for the eight sites planted in 1984

Stock type[1]	Farm sites				Forest sites			
	Hosking's	**Tikitere**	**Reporoa**	**Kanui Stn**	**Pouto**	**Rerewhakaaitu**	**Tahorakuri**	**L. Taupo**
S880	28.6 ab[3]	35.3 a	31.2 abc	34.3 ab	23.2 ab	29.5 abc	28.8 ab	33.9 a
S875	28.5 ab	32.8 abcd	29.7 abcd	32.3 b	22.4 abc	28.2 abcd	27.0 ab	31.8 a
S268	27.3 abc	31.9 abcd	30.7 abc	33.7 ab	23.2 ab	29.5 abc	28.7 ab	31.9 a
S850	30.4 a	32.0 abcd	32.7 a	36.5 a	25.0 a	31.2 ab	29.9 a	32.5 a
C880/1	27.8 abc	34.4 ab	31.5 ab	33.8 ab	22.9 ab	29.0 abc	28.5 ab	32.5 a
C850/2	30.4 a	33.9 abc	32.0 ab	32.6 b	25.1 a	27.9 bcd	28.4 ab	32.8 a
C880/3	28.3 ab	28.5 cd	27.8 bcde	33.8 ab	19.3 cd	26.1 cd	27.2 ab	29.3 ab
C875/3	26.0 bcd	28.0 d	26.6 cde	32.3 b	19.9 bcd	25.4 d	26.7 b	29.0 ab
C875/4K	24.2 cd	29.0 bcd	25.0 de	28.4 c	18.2 de	25.5 d	23.0 c	26.2 b
C875/4O	23.4 d	27.6 d	24.2 e	28.3 c	15.9 e	21.7 e	20.7 c	24.6 b
T/C	26.8 abcd	35.8 a	29.5 abcd	28.2 c	17.9 de	31.5 a	20.3 c	25.0 b
Site mean	27.4	31.7	29.2	31.8	21.2	27.8	26.3	30.0
Sig. (F-test)[2]	***	***	***	***	***	***	***	***

[1] See Table 2 for explanation of codes for stock types
[2] *** Significant at P≤0.001,
[3] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 26: DBHIB (mm) at 22 years of age for the eight sites planted in 1984

Stock type[1]	Farm sites				Forest sites			
	Hosking's	**Tikitere**	**Reporoa**	**Kanui Stn**	**Pouto**	**Rerewhakaaitu**	**Tahorakuri**	**L. Taupo**
S880	449 b[3]	532	468 ab	541 a	335 cde	393 bcd	408 abc	434 ab
S875	474 ab	501	463 ab	487 bc	337 cd	395 bcd	383 cd	407 bc
S268	454 b	500	470 ab	516 abc	335 cde	398 abcd	392 bc	418 abc
S850	493 ab	519	502 a	538 a	374 ab	417 abc	422 ab	429 ab
C880/1	463 ab	530	475 ab	520 abc	350 bc	397 bcd	397 bc	440 ab
C850/2	515 a	519	506 a	536 a	383 a	427 ab	440 a	458 a
C880/3	504 ab	477	472 ab	521 ab	310 e	401 abcd	413 abc	426 ab
C875/3	457 b	469	443 b	525 ab	334 cde	387 cd	395 bc	415 abc
C875/4K	477 ab	486	441 b	497 abc	321 de	404 abcd	382 cd	401 bc
C875/4O	488 ab	499	439 b	516 abc	337 cde	374 d	388 cd	398 bc
T/C	466 ab	514	489 ab	472 c	277 f	434 a	358 d	372 c
Site mean	477	502	470	513	336	402	397	419
Sig. (F-test)[2]	***	ns	***	***	***	***	***	***

[1] See Table 2 for explanation of codes for stock types

[2] ns= Not significant at P≤0.05, * **Significant at P≤0.001,

[3] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 27: Malformation at 22 years of age for the eight sites planted in 1984, where tree form was scored on a 1-9 scale (where 1 = not straight and/or multiple forks, and 9 = perfectly straight with no malformation)

Stock type[1]	Farm sites				Forest sites			
	Hosking's	Tikitere	Reporoa	Kanui Stn	Pouto	Rerewhakaaitu	Tahorakuri	L. Taupo
S880	6.54	4.21	5.09	4.60	6.44 bc[3]	6.57	6.50	6.75
S875	6.09	5.94	5.22	5.51	7.45 ab	7.21	6.87	7.25
S268	6.62	5.75	4.82	5.50	6.79 abc	6.93	6.14	6.87
S850	6.59	5.69	5.80	5.46	8.12 a	6.48	6.73	6.98
C880/1	5.92	4.04	3.98	4.43	6.99 abc	6.62	6.93	6.33
C850/2	7.73	4.51	4.92	5.66	7.75 ab	6.66	6.27	7.40
C880/3	6.29	4.28	4.14	5.05	6.55 bc	7.10	7.40	7.91
C875/3	6.96	5.16	4.65	5.37	7.12 abc	7.25	7.78	7.48
C875/4K	7.72	4.56	4.14	5.59	6.80 abc	6.91	7.08	7.10
C875/4O	6.40	5.70	5.30	4.79	6.93 abc	6.83	6.49	7.63
T/C	6.31	4.42	5.17	5.90	6.01 c	7.29	6.55	8.29
Site mean	6.65	4.93	4.84	5.30	7.00	6.90	6.79	7.27
Sig. (F-test)[2]	*	ns	Ns	ns	***	ns	ns	ns

[1] See Table 2 for explanation of codes for stock types

[2] ns= Not significant at P≤0.05, * Significant at P≤0.05, *** Significant at P≤0.001,

[3] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, P≥0.05)

Table 28: Acceptability percentage at 22 years of age for the eight sites planted in 1984, where acceptability was scored as 0 = unacceptable as a crop tree, and 1 = acceptable as a crop tree

Stock type[1]	Farm sites				Forest sites			
	Hosking's	**Tikitere**	**Reporoa**	**Kanui Stn**	**Pouto**	**Rerewhakaaitu**	**Tahorakuri**	**L. Taupo**
S880	41 bc[3]	31	27 ab	30	42 cde	51	50	47
S875	45 abc	48	38 ab	40	65 abc	63	59	61
S268	50 abc	19	18 b	48	49 bcd	52	49	46
S850	59 abc	50	34 ab	51	78 a	58	53	63
C880/1	37 c	22	20 ab	29	62 abcd	52	46	51
C850/2	69 ab	33	28 ab	52	71 ab	62	59	60
C880/3	43 abc	21	26 ab	42	41 de	62	62	66
C875/3	44 abc	28	17 b	42	53 bcd	66	63	64
C875/4K	74 a	29	18 b	50	44 cd	53	63	56
C875/4O	53 abc	48	48 a	44	58 abcd	57	57	67
T/C	50 abc	37	34 ab	46	20 e	62	55	56
Site mean	51	33	28	44	53	58	56	58
No. accept. stems/ha	90	59	59	100	191	167	152	130
Sig. (F-test)[2]	**	ns	ns	ns	***	ns	ns	ns

[1] See Table 2 for explanation of codes for stock types

[2] ns= Not significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$, * Significant at $P \leq 0.001$,

[3] For each site, means followed by the same alphabetical letter are not significantly different (LSD test, $P \geq 0.05$)

Table 29: Analysis of variance table for the eight sites and eleven stock types, planted in 1984

Source	df	DBHOB	Bark thickness	DBHIB	Malformation	Acceptability
Site	7	82.59 ***	36.10 ***	87.77 ***	24.12 ***	10.20 ***
Rep	85	3.97 ***	4.14 ***	3.78 ***	2.10 ***	2.01 ***
Stock type	10	7.94 ***	19.44 ***	6.74 ***	1.99 *	3.13 **
Site x stock type	70	3.97 ***	4.27 ***	3.55 ***	1.76 ***	2.02 ***
Error	4821					

[1] * Significant at P≤0.05, ** Significant at P≤0.01, *** Significant at P≤0.001

Table 30: Means for assessed DBH and bark thickness variables and standard errors averaged over the eight sites for the eleven treatments at 22 years of age, planted in 1984

Stock type[1]	DBHOB (mm)		Bark thickness (mm)		DBHIB (mm)	
	Mean	Std. error	Mean	Std. error	Mean	Std. error
S880	508	7.8	30.7	0.64	447	6.8
S875	492	7.5	29.3	0.62	433	6.5
S268	498	8.4	29.8	0.69	437	7.3
S850	526	7.5	31.3	0.62	464	6.5
C880/1	510	7.9	30.3	0.65	450	6.8
C850/2	535	7.2	30.5	0.59	474	6.2
C880/3	498	7.3	27.8	0.60	442	6.3
C875/3	483	6.9	26.8	0.57	430	6.0
C875/4K	478	7.2	25.0	0.59	428	6.2
C875/4O	477	7.3	23.3	0.60	430	6.3
T/C	477	7.1	26.9	0.58	424	6.2
Overall mean[2]	498		28.3		442	
Sig. (F-test)[3]	***		***		***	

[1] See Table 2 for explanation of codes for stock types
[2] Least squares overall mean (adjusted for numbers of trees remaining on each site)
[3] *** Significant at P≤0.001

Table 31: Means and standard errors for assessed form variables averaged over the eight sites for the eleven treatments at 22 years of age, planted in 1984

Stock type[1]	Survival (%)	Malformation		Acceptability (%)	
		Mean	Std. error	Mean	Std. error
S880	55	5.8	0.20	40	3.5
S875	60	6.4	0.19	52	3.4
S268	55	6.2	0.21	41	3.8
S850	60	6.5	0.19	56	3.4
C880/1	57	5.6	0.20	39	3.6
C850/2	63	6.3	0.18	54	3.2
C880/3	62	6.1	0.18	45	3.3
C875/3	67	6.4	0.18	47	3.1
C875/4K	64	6.2	0.18	48	3.2
C875/4O	63	6.3	0.18	54	3.3
T/C	65	6.3	0.18	45	3.2
Overall mean[2]	61	6.2		43	
Sig. (F-test)[3]	ns	*		**	

[1] See Table 2 for explanation of codes for stock types
[2] Least squares overall mean (adjusted for numbers of trees remaining on each site)
[3] ns not significant at P≤0.05,
* Significant at P≤0.05,
** Significant at P≤0.01,

Table 32: Assessed variables at Age 22 years, comparing the seedlings and cuttings for each level of genetic improvement (GF ranking) over the eight sites. C is used to indicate where the cuttings in a given comparison were better than the comparable seedlings, and S where seedlings were better than the cuttings. An * is used to indicate that the difference was significant, based on the standard errors.

Stock type	DBHOB	Bark thickness	DBHIB	Malformation	Acceptability
C1	C	S	C	C	S
C2	C	S	C	S	S
C3(880)	S	S*	S	C	C
C3(875	S	S*	S	C	C
C4(K)	S	S*	S	S	S
C4(O)	S*	S*	S	S	C
TC	S*	S*	S*	S	S*

DISCUSSION

The earlier results from the 1983 and 1984 field trials showed that the cuttings were generally taller than the seedlings at age six for the 1983 trials (Table 5) and age seven for the 1984 trials (Table 11). For DBH, there was a general trend in the 1983 trials for the C4 and C5 cuttings to be significantly smaller than the seedlings at age six (C4 cuttings at four of the five sites, and C5 cuttings at all of the five sites) (Table 7). In the 1984 trials, the DBH at age seven of the C1 and C2 cuttings was generally better than the seedling controls, but the C3 and C4 cuttings were generally slimmer (Table 12). The C3(880) cuttings were slimmer than the seedling controls on seven of the eight sites (significant on two sites), while the C3(875) cuttings were slimmer on five of the eight sites (significant on two sites). The C875(4K) cuttings were slimmer on seven of the eight sites (significant on one site), while the C875(4O) cuttings (with a physiological age of six years) were slimmer on seven of the eight sites (significant on five sites). These results had led to a recommendation that physiological age should be kept to three years or less if early diameter growth losses were to be avoided (Menzies *et al.* 1991b).

The later age results showed that bark thickness decrease significantly with increasing physiological age (Tables 22 and 32), and therefore DBHIB should be used to compare results across different physiological ages. The age 23 results for the 1983 trials confirmed these results, with overall average DBHIB over five sites for C4 and C5 cuttings being significantly slimmer than the seedlings (Table 22). However, for the eight 1984 trials, while overall the seedling controls had a larger DBHIB than the C3 and C4 cuttings, these differences were not significant, even for the C875(4O) cuttings, which had a physiological age of six years (Table 31). Interestingly, none of the cutting stock types at any of the eight sites was significantly smaller than their seedling controls (DBHIB), and at four of the eight sites, the C875(4O) cuttings, with a physiological age of six years, were larger than their seedling controls (Table 26). Thus there is not a consistent loss of diameter growth with increasing physiological age across all sites.

For stem form, earlier results showed that cuttings with a physiological age of two years or more were less prone to toppling (Tables 3 and 9), and had more defect-free trees (Table 8). Cuttings with a physiological age of three years or more had significantly more defect-free trees on farm sites and some forest sites. Therefore, cuttings with a physiological age of three years or more could be expected to have a comparatively smaller defect core in the butt log. At a later age, there were no significant or consistent differences in stem malformation or stem acceptability between seedlings and cuttings (Tables 22 and 32).

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