FIRST ASSESSMENTS of the 1992 and 1994 SPECIAL PURPOSE BREEDS TRIALS

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Report No. 121 August 2003

Stand Growth Modelling Cooperative
Radiata Pine Breeding Company Report No. 137

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Executive Summary

These trials were designed to test seedlots of different attributes along with different silvicultural treatments over a range of sites. There were important differences in trial design between the 1992 and 1994 trial series. Most of the seedlots in the 1992 series used open-pollinated seed collected in a seed orchard from sets of parents with high wood density, fast growth or long internodes, while the seedlots used in the 1994 series were controlled-pollinated. The 1992 series had only a single block of each treatment and seedlot combination, as there are six treatments (various levels of thinning and pruning), while the 1994 trial had only three treatments but also had two replicates of each combination.

These are two very good series of trials, with quite diverse seedlots which should be representative of current plantings. The two series achieve the same rankings of what were intended to be seedlots of very different growth, form and wood properties. However, the open-pollinated seedlots of the 1992 trial show much smaller differences between seedlots and more variation within seedlots than is found in the 1994 trial. The replication in the 1994 trial also seems to help to give a cleaner analysis.

There were two main comparisons between seedlots in these two trial series, best represented by the 1994 trial. The first comparison was between long internode and multinodal seedlots, where the long internode seedlot lived up to its description, but had a small gain in growth and no gain in form, while the multinodal seedlots had good gains in growth and form. The second comparison was between a low-density, fast growth seedlot and a high-density seedlot. The fast growth seedlot achieved ten per cent better growth and form than a GF7 seedlot used as a benchmark, but had ten per cent lower wood density. The high-density seedlot had good form, five percent better growth, but four per cent better wood density than the GF7 seedlot.

It was too early to see the effects of silviculture and whether it affected the seedlots differently. It was a surprise to see growth differences between stocking rates while trees were as young as six years old, although radiata pine stocking rates of 1000 stems per hectare are not common these days.

INTRODUCTION AND BACKGROUND

Forest Research has planted a number of genetic gain trials with improved radiata pine since 1978 and most of these have shown clear seedlot differences. The Special Purpose Breeds trials were intended to demonstrate genetic gain and also monitor the effects of different stocking or pruning on each seedlot. At the age of the assessments reported here, genetic differences should be manifested, but it is probably too early to examine the effects of the thinning and pruning treatments.

These trials were designed to test seedlots of different attributes along with different silvicultural treatments over a range of sites. There are important differences in trial design between the 1992 and 1994 trial series. Most of the seedlots in the 1992 series use open-pollinated seed collected in a seed orchard from sets of parents with high wood density, fast growth or long internodes, while the seedlots used in the 1994 series were controlled-pollinated. The 1992 series had only a single block of each treatment and seedlot combination, as there are six treatments (various levels of thinning and pruning), while the 1994 trial had only three treatments but also had two replicates of each combination.

The trials were measured for the Stand Growth Modelling Co-operative by the "mensuration field crew" and subjective assessments were scored for the Radiata Pine Breeding Company by the "GTI field crew". Tree identities were preserved, so that all traits could be analysed together, although this operation caused quite a few unexpected problems.

MATERIALS AND METHODS

Details of the trial sites are shown in Tables 1 and 2 and Figures 1 and 2. Treatments were revised some time after planting, so both proposed and actual treatments are shown in Tables 3 and 4. Seedlot details are listed in Tables 5 and 6. Assessment traits are shown in Tables 7 and 8. The Riverhead site of the 1992 trial had severe establishment and weed (gorse) problems, so was abandoned. Many trees toppled at the Takitoa site shortly after planting, but were staked upright and appeared to have recovered satisfactorily. Extra seedlots were planted at some sites of the 1992 trial, but these did not have the full range of treatments and so did not permit a fair comparison. These would have created a huge imbalance in an already fragile statistical design and hence their measurements were left out of the analysis.

Table 1. 1992 trial sites

Plot	Forest & compartment	Soil	Latitude	Altitude	Previous land use	Age (yrs) at measurement
FR172/1	Woodhill 36	sand	36° 46'	10 m	*P. radiata* plantation	9.0
FR172/2	Riverhead 25	clay	36° 46'		*P. radiata* plantation	Abandoned
FR172/3	Kaingaroa 1276	Tarawera ash	38° 20'	450 m	*P. radiata* plantation	7.5
FR172/4	Kinleith A6216	pumice	38° 17'	380 m	*P. radiata* plantation	7.6
FR172/5	Takitoa		46° 01'	40 m	*P. radiata* plantation	7.6
FR172/6	Otago Coast	Kaitangata hill	46° 02'	140 m	*P. radiata* plantation	7.6

Table 2. 1994 trial sites

Plot	Forest & compartment	Soil	Latitude	Altitude	Previous land use	Age (yrs) at measurement
FR215/1	Kaingaroa 1284	Tarawera ash	38° 20'	450 m	*P. radiata* plantation	6.1
FR215/2	Rakautao Hikurangi farm	clay	35° 29'	200 m	Improved pasture	6.0
FR215/3	Tokoiti 41		46° 46'	65 m	Improved pasture	6.5

Figure 1. 1992 trial sites

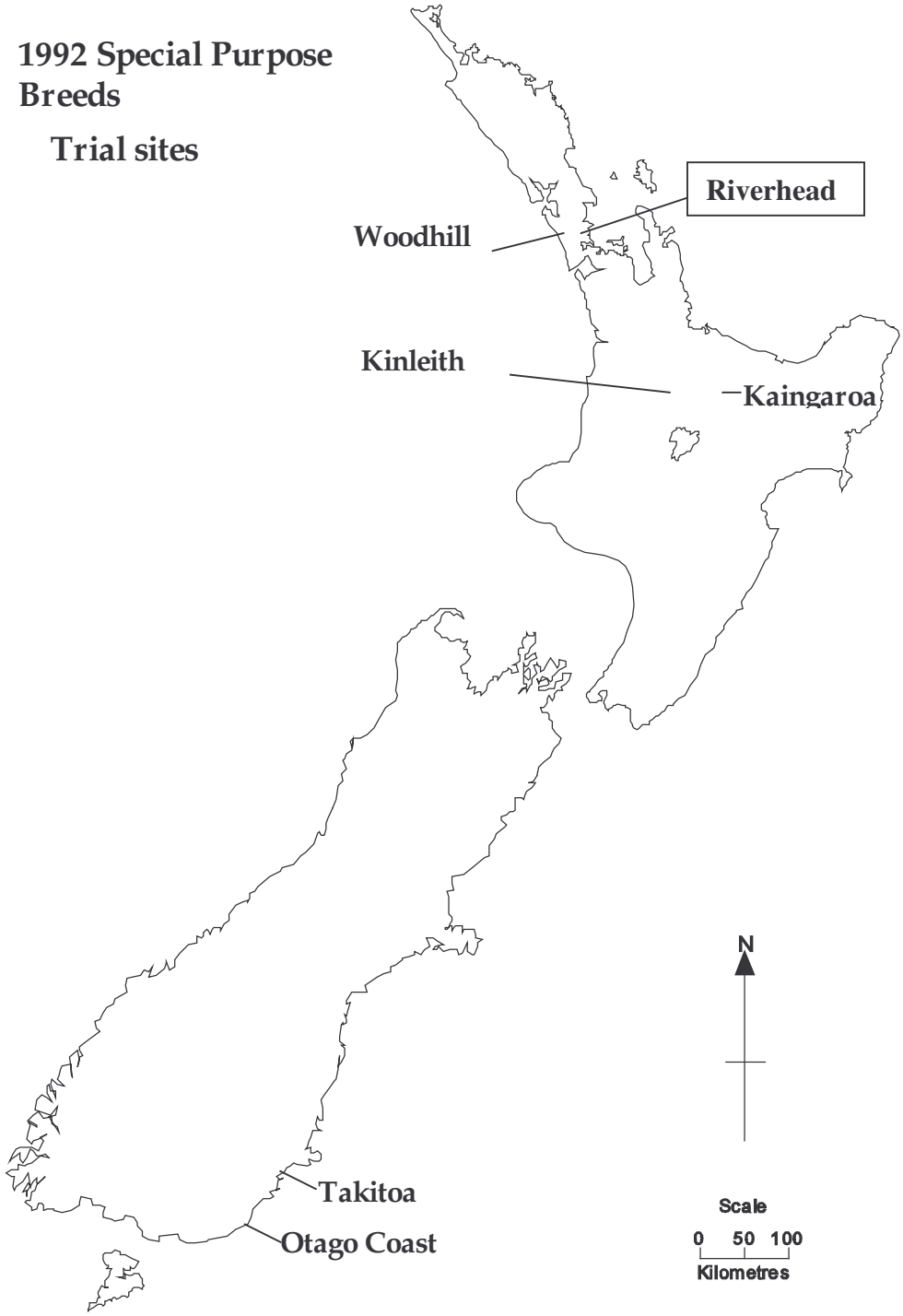

Figure 2. 1994 trial sites

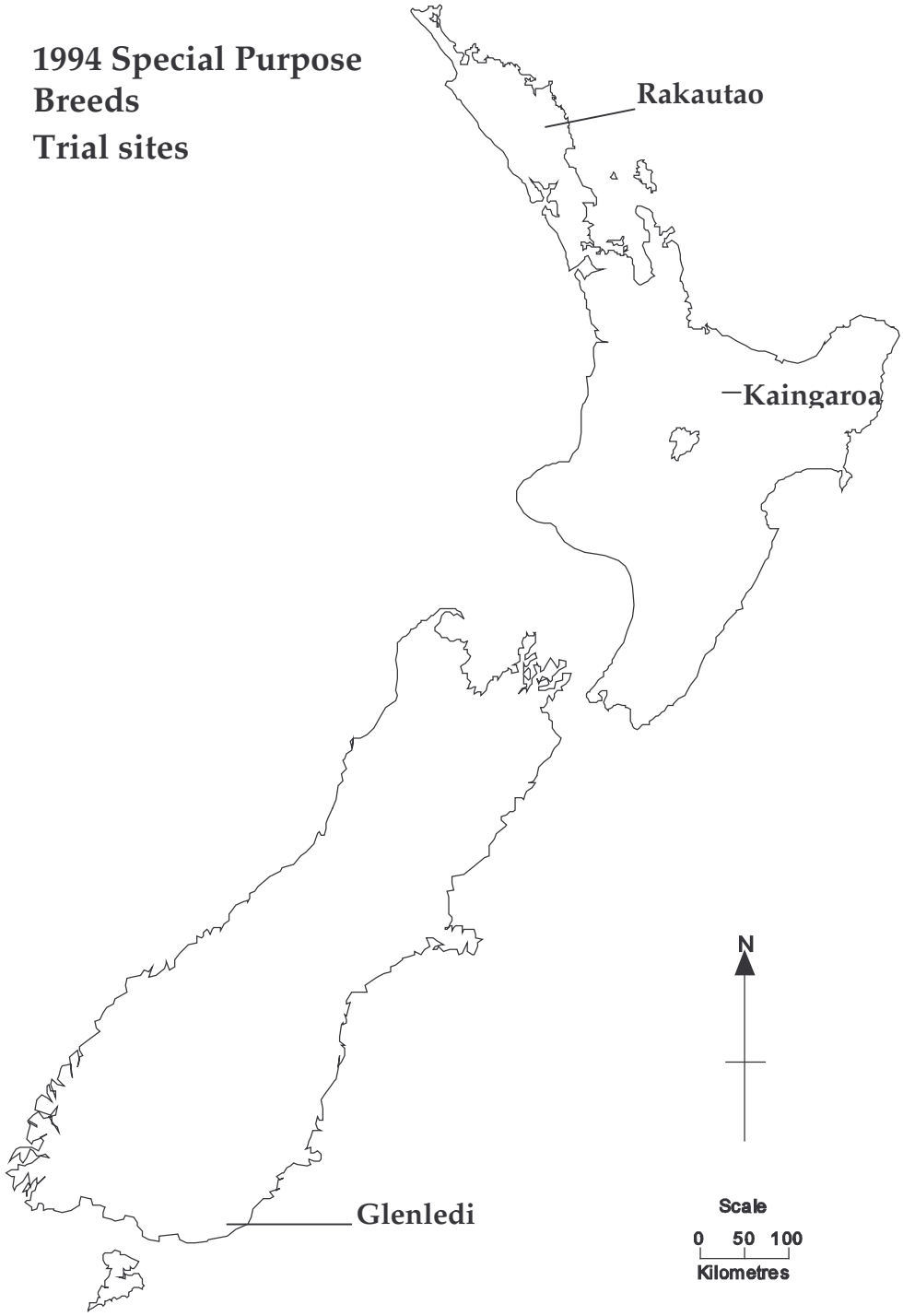

Table 3. Silvicultural treatments for 1992 trial

			Proposed treatment		Revised (actual) treatment	
Field code	**Initial spacing**	**Initial stocking**	**Final stocking**	**Pruning**	**Final stocking**	**Pruning**
1*	5 x 8 metres	250 spha	100 spha	pruned	250 spha	pruned
2 (1)	5 x 4 "	500 "	200 "	"	500 "	unpruned
3 (2)	5 x 2 "	1000 "	400 "	"	400 "	pruned
4 (1)	5 x 4 "	500 "	200 "	unpruned	500 "	unpruned
5 (2)	5 x 2 "	1000 "	400 "	"	400 "	pruned
6 (2)	5 x 2 "	1000 "	600 "	"	400 "	"
7 (2)	5 x 2 "	1000 "	1000 "	"	400 "	"

* this treatment was not assessed
(1), (2) are the revised treatment codes

Table 4. Silvicultural treatments for 1994 trial

			Proposed treatment		Revised (actual) treatment	
Field code	**Initial spacing**	**Initial stocking**	**Final stocking**	**Pruning**	**Final stocking**	**Pruning**
A (1)	5 x 4 metres	500 spha	200 spha	pruned	500 spha	unpruned
B (2)	5 x 2 "	1000 "	400 "	pruned	400 "	pruned
C (2)	5 x 2 "	1000 "	1000 "	unpruned	400 "	pruned

(1), (2) are the revised treatment codes

Table 5. Seedlot details for 1992 trial

Field code	**GF**	**Seedlot**	**Description**
A	27	91/296 & 91/297	Multinodal
B	LI25(13)	89/15/2	Long internode
C	18	91/523	High density
D	28	91/294	Low density
E	14	88/105	Gwavas 850
F	7	88/102	Climbing Select

Table 6. Seedlot details for 1994 trial

Field code	**GF**	**Seedlot**	**Description**
1	LI27(15)	mix of 3 crosses	Long internode
2	25	mix of 5 crosses	Multinodal
3	18	mix of 6 crosses	High density
4	30	850.055 x 268.539	Low density
5	7	88/102	Climbing Select
6	14	3/3/87/01/3	Gwavas 850

Table 7. Assessment traits for 1992 trial

Trait	Units	Description	Tree age*	Remarks
diameter	mm	measured by tape at 1.4 metres	7.5	
height	m.	measured by height pole	7.5	
straightness	1-9	1 = very sinuous, 9 = straight	7.5	
branching	1-9	1 = uninodal, 9 = multinodal	7.5	
malformation	1-9	1 = multiple forks, 9 = perfect	7.5	
acceptability	0, 1	0 is unacceptable due to poor straightness, growth, malformation or health	7.5	
dothistroma	1-30	percentage of infected crown	7.5	Kinleith only
spiral grain	degrees	average of 2 opposing measures	8.0	Takitoa only
density	kg/m^3	estimated from 5mm cores	8.0	Takitoa only

* Woodhill was measured at age 9, other sites at age 7.5

Table 8. Assessment traits for 1994 trial

Trait	Units	Description	Tree age	Remarks
diameter	mm	measured by tape at 1.4 metres	6-6.5	
height	m.	measured by height pole	6-6.5	
straightness	1-9	1 = very sinuous, 9 = straight	6-6.5	not scored if unpruned
branching	1-9	1 = uninodal, 9 = multinodal	6-6.5	not scored if unpruned
malformation	1-9	1 = multiple forks, 9 = perfect	6-6.5	not scored if unpruned
acceptability	0, 1	0 is unacceptable due to poor straightness, growth, malformation or health	6-6.5	not scored if unpruned
spiral grain	degrees	average of 2 opposing measures	8	subset of trees
density	kg/m^3	estimated from 5mm cores	8	subset of trees

ANALYSIS

The full analysis model was used for all traits, but a simplified model was used for the wood quality traits, which were only measured for 30 trees per seedlot and had unbalanced representation over treatments or replications. Seedlot was treated as a fixed effect for the 1992 trials, while site, treatment and all of their interactions were assumed to be random effects. Seedlot and treatment were treated as fixed effects for the 1994 trials, while site and replication were considered to be random, along with all interactions involving random effects.

Across-site analysis of each trait for the 1992 trials was conducted using the following model:

$$Y_{ijkl} = \mu + L_i + T_j + T_j * L_i + S_k + S_k * T_j + S_k * L_i + E_{ijk}$$

Where:

Y_{ijkl}	=	the observation on the l^{th} tree in the k^{th} seedlot in the j^{th} treatment in the i^{th} location (site)
μ	=	the overall trait mean
L_i	=	the effect of the i^{th} location
T_j	=	the effect of the j^{th} treatment
$T_j * L_i$	=	the interaction effect of the j^{th} treatment with the i^{th} location
S_k	=	the effect of the k^{th} seedlot
$S_k * T_j$	=	the interaction effect of the k^{th} seedlot with the j^{th} treatment
$S_k * L_i$	=	the interaction effect of the k^{th} seedlot with the i^{th} location
E_{ijk}	=	the random error associated with a plot of the k^{th} seedlot in the jth treatment in the i^{th} location

Individual analyses per site were also carried out using basically the same model, without location or its effect on interactions or the error term. There were many complications with the analyses on form traits, as the field crew could not see through the thick foliage on unpruned treatments. Similarly, coring trees for density and spiral grain measurements could only be done on the pruned treatments.

Across-site analysis of each trait for the 1994 trials was conducted using the following model, which differs from the 1992 trial analysis model with terms for replicate and its interactions:

$$Y_{ijklm} = \mu + L_i + R_j : L_i + S_k + S_k * L_i + S_k * (R_j : L_i) + T_l + T_l * S_k + T_l * (Rj : L_i) + E_{ijkl}$$

Where:

Y_{ijklm}	=	the observation on the mth tree in the lth treatment of the kth seedlot in the jth replicate in the ith location (site)
μ	=	the overall trait 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 seedlot
$S_k * L_i$	=	the interaction effect of the kth seedlot with the ith location
$S_k * (R_j : L_i)$	=	the interaction effect of the kth seedlot with the jth replicate within the ith location
T_l	=	the effect of the lth treatment
$T_l * S_k$	=	the interaction effect of the lth treatment with the kth seedlot
$T_l * (R_j : L_i)$	=	the interaction effect of the lth treatment with the jth replicate within the ith location
E_{ijkl}	=	the random error associated with a plot of the lth treatment and the kth seedlot in the jth replicate in the ith location

RESULTS AND DISCUSSION

The F tests from the overall analysis of variance for the 1992 trial are shown in Table 9. Site had a major influence on all traits in the 1992 trial, not surprisingly as the sites were chosen to be diverse. Growth differences were also exaggerated by the Woodhill site being measured 18 months after the other sites. Site means are shown in Table 10.

Treatment was generally not significant, mainly because the trees were too young for treatment effects to show, but also because the site x treatment interaction is significant (and the test for significance uses that as its denominator. There was an effect of stocking, where trees planted at 500 stems per hectare (spha) were shorter and fatter than those planted at 1000 spha. Treatment means are shown in Table 11. It is interesting that the form traits appeared worse in the pruned treatments. This apparent effect shows that it wasn't really possible to score the unpruned trees accurately, especially in plots planted at 500 spha.

Seedlots differed significantly for all traits except height and malformation, even though there were significant site by treatment by seedlot interactions. The significance of the interactions showed that the trial design was less precise than was intended. However, seedlot differences were considerable and can be seen in Table 12. The greatest difference was between the long internode seedlot and the other more multinodal seedlots. The long internode type of tree suffers negative correlations with growth and form and these effects can be seen clearly in this trial, where the most multinodal seedlot was best for form and the long internode seedlot was worst.

Analyses and means for individual sites are shown in Appendix 1.

Table 9. F tests from overall analysis of variance, 1992 trial

Source	df	diameter	height	straight	branch	malform	accept
Site	4	3.71*	16.57***	34.58***	14.65***	11.45***	18.29***
Treatment	5	2.28	2.24	0.33	0.29	3.02*	0.91
Site^{x}Treatment	19	3.72***	3.66***	2.16*	2.81**	1.54	2.99**
Seedlot	3	8.91**	1.53	26.75***	38.50***	2.58	9.72***
Seedlot^{x}Site	12	1.38	0.85	1.91	6.98***	2.24*	1.11
Seedlot^{x} Treatment	15	1.08	1.47	0.97	1.12	1.08	0.47
Site^{x}Treatment^{x} Seedlot	55	2.81***	3.96***	2.35***	2.33***	1.62**	2.32***
Error	4638						

* = F value is significant at the level of P…0.05
** = F value is significant at the level of P…0.01
*** = F value is significant at the level of P…0.001

Table 10. Site means, 1992 trial

site	description	n.	diameter	height	straight	branch	malform	accept
1	Woodhill	771	173 a	11.7 a	7.53 a	6.46 a	7.97 a	0.73 a
3	Kaingaroa	863	155 c	10.3 b	6.09 b	5.59 b	7.01 b	0.50 b
4	Kinleith	933	163 b	10.0 bc	5.33 c	4.10 d	7.28 b	0.47 b
5	Takitoa	1362	169 ab	9.7 c	5.39 c	4.62 c	6.19 c	0.33 c
6	Otago Coast	823	168 ab	9.1 d	5.22 c	3.82 d	5.79 c	0.32 c

Means which do not share a letter are significantly different at P…0.05 (Tukey multiple range test)

Table 11. Treatment means, 1992 trial

trt	description	n.	diameter	height	straight	branch	malform	accept
2	500-500 unpr	683	173 a	9.7 b	5.50	4.44	6.44 c	0.40
3	1000-400 prune	723	165 abc	10.5 a	5.78	4.85	6.40 c	0.38
4	500-500 unpr	771	170 ab	9.7 b	5.65	4.66	6.92 bc	0.39
5	1000-400 prune	797	163 bc	10.1 ab	6.27	5.17	7.34 ab	0.51
6	1000-400 prune	822	165 abc	10.2 ab	6.28	5.39	7.43 ab	0.55
7	1000-400 prune	481	160 c	10.2 ab	6.16	5.23	7.49 a	0.51

Table 12. Seedlot means, 1992 trial

Sdlt	description	n.	diameter	height	straight	branch	malform	accept
A	Multinodal	1022	175 a	10.0	6.70 a	6.20 a	7.19 a	0.59 a
B	Long Internode	1079	160 b	10.0	5.26 c	3.03 c	6.51 b	0.34 c
C	High Density	1102	163 b	10.1	5.98 b	5.35 b	7.03 a	0.45 b
D	Low density	1074	166 b	10.3	5.69 b	5.13 b	6.96 a	0.44 b

The F tests from the overall analysis of variance for the 1994 trial are shown in Table 13. Site had a strong influence on height, diameter and branching, but not on the other traits. Early growth rate at Kaingaroa was affected adversely by defoliation caused by the *Heliothus* larvae. Site means are shown in Table 14.

Replicates were marginally significant for diameter, but could not be tested for straightness, branching or malformation, as these traits could not be scored on the unpruned trees.

Treatments differed for the growth traits and for straightness, which may be due to the lack of information on some unpruned treatments. Treatment means are shown in Table 15. It appears that stocking was already affecting growth, in that the trees in lower stocked treatments were fatter and shorter, although it is normally assumed that competition would not be present at this age (6-6.5 years).

Seedlots differed significantly for all traits, with very large differences for traits like density and branching. Seedlot means are shown in Table 16. The differences were much greater than those found in the 1992 trial, showing that good gains in growth, form and wood properties could be achieved with controlled-pollinated seedlots.

Table 13. F tests from overall analysis of the 1994 trial

Source	df	height	diameter	straight	branch	malform	accept	spiral	density
Site	2	97.58***	86.80**	0.67	12.29**	9.61	19.91	0.26	3.94
rep(site)	4	9.14	7.61*	0	0	0	1.62	1.92	0
Sdlt	5	6.58**	15.65***	10.60***	136.82***	4.12*	25.76***	6.50**	29.99***
site*sdlt	10	1.50	0.46	7.36***	2.56*	4.67**	0.59	2.94	2.45
sdlt*rep (site)	13	0.82	1.55	0.35	0.55	0.31	1.30	0.45	0.39
Treat	2	32.75***	30.23***	6.10*	0.22	0.44	0.64	0.37	3.81
site*treat	4	1.17	16.46**	3.06	2.76	1.70	0.38	0.16	0
treat*rep (site)	6	0.95	0.72	0.55	0.23	0.48	0.47	1.05	0.28
treat*sdlt	10	0.93	0.81	1.48	0.85	0.76	1.02	1.29	0.31
treat*sdlt* rep(site)	44	4.63***	1.82***	1.52*	2.58***	2.03***	1.43*	2.75**	4.50***
Error	3538								

Table 14. Site means across all seedlots and treatments, 1994 trial

Site	description	n.	diameter	height	straight	branch	malform	accept	spiral	density
1	Kaingaroa	1143	130 c	7.76 b	6.15	4.65 b	6.60 a	0.46 a	-3.13	326 b
2	Rakautao	1215	200 a	11.94 a	6.05	5.64 a	5.56 b	0.36 b	-3.08	338 a
3	Glenledi	1280	165 b	7.94 b	6.04	5.62 a	6.55 a	0.34 b	-3.38	324 b

Table 15. Treatment means across all sites and seedlots, 1994 trial

Trt	description	n.	diameter	height	straight	branch	malform	accept	spiral	density
A	500-500 unpr	710	174 a	8.26 b	5.89	5.67	6.17	0.35		
B	1000-400 pr	1483	164 b	8.97 a	6.06	5.32	6.28	0.39	-3.16	328
C	1000-400 pr	1445	163 b	8.92 a	6.15	5.32	6.19	0.38	-3.35	330

Table 16. Seedlot means across all sites and treatments, 1994 trial

Sdlt	description	n.	diameter	height	straight	branch	malform	accept	spiral	density
1	Long Internode	675	164 bc	8.68 bc	5.55 b	2.43 e	5.52	0.26 c	-3.86 b	335 ab
2	Multinodal	620	170 ab	8.62 bcd	6.24 ab	6.76 a	6.36	0.39 b	-3.23 ab	337 ab
3	High Density	662	167 bc	9.08 ab	6.52 a	6.57 a	6.75	0.50 a	-4.35 b	348 a
4	Low density	665	177 a	9.33 a	6.57 a	6.10 b	6.43	0.49 a	-3.47 ab	298 c
5	GF7	392	147 d	8.08 d	5.52 b	4.88 d	6.24	0.28 c	-2.09 a	330 b
6	GF14	624	163 c	8.47 cd	5.73 b	5.31 c	6.02	0.29 c	-2.19 a	331 b

Genetic gains

The difference between the means for the GF7 seedlot and other seedlots were calculated as a percentage of the GF7 seedlot. These values serve as a measure of genetic gain and are shown in Table 17. The multinodal seedlots showed good gains in form, reflected in the acceptability trait, while the Long Internode seedlot was handicapped by the negative correlations between few branch clusters and growth and form traits.

The most interesting comparisons were the high density and low density seedlots. Both had excellent gains in form, but the low-density seedlot achieved ten per cent extra diameter growth at the cost of losing ten per cent in wood density. The high-density seedlot had four per cent extra diameter growth in addition to a useful five per cent gain in wood density. These gains of the high-density seedlot were excellent as they were fighting a negative correlation between growth rate and density.

Table 17. Genetic gain for the 1994 trial as a percentage of the GF7 seedlot

Sdlt	description	diameter	height	straight	branch	malform	accept	spiral	density
1	Long Internode	2.4	1.8	1.9	-52.8	-10.3	1.5	-85.5	1.2
2	Multinodal	4.4	0.5	14.5	32.7	2.2	49.7	-53.8	1.9
3	High Density	4.0	5.5	19.3	29.8	9.9	90.4	-108.7	5.2
4	Low Density	10.2	8.5	20.1	19.9	4.3	84.2	-65.7	-9.8
5	GF7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	GF14	1.6	1.2	4.6	3.5	-1.9	10.5	-4.6	0.0

Genetic gains for the 1992 trial were also estimated against the GF7 seedlot. As the GF7 seedlot was only present in treatment 2, only means for this treatment were used. The genetic gains are shown in Table 18, but the precision of the estimates is much lower than that of the 1994 trial. The multinodal seedlot (a mix of controlled crosses) also performs well, but the open-pollinated seed orchard seedlots do not achieve the same gains as those of the 1994 trial.

Table 18. Genetic gain for seedlots in treatment 2 (the only treatment containing a block of GF7) of the 1992 trial as a percentage of the GF7 seedlot.

Sdlt	description	diameter	height	straight	branch	accept	malform	spiral	density
A	Multinodal	8.9	3.2	15.1	25.6	44.0	6.7	-24.3	-4.1
B	Long Internode	1.2	-4.0	-4.7	-31.5	-18.5	-3.0	-10.8	-4.9
C	High Density	-3.0	-7.7	10.4	13.7	5.8	3.3	1.7	-0.4
D	Low density	3.7	-4.7	1.9	2.0	20.4	1.7	-17.4	-3.5
F	GF7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Conclusions

These are two very good series of trials, with quite diverse seedlots which should be representative of current plantings. The two series achieved the same rankings of what were intended to be seedlots of very different growth, form and wood properties. However, the open-pollinated seedlots of the 1992 trial showed much smaller differences between seedlots and more variation within seedlots than was found in the 1994 trial. The trial design with some replication in the 1994 trial also helped to give a cleaner analysis.

The 1994 trial clearly showed that some traits could be pushed a long way by breeding from progeny tested parents. The parents used in the high-density seedlot would be classed as "correlation breakers" which combine high density with good growth and the trial gives a first glimpse of the performance of the progeny of such trees.

It was too early to see the effects of silviculture and whether it affected the seedlots differently. It was a surprise to see growth differences between stocking rates while trees were as young as six years old, although radiata pine stocking rates of 1000 stems per hectare are not common these days.

Future Work

It was intended that internode index would be assessed on the second log. The most convenient time to do this is when the trees are about 14-15 metres tall, when the needles on the stem of the second log should all be killed off by shading.

When the thinning and pruning treatments have had time to take effect it will be worthwhile studying wood properties, to see how they are affected by silviculture. A further wood density assessment would also check whether the wide separation between the high and low density seedlots in the 1994 trial are maintained, or close up reflecting different density gradients.

It will also be worthwhile to track the growth patterns of these very different seedlots over time. It may be that the same silviculture will have different effects for each "breed".

Acknowledgements

The authors would like to thank Mike Carson, Paul Jefferson and Tony Firth for designing the trials, the Radiata Pine Breeding Company for funding the work and tending the trials, the assessment crews of both the Mensuration and Tree Improvement sections, Toby Stovold and Judy Hayes for data collation.

Appendix 1. F tests and means from individual sites, 1992 trial

F tests from analysis of variance at Woodhill, FR172/1

Source	Df	diameter	height	straight	branch	malform	accept
Treatment	5	34.61***	29.69***	3.28**	0.62	2.21	2.85*
Seedlot	3	11.27***	1.65	7.55***	41.18***	2.02	2.72*
Seedlot* Treatment	15	2.89***	2.24**	2.03*	2.56***	2.51**	2.14**
Error	767						

F tests from analysis of variance at Kaingaroa, FR172/3

Source	Df	diameter	height	straight	branch	malform	accept
Treatment	5	2.33*	20.82***	0.09	1.58	0.74	0.59
Seedlot	3	7.27***	0.71	60.06***	289.04***	8.75***	21.42***
Seedlot* Treatment	15	2.21**	4.96***	0.83	3.54***	0.44	0.46
Error	862						

F tests from analysis of variance at Kinleith, FR172/4

Source	Df	diameter	height	straight	branch	malform	accept	dothi
Treatment	5	5.74***	4.09**	3.91**	3.61**	2.94*	4.97***	3.96**
Seedlot	3	2.47	9.70***	24.57***	123.09***	1.35	10.98***	0.53
Seedlot* Treatment	15	1.94*	8.53***	2.85***	0.86	2.22**	1.71*	0.70
Error	965							

F tests from analysis of variance at Takitoa, FR172/5

Source	Df	diameter	height	straight	branch	malform	accept
Treatment	5	6.78***	27.48***	7.34***	7.83***	8.05***	15.93***
Seedlot	3	26.15***	0.65	50.54***	307.48***	7.84***	26.75***
Seedlot* Treatment	15	4.10***	5.15***	3.17***	1.90*	1.60	2.43**
Error	1021						

F tests from analysis of variance at Otago Coast, FR172/6

Source	Df	diameter	height	straight	branch	malform	accept
Treatment	5	6.38***	27.57***	6.26***	49.13***	2.37	2.29
Seedlot	3	26.07***	0.49	18.85***	72.60***	2.11	3.89**
Seedlot* Treatment	15	3.91***	5.15***	0.63	7.52***	0.30	0.51
Error	1021						

Appendix 1, continued

Seedlot means at Woodhill FR172/1

Sdlt	description	n.	diameter	height	straight	branch	malform	accept
A	Multinodal	202	182 a	119	7.94 a	7.05 a	8.05	0.77
B	Long Internode	195	166 ab	115	7.24 b	5.15 b	7.69	0.68
C	High Density	200	165 b	116	7.51 ab	6.73 a	8.13	0.71
D	Low density	194	177 ab	118	7.42 ab	6.89 a	8.02	0.75

Seedlot means at Kaingaroa FR172/3

Sdlt	description	n.	diameter	height	straight	branch	malform	accept
A	Multinodal	156	171 a	103	7.13 a	7.28 a	7.58 a	0.71 a
B	Long Internode	146	146 b	102	4.93 c	2.71 c	6.11 b	0.27 c
C	High Density	147	152 ab	104	6.22 b	6.24 b	7.17 a	0.54 b
D	Low density	133	152 ab	104	5.99 b	6.05 b	7.14 a	0.44 b

Seedlot means at Kinleith FR172/4

Sdlt	description	n.	diameter	height	straight	branch	malform	accept	dothi
A	Multinodal	239	165	96	6.04 a	5.17 a	7.34	0.60 a	12.1
B	Long Internode	249	157	98	4.80 b	2.50 d	7.28	0.36 b	9.9
C	High Density	256	166	103	5.56 b	4.62 b	7.39	0.49 ab	12.6
D	Low density	245	164	103	4.94 b	4.14 c	7.11	0.43 b	11.9

Seedlot means at Takitoa FR172/5

Sdlt	description	n.	diameter	height	straight	branch	malform	accept	spiral	density
A	Multinodal	240	178 a	96	6.38 a	6.36 a	6.74 a	0.49 a	3.88	321
B	Long Internode	272	165 b	96	4.75 b	2.51 c	5.44 b	0.22 c	3.46	318
C	High Density	273	168 b	97	5.34 b	5.05 b	6.45 a	0.30 b	3.07	333
D	Low density	260	167 b	97	5.21 b	4.75 b	6.21 ab	0.31 b	3.66	323

Seedlot means at Otago Coast FR172/6

Sdlt	description	n.	diameter	height	straight	branch	malform	accept
A	Multinodal	208	178 a	93 a	5.95 a	4.95 a	5.64	0.39
B	Long Internode	216	166 ab	90 b	4.38 c	2.03 c	5.71	0.18
C	High Density	189	160 b	88 b	5.37 ab	4.04 ab	5.44	0.31
D	Low density	210	168 ab	94 a	5.07 b	4.02 ab	6.35	0.36

Appendix 1, continued

Treatment means at Woodhill FR172/1

trt	description	n.	diameter	height	straight	branch	malform	accept
2	500-500 unpr	67	215 a	114 b	7.69	6.75	8.13	0.81
3	1000-400 prune	164	180 b	130 a	7.18	6.51	7.59	0.63
4	500-500 unpr	87	174 b	101 c	7.38	6.41	7.84	0.76
5	1000-400 prune	159	167 b	119 ab	7.77	6.26	7.91	0.75
6	1000-400 prune	164	167 b	120 ab	7.63	6.41	8.07	0.79
7	1000-400 prune	150	158 b	117 b	7.57	6.57	8.37	0.71

Treatment means at Kaingaroa FR172/3

trt	description	n.	diameter	height	straight	branch	malform	accept
2	500-500 unpr	80	150 b	90 b				
3	1000-400 prune	160	153 ab	106 a	6.07	5.39	7.00	0.48
4	500-500 unpr	91	170 a	98 ab				
5	1000-400 prune	136	154 ab	110 a	6.05	5.47	6.88	0.47
6	1000-400 prune	152	159 ab	107 ab	6.12	5.67	7.26	0.54
7	1000-400 prune	134	150 ab	108 a	6.12	5.85	6.87	0.49

Treatment means at Kinleith FR172/4

trt	description	n.	diameter	height	straight	branch	malform	accept	dothi
2	500-500 unpr	235	163	101	5.57	4.21 ab	7.26	0.58	
3	1000-400 prune	128	166	104	5.37	4.31 ab	6.77	0.37	15.1 b
4	500-500 unpr	223	170	102	4.98	4.01 ab	7.15	0.43	
5	1000-400 prune	116	157	96	5.07	3.78 b	7.65	0.41	9.4 ab
6	1000-400 prune	138	165	98	5.55	4.33 a	7.28	0.51	8.3 a
7	1000-400 prune	149	151	100	5.47	3.91 ab	7.68	0.45	13.6 ab

Treatment means at Takitoa FR172/5

trt	description	n.	diameter	height	straight	branch	malform	accept
2	500-500 unpr	234	175	89 c	4.94	4.24	5.62 b	0.15
3	1000-400 prune	255	169	101 a	5.42	4.80	5.66 b	0.29
4	500-500 unpr	172	168	90 c	5.63	4.60	6.15 ab	0.25
5	1000-400 prune	127	170	100 ab	5.72	4.74	6.83 ab	0.42
6	1000-400 prune	130	166	97 b	5.54	4.88	7.00 a	0.44
7	1000-400 prune	127		99 ab	5.37	4.55	6.90 ab	0.35

Treatment means at Otago Coast FR172/6

trt	description	n.	diameter	height	straight	branch	malform	accept
2	500-500 unpr	250	187 a	94 ab	5.38 a	4.22	5.97	0.35
3	1000-400 prune	169	159 b	84 c	4.99 b	3.22	5.51	0.27
4	500-500 unpr	85	169 ab	88 bc				
5	1000-400 prune	159	159 b	90 abc				
6	1000-400 prune	175	168 b	97 a				
7	1000-400 prune	168	176 ab	92 abc				

Appendix 2. F tests and means from the 1994 trial

F tests from analysis of variance at Kaingaroa, FR215/1

Source	Df	diameter	height	straight	branch	malform	accept
Rep	1	4.65	8.39	2.57	0	0	2.71
Seedlot	5	0.66	3.43	11.48**	143.48***	3.41	4.43
Rep*Seedlot	5	4.42*	2.43	1.34	0.20	0.62	1.36
Treatment	2	0.77	10.83	0.47	38.07	7.71	22.34
Rep*Treatment	2	2.24	2.72	2.99	0.00	0.18	0.06
Seedlot*Treatment	10	1.77	1.61	0.43	0.30	1.27	1.12
Rep*Seedlot* Treatment	10	1.30	2.53**	0.79	4.75***	0.97	1.04
Error	1107						

F tests from analysis of variance at Rakatao, FR215/2

Source	Df	diameter	height	straight	branch	malform	accept
Rep	1	23.22	0.04	0.07	27.20	5.49	0.26
Seedlot	5	6.57*	2.14	65.13***	152.18***	12.59*	14.68**
Rep*Seedlot	4	1.06	1.13	0.20	0.56	0.63	1.02
Treatment	2	317.96*	14.53	3.43	0.99	1.39	0.21
Rep*Treatment	2	0.19	1.65	0.86	0.51	0.67	0.34
Seedlot*Treatment	9	1.29	1.90	1.03	1.64	1.86	1.53
Rep*Seedlot* Treatment	7	1.16	1.63	1.61	2.14	1.46	1.16
Error	1184						

F tests from analysis of variance at Glenledi, FR215/3

Source	Df	diameter	height	straight	branch	malform	accept
Rep	1	8.97	0	0	3.96	0	1.47
Seedlot	5	8.09*	16.87**	34.03**	114.02***	18.07*	3.10
Rep*Seedlot	4	0.74	0.20	0.20	1.84	0.09	2.09
Treatment	2	0.89	29.89		2.56	1.02	0.03
Rep*Treatment	2	0.97	0.14	0.02	0.39	0.35	0.90
Seedlot*Treatment	10	1.72	0.83	0.89	1.65	0.28	1.18
Rep*Seedlot* Treatment	8	1.93	11.48***	2.05**	1.24	3.16**	1.45
Error	1205						

Seedlot means at Kaingaroa FR215/1

Sdlt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	density
1	Long Internode	210	127	7.80	5.91 bc	2.02 c	6.64	0.42	-3.99 b	328 b
2	Multinodal	153	131	7.35	6.37 ab	6.18 a	6.25	0.49	-2.70 ab	332 ab
3	High Density	194	131	8.09	6.61 a	6.11 a	7.17	0.61	-4.91 b	348 a
4	Low density	202	137	8.26	6.54 a	5.40 ab	6.76	0.54	-3.11 ab	300 c
5	GF7	202	126	7.56	5.62 c	4.23 b	6.18	0.33	-2.21 a	327 b
6	GF14	182	129	7.50	5.86 c	4.49 ab	6.53	0.39	-2.02 a	322 b

Appendix 2, continued

Seedlot means at Rakautao FR215/2

Sdlt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	density
1	Long Internode	231	197	11.63	5.34 c	2.20 c	4.07 b	0.20 d	-4.29 b	351 a
2	Multinodal	235	200	11.80	6.13 b	6.87 a	5.98 a	0.35 bc	-2.89 ab	344 ab
3	High Density	235	200	12.20	6.74 ab	6.78 a	6.02 a	0.49 ab	-4.59 b	352 a
4	Low density	232	213	12.15	6.82 a	6.38 a	5.92 a	0.51 a	-3.57 ab	298 c
5	GF7	67	196	11.49	5.20 c	5.80 b	5.83 a	0.20 d	-1.25 a	341 ab
6	GF14	215	191	12.10	5.32 c	5.41 b	5.51 a	0.25 cd	-1.75 ab	343 ab

Seedlot means at Glenledi FR215/3

Sdlt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	Density
1	Long Internode	223	164 ab	7.84	5.48 c	2.88 e	5.95	0.21	-3.34	325 b
2	Multinodal	217	166 ab	7.77	6.30 ab	6.93 a	6.76	0.38	-4.04	334 ab
3	High Density	218	165 ab	7.99	6.25 ab	6.65 ab	7.21	0.44	-3.57	344 a
4	Low density	234	175 a	8.67	6.38 a	6.28 b	6.70	0.44	-3.70	297 c
5	GF7	119	153 b	7.76	5.61 bc	5.03 d	6.56	0.29	-2.81	324 b
6	GF14	223	164 ab	7.50	6.00 abc	5.70 c	6.17	0.26	-2.78	327 b

Treatment means at Kaingaroa FR215/1

Trt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	density
A	500-500 unpr	240	134	7.20						
B	1000-400 prune	452	129	8.02	6.18	4.63	6.70	0.47	-2.98	325
C	1000-400 prune	451	130	8.02	6.11	4.67	6.51	0.45	-3.21	326

Treatment means at Rakautao FR215/2

Trt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	density
A	500-500 unpr	230	224	11.21	5.74	5.65	5.52	0.36		
B	1000-400 prune	514	194	12.22	6.02	5.68	5.49	0.35	-3.12	335
C	1000-400 prune	471	194	12.32	6.21	5.60	5.66	0.36	-3.50	340

Treatment means at Glenledi FR215/3

Trt	description	n.	diameter	ht	straight	branch	malform	accept	spiral	density
A	500-500 unpr	240	167	7.56	5.99	5.68	6.55	0.34		
B	1000-400 prune	517	166	8.04	5.99	5.57	6.69	0.34	-3.36	320
C	1000-400 prune	523	164	8.07	6.13	5.62	6.43	0.34	-3.40	328