PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

Theme: Radiata Management

Task No: 1.5 **Report No. FFR- RO24**
Milestone Number: 1.5.2

Special Purpose Breed Trials Analysis

Authors:
J D Hayes and J C Grace

Research Provider:
Scion

Date: January 2009

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 1992 special purpose breeds trials are being assessed at five locations:

- Woodhill
- Kaingaroa
- Kinleith
- Takitoa (Southland)
- Otago Coast.

These trials contain six different seedlots:

- GF7
- GF14
- GF18 (high wood density)
- GF27 (highly multinodal)
- GF28 (low wood density)
- GF13/LI25 (uninodal)

These trials contain two silvicultural treatments:

- Plant 500 stems/ha and leave, no prune
- Plant 1000 stems/ha and thin to 400 stems/ha, access prune only

Mean top height development was influenced by site conditions. The differences between seedlot were not significant, but the GF14 seedlot performed far better than the other seedlots at Woodhill. There was a significant difference due to treatment, with the treatment planted at 500 stem/ha having poorer height growth.

Basal area development was influenced by site conditions and seedlot but not silvicultural treatment. Basal area growth was highest for the GF27 seedlot at all sites except Woodhill, where the GF14 seedlot produced the highest basal area.

BACKGROUND

In 1999, there was an agreement between Stand Growth Modelling Cooperative and the Radiata Pine Breeding Cooperative (now Radiata Pine Breeding Company) to jointly support a series of trials to compare the performance of special-purpose breeds across regions. Two series were designed in 1991; one was planted in 1992 and the other in 1994. This report analyses the 1992 trial series only.

The Stand Growth Modelling Cooperative (SGMC) and the Radiata Pine Breeding Company (RPBC) jointly supported these trials which will extend knowledge gained from the genetic gain and silviculture/breed trials (Hayes, 2001). Data collected from these and other trials in the series will give a better understanding of the growth and performance of the improved breeds so that growth models can be developed or modified to reflect growth increase due to genetic improvement.

Plot establishment and silvicultural treatment has been completed according to plan in most cases. PSPs are measured annually for the first four years starting from the first winter after plot establishment. Each trial, once established, is measured during the same winter month each year. A full establishment report, including growth data from these trials at the first measurement is presented in Stand Growth Modelling Cooperative Report No. 101.

Scion staff carried out form assessments at the time of PSP plot establishment for all trials in the 1992 series. The data from these assessments were analysed and reported in two documents SGMC[1] Report No. 107 (Analysis by Trial and Seedlot) and RPBC[2] Report No. 137 (Analysis across Site by Trait). A summary of these results is attached in Appendix 1 and Appendix 2.

[1] SGMC = Stand Growth Modelling Cooperative
[2] RPBC = Radiata Pine Breeding Company

INTRODUCTION

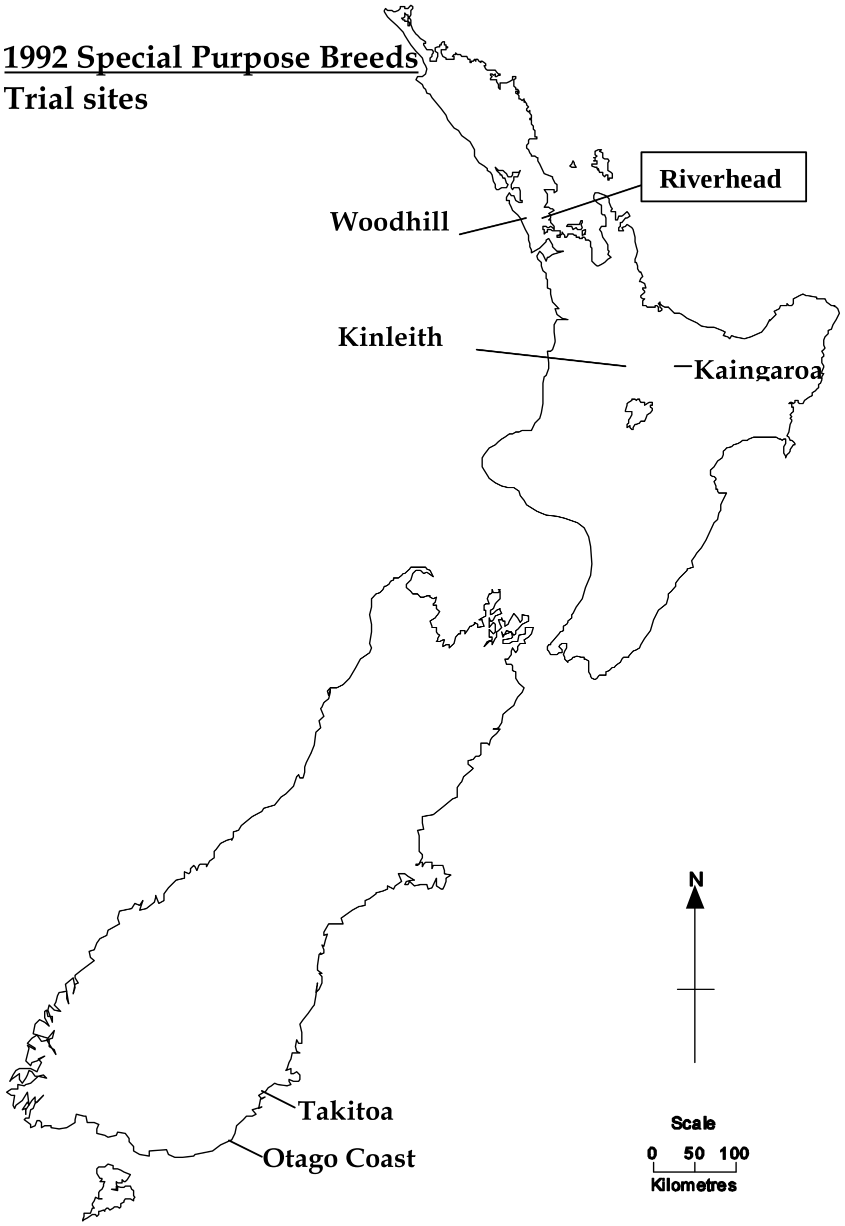
TRIAL LOCATIONS

Six sites were planted in the 1992 series, but one site at Riverhead Forest was abandoned before plot establishment. Overall, three different growth regions are represented by these trials. Table 1 shows details of the 1992 Special-purpose Breed trials that are now part of a large series of genetically improved trials now under the umbrella of Future Forests Research (FFR).

Table 1. Trial sites established as part of the 1992 Special-Purpose Breed trial series.

Trial Number *	Forest Name	Altitude (m)	Forest Owner as at January 2009	Growth Model Region	Site Category
FR 172/1	Woodhill	10	Hancock Forest Mgmt	Auckland Sands	Low SI
FR 172/3	Kaingaroa	450	Timberlands	Central N. Island	Medium SI
FR 172/4	Kinleith	380	Hancock Forest Mgmt	Central N. Island	High SI
FR 172/5	Takitoa	40	City Forests	Southland	High BA
FR 172/6	Otago Coast	140	Wenita Forest Products	Southland	Medium SI

* Trial FR172/2, Riverhead Forest was abandoned primarily due to a major gorse undergrowth problem.



PLOT ESTABLISHMENT

PSP plot establishment took place at various times between November 1999 and February 2001, when trials were aged between 7.6 and 8.8 years. The original plot design was not used at PSP plot establishment, in order to enable a larger number of replications per treatment to be established. Table 2 shows the actual trial design where Treatment 1 has two replications and Treatment 2 four replications.

Table 2. PSP Plot design in the 1992 special-purpose breed trials.

Silviculture					Planting stock					
Trt	Pruning	Stocking (stems/ha)		Thinning						
	Access only	Initial	Final	Ratio	GF7 (88/102)	GF14 (88/105)	GF18 (91/523)	GF27 (91/296-297)	GF28 (91/294)	GF13 (LI25) (89/15)
1	Unpruned	500	500	1:1	•		••	••	••	••
2	2m	1000	400	2.5:1		••	••••	••••	••••	••••

The planting stock used in these trials was selected to cover a range of special-purpose breeds such as high and low density, uninodal and highly multinodal, as well as some control seedlots of GF7 and GF14. Table 3 shows the range of seedlots used.

Table 3. Seedlots used in the 1992 Special-Purpose Breed trials.

Seedlot Number	Seedlot Rating	Breed	Description
88/102	GF7	Climbing select	Kaingaroa & Rotoehu climbing select
88/105	GF14	‘850’ orchard	OP mix of ‘850’ series from Gwavas, Kaingaroa and Waimihia
91/523	GF18*	High wood density	OP Kaingaroa seed orchard
91/296, 91/297 mix	GF27*	Highly multinodal	CP Proseed mix
91/294	GF28*	Low wood density	CP mix of top 16 ‘268’ clones x 850.55
89/15	GF13(LI25)	Uninodal	OP Tikokino mix of 7 clones

* Only a small number of parents have contributed to the seedlot mix, thus less confidence should be placed on the GF rating.

HEIGHT AND BASAL AREA DEVELOPMENT

Methods

There are a total of 127 PSP plots (excluding plots planted with a GF7 seedlot) that have been measured regularly from 2000 onwards. These plots have up to eight re-measurements (over 700 plot measurements) aged from 8 to 16 years. The latest measurement was in 2008 at age 16. The following data were extracted from the Scion PSP database system: Plot ID; forest; GF rating; age at measurement; stems/ha; mean top height (MTH), basal area (BA) and volume.

Note: The GF7 seedlot was not used in any analysis as there was no replication.

The trends in both MTH and basal area with age were plotted in several ways:

- By seedlot and labelled by site (Figures 1 and 2)
- By site and labelled by seedlot (Figures 3 and 4)
- By site and labelled by treatment (Figures 5 and 6)
- By treatment and labelled by site (Figures 7a and 7b)

The SAS® procedure, PROC GLM, was used to determine the influence of site and silvicultural treatment on the 2008 measurements (age 16 years) of MTH and BA. Independent variables considered were site, treatment (trt), and the interaction of site and treatment.

This procedure uses the method of least squares to fit mathematical equations to observed data. Both continuous variables (such as mean top height and basal area) and class variables (such as site and treatment) may be included in the equation as independent variables. An illustrative example equation is:

$$y = c + a_1 x_1 + a_2 x_2 + \sum_i b_{1i} z_{1i} + \sum_j b_{2j} z_{2j}$$

Where:

y	is the dependent variable to be predicted
c	is the model intercept
x_1, x_2	are continuous variables
a_1, a_2	are the model parameters associated with the continuous variables (actual predicted values are the model coefficients)
z_1, z_2	are class variables. These have the value 1 if the data correspond to that class, otherwise the value is zero
b_{1i}, b_{2j}	are the model parameters associated with the class variables (actual predicted values are model coefficients)

Results

For MTH the GF rating was not significant and for BA the treatment was not significant. For both MTH and BA the interaction between site and GF rating was not significant, so the model was run without the interaction term (the coefficients from this run are in Table 4). For MTH the interaction between site and treatment was significant, but not at the Kinleith site. The most significant difference by treatment was at the windy Southland site, whereas the Kinleith site (not significant by treatment) is more sheltered and has very dense undergrowth. It seems that the lower initial stocking may lower height growth. This result was also seen in the previous trials planted in 1987. The model explained 88% of the MTH variation and 60% of the BA variation.

PROC GLM analysis (Table 4), using data collected at age 16 years, indicated that MTH varied by less than 1 m for different seedlots, but BA varied by up to 5 m^2 for different seedlots.

Table 4. 1992 SPB Trials – Model coefficients from PROC GLM analysis of 2006 MTH and BA measurements (age 16yrs) where independent variables were Site, GF and TRT

Parameter	Value	MTH Coefficient (m)	BA Coefficient (m^2/ha)
Intercept		21.9	40.7
SITE	Woodhill	2.4	-10.6
SITE	Kaingaroa	6.8	0.8
SITE	Kinleith	5.6	-0.5
SITE	Takitoa	0.4	4.9
SITE	Otago Coast	0.0	0.0
GF	13 - long internode		-1.37
GF	14 – seed orchard		3.31
GF	18 – high wood density		-0.19
GF	27 – highly multinodal		4.70
GF	28 - low wood density		0.000
TRT*	1 (500 unthinned)	-0.8	
TRT*	2 (1000 thin to 400)	0.0	
Model R^2		0.88	0.60

* TRT = silvicultural treatment

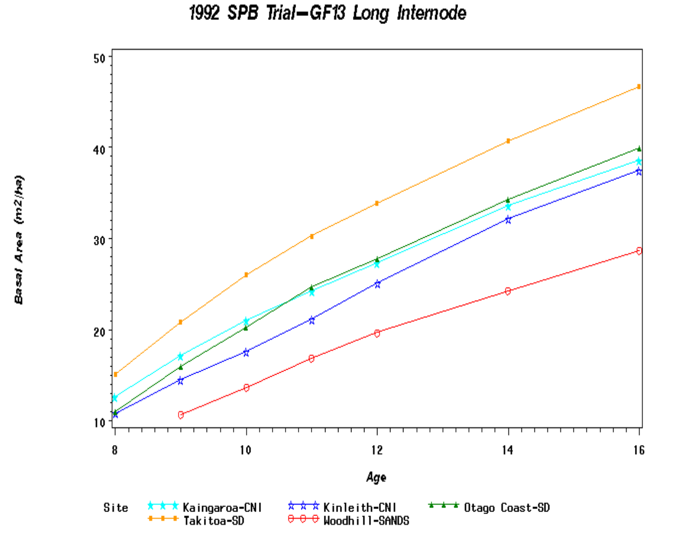
Figure 1. 1992 SPB Trials – Trends in MTH with Age for each Seedlot labelled by Site

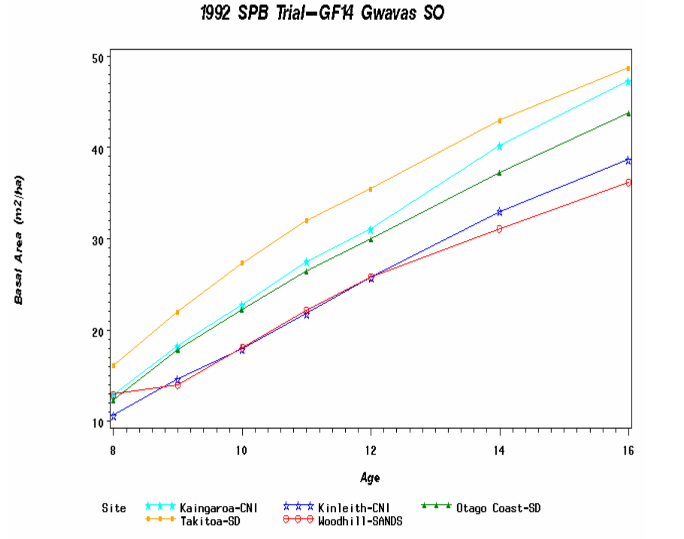
Comments:

Height growth is

- best at Kaingaroa and Kinleith
- intermediate at Woodhill
- lowest at the two Southland sites
- generally consistent across all seedlots
- maximum variation between the sites is the GF14 seedlot.

Figure 2. 1992 SPB Trials – Trends in Basal Area with Age for each Seedlot labelled by Site





Comments:

Basal area growth is

- generally highest at Takitoa for all seedlots
- least at Woodhill
- some interchange between other three sites across the seedlots
- maximum variation between the sites is the GF13 long internode seedlot

Figure 3. 1992 SPB Trials – Trends in MTH with Age for each Site labelled by Seedlot

Comments:

Height growth is

- generally very similar across all seedlots for a given site
- notable at Woodhill, where the GF14 seedlot is considerably better than all other seedlots

Figure 4. 1992 SPB Trials – Trends in Basal Area with Age for each Site labelled by Seedlot

Comments:

Basal area growth is

- the greatest between seedlots at Kaingaroa
- the least different at Takitoa between seedlots
- at Woodhill the GF14 seedlot performs best
- at the four other sites the GF27 (highly multinodal) is best.

Figure 5. 1992 SPB Trials – Trends in MTH with Age for each Site labelled by Treatment

Comments:

Height growth is

- little different between the treatments
- slightly better for Treatment 2 which has the higher initial stocking
- significant by treatment for all sites except Kinleith (a high site index but also dense undergrowth)

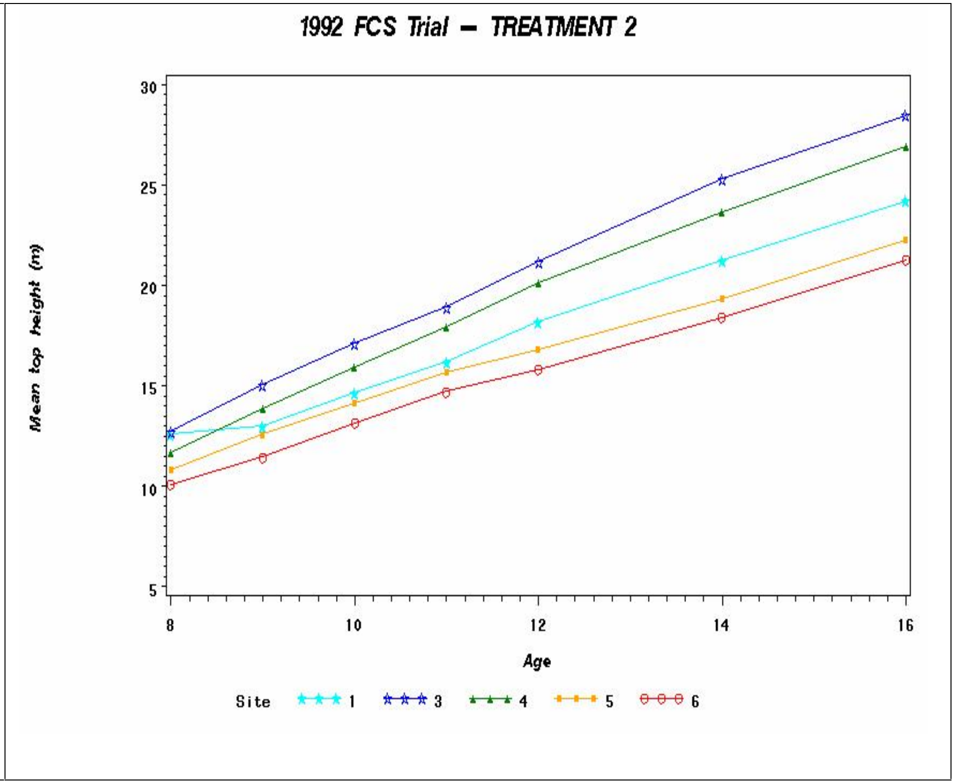
Figure 6. 1992 SPB Trials – Trends in BA with Age for each Site labelled by Treatment

Comments:

Basal area growth is

- inconsistent with treatment across the sites
- not significant by treatment, because of the reverse trend between Kaingaroa and Kinleith
- better for Treatment 2 only at the Kaingaroa site

Figure 7a. 1992 SPB trials - Trends in MTH with age for each treatment, labelled by site



Site 1 = Woodhill; Site 3 = Kaingaroa; Site 4 = Kinleith; Site 5 = Takitoa; Site 6 = Otago Coast

Figure 7b. 1992 SPB trials - Trends in Basal Area with age for each treatment, labelled by site

Site 1 = Woodhill; Site 3 = Kaingaroa; Site 4 = Kinleith; Site 5 = Takitoa; Site 6 = Otago Coast

ASSESSMENT OF STEM FORM (by PSP defect code)

Methods

Stem form is currently assessed and recorded on the PSP system in the form of defect codes by tree and by measurement. Defect codes considered as Malformations (MF) include the following: dead top, broken top, toppled, leaning, swept, crooked, forked or multi-leader. Defect codes considered for Straightness (ST) include the following: butt sweep, crooked, swept and leaning. To analyse these data, trees were identified as having a defect or not having a defect. Any tree that was assessed as having a defect at any measurement age was considered to be defective (some trees had more than one defect over time).

Each plot had a variable calculated to give the percentage of trees with stem defects (i.e. total number of trees with defects/ total number of trees in the plot). Figure 8 shows this percentage by seedlot and site.

Results

There were consistently more defects on the two Southland sites compared to the three North Island sites (Figure 8 – All). The long internode seedlot (GF13) shows slightly more malformation than other seedlots (Figure 8 – MF); not unexpectedly as the branch whorls tend to have less resistance particularly to wind (RPBC Report No. 137). Interestingly, low wood density seedlot (GF28) shows a reasonably high number of defects. The Sands site generally has the least defects overall, except for the GF27 seedlot. Figure 8, straightness (ST) only defects show the same trends by site as the malformation only defects.

Figure 8. 1992 SPB trials – Percentage of trees with defects for each seedlot, labelled by site

CONCLUSIONS

The 1992 Special Purpose Breed trial series was designed to have seedlots of very different growth, form and wood properties. The GF (growth) ratings varied from 7 to 28 for the 6 seedlots and the stem form ranged from highly multinodal to uninodal. This analysis of height growth showed no significant difference by seedlot, even though the growth ratings were very different. The basal area did show significant differences by seedlot (BA varied by up to 5 m^2), with the GF27 seedlot generally performing the best.

There were significant site differences, as expected, with the Woodhill site showing the least growth. This site was also different from the others in that the GF14 seedlot performed best.

The treatments in this trial were altered at plot establishment to allow for better replication. This resulted in only two similar treatments, where only initial planting stocking was very different but the final stocking was basically the same (Table 2). Also, there were two pruning treatments but again the difference was small. Consequently the treatment effect was not significant for BA (there was a reverse trend between Kaingaroa and Kinleith sites). There was a significant difference due to treatment for MTH for all sites except Kinleith (a high site index with dense undergrowth). The treatment planted at 500 stem/ha has poorer height growth overall.

Wood property data has not been collected for these trials yet, so no analysis by seedlot and density was carried out.

Form assessments using the GTI scoring methods were analysed in detail in 2001 (SGMC Report 107 and RPBC Report 137). The current analysis used the PSP defect code system. When growth data are collected, only stems with noticeable defects are scored. Nonetheless similar results were found to the early analysis which was based on all trees scored. The long internode seedlot (GF13) shows slightly more malformation than other seedlots, not unexpectedly as the branch whorls tend to have less resistance particularly to wind (RPBC Report 137). The two South Island sites showed a larger amount of malformation overall than the 3 North Island sites.

REFERENCES

<u>SGMC Reports</u>

100. Hayes, J.D. 2001. Trials designed to quantify growth and yield gains from genetically improved radiate pine – Fourth revision.

101. Hayes, J.D. 2001. Establishment report for the 1992 Special-purpose Breeds trials.

107. Hayes, J.D. 2001. Special-purpose Breed Trials – Form assessments.

<u>RPBC Report</u>

137. Low, C.B., Miller, M.A. First assessment of 1992 Special-purpose Breeds trials.

APPENDIX 1

Form Assessment and Growth Measurement Results by Trial

GTI staff carried out visual form assessments at the time of PSP plot establishment for all trials in the 1992 series. The trials were also measured for growth (height and diameter) at the same time as part of normal PSP establishment procedures. The following assessments (Table 1) are summarised by trial (site) and seedlot, and the seedlot means are provided:

Table 1. Assessment traits in the 1992 Special-Purpose Breed trial series

TRAIT	UNITS	DESCRITPION	AGE*
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

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

The 'Tukey' test was used (because the sample size was not equal for all treatments means) to test for significant differences between seedlots for the traits DBH (cm), height (m), straightness, branching and malformation. All trials had less than three plots planted in the GF7 seedlot. Consequently, the GF7 seedlot had significantly fewer trees in these trials, so this seedlot was not included in the analysis for significant differences. Also the acceptability assessment was not tested because not all plots were assessed.

Seedlot mean values with the same letter are not statistically different.

1. FR 172/1, Woodhill Forest, February 2001 assessment results

Age 8.8 years

GF	Seedlot	N(DBH)	diameter		height		straight		branch		malform		accept
7 *	Climbing Select	18	20.5		12.2		7.7		6.8		7.5		0.78
13	Long internode	206	15.7	b	11.5	b	7.2	c	5.2	b	7.7	a	0.68
14	Gwavas SO	86	18.2	a	13.1	a	7.7	ab	6.5	a	7.7	a	0.70
18	High Wood Density	208	15.9	b	11.6	b	7.5	bc	6.7	a	8.1	a	0.71
27	Highly Multinodal	217	17.1	ab	11.9	b	8.0	a	7.1	a	8.1	a	0.77
28	Low Wood Density	199	17.3	a	11.8	b	7.4	bc	6.9	a	8.0	a	0.75

* The GF7 seedlot was not included in the significant difference test because sample size was too small.

Diameter
The GF7 seedlot has the largest mean diameter. The GF14 seedlot is also doing well, as it is for height. There are very little significant differences between the other seedlots.

Height
The GF14 seedlot is the tallest, on average and is significantly different from the other seedlots (note - there are only two plots).

Straightness
The GF13 and GF27 seedlots are significantly different, but they are all relatively straight trees.

Branching
The long internode seedlot, GF13, is significantly different from the others, but this site shows the least uninodal tendency overall. The GF27 seedlot is the most multinodal, as expected.

Malformation
There are no significant differences between seedlots. Overall malformation is low at this site.

Acceptability
Overall acceptability is high at this site, with very little difference between seedlots.

2. FR 172/3, Kaingaroa Forest, November 1999 assessment results

Age 7.6 years

GF	Seedlot	N(DBH)	diameter		height		straight		branch		malform		accept
7*	Climbing Select	21	15.4		9.9		na		na		na		na
13	Long internode	221	14.5	b	10.2	a	4.9	c	2.7	c	6.1	b	0.21
14	Gwavas SO	81	14.5	b	10.4	a	6.0	b	5.8	b	6.9	ab	0.32
18	High Wood Density	226	15.2	b	10.4	a	6.2	b	6.3	b	7.2	a	0.48
27	Highly multinodal	225	17.1	a	10.3	a	7.1	a	7.3	a	7.6	A	0.58
28	Low Wood Density	199	15.1	b	10.4	a	6.0	b	6.1	bc	7.11	A	0.39

* The GF7 seedlot was not included in the significant difference test because sample size was too small. No form assessments were carried out for this seedlot.

Diameter
The GF27 seedlot is significantly larger for diameter growth. There are no significant differences between the other seedlots.

Height
There are no significant differences between seedlots.

Straightness
The GF27 seedlot is significantly different, and these trees are much straighter than other seedlots.

Branching
The long internode seedlot, GF13, is significantly different and highly uninodal, as expected. The GF27 seedlot is highly multinodal as expected, and has the highest rating of all sites.

Malformation
There is very little difference between seedlots. Overall malformation is low at this site.

Acceptability
All seedlots except GF27 have a less than 50% acceptance as a final crop tree. The GF13 seedlot is very low with only 21% acceptance.

3. FR 172/4, Kinleith Forest, December 1999 assessment results

Age 7.6 years

GF	Seedlot	N(DBH)	diameter	height	straight	branch	malform	accept
7*	Climbing Select	22	16.3	9.8	4.4	3.8	6.8	0.41
13	Long internode	203	13.2 ab	9.8 ab	4.9 c	2.5 c	7.4 a	0.36
14	Gwavas SO	82	12.4 b	10.0 ab	5.8 ab	4.1 b	7.0 a	0.42
18	High Wood Density	214	14.4 a	10.3 a	5.4 bc	4.5 b	7.5 a	0.48
27	Highly multinodal	203	14.2 a	9.6 b	6.3 a	5.2 a	7.7 a	0.59
28	Low Wood Density	195	14.4 a	10.3 a	5.1 c	4.1 b	7.1 a	0.43

* The GF7 seedlot was not included in the significant difference test because sample size was too small.

Diameter
The GF7 seedlot has the largest mean diameter. There is very little difference between the other seedlots.

Height
GF18 and GF28 are the tallest seedlots, on average, but there is little significant difference between the seedlots.

Straightness
The seedlots are variable for straightness, with the GF7 seedlot the worst. The GF27 seedlot has a higher than average rating, and is significantly different from the other seedlots except GF14.

Branching
The long internode seedlot, GF13, is significantly different and strongly uninodal, as expected. At this site all seedlots do have a uninodal tendency though, except the highly multinodal GF27 seedlot.

Malformation
There are no significant differences between seedlots. Overall malformation is low at this site.

Acceptability
All seedlots except GF27 have a less than 50% acceptance of live trees for the final crop. The GF13 seedlot has the lowest acceptance of 36%.

4. FR 172/5, Takitoa Forest, February 2000 assessment results

Age 7.8 years

GF	Seedlot	N(DBH)	diameter	height	straight	branch	malform	accept
7*	Climbing Select	25	19.5	8.8	4.7	3.2	6.5	0.15
13	Long Internode	243	18.6 bc	9.6 A	4.9 b	2.6 c	5.6 c	0.20
14	Gwavas SO	119	19.7 a	9.7 A	6.3 a	6.4 a	7.4 a	0.26
17*	Local clone	265	19.3 ab	9.9 A	5.8	4.1	5.7	na
18	High Wood Density	241	18.7 bc	9.7 A	5.3 b	5.1 b	6.5 abc	0.30
27	Highly Multinodal	232	19.2 ab	9.6 A	6.5 a	6.5 a	6.9 ab	0.45
28	Low Wood Density	245	18.3 c	9.7 A	5.3 b	4.8 b	6.3 bc	0.32

* The GF7 seedlot was not included in the significant difference test because sample size was too small. The GF17 seedlot was not included in the significant difference test for the straightness, branching and malformation assessments because the sample size was too small.

Diameter
The GF14 seedlot has the largest diameter and the GF28 the smallest on average, and these are significantly different.

Height
The GF7 seedlot has the smallest mean height, and the GF17 (local clone) has the tallest mean height.. There are no significant differences between the seedlots.

Straightness
Generally there is a low rating for straightness at this site, with the GF27 and GF14 seedlots performing best for straightness.

Branching
The GF14 and GF27 are shown to be very multinodal. At this site all other seedlots have a uninodal tendency though. The long internode seedlot, GF13, as expected, has the lowest number of whorls per year and the GF7 seedlot is also highly uninodal in this trial.

Malformation
There are no serious malformation problems indicated at this site. The GF14 and GF13 are the only seedlots that are significantly different.

Acceptability
The GF17 seedlot was not assessed at this trial. Overall acceptability is low at this site. Trees of GF7 and GF13 seedlots, in particular, have a very low acceptability rate (≤ 20%).

5. FR 172/6, Otago Coast Forest, February 2000 assessment results

Age 7.8 years

GF	Seedlot	N(DBH)	diameter	height	straight	branch	malform	accept
7*	Climbing Select	0	na	na	na	na	na	na
13	Long Internode	194	16.4 bc	9.0 ab	3.9 b	2.0 c	5.1 a	0.17
14	Gwavas SO	81	17.4 ab	9.2 ab	5.7 a	4.6 ab	6.1 a	0.34
18	High Wood Density	217	15.7 c	8.8 b	5.3 a	3.7 b	5.6 a	0.31
27	Highly Multinodal	209	17.7 a	9.3 ab	5.8 a	4.8 a	5.5 a	0.39
28	Low Wood Density	218	16.6 bc	9.4 a	4.9 ab	4.0 ab	6.8 a	0.36

* There are no plots in the GF7 seedlot at this site

There are <50 observations for each seedlot for the straightness, branching and malformation assessments at this site. This may bias the results.

Diameter
There are significant differences between two seedlots only, the GF14 and GF18, which have the largest and smallest diameters, on average, respectively.

Height
There are significant differences between two seedlots only, the GF18 and GF28 which have the shortest and tallest trees, on average, respectively.

Straightness
This site has the lowest straightness values overall (i.e. trees tend to be rather crooked). There is very little significant difference between seedlots.

Branching
The GF13 seedlot, as expected, is significantly more uninodal than other seedlots. At this site though, all seedlots show a uninodal tendency, with no branching values >5 (even the highly multinodal seedlot).

Malformation
There are no significant differences between the seedlots but this site has the lowest (worst) malformation values overall. This site shows a tendency for greater malformation but the values are still above average.

Acceptability
Acceptability is particularly low for the GF13 seedlot (only 17% of live trees are acceptable as final crop trees). This seedlot also has noticeably low values for straightness and malformation. All seedlots have < 40% acceptance of trees for the final crop, which means this is a poor site for form.

APPENDIX 2

Form Assessment Analysis across Site by Trait

Assessment traits that were measured at age 7.5 in all trials (except the Woodhill site - age 9 assessment) are shown in Table 1.

There were two main comparisons between seedlots. 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.

Analysis:
An across site analysis of each trait were carried out 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

Seedlot was treated as a fixed effect, while site, treatment and all of their interactions were assumed to be random effects.

Results:

The F tests from the overall analysis of variance for the 1992 trial are shown in Table 1. 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 2.

Treatment[3] 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 3. 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 4. 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.

Table 1. F tests from overall analysis of variance in the 1992 Special-Purpose Breed trial series

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

[3] The treatments analysed were the proposed treatments for the trial, but these were changed at PSP plot establishment to allow better replication.

Table 2. Site means, 1992 trials

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 3. Treatment means, 1992 trials

treat	description	n.	diameter	height	straight	branch	malform	accept
2	500-200 prune	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	500-200 unpr	771	170 ab	9.7 b	5.65	4.66	6.92 bc	0.39
5	1000-400 unpr	797	163 bc	10.1 ab	6.27	5.17	7.34 ab	0.51
6	1000-600 unpr	822	165 abc	10.2 ab	6.28	5.39	7.43 ab	0.55
7	1000, no silv.	481	160 c	10.2 ab	6.16	5.23	7.49 a	0.51

Table 4. Seedlot means, 1992 trials

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

Discussion:

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 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.