New Zealand Forest Site Management Cooperative

INSTALLATION REPORT FOR NZFSMC TEKAPO BORON TRIAL FR358/3

BY

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Sustainable Management of Forest Ecosystems
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Planting the Tekapo boron trial, winter 2000.

This report is confidential to members of the NZ Forest Site Management Cooperative.

EXECUTIVE SUMMARY

This report describes the following aspects of the NZFSMC boron trial FR358/3:

- the objectives for the trial,
- site selection criteria (location, associated soils information, historical foliage data and recent environmental data);
- trial design (treatments, plot details and planting stock),
- installation issues and procedures including layout of plots in the trial; allocation of blocking and treatments; fertiliser requirements,
- schedule for future measurements and assessments and data storage; statistical analysis, and reporting.

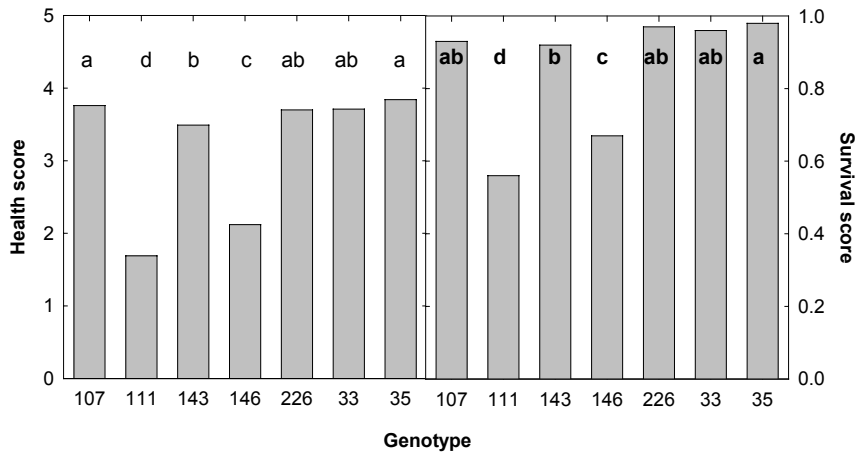
In brief, the trial was installed in the dryland forestry research area on Balmoral Station (McKenzie Basin), in August and September 2000. The planting lines were ripped and scarified. The planting material consisted of 7 genotypes: 3 families and 4 clones of radiata pine. There were 4 replicates of the following 8 treatments:

- B added as ulexite (~10% B) at rates of at 0, 8, 16 and 32 kg B/ha, by
- ± weed control.

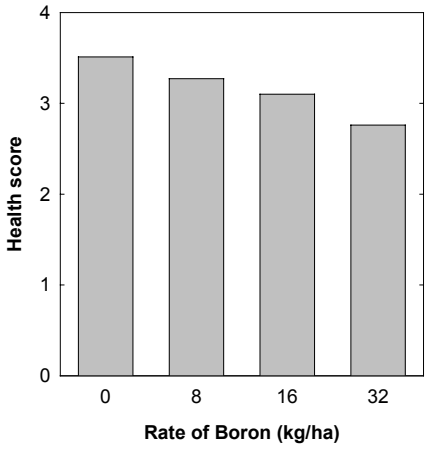
Fertiliser was applied in November 2000. Initial weed control, across all of the plots, was provided by the scarification when the trial was ripped. Additional weed control will be applied in the spring of 2002.

Since establishment and the initial measurement (winter 2000), the survival and health of the trees was assessed one year after planting (September 2001). Of the three significant factors (blocking, B rate and genotype), genotype explained the greatest proportion of variation in the survival and health of the trees.

After one year, survival across the trial was 85%. An analysis of the survival data indicated that two of the 7 genotypes had particularly poor survival rates and low health scores - clones 111 and 146. →



Survival was not affected by the rate of B addition but the health scores were. As the rate of B increased, the health score significantly decreased.



Survival and health scores were lowest in Block 4 of the trial, which was located nearest to the edge of the terrace.

INTRODUCTION

Background to the FR358 trial series

The background to the FR358 trial series was described by Olykan *et al.* (2000). The 'Tekapo' trial is the third in the series. The other two trials are Balmoral (FR358/1, Balmoral Forest, North Canterbury) and Lake Taupo (FR358/2, Lake Taupo Forest, Central North Island).

FR358 objectives

The objectives of the trial series are to test the following hypotheses on a range of sites that vary in rainfall (total annual rainfall and seasonal distribution), soil boron (B) supply (which is closely linked to soil moisture), and other soil physical and chemical characteristics such as water holding capacity and organic matter content.

Hypotheses:

- B addition significantly improves wood cell characteristics and wood quality in radiata.
- Weed control improves B availability to trees by increasing soil moisture availability and removing competition for B.
- A measure of the rainfall in the spring/summer season prior to foliage sampling in March can assist in the diagnosis of foliar B concentrations.
- Internal retranslocation significantly increases the efficiency of B use and prolongs the effect of added B.
- The soil can act as a reservoir of B for a number of years after B addition.

SITE SELECTION AND SOILS

Site selection

Davis *et al*. (2001) summarised a suite of trials conducted in the South Island high country with breeds of radiata pine, ponderosa pine (*Pinus ponderosa*) and Corsican pine (*Pinus nigra*) on a number of different soil types. The object was to identify fertiliser requirements (N, P, S and B) for the establishment of pines and Douglas fir in the high country. The only nutrient that the trees responded too was B. The responses included significant improvements in foliar B concentrations, form and height growth.

The major characteristics of the Tekapo site are low annual rainfall with a risk of summer drought, hard frosts and snow possible in winter, and slow growth rates.

Site and soil details

General forest stand information

The dryland forestry research site at Tekapo is on Balmoral Station, in the McKenzie Basin, and is owned by Andrew and Karen Simpson (**Figure 1**).

The trial site is on a large flat terrace, at an altitude of 730 m asl, and is located at E2303500 N5682700. This is the first rotation of trees on this site. The existing ground cover vegetation is brown top, fescue, *Hieracium*, and tussock. Rabbits and hares have been a significant pest problem and although numbers were relatively low in 2000, when the trial was established, there is evidence that the populations are rebuilding. Periodic rabbit control occurs.

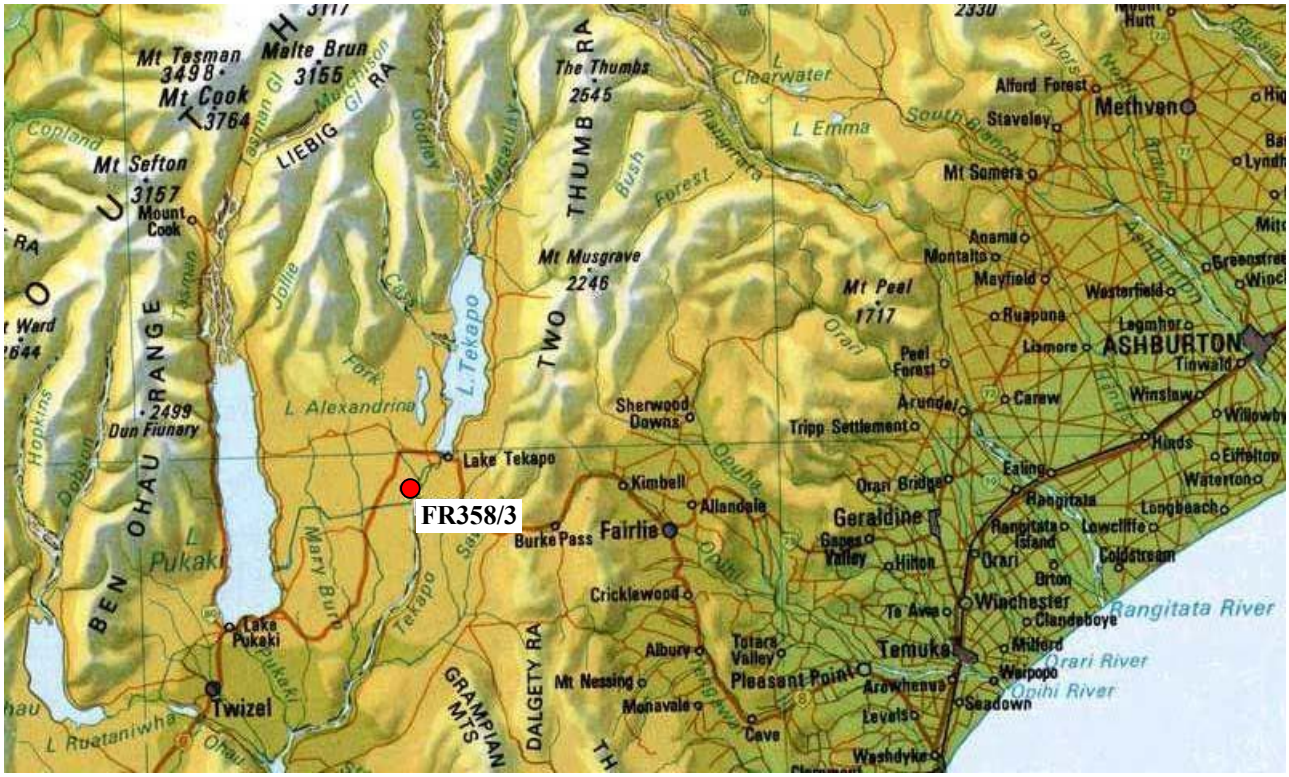
Historical foliage data

Davis *et al*. (2001) summarised the foliar nutrient concentrations of radiata pine grown in a trial on the Pukaki soil. The results are presented in **Table 1** and are a mean of the treatments in the trial.

Table 1: Summary of foliar nutrient concentrations for radiata pine on the Pukaki soil (from Davis *et al.* 2001).

N	P	S	K	Ca	Mg	B	Zn	Cu
--- % ---						--- µg/g ---		
1.36	0.14	0.08	0.53	0.28	0.09	8	12	3.1

Figure 1: Location of the research area in the McKenzie Basin, South Island high country.



Soils

The soils on the terrace are Pukaki soils. This is an Orthic Brown soil consisting of 40-50 cm brown soil, formed in deposits of loess, over gravels. The chemical properties of the soil are described in **Table 2**.

Table 2: Summary of chemical properties for the Pukaki soil (from Davis *et al.* 2001).

pH	C	N	C/N	P	K	Ca	Mg
	--- g/100g ---			µg/g	--- c mol+/kg ---		
5.5	5.0	0.28	18	19	0.49	5.0	0.89
5.3	4.1	0.33	12.3	25	0.36	6.9	1.25
5.5	4.6	0.27	16.8	23	0.47	5.0	0.79

Soil boron

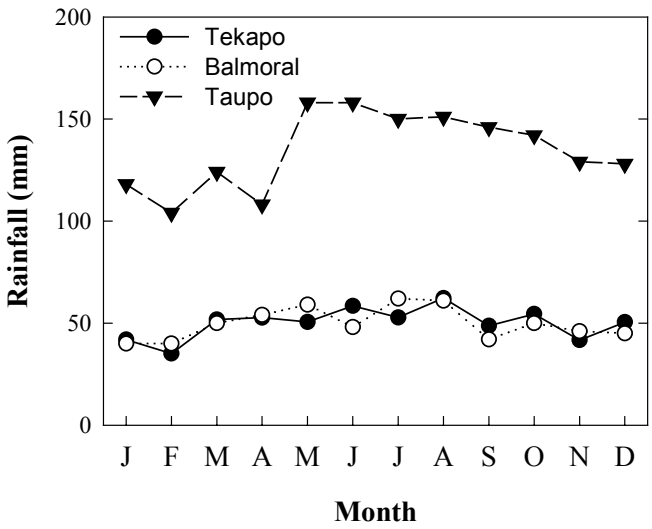
Total 'available' soil B was measured at 7.6 ppm for this Tekapo site.

Environmental conditions

The total annual rainfall at Tekapo (taken at the airport about 3 km from the trial site) is 601 mm. Rainfall distribution during the year is relatively even with February having the lowest rainfall (**Figure 2**). The long term average rainfall pattern is very similar to that at Balmoral Forest. The Lake Taupo trial has a much higher monthly rainfall, particularly during the winter months.

The high country dryland climate is a difficult one for growing trees as the moisture stress is exacerbated in the summer by frequent strong, drying winds, increasing evapotranspiration. Winters can be extremely cold, with temperatures of -17° C and -19° C being recorded in July of 1991 and 1995 respectively.

Figure 2: Long-term average monthly rainfall in the B trial series, FR358.



TRIAL DESIGN

Treatments

The trial has a randomised block design with a factorial of the following treatments:

- rates of B (added as ulexite, ~10% B) at 0, 8, 16 and 32 kg B/ha, by
- weed control (plus or minus).

There were a total of 8 treatments (**Table 3**), which were replicated 4 times to give a total of 32 plots.

This trial does not have any B added at 4 kg/ha or an optimum treatment.

Table 3: Treatments added at Tekapo.

Trtmt no.	Treatments	
	Boron kg/ha	Weed control (+/-)
1	0	- (No)
2	8	- (No)
3	16	- (No)
4	32	- (No)
5	0	+ (Yes)
6	8	+ (Yes)
7	16	+ (Yes)
8	32	+ (Yes)

Plot size

- Outer plot size: 40 x 40 m = 0.16 ha/plot.
- Inner plot size: 24 m x 20 m = 0.048 ha (30% of total plot area).

Area covered by the trial plots is 5.12 ha.

Planting stock

The radiata pine planting stock for the B trials was provided by CHH (3 families) and FCF (4 clones). The Balmoral and Lake Taupo trials have 5 radiata clones; Tekapo does not have clone 230P.

Stocking rate

The proposed planting pattern was 4 m (between rows) x 2 m (within rows) to give a final stocking of 840 sph.

TRIAL INSTALLATION

The Tekapo trial, FR358/3, was established in August 2000, two years after the establishment of Balmoral and Lake Taupo.

Installation issues

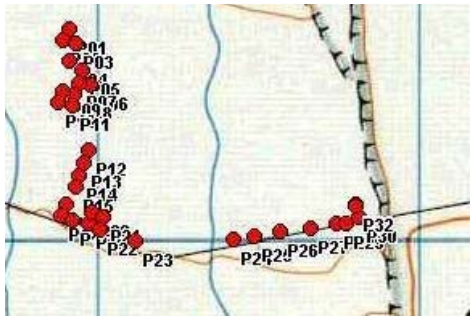
Throughout the site there are areas known as 'blowouts' which are wide channels, often only 20-30cm deep, where the topsoil has been eroded by the wind. The depth of topsoil in these channels was therefore much thinner. It was easy to identify these areas visually both in the change in micro-topography and the differences in vegetation - often no grasses or tussocks grew in the blowouts. For the layout of the trial it was essential that the blowouts were avoided.

Another issue was the consolidation of the tree block in the research area as an open area without forestry was required for other long-term research projects. We therefore located plots along the western and southern edges of the current plantings

Installation of plots

Outer plot pegs were installed in early August 2000. The GPS plot locations are shown in **Figure 3** and **Appendix 1**.

Figure 3: GPS of plots in the Tekapo B trial, FR358/3.



Site preparation

The plots were ripped and scarified (10-11 August 2000) at 4 m spacing. All rip lines ran in a west-east direction. The purpose of ripping was to make it easier to plant the site and the scarification of a 20 cm band of vegetation either side of the rip provided early weed control (see **Photo 1**).

Blocking and allocation of treatments

Blocking of the plots was based on location, as there were no obvious variations in topography or soils across the terrace. The treatments were randomly allocated to the plots within each block (**Appendix 2**).

Photo 1: Newly planted seeding in the rip line. Note scarified area either side of the rip.

Preparation and planting of stock

Preparation of the planting stock

Each genotype, to be planted in the inner plot, was labeled with a white tag with the genetic code[1]. The tag was attached to the upper part of the seedling so that it was not buried during planting.

After delivery from the nurseries, the planting material was kept in a cool store (4ºC). Preparation of the stock for planting involved combining the genotypes for each inner plot. The required number of each genotype was taken from the cooler, bundled (1 bundle for each row consisting of 1 of each genotype + 3 of the genotypes randomly selected giving a total of 10/bundle) and tied with string. The inner plot bag, containing 6 bundles, was put in a planter box and returned to the cooler.

Planting

Planting took place 30-31 August 2000 after a heavy snowfall on the site (see **Photo 1**). The soil was moist during planting. The conditions were overcast and cool.

Sixty individual trees were planted in the inner plots and consisted of 9 individuals/clone (36) and 8 individuals/family (24). Standard GF17 radiata pine stock was planted (supplied by CHH) in the buffers.

Rabbit repellent application

After planting, each tree was sprayed with 'Plant-Plus' rabbit repellent[2] at a rate of 10 ml per tree.

Fertiliser requirements and addition

Fertiliser requirements

The total amount of fertiliser required per plot is shown in **Appendix 3**. The B fertiliser was Boronat 32 (Forestry Grade). This product is 32% B_2O_3 which is equivalent to 10% B. (a pelletised form of ulexite) was supplied in kind by Ravensdown (Sockburn, Christchurch).

Fertiliser application

The fertiliser was broadcast by hand on November 21st, 2000. There was no rain during the application.

Weed control measures since 2000

Initial weed control, across all of the plots, was provided by the scarification when the trial was ripped. There has been no weed control treatment applied since planting. The trial will be assessed in the spring of 2002 to evaluate the need for chemical weed control. Baker (1996) has described effective methods of weed control for this high country site.

Environmental conditions since installation

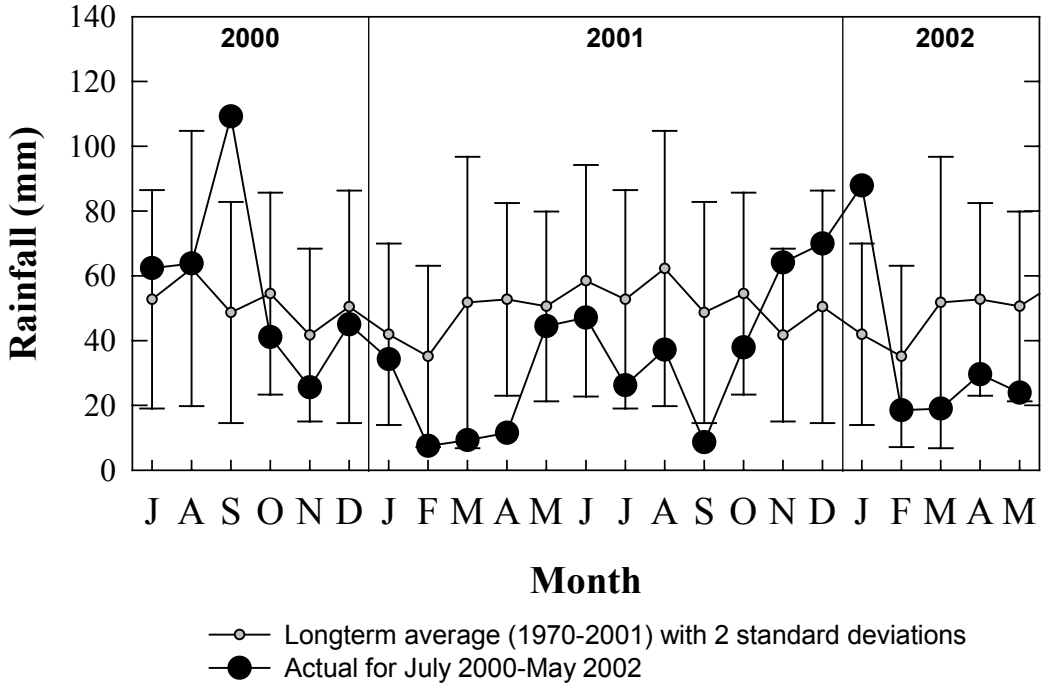
Rainfall since planting in August 2000 is shown in **Figure 4**. The February to April 2001 period, following planting, was extremely dry as only 28 mm fell during these 3 months which was 20% of the expected 140 mm. The late summer and autumn of 2002 was also a dry period (91 mm fell, which was

[1] CHH families 226, 33 and 35. FCF clones 107, 111, 143 and 146.

[2] Plant plus purchased through Roe Koh and Associates Ltd, Christchurch.

48% of an expected 190 mm) after a relatively wet November to January (222 mm, 165% of an expected 134 mm).

Figure 4: Actual rainfall from July 2000 until May 2002 compared to the long-term average rainfall at Tekapo.



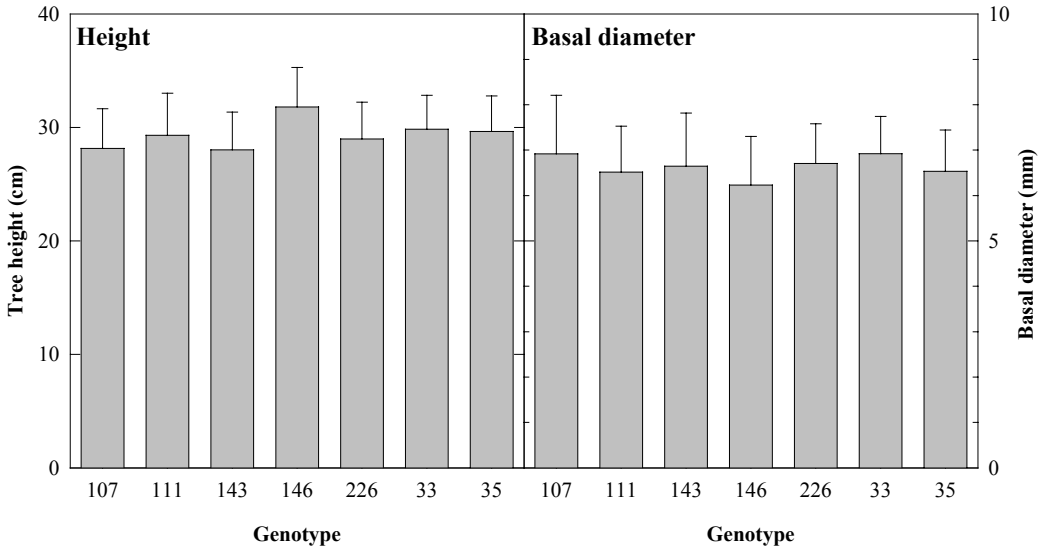
INITIAL MEASUREMENT AND ASSESSMENT AT ONE YEAR: METHODS AND RESULTS

Mapping genotypes and initial measurement

The mapping of all genotypes and the initial measurements were done on 1 September 2000, immediately after planting. The procedure for numbering the individuals in the inner plot is shown in **Appendix 4**. The genotype of each individual in the inner plot was identified from its tag and recorded and the height and root collar diameter measured and recorded. A summary of this data for each plot is presented in **Appendix 5**.

Based on the individual data, mean tree height was 29 cm (individual range of 17 to 42 cm) and mean tree root collar diameter was 6.6 mm (individual range of 2.8 to 11.1 mm). There were no significant differences between the genotypes in terms of height and basal diameter once planted (**Figure 5**).

Figure 5: Initial height and basal diameter measurement of the radiata genotypes planted in the Tekapo B trial, FR358/3.



Survival and health scores after one year

A scoring system was used to assess the health of the trees in September 2001 one year after planting (**Table 4**).

Table 4: Scoring system to assess the health of trees in the Tekapo B trial one year after planting.

Score	Comment
0	Dead
1	Barely alive - a few needles slightly green or yellow
2	Many symptoms of ill health, dead tops/branch tips may be present. Will probably survive.
3	Needle tips browning off, nutrient deficiency (slightly yellow), dead tops/branch tips may be present. Will definitely survive.
4	Few dead needles, no dead tops/branch tips, some yellow needle tips.
5	Perfect

The data were analysed to find out if the blocking of the plots, rate of B and/or genotype had affected the health score of the trees or their survival. For the survival scores, dead trees had a score of 0 while living trees had a score of 1.

The results indicated that all of the factors had a highly significant (p<0.001) on health scores while block and genotype were highly significant for the survival scores. The effect of B on survival scores was not significant. The factor explaining the most variation in the data was genotype (**Table 5**).

Table 5: Details from ANOVA of health and survival for block, boron rate and genotype.

		Health score			Survival score		
Source	**DF**	**Type III SS**	**F value**	**Prob>F**	**Type III SS**	**F value**	**Prob>F**
Block	3	41	8.6	<0.0001	1.8	6.0	0.0005
Boron	3	140	29.2	<0.0001	0.3	1.0	0.39
Genotype	6	1334	138.1	<0.0001	48.5	80.4	<0.0001

The survival rate across the trial was 85%.

In Block 4, fewer trees survived and health scores were lower

Block 4 consisted of those plots that were nearest to the edge of the terrace (see **Appendix 1**). Fewer trees survived in this block and the trees had lower health scores compared to the other blocks (**Table 6**).

Possible reasons for the lower scores in Block 4 may include stonier soils that more susceptible to drying out, shallower soils providing less water holding capacity, or poorer air drainage (i.e., more susceptible to frosting) than the other blocks.

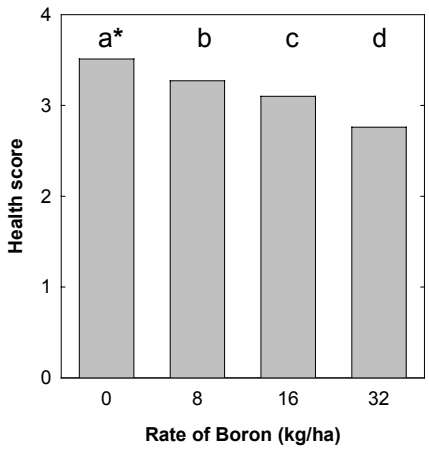
Table 6: Effect of blocking on health and survival scores at Tekapo.

Block	Health score	Survival score
1	3.2 a	0.87 a
2	3.2 a	0.85 a
3	3.3 a	0.89 a
4	2.9 b	0.80 b

Increasing Boron addition significantly decreased health scores

As the rate of boron increased from 0 to 32 kg/ha, the health scores significantly (p<0.05) decreased from 3.5 in the control to 2.8 where B had been applied at 32 kg/ha (**Figure 6**).

Figure 6: 2001 health scores were affected by B addition at Tekapo.



* Means with the same letter are not significantly different (p<0.05)

Genotype significantly affected survival and health scores

The variation in the health and survival scores of the radiata genotypes is shown in **Figure 7**. Of the 7 genotypes, two clones had significantly lower health and survival scores - 111 and 146.

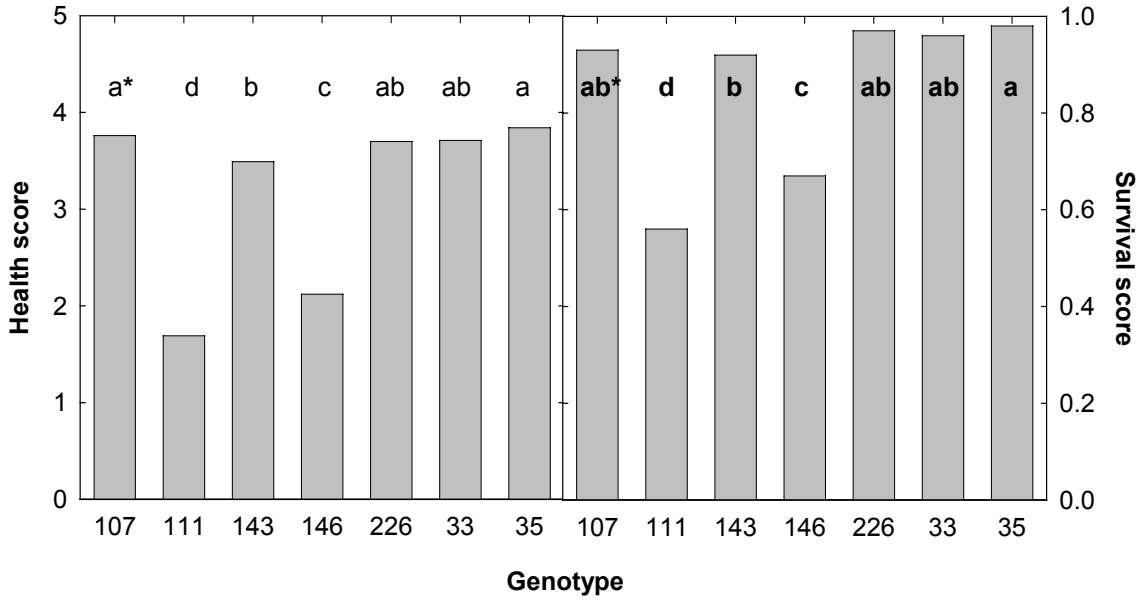


Figure 7: There were significant differences between the 2001 health and survival scores of the radiata genotypes in the Tekapo B trial. **[* Means with the same letter are not significantly different (p<0.05)].**

There was little difference between the other 5 genotypes where survival rates in the first year were high. There was a strong positive correlation between the health and survival scores of the genotypes.

SCHEDULE OF FUTURE MEASUREMENTS, ASSESSMENTS AND SAMPLING OF FOLIAGE AND SOILS

There are a number of growth measurements, foliage and soil sampling, and visual assessments proposed for this trial (see **Table 7**). It is expected that the following will be funded by NZFSMC:

- Regular foliage sampling, by plot, needle weights and chemical analysis of samples.
- Periodic soil sampling and analysis.
- Regular measurements of tree height, root collar diameter/dbh.
- Periodic visual assessment of form with particular emphasis on identifying the presence of B deficiency symptoms.

Table 7: Schedule of general measurements, soil and foliage sampling, assessments and biomassing for the Tekapo B trial, FR358/3.

Year	Month	Measure	Sampling		Assess	Biomass
			Foliage	Soil		
2000	August	Initial				
2001	September				✓-survival	
2002	August	✓				
2003	March		✓	✓		
2004	March		✓			
2005	August	✓				

Shaded tasks have been completed.

Additional boron research projects will also be carried out in this trial using PGSF funding and may include the following research projects:

- Investigation of the role of sugar alcohols in the internal retranslocation of B in radiata pine genotypes.

- Regular soil sampling to identify B fractions in the soil and determine the longevity of B in the soil as a result of fertiliser addition.
- Periodic biomass studies (above and below-ground radiata and weeds) to provide information relating to B cycling and tree growth and nutrient content and material for the measurement and assessment of wood cell characteristics (as done by M. Skinner and A. Singh) and wood quality.

FUTURE MAINTENANCE OF THE TRIAL

Forest Research staff will be regularly visiting the sites and will maintain the plot pegs (location and plot number tags) and tree numbering.

Weed control

It is envisaged that chemical and/or manual methods of weed removal will be used. The chemicals and rates of active ingredient used will depend on the weeds present on the site and the information in Baker (1996).

Rabbit control

Periodic rabbit control is carried out on site.

DATA MANAGEMENT, ANALYSIS AND REPORTING

Data management

All data is being stored on the Forest Research PSP system and held on Excel spreadsheets by Forest Research staff who are team members of this project.

Data analysis

Data will be analysed in the year in which it is collected. Standard ANOVA will be used and other statistical methods where appropriate.

Reports and papers

Updates and verbal presentations summarising the measurements, foliage and soil analysis results, and assessments from all of the trials in this series will be produced for the NZFSMC periodically. In the long term, the results of these trials will be published.

ACKNOWLEDGMENTS

The authors gratefully acknowledge:

- Nick Ledgard and Murray Davis (Forest Research) for their assistance in identifying the trial location.
- Andrew and Karen Simpson, owners of Balmoral Station, for hosting the trial on their land.
- Andrew Simpson for providing inkind labour and machinery to rip the planting lines.
- FCF and CHH for supplying planting stock inkind. CHH also provided radiata material for planting the buffers.
- Mark Ryan (FCF) and Grant Hastings (CHH) for organising the planting stock.
- The planting team from Simon Woods Ltd in Rangiora (Tony, Lynda, Brian, Vanessa, Josh and Jared) for doing a great job.
- Gordon Baker for supervising the planters and ensuring a high standard of planting.
- Ravensdown (Sockburn, Christchurch) for supplying Boron fertiliser inkind.
- The NZ Army for doing a bunny shoot in 2001.

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Davis, M., Ledgard, N. and Nordmeyer, A. (2001). "Determining fertiliser requirements for the establishment of pines and Douglas fir in the South Island high country." **New Zealand Journal of Forestry Science** 31(1): 18-33.

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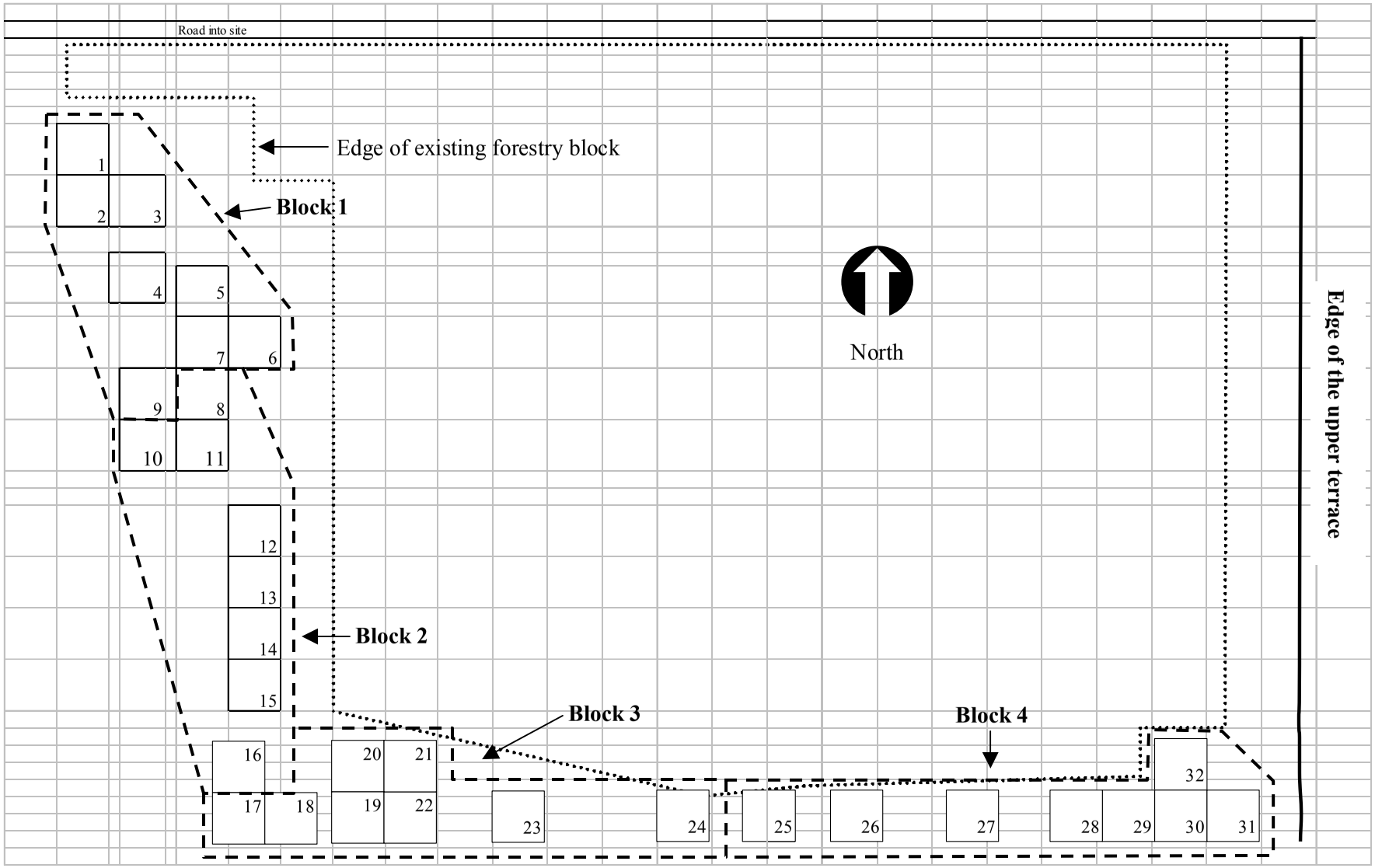
Appendix 1: Map of plot layout for the Tekapo B trial, FR358/3 (not to scale).



Appendix 2: **Allocation of block number and treatments to plots in the Tekapo B trial (FR358/3).**

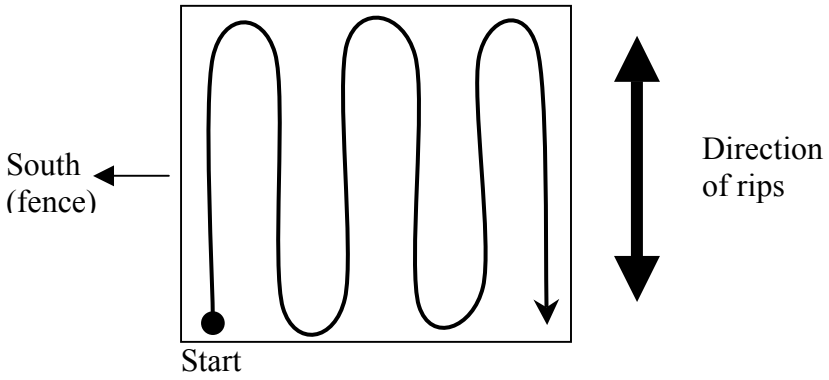
Plot no.	Block	Trt no.	B	WC
1	1	8	32	Yes
2	1	7	16	Yes
3	1	6	8	Yes
4	1	4	32	No
5	1	2	8	No
6	1	3	16	No
7	1	1	0	No
8	2	1	0	No
9	1	5	0	Yes
10	2	3	16	No
11	2	7	16	Yes
12	2	4	32	No
13	2	5	0	Yes
14	2	8	32	Yes
15	2	2	8	No
16	2	6	8	Yes
17	3	5	0	Yes
18	3	4	32	No
19	3	7	16	Yes
20	3	6	8	Yes
21	3	1	0	No
22	3	3	16	No
23	3	8	32	Yes
24	3	2	8	No
25	4	3	16	No
26	4	6	8	Yes
27	4	7	16	Yes
28	4	4	32	No
29	4	2	8	No
30	4	1	0	No
31	4	8	32	Yes
32	4	5	0	Yes

Appendix 3: **B fertiliser requirements and calculations for the Tekapo B trial FR358/3.**

Treatment no.	WC	B (kg/ha)	B (kg/treatment)	Ulexite (kg/treatment)	Ulexite (kg/plot)
1	No	0	-	-	-
2	No	8	5.12	51.2	12.8
3	No	16	10.24	102.4	25.6
4	No	32	20.48	204.8	51.2
5	Yes	0	-	-	-
6	Yes	8	5.12	51.2	12.8
7	Yes	16	10.24	102.4	25.6
8	Yes	32	20.48	204.8	51.2
Totals			**71.68**	**716.8**	

Each treatment is replicated 4 times covering 0.64 ha (i.e. 4 plots x 0.16ha/plot).

Appendix 4: Procedure for numbering the individual trees in the inner plot at the Tekapo B trial (FR358/3).



Appendix 5: Summary of the initial measurement data for each plot in the Tekapo B trial (FR358/3).

Plot	Height (cm)		Root collar diameter (mm)	
	Mean	Std.dev.	Mean	Std.dev.
1	29.4	3.25	7.3	1.09
2	31.1	3.49	7.1	1.12
3	31.0	3.77	7.0	1.10
4	31.1	3.28	7.1	1.17
5	30.9	3.15	7.1	1.13
6	29.2	3.33	6.9	1.16
7	28.4	3.84	7.0	1.02
8	29.1	3.53	6.7	1.02
9	29.1	3.47	6.6	1.04
10	29.9	3.48	6.8	0.95
11	31.1	3.18	6.7	1.04
12	29.3	3.44	6.8	1.16
13	29.9	3.62	6.7	0.71
14	29.6	3.52	6.7	1.10
15	28.0	4.29	6.5	0.99
16	29.8	3.29	6.7	0.96
17	29.6	3.30	6.7	1.06
18	29.5	4.68	6.7	1.06
19	28.1	3.64	5.9	0.98
20	28.6	3.32	6.7	1.01
21	28.4	3.80	6.5	0.88
22	27.0	3.05	6.2	0.91
23	29.4	3.43	6.5	1.07
24	28.0	3.52	6.5	0.98
25	29.4	3.15	6.2	0.89
26	29.5	3.09	6.1	0.98
27	29.2	4.33	6.7	1.00
28	29.1	3.40	6.2	0.97
29	28.5	2.63	6.2	1.10
30	29.0	3.63	6.7	1.00
31	29.9	3.31	6.4	0.78
32	29.9	3.51	6.1	1.04