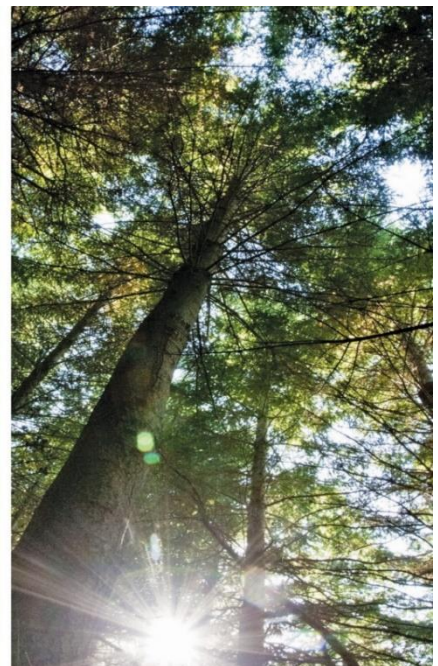
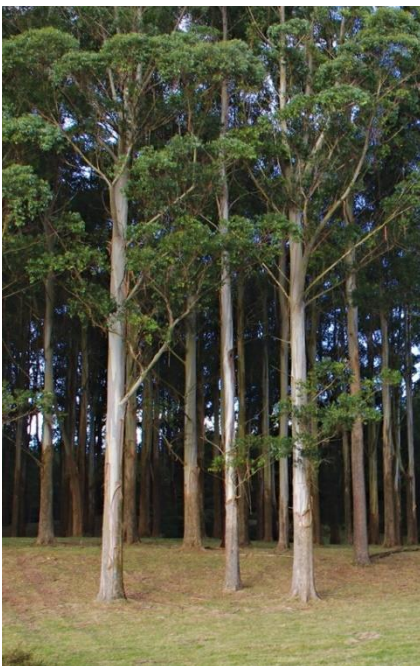


The decay resistance of alternative species in an accelerated framing test

Assessment of decay after one year's exposure

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EXECUTIVE SUMMARY

Sets of framing samples were exposed in high humidity conditions of 85-90% relative humidity and 25 – 27°C. The species and preservative treatments included in this test were:

- *Eucalyptus fastigata*, mixed heartwood\sapwood, untreated and boron treated.
- *Eucalyptus fastigata*, LVL, untreated and boron treated.
- *Eucalyptus nitens*, untreated and boron treated.
- *Eucalyptus regnans*, heartwood, untreated
- *Cupressus macrocarpa*, young and old trees, heartwood, untreated.
- *Cupressus x ovensii*, heartwood, untreated.
- Larch, heartwood, untreated.
- Douglas fir, mixed heartwood\sapwood, untreated.
- Radiata pine, mixed heartwood\sapwood, untreated and H1.2 boron treated.

All of the framing samples were periodically sprayed with water at approximately two weekly intervals to maintain the wood moisture content at a level suitable for decay to progress. Before exposure in the high humidity condition, samples were also soaked in water for two hours.

The method of testing followed the procedure described in Australasian protocols in this case for the Hazard class H1.2. This test method simulates the common framing joint in house framing between studs and plates, where in a leaky building, moisture may become trapped and provide suitable conditions for fungi to establish.

After one year's exposure in accelerated decay conditions;

- Lightly established decay had developed in untreated *Eucalyptus fastigata* mixed heartwood\sapwood solid wood, untreated *Eucalyptus regnans* heartwood, untreated Douglas fir mixed heartwood\sapwood and untreated radiata pine mixed heartwood\sapwood.
- The first stages of decay had developed in untreated *Eucalyptus fastigata* LVL, untreated *Eucalyptus nitens*, untreated *Cupressus macrocarpa* from young and old trees, and untreated *Cupressus x ovensii*.
- There was no decay observed in any of the boron treated samples. This includes boron treatment of solid wood of *Eucalyptus fastigata* and radiata pine along with laminated *E. nitens* and *Eucalyptus fastigata* LVL.

It is recommended that this test is continued and assessed after two year's exposure in accelerated decay conditions.

INTRODUCTION

This trial was established to determine the decay resistance of New Zealand grown alternative species using an accelerated decay test developed by Scion (Hedley et al, 2009; Singh et al 2014) and described in the Australasian protocols for assessment of wood preservatives (Australasian Wood Preservation Committee; 2015).

The groups of samples included in this test were:

- *Eucalyptus fastigata*, mixed heartwood\sapwood, untreated.
- *Eucalyptus fastigata*, mixed heartwood\sapwood, boron treated.
- *Eucalyptus fastigata*, LVL, untreated.
- *Eucalyptus fastigata*, LVL, boron treated.
- *Eucalyptus nitens*, mixed heartwood\sapwood, laminated.
- *Eucalyptus nitens*, heartwood, laminated, boron treated.
- *Eucalyptus regnans*, heartwood, untreated
- *Cupressus macrocarpa*, young trees, heartwood, untreated.
- *Cupressus macrocarpa*, old trees, heartwood, untreated.
- *Cupressus x ovensii*, heartwood, laminated, untreated.
- Larch, heartwood, untreated.
- Douglas fir, mixed heartwood\sapwood, untreated.
- Radiata pine, mixed heartwood\sapwood, untreated.
- Radiata pine, mixed heartwood\sapwood, H1.2 boron treated.

This test method simulates the common framing joint in house framing between studs and nogs, where in a leaky building, moisture may become trapped and provide suitable conditions for fungi to establish.

This report presents the decay assessment after one year's exposure.

MATERIALS AND METHODS

Source of timber

Timber samples included in the trial and the source of the timber are listed in Table 1. All samples were 90 x 45 mm in dimensions. Appendix 1 includes further details about the timber source, including where known, tree age and people involved in selection to timber.

Due to the limited availability of larger dimension sawn timber, samples in some groups were laminated to produce a 90 x 45 mm sample for testing (*Eucalyptus nitens* and *Cupressus x ovensii*).

Table 1: Summary of the groups of “I” frame samples and types of wood for this study
(10 samples for each group)

Type of wood \ Treatment	Source of timber	Tree age (years)
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, untreated	Tai Tane forest, Marlborough; Paul Millen and Scion staff	24
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, boron treated	Tai Tane forest, Marlborough, pressure treated at Scion Paul Millen and Scion staff	24
<i>Eucalyptus fastigata</i> , LVL, untreated	Tai Tane forest, Marlborough, Paul Millen and Scion staff	-
<i>Eucalyptus fastigata</i> , LVL, boron treated	Tai Tane forest, Marlborough, Pressure treated at Scion Paul Millen and Scion staff	-
<i>Eucalyptus nitens</i> , heartwood, laminated, untreated	John Fairweather; North Canterbury	20-30
	Southwood Exports; Goldingham forest, Catlins Scion staff	18
<i>Eucalyptus nitens</i> , mixed heartwood\sapwood, boron treated	John Fairweather; North Canterbury	20-30
	Southwood Exports; Goldingham forest, Catlins, Scion staff diffusion treated at Scion	18
<i>Eucalyptus regnans</i> , heartwood, untreated	John Fairweather; Mt Cargill, Otago	35
<i>Cupressus macrocarpa</i> , young trees, heartwood, untreated	Ruapehu sawmill; Bulls region Vaughan Kearns	22
<i>Cupressus macrocarpa</i> , old trees, heartwood, untreated	Ruapehu sawmill; Waimarino Vaughan Kearns	60 - 80
<i>Cupressus x ovensii</i> , heartwood, laminated, untreated	SWP sawing study; Rotoehu forest; Scion staff	22
Larch, heartwood, untreated	Timbers of NZ; Mt Cook station; Dean Satchell	45
	Earnslaw One; Naseby forest; Mark Dean	
Douglas fir, mixed heartwood\sapwood, untreated	Donelleys sawmill, Reporoa; Scion staff	-
Radiata pine, mixed heartwood\sapwood, untreated	Scion stock; Scion staff	-
Radiata pine, mixed heartwood\sapwood, H1.2 boron treated	Rotorua timber retailer; Scion staff	-

Boron treatment schedule

The *Eucalyptus fastigata* samples, both solid timber and LVL, were pressure treated with boron at Scion using the following schedule:.

Bethell treatment schedule:

-15kPa for 15 minutes, 1 hour @1400kPa and 15 minute final vacuum.

The *Eucalyptus nitens* timber was diffusion treated from green in 25 mm thick boards, which were laminated after treatment and drying. Two commercial boron formulations were used. Timber was then stacked under cover for 12 weeks.

Preparation of samples

The “I” frame samples were prepared from 90 x 45 mm timber. Two 100 mm end blocks were end coated and were stapled across the ends of the 700 mm sample to form an “I” shape (Figure 1). Ten samples were prepared for each group.

The “I” shaped samples were soaked in a tank of water for two hours to raise the moisture content and to simulate rain wetting that may occur during building construction. Moisture meter measurements taken on the timber after water soaking were around 30% moisture content.

Feeder blocks were inoculated with *Antrodia xantha* and *Oligoporus placenta* fungus and grown in the laboratory until the fungi were established. The strain of these two fungi were isolates from the leaky buildings (Stahlhut 2008). The feeder blocks were nailed to each “I” sample, with *A. xantha* fungus attached approximately 5-10 mm from one end of the sample and *O. placenta* fungus attached approximately 5-10 mm from the other end of the sample (Figure 1). Additional feeder blocks were attached to the edge of the *Eucalyptus fastigata* LVL samples.

The “I” frame samples were stacked in the Accelerated Decay House (a controlled environment room maintained at 25-27°C with more than 85% relative humidity). All the samples were periodically sprayed with water at approximately two weekly intervals to maintain the wood moisture content at a level suitable for decay to progress. The intention was to keep the moisture content of the timber above 30% to ensure fungal growth, as would be the case with a weather tightness failure or leaks from water pipes.

Assessment methods

All samples were assessed after twelve months exposure. At assessment time, the stacks were dismantled, samples were removed, weighed and visually assessed for spread of mould, and spread of mycelium from the feeder blocks. The surfaces of each sample were tested with a blunt probe to determine whether decay fungi were damaging the framing. Staples were removed from one side of the sample so that end joints could be opened and the internal joint area could also be assessed for decay.

Mould and surface mycelium is common in a damp environment. Mould and mycelium can be hazardous to health. Presence of mould and surface mycelium can provide an optimal environment for the initiation of decay. However, the presence of surface mycelium or mould does not always indicate that decay is present or likely to occur.

The rating systems (ASTM D 1758) for the deterioration were as follows:

Description of assessment rating's

Mycelium spread

- 1 No mycelium development onto the sample surface from the feeder block
- 2 Mycelium growth from the feeder block onto the surface, spread less than 5 mm.
- 3 Mycelium from the feeder block on the surface, spread 5-50 mm.
- 4 Active mycelium from the feeder block on the surface, spread greater than 50 mm.
- 5 Extensive mycelium over the sample surface, less than 50% of the surface area.
- 6 Extensive mycelium over the sample surface, more than 50% of the surface area.

Decay ratings

- 10 No decay or insect damage.
- T Trace, discolouration, mycelium or softening, not positively identified as decay.
- 9 First stages of decay, small areas, not more than 1 mm deep.
- 8 Lightly established decay, patches 1-5 mm deep.
- 7 Well established decay, extensive surface decay or patches to 20 mm deep.
- 6 Established and progressive decay over wide areas with patches greater than 20 mm deep.
Severe decay over the majority of the surface with patches more than 40 mm
- 4 deep.
- 0 Failed. Decay completely through the sample.

Mould ratings

- 1 No perceivable mould.
- 2 Light mould in small patches or widely scattered spots.
- 3 Extensive mould as numerous scattered spots or widespread light mould.
- 4 Severe mould, up to 50% of the surface covered.
- 5 Severe mould, more than 50% of the surface covered.

RESULTS AND DISCUSSION

Boron treatment and analysis

Table 2 shows the average uptake for each of the wood types and a list of the individual sample uptakes is shown in Appendix 2.

Table 2: Summary of boron uptake for each wood type

Wood type	Average uptake (l/m ³)	Target solution (g BAE/l)	Calculated retention (g BAE/100g)
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, boron pressure treated	128.8	20.2	0.47
<i>Eucalyptus fastigata</i> , LVL, boron pressure treated	431.8	6.4	0.48
<i>Eucalyptus nitens</i> , mixed heartwood\sapwood, laminated, boron diffusion treated	33.3 kg/m ³	-	-

Table 3 shows a summary of the analysis results taken before exposure, with photos of spot tests for heartwood\sapwood and penetration, and the full analysis report listed in Appendix 3.

Table 3: Summary of analysis results before exposure

Wood type	Sapwood (%)	Retention analysis BAE ¹ XS ² (%m/m)	Max retention BAE	Min retention BAE	BAE C9 ³ (%m/m)
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, boron treated	12	0.55	0.59	0.49	N/A ⁴
<i>Eucalyptus fastigata</i> , LVL, boron treated	74	0.18	0.20	0.15	0.16
<i>Eucalyptus nitens</i> , mixed heartwood\sapwood, boron treated	5	1.52	2.25	0.80	0.87
Radiata pine, mixed heartwood\sapwood, H1.2 boron treated	58	1.14	1.55	0.75	0.59

¹ BAE = Boric acid equivalent

² XS = cross section

³ C9 = central 9th

⁴ N/A = no sample to test

The sapwood\heartwood spot tests showed that all *Eucalyptus fastigata* solid wood samples were predominantly heartwood (Figure 15). The penetration spot test showed poor penetration of boron wood preservative (Figure 16). All of the *Eucalyptus fastigata* solid wood samples achieved a retention of 0.40 %m/m in the sapwood (Table 3; Appendix 3).

The sapwood\heartwood spot tests showed that the *Eucalyptus fastigata* LVL samples contained high levels of sapwood, (Figure 17). The penetration spot tests for the *Eucalyptus fastigata* LVL showed poor penetration of boron wood preservative (Figure 18). None of the *Eucalyptus fastigata* LVL samples achieved a retention of 0.40 %m/m (Table 3; Appendix 3).

The sapwood\heartwood spot tests showed that the *Eucalyptus nitens* samples were predominantly heartwood, although this varied between the two laminates in each board (Figure 19). The penetration spot tests for the *Eucalyptus nitens* showed good penetration of boron wood preservative from the quarter sawn edges (Figure 20). All of the *Eucalyptus nitens* samples achieved a retention of 0.40 %m/m (Table 3; Appendix 3).

The sapwood\heartwood spot tests showed that the radiata pine samples were predominantly sapwood, but two samples were completely heartwood (Figure 21). The penetration spot tests for radiata pine showed good penetration of the sapwood with boron wood preservative (Figure 22). All of the radiata pine samples achieved the required specified (NZS 3640) retention of 0.40 %m/m (Table 3; Appendix 3).

Decay assessment after one year's exposure

Table 4 shows the summary of the inspection of frame test samples after one year's exposure. The full set of assessment data is contained in Appendix 4.

Table 4: Summary of assessment results after one year's exposure (average for each group)

Type of wood	Mycelium (Lower rating is better)		Decay - Surface (Higher rating is better)		Decay - Joint (Higher rating is better)		Mould (Lower rating is better)	
	Op ¹	Ax ¹	Op	Ax	Op	Ax	Op	Ax
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, untreated	2.0	3.3	9.2	8.0	8.4	7.4	1.5	1.4
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, boron treated	1.4	1.4	10.0	10.0	10.0	10.0	1.3	1.1
<i>Eucalyptus fastigata</i> , LVL, untreated	1.8	1.5	9.5	9.7	10.0	9.8	1.0	1.3
<i>Eucalyptus fastigata</i> , LVL, boron treated	1.7	1.3	10.0	10.0	10.0	10.0	4.0	4.2
<i>Eucalyptus nitens</i> , heartwood, laminated, untreated	2.0	2.9	9.7	8.9	9.7	8.6	1.0	1.0
<i>Eucalyptus nitens</i> , mixed heartwood\sapwood, laminated, boron treated	1.0	1.1	10.0	10.0	10.0	10.0	1.2	1.3
<i>Eucalyptus regnans</i> , heartwood, untreated	1.9	2.4	8.8	8.2	9.0	8.2	1.0	1.0
<i>Cupressus macrocarpa</i> , young trees, heartwood, untreated	1.3	1.5	10.0	10.0	10.0	9.8	1.6	1.7
<i>Cupressus macrocarpa</i> , old trees, heartwood, untreated	2.9	3.1	9.5	10.0	9.7	10.0	1.7	1.7
<i>Cupressus x ovensii</i> , heartwood, laminated, untreated	1.0	2.5	10.0	9.7	10.0	9.6	1.0	1.0
Larch, heartwood, untreated	1.0	1.0	10.0	10.0	10.0	10.0	1.1	1.2
Douglas fir, mixed heartwood\sapwood, untreated	3.6	3.0	8.6	7.8	8.2	7.1	1.7	2.1
Radiata pine, mixed heartwood\sapwood, untreated	4.9	3.7	5.3	4.5	5.5	4.5	3.4	3.0
Radiata pine, mixed heartwood\sapwood, H1.2 boron treated	1.0	1.0	10.0	10.0	10.0	10.0	2.6	2.7

¹ Op and Ax represent different ends of the "I frame" samples with feeder blocks inoculated with *Oligoporus placenta* and *Antrodia xantha*.

***Eucalyptus fastigata* solid wood after one year's exposure**

After one year's exposure, moderate mycelium growth was observed on many of the untreated *Eucalyptus fastigata* samples. The presence of mycelium does not necessarily indicate the presence of wood decay. The early stages of decay were observed on the surface and in the joint of many samples, with higher levels of decay observed at the end of the sample with the *Antrodia xantha* (Ax) feeder block (Figure 2).

The boron treated *Eucalyptus fastigata* samples had less mycelium growth than the untreated samples and no decay was observed on any of the samples (Figure 3).

***Eucalyptus fastigata* LVL after one year's exposure**

Established decay was observed on some of the untreated *Eucalyptus fastigata* LVL samples (Figure 4). Mould was not observed on the *Eucalyptus fastigata* LVL samples.

A high level of mould was observed on the boron-treated *Eucalyptus fastigata* LVL samples. No decay was observed on any of the boron-treated LVL samples.

***Eucalyptus nitens* after one year's exposure**

Many of the untreated *Eucalyptus nitens* samples had extensive mycelium growth (Figure 5) but no mould growth was observed. The first stages of decay or lightly established decay was observed on the surface and in the joint of many of the untreated *Eucalyptus nitens* samples (Figure 6).

Less mycelium was observed on the boron treated *Eucalyptus nitens* samples. No decay was observed on any of the boron treated *Eucalyptus nitens* samples (Figure 7).

***Eucalyptus regnans* after one year's exposure**

Most of the untreated *Eucalyptus regnans* samples had extensive mycelium growth but no mould growth was observed. Lightly established decay was observed on the surface or in the joint of most of the untreated *Eucalyptus regnans* samples (Figure 8).

***Cupressus macrocarpa* after one year's exposure**

Higher levels of mycelium was observed on the untreated *Cupressus macrocarpa* from the old trees than from the young trees. The first stages of decay was observed at the Op feeder block on some of the *Cupressus macrocarpa* from the old trees (Figure 9). Decay was observed on one of the *Cupressus macrocarpa* from the young trees.

***Cupressus x ovensii* after one year's exposure**

Mycelium growth was observed on *Cupressus x ovensii* samples around the Ax feeder block (Figure 10) and the first stages of decay were observed on some of the untreated *Cupressus x ovensii* samples at the end with the Ax feeder block. No mould was observed on any of the *Cupressus x ovensii* samples.

Larch after one year's exposure

Mycelium was not observed on any of the Larch samples and minor mould was present on two of the ten Larch samples. No decay was observed on any of the Larch samples (Figure 11).

Douglas fir after one year's exposure

Significant mycelium growth was observed on many of the untreated Douglas fir samples. Established decay was observed on most of the untreated Douglas fir samples (Figure 12).

Radiata pine after one year's exposure

Moderate mycelium and mould growth was observed all of the untreated radiata pine samples. Established and severe decay was observed on all untreated radiata pine samples (Figure 13).

No mycelium growth was observed on the boron treated radiata pine and moderate mould was observed on all of the boron treated radiata pine samples. No decay was observed on any of the boron treated radiata pine samples (Figure 14).

CONCLUSION

After one year's exposure to accelerated decay conditions, the following conclusions can be drawn from this report:

- Decay had not developed in boron treated *Eucalyptus fastigata* solid wood, boron treated *Eucalyptus fastigata* LVL, boron treated *Eucalyptus nitens*, boron treated radiata pine, and untreated Larch.
- The first stages of decay had developed in untreated *Eucalyptus fastigata* LVL, untreated *Eucalyptus nitens*, untreated *Cupressus macrocarpa* from young and old trees, and untreated *Cupressus x ovensii*.
- Lightly established decay had developed in untreated *Eucalyptus fastigata* solid wood, untreated *Eucalyptus regnans*, untreated Douglas fir and untreated radiata pine. The worst decay was observed in untreated radiata pine which had severe decay in most samples.

ACKNOWLEDGEMENTS

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The authors acknowledge the assistance of Gavin Durbin in conducting the boron treatment of samples for this test.

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LIST OF FIGURES

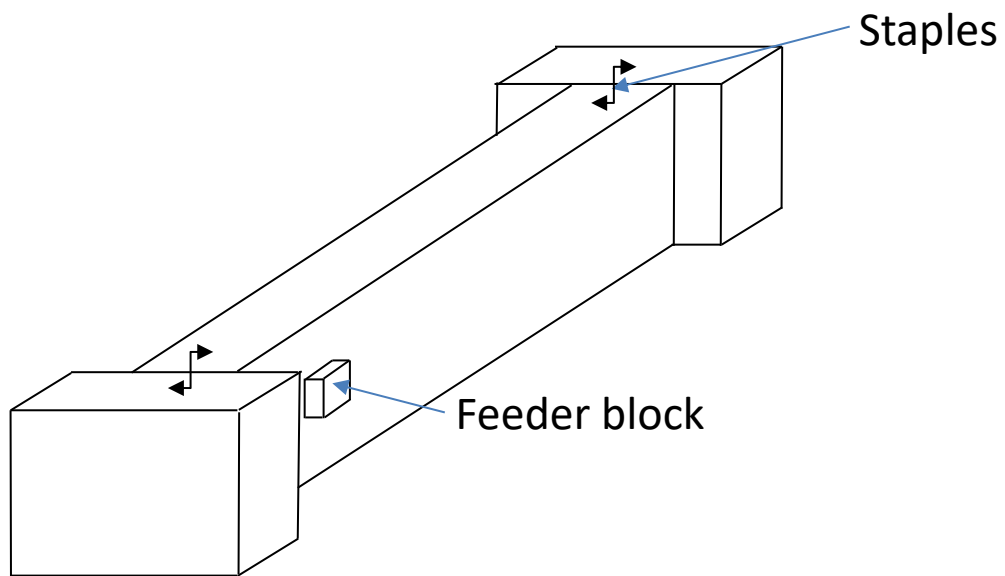


Figure 1: Diagram showing I-frame



Figure 2: Severe decay in the joint of untreated *Eucalyptus fastigata* after one year's exposure (sample 13).

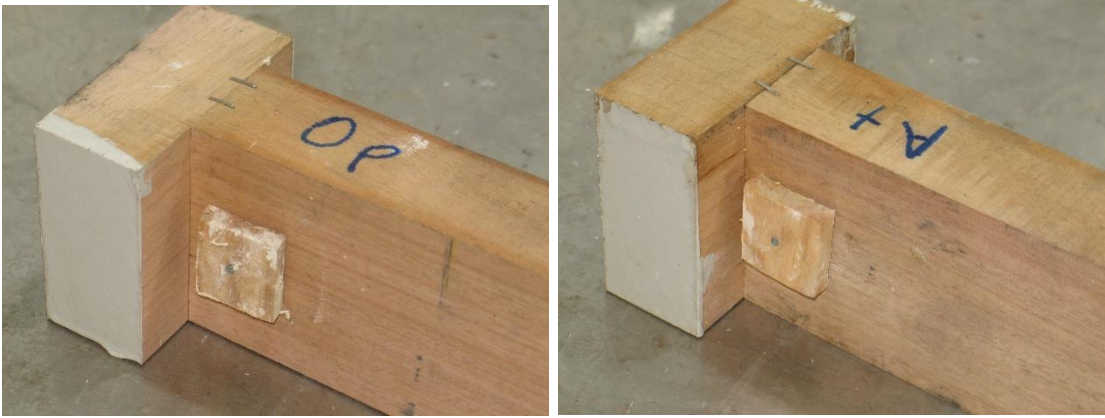


Figure 3: No mycelium growth or decay on boron treated *Eucalyptus fastigata* after one year's exposure (sample 9).



Figure 4: Lightly established decay on the edge and in the joint of untreated *Eucalyptus fastigata* LVL after one year's exposure (sample 24).



Figure 5: Extensive mycelium over half of the surface of an untreated *Eucalyptus nitens* sample after one year's exposure (sample 53).



Figure 6: Lightly established decay on the surface and in the joint of an untreated *Eucalyptus nitens* sample after one year's exposure (sample 57).



Figure 7: No mould, mycelium or decay on the surface of boron treated *Eucalyptus nitens* sample after one year's exposure (sample 47).

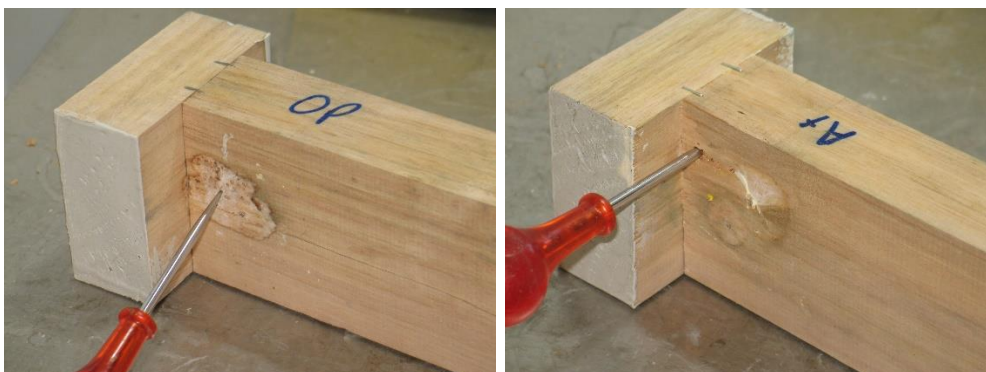


Figure 8: Established decay on the surface of an untreated *Eucalyptus regnans* sample after one year's exposure (sample 132).



Figure 9: Decay on the surface and in the joint of an untreated *Cupressus macrocarpa* sample from an old tree, after one year's exposure (sample 84).

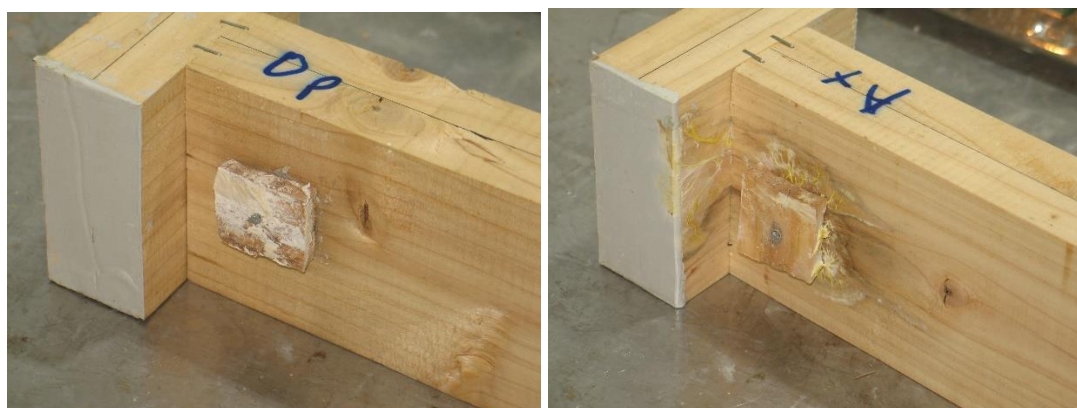


Figure 10: No mycelium growth at the Op feeder block and moderate mycelium growth at the Ax feeder block of an untreated *Cupressus x ovensii* sample after one year's exposure (sample 108).

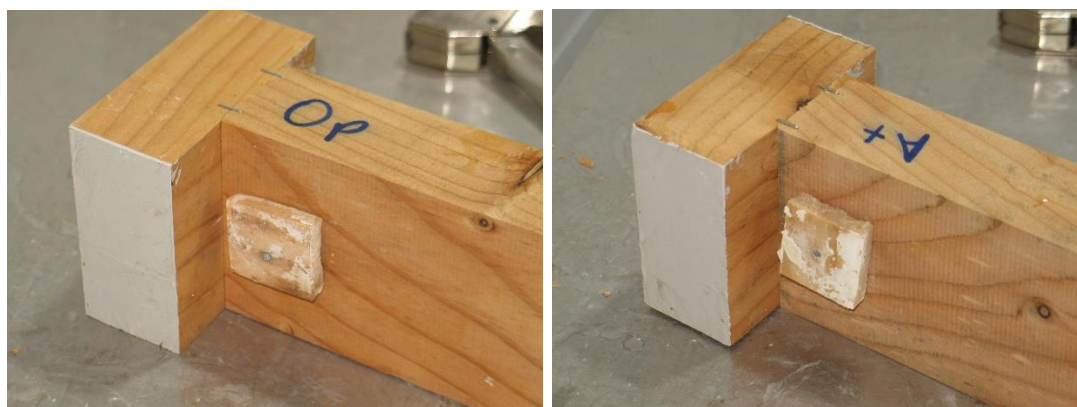


Figure 11: No mycelium or mould growth, or decay, on an untreated *Larch* sample after one year's exposure (sample 115).



Figure 12: Well established decay in the joints of an untreated *Douglas fir* sample after one year's exposure (sample 125).

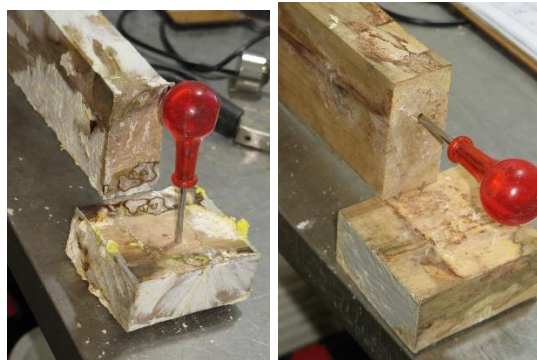


Figure 13: Established decay in the joints of an untreated radiata pine sample after one year's exposure (sample 65).



Figure 14: No decay and moderate mould on a boron treated radiata pine sample after one year's exposure (sample 80).

APPENDIX 1:

Table 5: Source of timber for frame tests

Type of wood \ Treatment	Source of timber	Number of trees	Tree age (years)	Selected by	Approximate quantity of timber delivered (lm)
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood	Tai Tane forest, Marlborough	-	24	Paul Millen and Scion staff	110
<i>Eucalyptus fastigata</i> , LVL	Scion trial	-	-	Scion staff	
<i>Eucalyptus nitens</i> , heartwood, heartwood\sapwood	John Fairweather; North Canterbury	-	Canterbury 20-30	John Fairweather	192
	Southwood Exports; Goldingham forest, Catlins	4 from Goldingham forest	Goldingham forest 18	Scion staff	384
<i>Eucalyptus regnans</i> , heartwood	John Fairweather; Mt Cargill, Otago	3	35	John Fairweather	20
<i>Cupressus macrocarpa</i> , young trees, heartwood	Ruapehu sawmill; Bulls region	-	22	Vaughan Kearns	400
<i>Cupressus macrocarpa</i> , old trees, heartwood	Ruapehu sawmill; Waimarino	-	60 - 80	Vaughan Kearns	400
<i>Cupressus x ovensii</i> , heartwood, laminated	SWP sawing study; Rotoehu forest	7	22	Scion staff	182
Larch, heartwood	Timbers of New Zealand; Mt Cook station	1 from Mt Cook	45	Dean Satchell	10
	Earnslaw One; Naseby forest	-		Mark Dean	4
Douglas fir, mixed heartwood\sapwood	Donelleys sawmill, Reporoa	-	-	Scion staff	-
Radiata pine, mixed heartwood\sapwood	Scion stock	-	-	Scion staff	-
Radiata pine, mixed heartwood\sapwood, H1.2 boron treated	Rotorua timber retailer	-	-	Scion staff	-

APPENDIX 2: BORON TREATMENT METHODS

Records of the boron treatments of *Eucalyptus fastigata* and *Eucalyptus nitens* are shown in the following tables.

Table 6: *Eucalyptus fastigata*, mixed heartwood/sapwood, boron pressure treatment

Frame test ID	Treatment ID	Uptake (l/m ³) ¹	Calculated retention (g BAE/100g)
1	N/PB1	129.8	0.46
2	N/PB2	127.0	0.49
3	N/PB3	144.1	0.56
4	N/PB4	125.6	0.49
5	N/PB5	116.4	0.45
6	N/PB6	181.8	0.58
7	N/PB7	73.1	0.29
8	N/PB8	139.5	0.47
9	N/PB9	128.5	0.45
10	N/PB10	122.7	0.46

¹Target solution was 20.2 g BAE/l.

Table 7: *Eucalyptus fastigata*, LVL, boron pressure treatment

Frame test ID	Treatment ID	Uptake (l/m ³) ¹	Calculated retention (g BAE/100g)
31	2B	437.3	0.47
32	G1A	425.6	0.44
33	4J	452.9	0.52
34	G6B	455.4	0.54
35	Y1I	456.7	0.53
36	P1I	424.6	0.48
37	3B	420.1	0.47
38	G2C	435.3	0.50
39	P2I	404.0	0.45
40	1J	406.5	0.41

¹Target solution was 6.36 g BAE/l.

The *Eucalyptus nitens* samples were either dipped or brushed with a boron formulation, as 25 mm thick boards. These boards were later dried and laminated to provide test material for the Frame test.

Table 8: *Eucalyptus nitens*, mixed heartwood/sapwood, laminated, boron diffusion treatment

Treatment ID	Uptake (g)		Calculated uptake (kg/m ³)		
Formulation 1 ¹	1 st dip	2 nd dip	1 st dip	2 nd dip	Total
1B	80	9	32.0	3.6	35.6
2C	79	21	31.6	8.4	40.0
3A	72	14	28.8	5.6	34.4
4B	70	12	28.0	4.8	32.8
5A	67	14	26.8	5.6	32.4
6A	69	17	27.6	6.8	34.4
7C	77	19	30.8	7.6	38.4
8A	63	17	25.2	6.8	32.0
9A	81	20	32.4	8.0	40.4
10B	71	11	28.4	4.4	32.8

Formulation 2¹	1st coat	2nd coat	1st coat	2nd coat	Total
1C	54	33	21.6	13.2	34.8
2A	56	35	22.4	14.0	36.4
3B	49	30	19.6	12.0	31.6
4C	49	29	19.6	11.6	31.2
5C	52	32	20.8	12.8	33.6
6B	52	27	20.8	10.8	31.6
7B	49	25	19.6	10.0	29.6
8C	42	-	16.8	0.0	16.8
9B	56	25	22.4	10.0	32.4
10C	61	26	24.4	10.4	34.8
Average	62	22	25.0	8.3	33.3

¹ Formulation 1 was 15% boron and formulation 2 was 30% boron.

APPENDIX 3: BORON RETENTION ANALYSIS

Eucalyptus fastigata, mixed heartwood\sapwood, boron treated

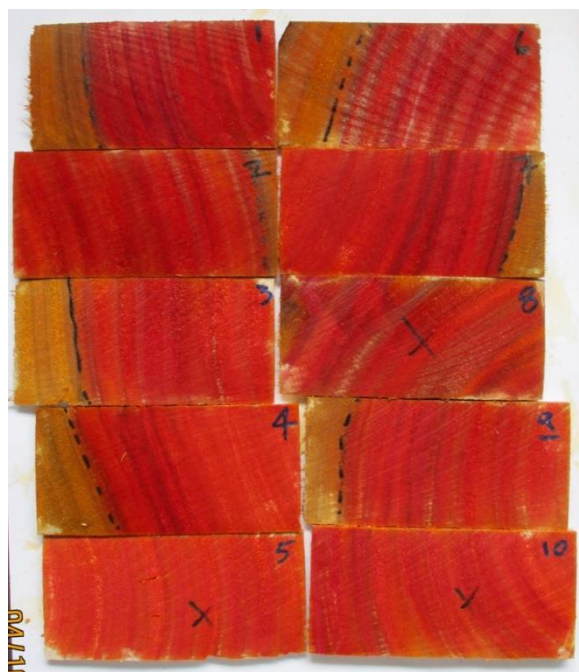


Figure 15: Heart\sap spot test images of *Eucalyptus fastigata* in cross section

Note: Heart\sap wood distribution needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.



Figure 16: Penetration\sap spot test images of *Eucalyptus fastigata* in cross section

Note: Boron penetration needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.

ANALYSIS REPORT

29 June 2023

Attention: Ian Simpson \ Tripti Singh

Laboratory Reference: LMS13468

Date submitted: 30.05.2023

Sample Description: 10x Boron treated E. Fastigata solid timber samples

Analysis required: Boron retention and penetration analysis

Lab sample ID	Client ID	Sapwood (%)	Retention analysis BAE (% m/m)	Penetration analysis BAE (% m/m)
P05433	1	25	0.52	N/A
P05434	2	5	0.54	N/A
P05435	3	25	0.54	N/A
P05436	4	20	0.59	N/A
P05437	5	0	N/A	N/A
P05438	6	25	0.57	N/A
P05439	7	10	0.57	N/A
P05440	8	0	N/A	N/A
P05441	9	10	0.49	N/A
P05442	10	0	N/A	N/A

Method: Analysis - HNO₃ / H₂O₂ microwave assisted digestion, ICPMS
Boron - AS/NZS 1604.3:2021 Section 3.3

Notes: Heartwood was removed for retention and penetration analysis
N/A- no sample to test

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***Eucalyptus fastigata*, LVL, boron treated**



Figure 17: Heart\sap spot test images of *Eucalyptus fastigata* LVL in cross section

Note: Heart\sap wood distribution needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.



Figure 18: Penetration \sap spot test images of *Eucalyptus fastigata* LVL in cross section

Note: Boron penetration needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.

ANALYSIS REPORT

29 June 2023

Attention: Ian Simpson \ Tripti Singh

Laboratory Reference: LMS13468
Date submitted: 30.05.2023
Sample Description: 10x Boron treated E. Fastigata LVL samples
Analysis required: Boron retention and penetration analysis

Lab sample ID	Client ID	Sapwood (%)	Retention analysis BAE (% m/m)	Penetration analysis BAE (% m/m)
P05443	31	77	0.17	0.15
P05444	32	55	0.16	0.16
P05445	33	91	0.20	0.20
P05446	34	95	0.18	0.18
P05447	35	64	0.17	0.15
P05448	36	48	0.18	0.14
P05449	37	92	0.18	0.17
P05450	38	77	0.19	0.19
P05451	39	64	0.18	0.17
P05452	40	82	0.15	0.14

Method: Analysis - HNO₃ / H₂O₂ microwave assisted digestion, ICPMS
Boron - AS/NZS 1604.3:2021 Section 3.3

Notes: Heartwood was removed for retention and penetration analysis
N/A- no sample to test

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***Eucalyptus nitens*, mixed heartwood\sapwood, laminated, boron treated**



Figure 19: Heart\sap spot test images of laminated *Eucalyptus nitens* in cross section

Note: Heart\sap wood distribution needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.



Figure 20: Penetration \sap spot test images of laminated *Eucalyptus nitens* in cross section

Note: Boron penetration needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.

ANALYSIS REPORT

29 June 2023

Attention: Ian Simpson \ Tripti Singh

Laboratory Reference: LMS13468
Date submitted: 30.05.2023
Sample Description: 10 x Boron treated E.Nitens laminated
Analysis required: Boron retention and penetration analysis

Lab sample ID	Client ID	Sapwood (%)	Retention analysis BAE (% m/m)	Penetration analysis BAE (% m/m)
P05453	41	5	2.25	N/A
P05454	42	10	1.12	N/A
P05455	43	0	N/A	N/A
P05456	44	10	0.80	N/A
P05457	45	0	N/A	N/A
P05458	46	0	N/A	N/A
P05459	47	0	N/A	N/A
P05460	48	25	1.77	0.87
P05461	49	2	1.64	N/A
P05462	50	0	N/A	N/A

Method: Analysis - HNO₃ / H₂O₂ microwave assisted digestion, ICPMS
Boron - AS/NZS 1604.3:2021 Section 3.3

Notes: Heartwood was removed for retention and penetration analysis
N/A- no sample to test

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Radiata pine, mixed heartwood\sapwood, H1.2 boron treated

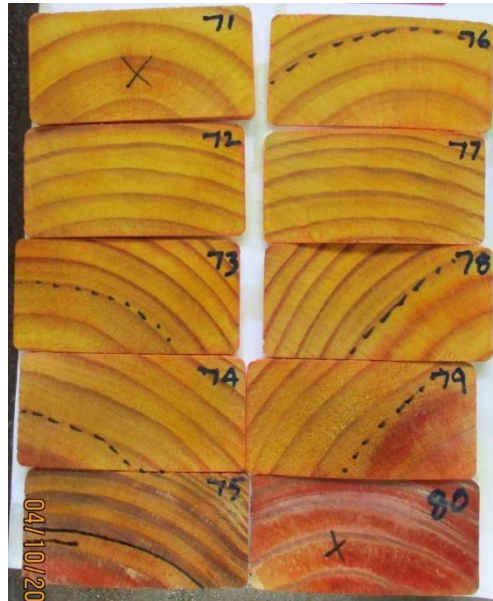


Figure 21: Heart\sap spot test images of radiata pine in cross section

Note: Heart\sap wood distribution needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.



Figure 22: Penetration \sap spot test images of radiata pine in cross-section

Note: Boron penetration needs to be determined on actual samples, photographs should be considered as indicative only as colour will vary with the image collection device, printer and computer screen used.

ANALYSIS REPORT

29 June 2023

Attention: Ian Simpson \ Tripti Singh

Laboratory Reference: LMS13468

Date submitted: 30.05.2023

Sample Description: 10 x Pinus radiata H1.2

Analysis required: Boron retention and penetration analysis

Lab sample ID	Client ID	Sapwood (%)	Retention analysis BAE (% m/m)	Penetration analysis BAE (% m/m)
P05463	71	0	N/A	N/A
P05464	72	100	0.95	0.78
P05465	73	75	1.48	1.04
P05466	74	85	1.55	0.53
P05467	75	75	0.75	0.34
P05468	76	20	1.18	N/A
P05469	77	100	0.92	0.39
P05470	78	60	1.24	0.65
P05471	79	60	1.08	0.41
P05472	80	0	N/A	N/A

Method: Analysis - HNO₃ / H₂O₂ microwave assisted digestion, ICPMS
Boron - AS/NZS 1604.3:2021 Section 3.3

Notes: Heartwood was removed for retention and penetration analysis
N/A- no sample to test

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APPENDIX 4: INDIVIDUAL SAMPLE RATINGS AFTER ONE YEAR'S EXPOSURE

Table 9: Individual sample ratings after one year's exposure in accelerated conditions

Sample ID	Op ¹ Mould	Op Mycelium	Op Decay Surface	Op Decay Joint	Ax ¹ Mould	Ax Mycelium	Ax Decay Surface	Ax Decay Joint
<i>Eucalyptus fastigata</i> , heartwood\sapwood, untreated								
11	1	1	10	10	1	5	8	8
12	2	3	9	8	2	2	9	8
13	2	3	8	7	2	3	6	6
14	2	3	8	8	2	4	7	6
15	2	1	9	8	2	3	7	8
16	2	1	10	8	1	4	6	6
17	1	3	10	9	1	1	10	8
18	1	1	8	8	1	4	7	6
19	1	1	10	10	1	3	10	10
20	1	3	10	8	1	4	10	8
<i>Eucalyptus fastigata</i> , mixed heartwood\sapwood, boron treated								
1	1	3	10	10	2	3	10	10
2	1	1	10	10	1	1	10	10
3	1	1	10	10	1	1	10	10
4	3	2	10	10	1	1	10	10
5	1	1	10	10	1	1	10	10
6	1	2	10	10	1	1	10	10
7	1	1	10	10	1	1	10	10
8	2	1	10	10	1	1	10	10
9	1	1	10	10	1	3	10	10
10	1	1	10	10	1	1	10	10
<i>Eucalyptus fastigata</i> , LVL, untreated								
21	1	3	10	10	2	1	10	10
22	1	1	10	10	2	1	10	10
23	1	3	10	10	1	1	10	10
24	1	3	10	10	1	3	8	8
25	1	1	10	10	1	2	10	10
26	1	1	8	10	1	2	10	10
27	1	2	10	10	1	2	10	10
28	1	1	10	10	1	1	10	10
29	1	1	10	10	1	1	10	10
30	1	2	7	10	2	1	9	10
<i>Eucalyptus fastigata</i> , LVL, boron treated								
31	5	1	10	10	5	1	10	10
32	5	2	10	10	5	1	10	10
33	4	1	10	10	4	1	10	10
34	2	2	10	10	5	1	10	10
35	4	2	10	10	4	1	10	10
36	5	1	10	10	5	2	10	10
37	5	3	10	10	4	1	10	10
38	4	3	10	10	4	1	10	10
39	1	1	10	10	1	1	10	10
40	5	1	10	10	5	3	10	10

¹ Op and Ax represent different ends of the "I frame" samples with feeder blocks inoculated with *Oligoporus placenta* and *Antrodia xantha*.

Table 9 continued: Individual sample ratings after one year's exposure in accelerated conditions

Sample ID	Op ¹ Mould	Op Mycelium	Op Decay Surface	Op Decay Joint	Ax ¹ Mould	Ax Mycelium	Ax Decay Surface	Ax Decay Joint
<i>Eucalyptus nitens</i> , heartwood, laminated, untreated								
51	1	5	10	10	1	1	10	10
52	1	1	10	10	1	4	8	8
53	1	1	10	10	1	5	10	10
54	1	1	10	10	1	2	10	10
55	1	1	10	10	1	1	10	10
56	1	6	9	9	1	3	9	8
57	1	1	10	10	1	3	8	8
58	1	2	10	10	1	2	9	7
59	1	1	8	8	1	5	7	8
60	1	1	10	10	1	3	8	7
<i>Eucalyptus nitens</i> , mixed heartwood/sapwood, laminated, boron treated								
41	1	1	10	10	1	2	10	10
42	1	1	10	10	2	1	10	10
43	1	1	10	10	1	1	10	10
44	1	1	10	10	2	1	10	10
45	2	1	10	10	1	1	10	10
46	2	1	10	10	1	1	10	10
47	1	1	10	10	1	1	10	10
48	1	1	10	10	2	1	10	10
49	1	1	10	10	1	1	10	10
50	1	1	10	10	1	1	10	10
<i>Eucalyptus regnans</i> , heartwood, untreated								
131	1	3	T	10	1	3	8	8
132	1	3	8	7	1	3	7	7
133	1	2	10	10	1	1	10	10
134	1	1	8	7	1	3	7	7
135	1	3	8	9	1	1	T	10
136	1	2	10	10	1	3	9	T
137	1	2	8	9	1	3	8	8
138	1	1	10	10	1	3	7	8
139	1	1	8	9	1	1	8	7
140	1	1	8	9	1	3	8	7

¹ Op and Ax represent different ends of the "I frame" samples with feeder blocks inoculated with *Oligoporous placenta* and *Antrodia xantha*.

Table 9 continued: Individual sample ratings after one year's exposure in accelerated conditions

Sample ID	Op ¹ Mould	Op Mycelium	Op Decay Surface	Op Decay Joint	Ax ¹ Mould	Ax Mycelium	Ax Decay Surface	Ax Decay Joint
<i>Cupressus macrocarpa</i> , young trees, heartwood, untreated								
91	2	1	10	10	2	1	10	10
92	2	1	10	10	2	3	10	10
93	3	1	10	10	2	1	10	10
94	2	1	10	10	2	1	10	10
95	2	1	10	10	2	1	10	10
96	1	1	10	10	1	3	T	8
97	1	1	10	10	2	1	10	10
98	1	1	10	10	1	2	10	10
99	1	3	10	10	1	1	10	10
100	1	2	10	10	2	1	10	10
<i>Cupressus macrocarpa</i> , old trees, heartwood, untreated								
81	1	4	10	10	1	4	10	10
82	1	3	10	10	1	4	10	10
83	1	3	10	10	1	4	10	10
84	3	4	8	7	3	3	10	10
85	2	3	10	10	2	5	10	10
86	1	1	10	10	1	1	10	10
87	2	4	9	10	2	4	10	10
88	2	3	9	10	2	4	10	10
89	2	1	10	10	2	1	10	10
90	2	3	9	10	2	1	10	10
<i>Cupressus xovensii</i> , heartwood, laminated, untreated								
101	1	1	10	10	1	3	10	10
102	1	1	10	10	1	4	10	10
103	1	1	10	10	1	3	9	8
104	1	1	10	10	1	3	9	9
105	1	1	10	10	1	3	T	T
106	1	1	10	10	1	1	10	10
107	1	1	10	10	1	1	10	10
108	1	1	10	10	1	3	9	9
109	1	1	10	10	1	1	10	10
110	1	1	10	10	1	3	10	10

¹ Op and Ax represent different ends of the "I frame" samples with feeder blocks inoculated with *Oligoporus placenta* and *Antrodia xantha*.

Table 9 continued: Individual sample ratings after one year's exposure in accelerated conditions

Sample ID	Op ¹ Mould	Op Mycelium	Op Decay Surface	Op Decay Joint	Ax ¹ Mould	Ax Mycelium	Ax Decay Surface	Ax Decay Joint
Larch, heartwood, untreated								
111	1	1	10	10	2	1	10	10
112	1	1	10	10	1	1	10	10
113	1	1	10	10	1	1	10	10
114	1	1	10	10	1	1	10	10
115	1	1	10	10	1	1	10	10
116	1	1	10	10	1	1	10	10
117	1	1	10	10	2	1	10	10
118	2	1	10	10	1	1	10	10
119	1	1	10	10	1	1	10	10
120	1	1	10	10	1	1	10	10
Douglas fir, mixed heartwood/sapwood, untreated								
121	2	1	10	10	2	1	10	7
122	1	5	8	7	2	4	8	7
123	2	5	8	10	2	3	8	7
124	1	5	8	10	2	4	7	7
125	1	6	8	6	1	5	7	7
126	2	6	9	7	3	3	6	6
127	4	3	6	4	3	1	7	6
128	1	1	10	10	1	3	9	8
129	2	3	9	8	3	3	6	6
130	1	1	10	10	2	3	10	10
Radiata pine, mixed heartwood/sapwood, untreated								
61	6	1	4	4	2	5	4	4
62	2	5	6	6	3	2	4	4
63	2	6	6	7	2	5	4	4
64	4	4	7	7	3	4	7	7
65	3	6	6	6	3	3	4	4
66	3	6	4	6	3	5	4	4
67	2	6	6	4	3	2	4	6
68	4	5	6	7	4	5	6	4
69	4	5	4	4	4	3	4	4
70	4	5	4	4	3	3	4	4
Radiata pine, mixed heartwood/sapwood, H1.2 boron treated								
71	3	1	10	10	3	1	10	10
72	2	1	10	10	2	1	10	10
73	2	1	10	10	2	1	10	10
74	2	1	10	10	2	1	10	10
75	3	1	10	10	2	1	10	10
76	2	1	10	10	3	1	10	10
77	2	1	10	10	3	1	10	10
78	3	1	10	10	3	1	10	10
79	2	1	10	10	2	1	10	10
80	5	1	10	10	5	1	10	10

¹ Op and Ax represent different ends of the "I frame" samples with feeder blocks inoculated with *Oligoporus placenta* and *Antrrodia xantha*.