Grade recoveries from sawing 22-year-old unpruned cypress clones

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EXECUTIVE SUMMARY

A Scion clonal cypress trial established in 1997 provided the opportunity to determine the grade recoveries of sawn timber from two cypress clones; GH5 (*Cupressus lusitanica*) and Ovensii (*Cupressus lusitanica x Chamaecyparis nootkatensis*). As well as giving information on the wood properties from these new clones, this study demonstrates the viability of young trees for sawn timber production. Cypresses are typically pruned and thinned to maximise clearwood recovery while minimising the incidence of bark encased knots, which substantially downgrade the timber. Harvesting unpruned trees at a young age reduces the incidence of bark encased knots, and provides high appearance grade recoveries for a low-intensity silvicultural regime.

The two clones were grown as part of a cypress hybrid trial in Rotoehu forest, in New Zealand's North Island. The GH 5 clone was harvested from a clonal block planted at 800 stems per hectare and were unpruned and unthinned. The GH 5 clone was notable for is wavy stem form but fine branching. The Ovensii clone was harvested from row plots and were mostly of straight form. Fourteen trees were harvested, and the 36 logs were sawn at Ruapehu sawmill in Raetihi with a sawn timber recovery of 58% from an average SED of 233mm and with approximately 50% nominal grade recoveries. The dried boards were visually graded for appearance and structural grades, and acoustic stiffness measured on a subset of the boards.

Overall volume recoveries were good, with 51% of the volume of logs harvested converted into graded timber. Grade recoveries were very high with over 90% of boards reaching the top appearance grade (modified Dressing grade, which allows a maximum intergrown knot size of 50mm), and almost all boards reaching No. 1 framing grade. Grade recoveries were slightly higher in the *C. x ovensii* boards, due to a lower incidence of bark encased knots compared with the *C. lusitanica* clones (GH5). Bark encased knots are an issue for older unpruned trees, and as the trees grow older the number of bark encased knots is expected to increase. The number of bark encased knots in the *C. x ovensii* boards were very low, and it is not clear how quickly these would increase over time, and whether the trees could be harvested at a later age without a significant increase in the incidence of bark encased knots.

A brief economic analysis was performed to gauge the viability of sawing young unpruned trees. Three scenarios, each with an emphasis on different products, were compared: Thermally modified cladding; Interior panelling; and exterior products from 100% heartwood boards. For both clones the thermally modified cladding scenario had the highest margins (product price minus processing cost). This suggests that producing thermally modified cladding from young unpruned trees could be viable, and that the continued development and testing of thermally modified cypress is a priority. For the *C. x ovensii*, the higher proportion of heartwood means that sawing into conventional outdoor products (which require 100% heartwood) could also be viable; the heartwood-only scenario had the same average margin as the thermal modification scenario (31%). For the GH5, the heartwood-only scenario gave the lowest average margin (16%). Considerable variations in processing cost and product prices were found between different sources, and it is not known how sensitive the cypress timber market would be to increased supply of timber. The processing of cypress (including thermal modification) will be investigated in more detail in upcoming WoodScape modelling work being undertaken at Scion.

Acoustic stiffness was similar in each species (average 8.7 GPa) with a lot of variation between boards. The basic (oven dry) density of *C. x ovensii* was significantly higher than the GH5 (average 450kg/m^3 and 360 kg/m^3 respectively).

Overall the silviculture regime used for growing (plant and leave 800 stems per hectare) gave good grade recoveries, and the *C. x ovensii* clone had a high proportion of heartwood (average 61%, compared to 30% for the GH5). It may be possible to grow this clone for longer, to increase the volume of heartwood in the logs without the formation of excessive numbers of bark encased knots, but further work would be needed to confirm this.

INTRODUCTION

In order to have confidence to plant a particular species, or follow a particular silvicultural regime, it is helpful to understand the grades of timber that are likely to be obtained from the trees at harvest. The last research study into grade recoveries and wood quality for cypress was undertaken in 2005 (Low, et al., 2005). In this pilot study both appearance grade recoveries and structural visual grades were assessed from young pruned trees (21 years old) for a range of cypress species in order to test whether it is viable to harvest young cypress for timber. The study had good sawn timber recoveries for *C. lusitanica* (average 52% by volume) but had a high proportion of box grade timber (23%). There is now an opportunity to repeat this work using new cypress clones, from an unpruned regime.

The current study measured grade recoveries from two cypress clones, a *C. lusitanica* clone “GH5” and the hybrid *C. x ovensii* “Ovensii” selected from a cypress clonal trial, FR328/6, established in 1997 at compartment 131, Rotoehu Forest. The trial had received no pruning or thinning and was essentially a plant-and-leave regime. The purpose of this study was to quantify grade recoveries for 22-year-old trees with good growth and form, for a low-cost unpruned regime at an optimum stocking.

Both appearance and structural grades have been measured in this study. Cypress is primarily an appearance timber and substitute for high-value native softwoods now in short supply. However, regard should also be given for marketing lower grades into structural applications. Cypress heartwood is more durable than Douglas-fir heartwood (Page, et al., 2008) and is the only softwood suitable for structural applications without treatment in New Zealand (Standards Association of New Zealand, 2003). Cypress sapwood is more durable than Douglas-fir sapwood (Page, et al., 2008) and is therefore suitable for use untreated in buildings of simple design (New Zealand Ministry of Business, 2019) as structural timber, which would be a significant market advantage if stiffness deficiencies could be overcome through breeding.

The intention of this study was to provide pilot grade recoveries from trees with good genetics, under an optimised regime and where the wood is dried and graded to best practice. Recoveries were measured as docked lengths of higher value appearance grades where possible, and long length structural grades where appearance grades were not practical.

METHODS

The tree selection and sawing is described in detail in Stovold, et al. (2019), and are described briefly here.

Scion established a cypress clone trial in 1997, and trees from two clones were selected for this sawing study; GH5 (*Cupressus lusitanica*) and *C. x ovensii* ("Ovensii"). The trees were grown with a low intensity silvicultural regime and had not been pruned or thinned. The stocking rate at harvest was around 555 spha for the GH5. A sample plot was put in before harvesting.

Six trees of *C. x ovensii* and 8 trees of GH5 were selected to be harvested and sawn. Each tree yielded 2-3 logs 6m long. Prior to sawing, the following measurements were made on each log:

- Branch index (average of the maximum branch size in each quarter of the log)
- Sapwood and heartwood diameters
- Hitman (acoustic stiffness)
- Measure log length and large end diameter
- Measure sweep (the maximum deflection from a string line in cm)

Small end diameters were assumed to be the same as the large end diameters of the log above. For the top logs small end diameter was estimated from the large end diameter and the average taper of the lower logs in the tree. Log volumes were calculated from the log length and the average of the large and small end diameters.

The logs were sawn at Ruapehu sawmill using a Woodmizer bandsaw and Woodmizer twin-blade edger. Barcodes were applied to each end of each log to allow for individual boards to be traced back to the log, and position in log they were cut from. Boards were cut to 25, 38 or 50mm (nominal) thickness, and edged in 25mm increments to widths between 75 and 300mm wide.

Following sawing the boards were air dried in Raetihi and transported to Scion once they were between 13-17% moisture content. The boards were stored indoors for two weeks prior to grading to allow the boards to equilibrate to the conditions in the shed, as is standard practise when testing timber at Scion.

The boards were graded according to the appearance grades for exotic softwoods in NZS 3631 (Standards Association of New Zealand, 1988):

- Dressing grade with modifications ("Cladding grade")
- Merchantable grade
- Box grade

The boards were also graded according to structural grades (No. 1 framing) in NZS 3631.

Because the logs were unpruned, there were no clears-grade boards. The Cladding grade is almost identical to Dressing Grade for Class 3 timber specified NZS 3631, but has the additional requirement of maximum 50mm diameter for intergrown or partially intergrown knots to meet grade requirements for cladding in NZS 3602:2003 (Standards Association of New Zealand, 2003). In addition to these appearance grades, each board was graded for structural No. 1 framing.

Due to the need to retain the log-end barcodes, the boards were not docked after edging, as would normally occur prior to grading. For this reason, the grades were assigned as if the boards had been docked. For each board the nominal width and thickness were recorded and a length and a grade was assigned to indicate the volume of the board that met that particular grade. The proportion of heartwood (to the nearest 10%) was estimated for each board.

A small proportion (~4% by volume) of boards did not have log-end barcodes. Each of these boards was matched to the correct log using a combination of factors:

- Appearance (to determine the species)
- Order in which green measurements were made (boards from the same log were generally measured at a similar time)
- Identifying missing boards in the sawing pattern of each log
- Percentage heartwood or presence of pith

Sawn timber recovery was calculated from the green dimensions of each boards (minus obvious taper on board ends that needed to be retained for their log-end barcodes). Grade recoveries were calculated as the nominal volume of dry timber in each grade divided by the volume of logs sawn. During the grading the larger boards (> 5kg weight) had their acoustic stiffness measured, either with a Hitman HM200 or using the Scion Joescan. Acoustic stiffness is a useful measure for sorting boards into stiffness classes for structural applications. To determine acoustic stiffness, nominal density (density of wood plus associated moisture) is measured. Due to large differences in nominal density between the two clones, basic (oven-dry) density was also measured on boards selected from 12 of the 14 trees.

To determine the effect of tree height on the variables of interest, each board can be matched to either the large or small end of each log. This, combined with the board length gives the height in the tree at which each board started and ended. To simplify the analysis, each board was assigned to either the top or the bottom of its log height class, according to whether the attached barcode was from the large or small end of the log. Some boards (~25% of total volume) were longer than half the length of the original log, so these boards were classified according to the half of the log that contained most of the board. A small proportion of boards (10% total volume) were the full length of the original log, these were arbitrarily assigned to the large end of the log.

RESULTS

The specifics of the tree selection and sawing process are reported in Stovold, et al. (2019). Briefly, a sample plot was measured for the GH5 and at the time of measurement the stand had a stocking of 555spha. Using the FGR Cypress calculator, the standing volume was estimated at 270m^3/ha, and the average DBH was 26.6cm. The largest 14 *C. x ovensii* trees were measured and these had an average DBH of 24.8cm.

Sawn timber recovery

The volume of green timber for each clone is shown in Table 1, separated into log size classes based on the mid-log diameter (average of SED and LED). For the *C. x ovensii* logs there isn't an obvious trend between sawn timber recovery and log size. For the GH5 logs, the smallest log class has a lower recovery than the larger logs, but as there is only one log in this size class it is difficult to draw any conclusions from this. A more comprehensive analysis of log size and grade recoveries is discussed below.

Table 1: Green recovery (in m^3) for each clone, broken down into log size classes.

Mid log diameter (mm)		150 - 199	200 - 249	250 - 299	300+	Total
OV	m^3	0.59	0.33	0.77		1.69
	%	55	66	57		58
	n	7	2	4		13
GH5	m^3	0.06	0.97	1.21	2.25	4.49
	%	45	53	63	58	58
	n	1	8	6	8	15

The overall sawn timber recovery of 58% is good. Low, et al. (2005) had an average sawn timber recovery of 52% for *C. lusitanica*, for slightly larger logs (average SED of 276mm compared to 233mm here). It should also be noted that the timber sawn in Low, et al. included a large volume of Box grade boards (up to 23% of the timber volume) whereas the current study had virtually no Box grade timber (see grade recoveries below).

Grade recoveries

The overall recovery of graded timber by log height is shown in Table 2. The percentage recoveries are slightly lower than the sawn recoveries in Table 1, which reflects the graded length of some boards being shorter than the actual sawn length. This simulates docking the boards to avoid defects and maximise recovery of more valuable grades. For GH5 recovery was higher in second logs compared with butt logs and for both clones, recovery was significantly lower in third logs. For the GH5 logs, taper was significantly higher in the butt log compared with the second logs. There was no significant difference in taper between the butt and second logs of *C. x ovensii*. As small end diameters of the third logs were not measured, taper values for these logs have only been estimated, so have not been included in the statistical analysis.

Table 2: Log properties and graded timber recoveries by height up the tree.

Clone	Log	No. logs	s.e.d (mm)	Vol timber (m^3)	log taper (mm/m)	BIX (cm)	Recovery (%)
GH5	a	8	275	1.97	13.7	3.0	51
	b	8	230	1.42	7.4	3.8	57
	c	7	189	0.59	8.2*	5.8	42
C. x ovensii	a	6	215	0.90	12.3	3.3	49
	b	6	148	0.50	10.9	3.8	49
	c	1	140	0.02	7.7*	3.5	44

* calculated from estimated SED values

The percentage recoveries of each grade are shown for the two clones in Table 3. A very high proportion of boards met the Cladding grade, with a slightly higher proportion of *C. x ovensii* boards meeting this grade (96% compared with 90% for GH5). Nearly all boards met the No. 1 framing grade (one GH5 board was downgraded to Box). Not surprisingly for trees this age, the proportion of heartwood was relatively low, but the *C. x ovensii* boards had a significantly higher proportion of heartwood than GH5. The average board length was not significantly different between the two clones. The average width of the GH5 boards was greater than that of the *C. x ovensii* boards, which was not surprising as the GH5 logs were larger (average DBH 344mm for GH5 vs. 290mm for *C. x ovensii*). From the stand measurements made on the GH5 sample plot, the expected volume of graded timber per hectare of planted area is shown for this clone in Table 3.

Table 3: Recoveries of each grade, plus proportion of heartwood.

Grade	Overall	GH5	*C. x ovensii*
Cladding (%)	92	90	96
Merch (%)	8.2	9.7	3.9
No. 1 Framing	100	100	100
Box (%)	0.1	0.1	0.0
Prop. Heartwood (%)	45	38	64
Average board length (m)	2.6	2.7	2.6
Average board width (mm)	160	167	145
Total volume (m^3)	5.4	4.0	1.4
% recovery	51	51	49
Recovery per hectare (m^3)		139	

While the boards were gradesawn to maximise the recovery of wide boards, it is worth noting that in No. 1 framing grade the permitted sizes for knots are expressed as a proportion of the board width (less than 1/3 width of boards <150mm wide, less than ¼ width of boards >150mm wide). As the majority of the boards are greater than 100mm wide, some boards will have knots that are permissible at their current width, but if they were to be re-sawn to narrower boards, the knots would take up a larger proportion of the board cross section and would no longer meet No. 1 framing requirements without docking to remove the knots. The incidence of these larger knots was not noted, so it is unknown how many boards would be affected in this way.

Figure 1: Large knot that is permissible for No. 1. Framing grade in a 150mm wide board but would no longer be permissible if the board was re-sawn to 100mm wide.

All the GH5 boards downgraded to Merchantable grade were downgraded because of the presence of bark encased knots. For the *C. x ovensii* boards, 2.5% of boards were downgraded due to bark encased knots, and 0.8% due to holes. One GH5 board was downgraded to Box grade due to a large bark encased knot. Defects such as wane were removed during edging, so this is not listed as a defect. Compared with Low, et al. (2005), the proportion of Merchantable and Box grade boards is very low. This is because the boards were gradesawn and slow air dried, but also in part because the grading method used here graded the boards as if they had been docked to remove defects, rather than grading the full length of the board, as was done in Low et al. This is reflected in the average board lengths shown in Table 2 – these are slightly less than the expected average rough sawn length of 3m (half the log length). Despite these differences in grading technique Low et al. still had a reasonable proportion of boards with defects such as knots, surface checks and distortion which could not easily be removed by altering the board dimensions during grading, that were still not present to a significant extent in the current study. Some, but not all, of the additional degrade in Low et al. could be attributed to pruning scars, which were not present in this study. Low et al. also had relatively low recoveries of No. 1 framing timber (59% of log volume for *C. lusitanica*) due to defects such as distortion, insect attack and decay. No problematic levels of distortion were seen in the current study, and no insect attack or decay was recorded as reasons for downgrading the timber, although some insect attack has been found in *C. x ovensii* boards being sawn for downstream testing (B. Davy pers. comm.).

Because bark encased knots were the major reason for downgrading boards from Cladding to Merchantable grade, it is worth looking at them in more detail. Bark encased knots form from branches that have died, and in unpruned, unthinned stands you would expect lower branches to die and become bark encased first. There is evidence that cypress branches remain alive (and thus do not become encased) for a number of years after they lose foliage and have stopped growing. This effect may be longer lasting at lower stocking rates (Mansikkala, 2002). As bark encased knots reduce the value of the timber, for maximum recovery the trees either have to be harvested before bark encasement of the lower branches starts, or the lower branches need to be removed by pruning. The proportion of boards downgraded due to bark encased knots is shown in Table 4, including a breakdown of the approximate height in the tree of each board. The GH5 logs had a small proportion of bark encased knots at every log height, but the majority of the knots were in the lower half of the first log (roughly 0-3m from the ground). The *C. x ovensii* timber had a much smaller proportion of bark encased knots, and these were only in the lower half of the first log. As the branches at the bottom of the stem are the first to become shaded and die, you would expect bark encased knots to start appearing in the butt log before the rest of the tree.

Table 4: Percentage (by volume) of boards downgraded due to bark encased knots, separated by height in the tree.

Log	A		B		C	
End	Bottom	Top	Bottom	Top	Bottom	Top
Approx height	0-3m	3-6m	6-9m	9-12m	12-15m	15+m
GH5	8.5	0.9	0.2	0.0	0.2	0.1
C. x ovensii	0.8					

If the GH5 trees were left for longer before being harvested, it is likely that the proportion of bark encased knots would keep increasing, increasing total volume but reducing the proportion of Cladding grade timber. The proportion of bark encased knots was very low in the *C. x ovensii* timber and it is possible that the trees could continue to grow for a number of years before the incidence of bark encased knots became significant. This hybrid may have greater shade tolerance and appears to have a greater propensity for lower branches to remain alive (P. Millen, pers. comm.), which would be consistent with the low incidence of bark encased knots. To better understand the formation of bark encased knots in *C. x ovensii*, a study could be performed where trees of different ages and stockings were felled and knots at different tree heights examined for bark encasement.

The sawing pattern used was intended to maximise recovery in boards with sweep or excessive taper. To test this, the impact of taper and sweep on volume recovery was assessed using a linear model. The volume of boards recovered from each log was modelled as a function of sweep and taper, taking into account which clone each log belonged to, plus the effect of log height and tree DBH. The coefficients from the model are shown in Table 5. Sweep and taper were not significant predictors of volume of boards recovered – meaning that similar volumes of timber were being recovered from logs with high sweep or taper, compared with logs with low sweep or taper. This is a positive result and suggests that the sawing pattern used can reduce the effects of sweep and taper on volume recovery.

Table 5: Linear model relating volume of graded timber cut from each log to sweep and taper, taking into account tree size, log height and tree species.

	Estimate	Standard Error	t value	p
Intercept	0.08	0.06	1.28	0.21
Sweep	-0.00	0.00	-1.26	0.22
Taper	-0.00	0.00	-2.00	0.06
DBH	0.00	0.00	3.31	0.002
Log height in tree	-0.01	0.00	-16.01	<0.001
Species (ovensii or GH5)*	-0.06	0.01	-4.32	<0.001

* this represents the expected difference in timber volume for the *C. x ovensii* logs compared an equivalent GH5 log.

No. observations: 36
Dependent variable: Volume of timber per log
Model fit:
$F(5,30) = 91.7$, $p < 0.001$
$R^2 = 0.94$
Adj. $R^2 = 0.93$

Grade recoveries for individual logs are given in Appendix 2. Overall recoveries for individual logs varied from 25% to 64%, but the majority (80% of logs) had recoveries between 40 to 59%. The nominal recovery of each log is shown as a function of the mid-log diameter in Figure 2. On average the GH5 logs have a larger mid-log diameter, and a slightly higher recovery, but there is too much scatter in the data to see any obvious trends between log diameter and percentage recovery. This shows that the range of log diameters being sawn was appropriate, and good recoveries were still being obtained with small logs.

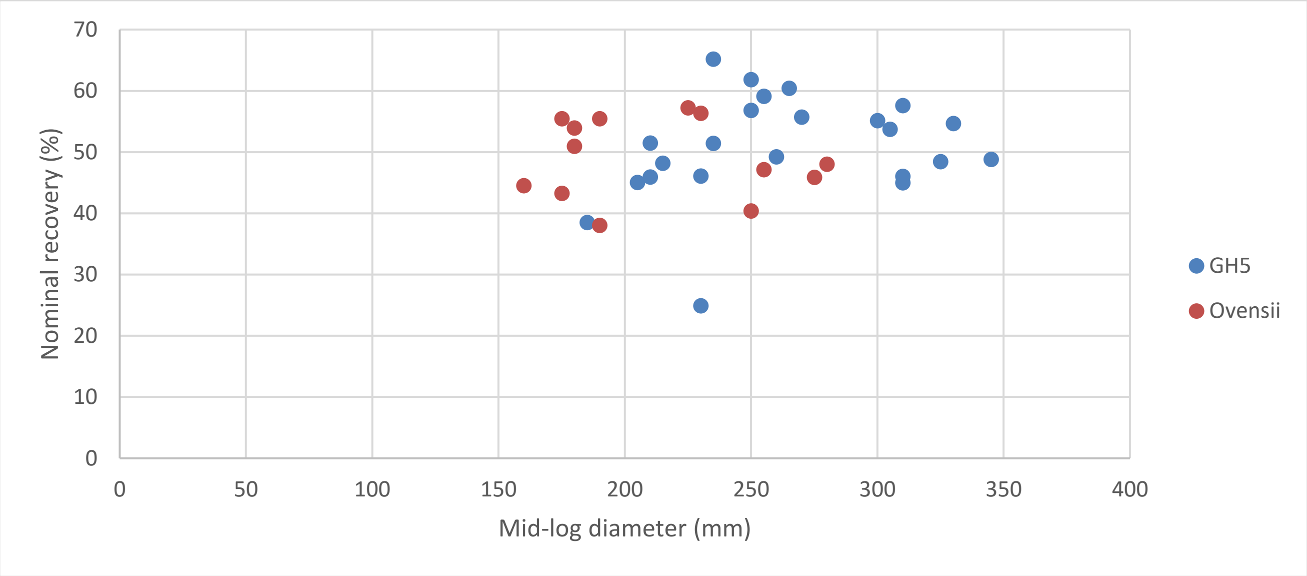

Figure 2: Sawn timber recovery as a function of log diameter.

The acoustic stiffness values for each board is plotted against the height up the tree of the mid-point of each board in Figure 3, to see if there is an effect of log height on board stiffness. For the *C. x ovensii* boards, only boards from the first and second logs were measured, giving limited information about the trend with tree height, however from this limited data, there does not appear to be a relationship between acoustic stiffness and the height up the tree. As a follow up to this study, mechanical testing of small clear samples will be undertaken on *C. x ovensii* with samples cut from a range of positions in the tree (including radial positions, and height up the tree). This work is covered by a separate work plan (SWP-WP135). The combination of acoustic stiffness values, and mechanical test data from the same boards would enable correction factors to be developed so acoustic stiffness can be used to sort boards into structural stiffness classes.

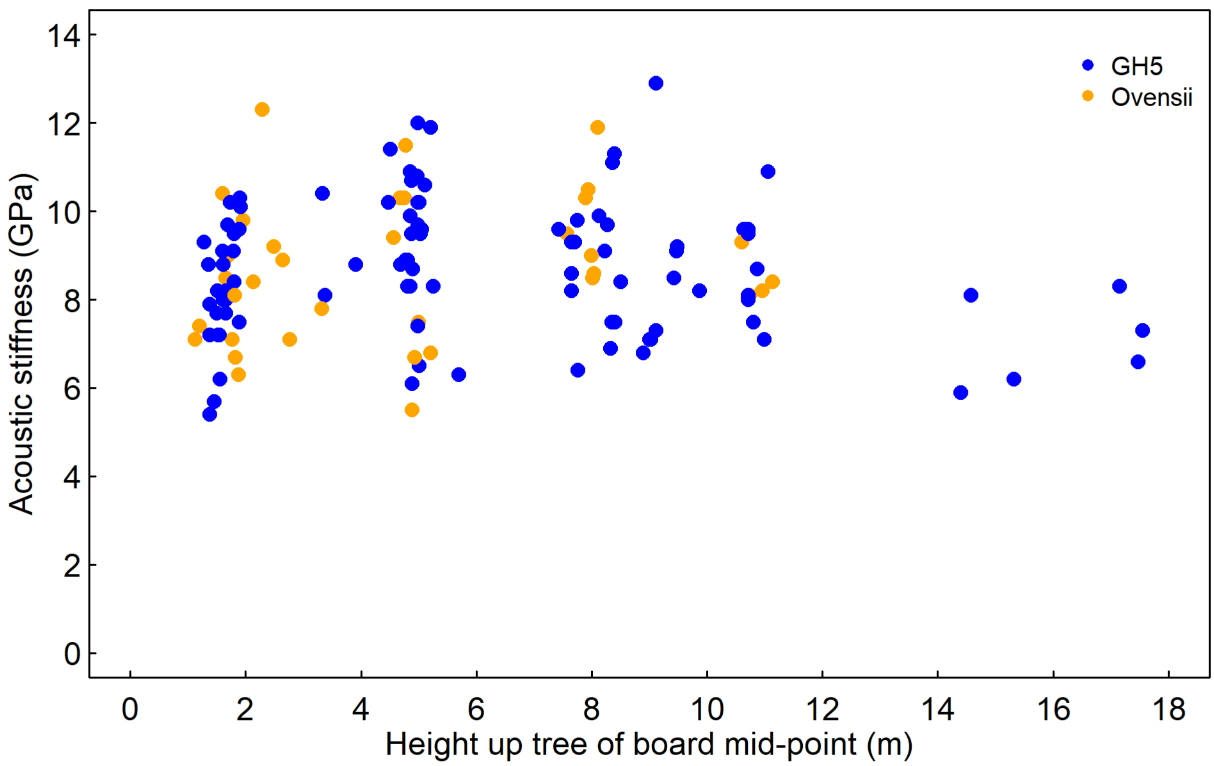

Figure 3: Acoustic stiffness as a function of the height up the tree of the mid-point of each board.

To measure the acoustic stiffness of the boards, the nominal density (density of wood plus moisture) of the board must be determined. During testing it was found that the *C. x ovensii* boards had a substantially higher nominal density than the GH5 boards. Nominal density is strongly affected by the wood moisture content, which was not measured during the acoustic stiffness measurements. To confirm this difference in density, basic (oven-dry) density was measured from boards cut from 6 trees of each clone. These results are shown in Figure 4. The *C. x ovensii* had a significantly higher basic density than the GH5 (average 450kg/m^3 compared to 360 kg/m^3).

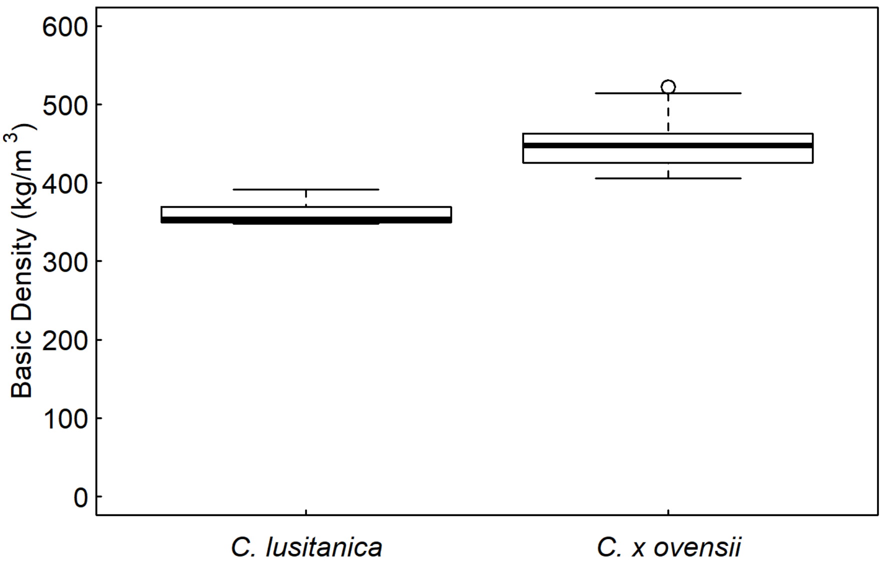

Figure 4: Basic (oven dry) density for each clone. The difference in density between the two species is significantly different (95% confidence level).

Economic analysis

In order to estimate product values for the sawn timber, three different combinations of products have been compared:

- Thermally modified cladding plus ‘untreated’ (sapwood-containing) framing (“Thermal scenario”)
- Interior panelling plus ‘untreated’ framing (“Interior scenario”)
- Heartwood-only cladding and framing plus interior panelling (“Heartwood-only scenario”)

Details of the specifications of each product are given in the Appendix. Thermal modification is a process that shows promise for increasing the durability of cypress sapwood to the level required for cladding in New Zealand, so it has the potential to enable wide weatherboards to be produced from young trees. The economics of thermally modifying cladding-grade boards is compared to that of selling the timber for interior panelling, which has lower processing costs, but commands a lower price in the market.

The third combination of products represents current typical use of cypress timber, where 100% heartwood boards are required for outdoor use. This is intended as a worst-case scenario; these were not the intended products when the timber was sawn, and producing heartwood-only boards from young trees leads to a lot of volume being lost when the sapwood is removed, so is not generally seen as being a viable processing option.

The proportion of boards meeting each end use are shown in Figures 5 & 6. For the first two scenarios, the end use of the timber depended on the thickness the board had been sawn to (50mm for framing, 25mm for cladding or panelling). The 50mm thick boards tended to be sawn from the largest logs, which accounts for the much greater proportion of framing timber for GH5 compared to *C. x ovensii*. Overall the proportion of boards suitable for thermally modified weatherboards is very high for both species.

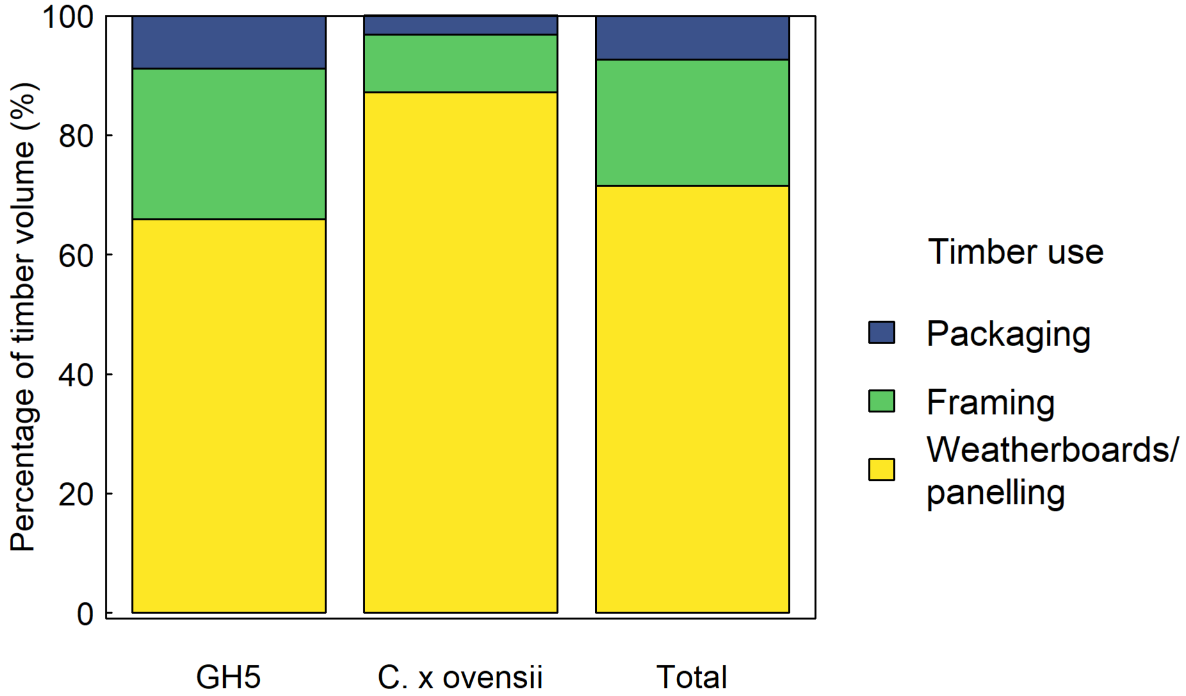

Figure 5: Proportion of graded timber meeting the specifications for the Thermal and Interior scenarios, for each clone. Slabwood produced during sawing is not included in this graph.

For the heartwood-only scenario the *C. x ovensii* had a significantly higher proportion of weatherboards than the GH5, and had a similar proportion of decking/framing boards, giving a higher proportion of end uses requiring durable timber. The low proportion of decking or framing boards reflects the fact that the majority of boards met the Cladding grade, so were suitable for weatherboards. The GH5 had a higher proportion of interior panelling boards, reflecting the lower heartwood content of these trees, leading to more good quality timber with a low heartwood content. The proportion of packaging grade and offcuts were similar between the two species, but slightly higher for the GH5. End uses requiring durability (such as weatherboards) are likely to have a larger market than interior uses (such as panelling) so for existing products and markets recovery of heartwood-only boards is a priority.

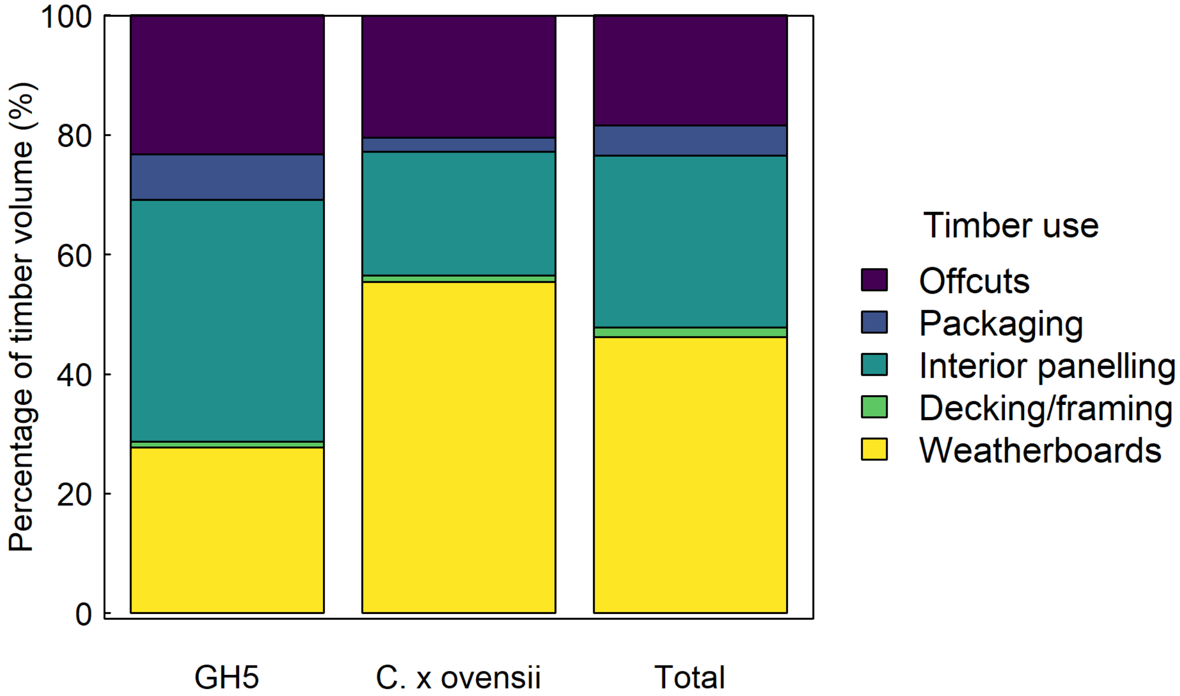

Figure 6: Proportion of graded timber meeting the specifications for the heartwood-only scenario, for each clone. Slabwood produced during sawing are is included in this graph.

To give an indication of the relative values of each end use, prices were obtained from a range of sources including sawmills and retailers. These prices can be found in the Appendix. Prices varied substantially between sources, so they have been presented as a range. The primary reason for boards not being suitable for weatherboards was not having sufficient heartwood width. If the trees were harvested at a slightly older age, the volume of the heartwood would increase, and a larger proportion of boards would meet the minimum width requirements for weatherboards, increasing the value of the product mix possible from the logs. This would need to be weighed against the potential risk of increased frequency of bark encased knots, and consequent downgrading of the timber. When sawing young trees for heartwood-only boards, the loss of recovery from removing and discarding sapwood should also be taken into account.

The price per m^3 of sawn timber can be compared with the cost of buying and processing the logs. There has been some recent published data for smaller small branched logs (Macrocarpa, Laurie Forestry August 2020), shown in Table 6. The maximum SED of the logs in the current study was 29cm, so only the log prices for logs less than 30cm SED are shown here.

Table 6: Macrocarpa log price (mill door) August 2020.

Grade	Min. SED	Low	High	Average
Small Branch (knot <6cm)	20	$135	$145	$140

The cost per m^3 of sawing the timber was provided by Ruapehu Sawmill at \$240 - \$360/m^3 including stacking, handling and packaging. (V. Kearns pers. comm.).

Machining timber to final profiles was estimated at \$266-\$300/m^3.

Thermal modification was estimated at around \$400/m^3 including the cost of the modification itself and a transport cost to a site with a thermal modification kiln (V. Kearns & P. Hall pers. comm.).

From the range of operating costs, and the range of product prices, a maximum and minimum margin can be calculated for each mix of products. These are shown in Table 7.

Table 7: Processing costs, product prices and margins for each species and each scenario.

	Product mix	Min product price ($/m³)	Max product price ($/m³)	Min processing cost ($/m³)	Max processing cost ($/m³)	Min margin (%)	Max margin (%)	Av margin (%)
Ovensii	**Thermal**	881	1084	651	831	6	67	36
	Interior	627	746	500	646	-3	49	23
	Heartwood	662	822	474	617	7	73	40
GH5	**Thermal**	878	1065	621	794	11	71	41
	Interior	675	794	500	646	4	59	32
	Heartwood	578	711	470	612	-6	51	23

A high-level sensitivity analysis showed that the interior panelling mix of products would either require a 15% increase in price, or a 15% reduction in processing costs to give the same margins as the thermally modified cladding.

For all scenarios the minimum margin (assuming maximum processing costs and minimum price) are all close to zero, but the maximum margins are positive, and the average margins are also all positive. Not surprisingly the thermally modified cladding gives the highest average margin at 36% for *C. x ovensii*, and 41% for GH5. For the interior panelling scenario the GH5 had an average margin nearly double that of the *C. x ovensii*, due to the higher proportion of framing timber sawn from the GH5 logs. For the heartwood-only scenario, the *C. x ovensii* had an average margin of 40%, similar to the thermally modified cladding scenario. This is a promising result for a somewhat unrealistic scenario where heartwood-only boards are produced from small logs. Due to the lower proportion of heartwood in the GH5 logs, the heartwood-only scenario only had an average margin of 23%.

There is significant variation in the prices, and processing costs used here for different products, and the market size for cypress timber is unknown, so there is considerable uncertainty around this economic analysis. Work underway at Scion to extend the WoodScape™ model to include products such as thermally modified cypresses will provide a more in-depth analysis of the economics of this area.

An analysis of the economics of growing trees with this regime is covered in a separate report (Stovold, 2020).

CONCLUSION

The volume recoveries for both the GH5 and *C. x ovensii* were very good, with green sawn recoveries of 58% for both species (1m^3 of log basis). Nominal recovery of graded timber was slightly lower (51 and 49% for GH5 and *C. x ovensii* respectively) but the grade recoveries of the two highest grades (Cladding and No. 1 framing) were very high, with almost all boards meeting the No. 1 framing grade, and more than 90% of boards meeting the Cladding grade. A small number of boards were Merchantable grade, and almost no boards were Box grade. In addition to grading, boards were divided into end uses according to three different scenarios. The first scenario was for a thermally modified cladding product, where sapwood-containing boards are able to be used outdoors. By volume, 87% (ovensii) and 66% (GH5) of the timber sawn was suitable for thermally modified cladding, and an analysis of a range of product prices and processing costs gave an average margin of 31 & 38% (ovensii and GH5, respectively) for the product prices over the cost of the logs plus processing. The second scenario focussed on interior panelling and had much lower average margins at 18 & 28% (ovensii and GH5, respectively). The third scenario, focussed on heartwood-only boards for exterior applications, is not one you would normally consider from small logs from young trees, but for the *C. x ovensii*, the margins from this were surprisingly high (31%). Due to the lower heartwood content of the GH5 logs, they had a much lower margin for the third scenario (16%).If the trees were harvested later and allowed to grow larger, the volume of heartwood in the trees would increase, and a higher proportion of 100% heartwood boards could be cut. There is significant variation in the prices used here for different products, and the market size for cypress timber is unknown, so there is considerable uncertainty around the economic analysis.

Very few of the boards were downgraded due to bark encased knots, which is a positive result, as these are a major issue for unpruned trees. With such low incidences of knots, it is possible that the trees could have been left to grow for longer without increasing the incidence of bark encased knots to a problematic degree. Further work on the rate of branch death and bark encasement in *C. x ovensii* would provide useful data on this.

There was no correlation between volume of timber sawn, and levels of sweep and taper in the logs, suggesting that the sawing pattern used was effective in minimising the effect of sweep and taper on sawing recovery.

Acoustic stiffness was similar between the two clones. The basic (oven dry) density of *C. x ovensii* was significantly higher than the GH5 (average 450kg/m^3 and 360 kg/m^3 respectively).

Overall the grade recoveries of both species are very promising, showing that good recoveries of appearance and structural grade timber is possible from young unpruned trees, and the value of this timber is in a similar ballpark to the cost of production. Both species would be suitable for the production of thermally modified cladding, underscoring the importance of continuing durability testing and development work for this product. The results are particularly promising for the *C. x ovensii*, which has a higher proportion of heartwood, and has very low numbers of bark encased knots. It may be possible that these trees could be grown for a number more years, to increase the proportion of wide heartwood boards without developing excessive numbers of bark encased knots, but further work would be required to confirm this.

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APPENDIX 1: SPECIFICATIONS FOR EACH END USE AND PRODUCT PRICES

Thermally modified cladding scenario

- Weatherboards
    - Cladding grade
    - 25mm thickness
- Framing
    - No. 1 framing grade
    - 40-50mm thickness
- Packaging
    - Merchantable grade
- Slabwood
    - Wood removed during sawing that was not included in grading, minus the volume of sawdust
- Sawdust
    - Estimated as 10% of the log volume not converted to graded timber

Interior panelling scenario

- Interior panelling
    - Cladding grade
    - 25mm thickness
- Framing
    - No. 1 framing grade
    - 40-50mm thickness
- Packaging
    - Merchantable grade
- Slabwood
    - Wood removed during sawing that was not included in grading, minus the volume of sawdust
- Sawdust
    - Estimated as 10% of the log volume not converted to graded timber

Heartwood-only cladding and framing scenario

- Weatherboards
    - Cladding grade
    - Heartwood width >75mm
- Decking or framing
    - No. 1 framing grade
    - Heartwood width >100mm
- Interior panelling
    - Cladding grade
    - No restrictions on sapwood content
- Packaging
    - Merchantable grade
- Offcuts
    - Sapwood trimmed from the edges of Weatherboard and decking grades
    - Any full-sized boards not meeting any of the criteria above

- Slabwood
    - Wood removed during sawing that was not included in grading, minus the volume of sawdust
- Sawdust
    - Estimated as 10% of the log volume not converted to graded timber

Table A1: Product prices for each end use.

Product	low price ($/m^3 ex mill)	high price ($/m^3 ex mill)
Cladding	1800	2200
Framing	1620	1800
Interior panelling	1200	1400
Packaging	500	600
Firewood (offcuts/slabwood)	77	130
Sawdust	23	29

Where only a single price could be found for a product, the low and high prices are +/- 10% of this price.

APPENDIX 2: GRADE RECOVERIES BY LOG AND BY TREE

Table A1. GH5 trees

Tree #	Height	sweep (cm)	Timber volume (m^3)	Log volume (m^3)	BIX (cm)	HW Prop. (%)**	taper (cm/m)	LED (mm)	SED (mm)	Overall recovery graded timber % of log volume	Grade recoveries* Cladding (%)	Merch (%)	1F (%)	Box (%)
3	A	6	0.21	0.46	2.5	12	16	360	260	45	43	2	45	0
3	B	6	0.17	0.26	4.25	43	8	260	210	65	65	0	65	0
3	C	5	0.05	0.13	5.5	22	10	210	160	38	38	0	38	0
4	A	3	0.24	0.43	3	12	10	330	270	55	46	9	55	0
4	B	5	0.15	0.29	3	24	11	270	200	51	51	0	51	0
6	A	6	0.24	0.45	3	23	8	330	280	54	54	0	54	0
6	B	8	0.18	0.31	3.75	39	8	280	230	59	59	0	59	0
6	C	5	0.09	0.18	7.75	34	7	230	190	51	52	0	52	0
8	A	8	0.29	0.52	3	40	13	370	290	55	41	14	55	0
8	B	4	0.19	0.35	3.5	36	7	290	250	56	56	0	56	0
8	C	6	0.12	0.27	4.5	36	7	250	210	46	43	3	46	0
9	A	9	0.25	0.51	2.5	18	18	380	270	48	39	10	48	0
9	B	5	0.19	0.30	2.5	34	7	270	230	62	62	0	62	0
9	C	4	0.09	0.20	5.5	37	8	230	180	45	42	3	45	0
10	A	3	0.27	0.46	3	18	13	350	270	58	45	13	58	0
10	B	7	0.17	0.30	4.5	32	7	270	230	57	55	2	57	0
10	C	4	0.09	0.21	5.75	31	7	230	190	46	44	2	46	0
12	A	10	0.21	0.46	3.5	21	13	350	270	46	33	13	45	1
12	B	7	0.16	0.32	5	48	3	270	250	49	49	0	49	0
12	C	8	0.06	0.26	4.75	46	6	250	210	25	25	0	25	0
14	A	8	0.28	0.57	3.25	27	18	400	290	49	35	14	49	0
14	B	6	0.20	0.34	3.5	28	8	290	240	60	60	0	60	0
14	C	5	0.08	0.16	6.5	30	12	240	190	48	48	0	48	0

* All calculated as a percentage of the log volume

** Heartwood proportion calculated as the percentage cross sectional area of heartwood

Table A2. *C. x ovensii* trees

Tree #	Height	sweep (cm)	Timber volume (m^3)	Log volume (m^3)	BIX (cm)	HW Prop. (%)**	taper (cm/m)	LED (mm)	SED (mm)	Overall recovery graded timber % of log volume	Cladding (%)	Grade recoveries* Merch (%)	1F (%)	Box (%)
17	A	10	0.12	0.30	3	67	13	290	210	40	37	3	40	0
17	B	0	0.10	0.17	3.5	73	7	210	170	55	55	0	55	0
17	C	0	0.02	0.05	3.5	51	15	170	140	45	44	0	44	0
19	A	8	0.14	0.24	3	72	8	250	200	57	55	2	57	0
19	B	3	0.09	0.16	3	62	8	200	150	55	55	0	55	0
26	A	5	0.17	0.36	3.75	67	18	330	220	46	41	5	46	0
26	B	0	0.08	0.16	5.5	60	13	220	140	51	51	0	51	0
27	A	3	0.14	0.25	2.5	56	7	250	210	56	56	0	56	0
27	B	3	0.08	0.18	3	61	11	210	140	43	43	0	43	0
31	A	3	0.18	0.38	3.75	57	13	320	240	48	44	4	48	0
31	B	0	0.08	0.21	4.5	54	16	240	140	38	38	0	38	0
32	A	2	0.15	0.31	4	56	15	300	210	47	45	2	47	0
32	B	3	0.08	0.15	3	53	10	210	150	54	54	0	54	0

* All calculated as a percentage of the log volume
** Heartwood proportion calculated as the percentage cross sectional area of heartwood