Peeling and sawing pruned *E. fastigata* for high-stiffness veneers: Part 2. Dry grade recovery and downstream testing

Authors: Rosie Sargent, Steve Riley

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EXECUTIVE SUMMARY

The feasibility of producing high stiffness veneers from *E. fastigata* has been investigated. Previous work found that the net veneer recovery was good (60% of peelable volume) and the Metriguard stiffness measurements were much higher than those typical of radiata pine (average of 14.3GPa, compared to 9.9GPa for radiata pine). Here the Metriguard measurements have been verified by separate density and time of flight measurements.

Logs that were not suitable for peeling (due to end splitting or log defects such as sweep and knots) were sawn into 100x25mm, or 100x50mm boards. This resulted in the logs being sawn having higher than average levels of growth stress, which will influence the results. The sawing pattern used led to a large volume of wood being trimmed from the board edges, which gave a low sawing recovery (35% net recovery) but should not have impacted the quality of the timber. The boards were air dried, and many of the boards exhibited collapse during drying. Once the boards were close to fibre saturation (20-30% MC) they were steamed to recover the collapse, then kiln dried. The boards showed no collapse following drying but did develop high levels of crook.

The major defects seen in the graded boards were crook (present in around 56% of boards), kino veins (present in 36% of boards) and knots (present in 26% of boards). 10% of boards achieved clears grade, 22% high feature grade and 22% cuttings grade. If crook was ignored (assuming it could be removed by improving the sawing process) 19% of boards achieved clears grade, 55% high feature grade and 8% cuttings grade. Overall, this shows that sawing and drying pruned *E. fastigata* is possible, but the sawing methods need to be improved to increase overall recovery and to mitigate the effects of crook.

A high level economic analysis showed that the value of products from these logs would need to be increased to make the process viable. Increasing the recovery of sawn timber would go some way towards addressing that, but finding higher value applications for the logs that were not suitable for this study would have a greater impact.

INTRODUCTION

There is a demand for high stiffness veneers that cannot be supplied from the existing radiata pine resource. Fast grown eucalypt species have the potential to produce higher stiffness timber than radiata pine of a similar age. Here the feasibility of peeling and sawing 24-year-old pruned *E. fastigata* is investigated. The production of the veneers and green sawn timber is covered in a separate report (Sargent, et al., 2020). Around 45% (by volume) of the logs were unsuitable for peeling, generally because of end splitting, or because the logs did not meet the specifications for peeling (due to sweep or branch size). This means that logs that were sawn are likely to have higher than average levels of growth stress, and possibly larger numbers of defects such as knots. Net recovery of veneer was very good (60% of peelable volume) and veneer stiffness was substantially higher than radiata pine (average 14.3GPa, compared to 9.9GPa for radiata pine).
In this report the dried timber is graded, and the veneer stiffness and density measurements from the Metriguard are validated with independent measurements.

METHODS

The methods for producing peeled veneer and sawn timber are outlined in Sargent, et al. (2020). A separate study has been performed by Hexion to assess the gluing properties of the veneers and this has been reported separately (Bruce, 2020).

Validation of Metriguard measurements

To confirm the accuracy of the measurements made by the Metriguard 2800 DME grader at JNL, a subset of 90 veneers were selected at Scion and their density and acoustic velocity measured.

Nominal density (density of wood plus moisture in the sheet) was calculated from the sheet dimensions and the sheet weight immediately prior to determining the acoustic velocity. The sheets had been stored in a Scion laboratory for more than 6 months, so were assumed to be an even moisture content. A small number of sheets were oven dried to give an average moisture content of 7% for the sheets. This value was used to calculate an oven dry density from the nominal density values.

Acoustic velocity was measured using an Olympus pulse generator plus receiver. This applies a short burst of ultrasound to the sheet, then records the reflected ultrasonic waves to determine the speed of sound in the sheet. The speed of sound in a material is related to its stiffness as follows:

$$\sigma = \beta v^2$$

where v = speed of sound = distance between sensors (m)/ time of flight (secs)
β = mass of sheet (kg)/ volume of sheet (m^3)
σ = Modulus of elasticity (MOE or stiffness) (Pa)

Although attempts were made to keep the veneer sheets in order between when they were peeled and when they were delivered to Scion, it is likely that this order has been lost. For this reason, in each log stiffness class (high, medium or low stiffness) the individual measurements were compared to the entire population of veneers in that stiffness class to determine if they are likely to belong to the same population.

The MOE value reported by the Metriguard was used as-is. The density value reported by the Metriguard is a nominal density, and this was converted to an oven dry density using the average sheet MC reported by the Metriguard.

Grade recovery of sawn timber

The sawn timber was fillet stacked and air dried in an open sided, south-facing shed. Following air drying to 20-30% MC, the boards were showing significant levels of collapse. This was unexpected, as *E. fastigata* is commonly said to be easy to dry. Following air drying the 50mm boards had some distortion, but in general the boards were reasonably straight.

The air dried boards were kiln dried according to the schedule recommended in Haslett (1988), including 4 hours pre-steaming to recover collapse, followed by drying at 70/55°C to around 12%MC (assessed using hot checks with a moisture meter) and 2 hours of final steaming.

Following drying it was intended to machine ~1mm off each face of the boards to assist with grading, but around 60% of boards were so distorted (primarily crook) that it was not possible to machine them. These boards were returned to Scion rough sawn, while the remaining boards were machined as planned.

The boards were graded by Paul Carpenter from Graderight using the following grades:

- Clears
- High Feature Flooring
- Cuttings
- Box

All grades are from NZS 3631 (Standards Association of New Zealand, 1988), except High Feature Flooring which is from AS 2796.2 (Standards Australia, 2006). It was originally intended to include dressing grade from NZS 3631 but the requirements for this grade is very similar to that of high feature flooring, so it was not included, as there would be significant overlap between the two grades.

In addition to the appearance grades, the 50mm thick boards were also graded to No. 1. Framing grade and the length of the board meeting No. 1 framing was recorded.

Because the logs to be sawn had higher than average levels of growth stress, and the sawing was not optimised for eucalypts, it is not known if the levels of crook seen in the boards are representative of what would be seen if best practise were followed. For this reason, boards that were downgraded due to crook were assigned a second grade which they would have achieved had the crook not been present.

Following grading around one-third of the boards had 100mm docked from one end to assess for drying defects such as within ring checks and collapse.

RESULTS

Validation of Metriguard measurements

The basic (oven dry) density measurements from the Metriguard and from the Scion measurements are compared in Figure 1. The veneers have been sorted into their three log groups – because these markings are attached to each veneer we are confident that each veneer has stayed in the correct group between when they were measured in the Metriguard and when they were measured at Scion. Within each group the Scion measurements gave significantly higher density measurements, especially for the sheets peeled from the higher stiffness logs.

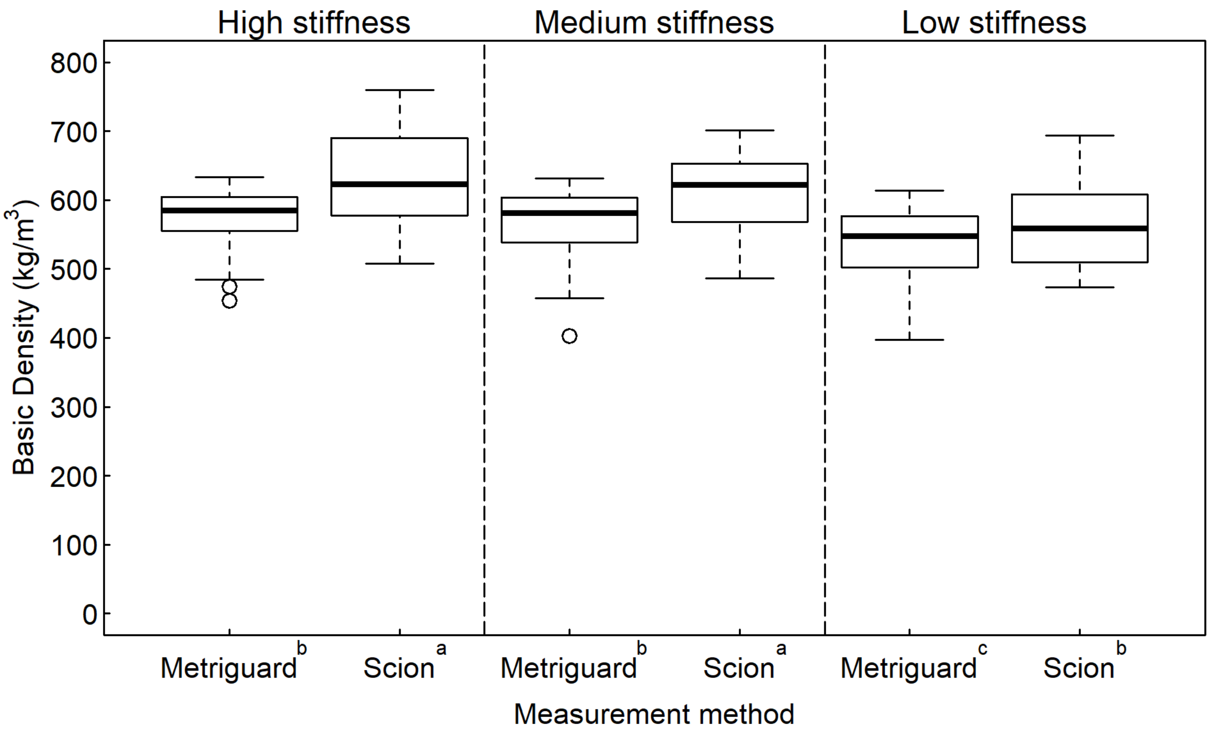

Figure 1. Basic density measured at Scion, or by the Metriguard at JNL Wairarapa

The MOE values calculated by the Metriguard, and at Scion are shown in Figure 2. The Scion measurements are, on average, lower than the Metriguard measurements, but this difference is only significant for the sheets from the medium stiffness logs. Overall, this suggests that the Metriguard MOE measurements may be a little high for *E. fastigata*, but they are likely to be reasonably accurate. The MOE measurements made at Scion still show that the majority of the veneers are above the average radiata pine stiffness at JNL Wairarapa (Average 14.1GPa for *E. fastigata* compared to 9.9GPa for radiata pine) (Sargent, et al., 2020).

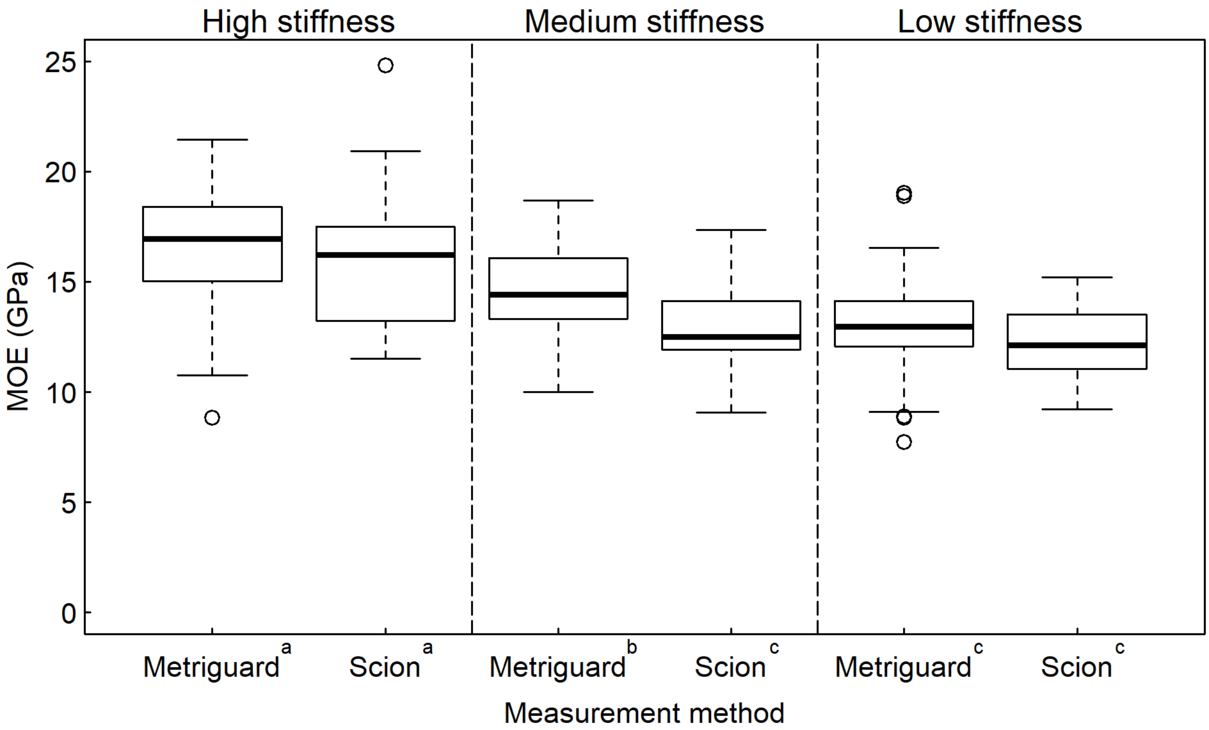

Figure 2. Modulus of Elasticity (MOE) measured at Scion, and by the Metriguard at JNL Wairarapa. Superscript letters indicate groupings that are not significantly different (95% confidence level).

Grade recovery of sawn timber

Grade recoveries by board thickness are shown in Table 1. These are presented as the volume of planed timber, and as a percentage of the green timber volume. As well as the grades assigned to the boards themselves (labelled ‘crook included’) a second grade is given to show the grade that would have been achieved if no distortion was present in the boards (labelled ‘crook ignored’). The proportion of clears and high feature grade timber was similar between the 25 and 50mm thickness, but the 50mm thick boards had a higher proportion of box grade boards and fewer cuttings grade boards. When crook was ignored in the grading, the proportions of cuttings and box grade boards were similar for the two thicknesses. Because some boards were planed prior to grading and some were not, the volume calculations were based on all the boards having the nominal planed dimensions of 21x92mm or 43x93mm.

Table 1. Grade recoveries by board thickness. As well as actual grade recoveries ('crook included') grade recoveries possible in crook-free boards are included ('crook ignored').

		Nominal thickness (mm)	Clears	High Feature	Cuttings	Box
Volume (m^3)	Crook included	25	0.16	0.34	0.50	0.53
		50	0.10	0.24	0.08	0.72
	Crook ignored	25	0.30	0.75	0.14	0.27
		50	0.19	0.61	0.06	0.17
Volume (% of green sawn vol)	Crook included	25	8.4	18.2	26.7	28.4
		50	6.9	16.5	5.5	50.3
	Crook ignored	25	16.3	40.1	7.6	14.3
		50	13.0	42.1	3.8	11.6

The reasons for downgrading boards are shown in Figure 3, along with the percentage of boards (by volume) exhibiting each defect. Because most boards had more than one defect the percentages of boards shown will not sum to 100%. The percentage (by volume) of boards in each grade are shown underneath the x-axis. Crook is the most common defect present in boards graded as cuttings or box, with nearly all the boards in box and cuttings grades having crook. Kino was the second most common defect in box boards but was usually not the primary reason for boards being downgraded to box. Splits, ring shakes and checks were a common defect in box grade boards with around 15% of boards having excessive splitting or checks. Knots were almost as common, with around 10% of box boards downgraded due to knots. Boards in the high feature grade were primarily downgraded because of kino or gum veins. A small proportion of boards in high feature grade had knots, but these tended to be single isolated knots, rather than the widespread knotty appearance that would be expected for a typical high feature grade.

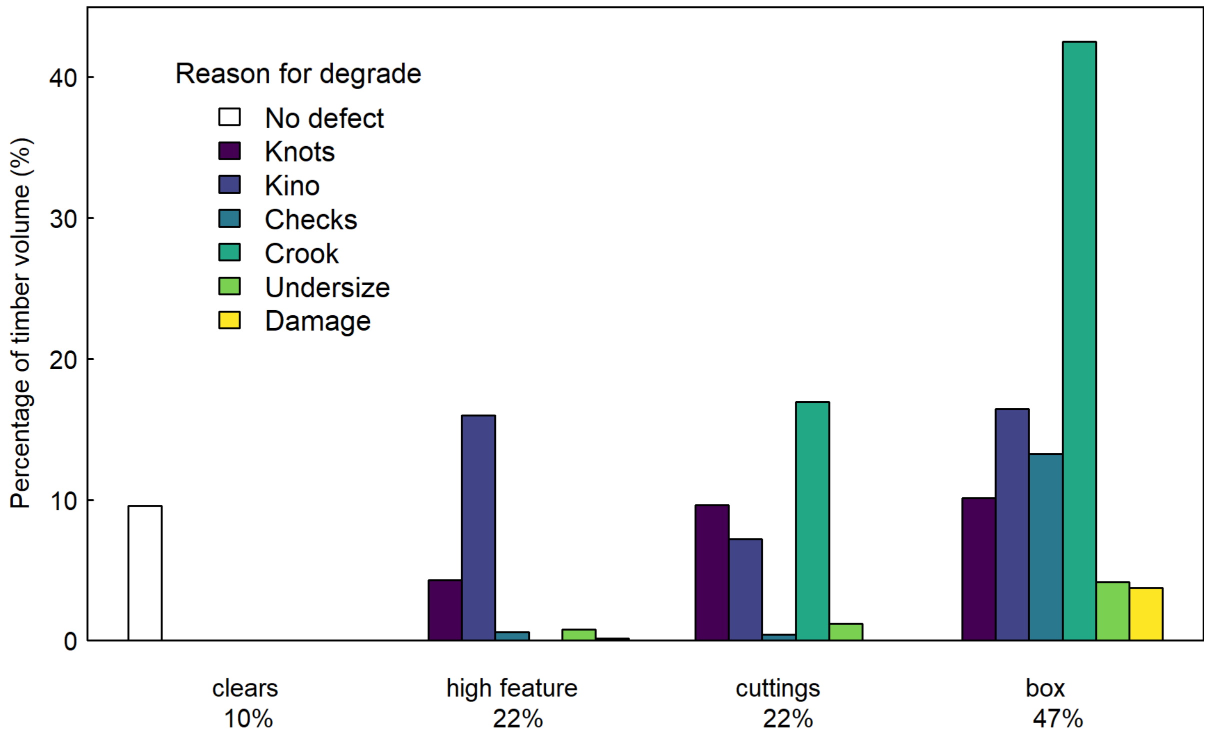

Figure 3. A breakdown of defects present in each timber grade. The x-axis shows the percentage (by volume) of timber in each grade and the y-axis shows the proportion of the total volume of timber with a particular defect. Most boards recorded more than one kind of defect, so the percentages sum to more than 100%.

Boards were typically downgraded to cuttings grade due to crook, with knots and kino veins being the next most common defects. Jones, et al. (2010) quarter-sawed *E. fastigata* butt logs, using a different sawing pattern to that used here, they saw evidence of crook in green boards, and following drying 83% of boards were above the permitted grade limits for crook. In the current study the boards appeared reasonably straight when green but following drying many boards had developed crook and 56% of boards were downgraded as a result.

If crook is ignored, the proportion of boards in each grade is shown in Figure 4. Kino is the most common defect in the high feature grade, with knots the second most common defect. Knots are the most common defect in cuttings grade and checks and splits are the most common defect in box grade. Many of the boards had end splitting, which was graded as offcuts (assuming the boards would be docked during grading). Around 10% of the dry timber volume was lost due to such offcuts.

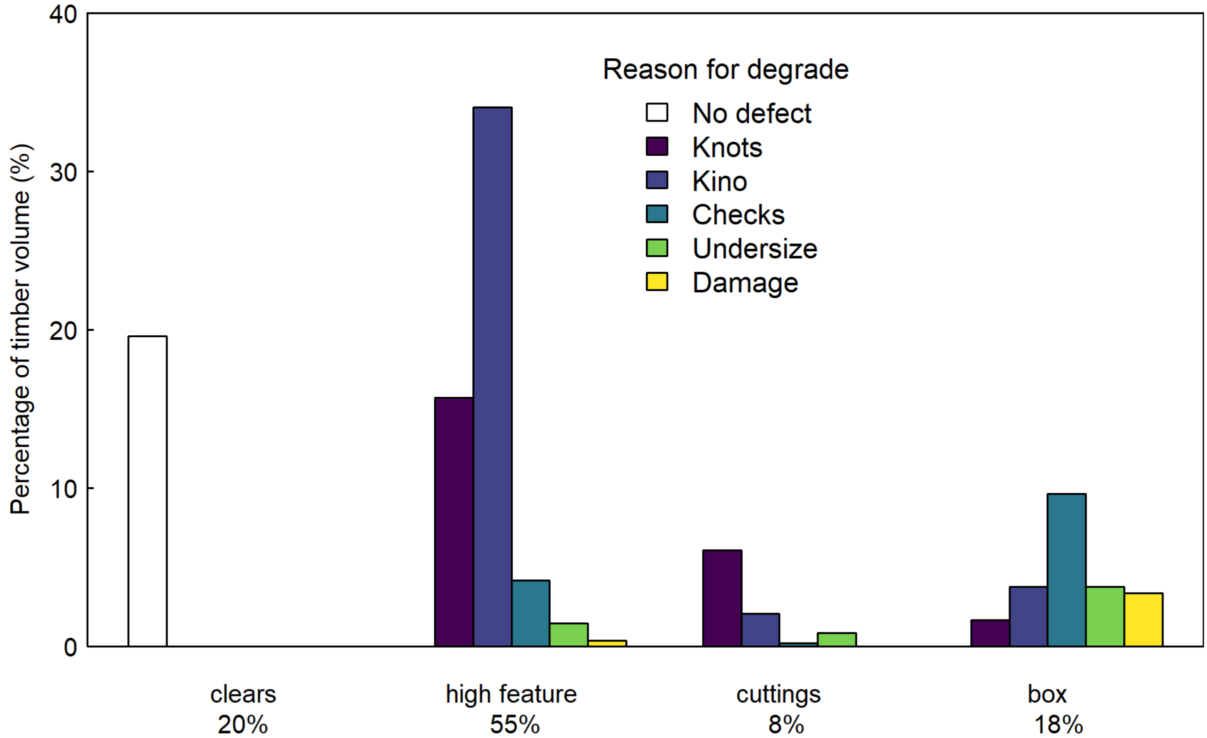

Figure 4. A breakdown of defects present in each timber grade, ignoring the effect of crook.

For No 1. Framing, the grade recovery was 24% of rough sawn volume, which increased to 57% if crook was ignored. Because these boards contained few knots, the lengths of sections achieving No. 1 framing were generally close to the length of the board (average section length of 2.7m, out of a 3m board).

Individual boards can be traced back to the log they were sawn from, and consequently to the height in the tree that log came from. Up to five 3.25m long logs were cut from each tree, with the majority (~65% by volume) of the sawn boards coming from butt and first logs (Table 2). Only one 5th log was included in the sawing study, and it only yielded 3 box grade boards, so it has been excluded from this analysis. The proportion (by volume) of boards in each grade within each log position is shown in Figure 5. The trees were all pruned to 8m, which occurs between logs two and three (log 3 starts ~6.8m up the tree), so it is interesting to see that logs two and three have a similar proportion of clear boards. In log four the proportion of clear boards is very small, and the proportion of cuttings boards is much larger.

Table 2. Percentage (by volume) of boards in each grade and each log position, plus the proportion of logs (by volume) cut at each log position

Log #	Clears	High Feature	Cuttings	Box	Total	% logs	% pruned logs
1	4.3	6.5	5.5	13.6	29.8	27.7	27.7
2	3.3	9.8	7.5	16.0	36.7	39.6	39.6
3	2.0	3.7	4.2	10.6	20.4	18.6	8.1
4	0.2	2.2	4.6	6.0	13.0	14.1	

The proportion (by volume) of boards in each grade within each log position is shown in Figure 3. The trees were all pruned to 8m, which occurs between the 2nd and 3rd logs (3rd log starts ~6.8m up the tree). This can be seen clearly in Table 2, where butt and first logs are exclusively pruned logs, but only around half of the 3rd logs were graded as pruned logs. Given the much lower proportion of pruned 3rd logs it is interesting to see that the 2nd and 3rd produced a similar proportion of clear boards. In the 4th logs the proportion of clear boards is very small, and the proportion of cuttings boards is much larger.

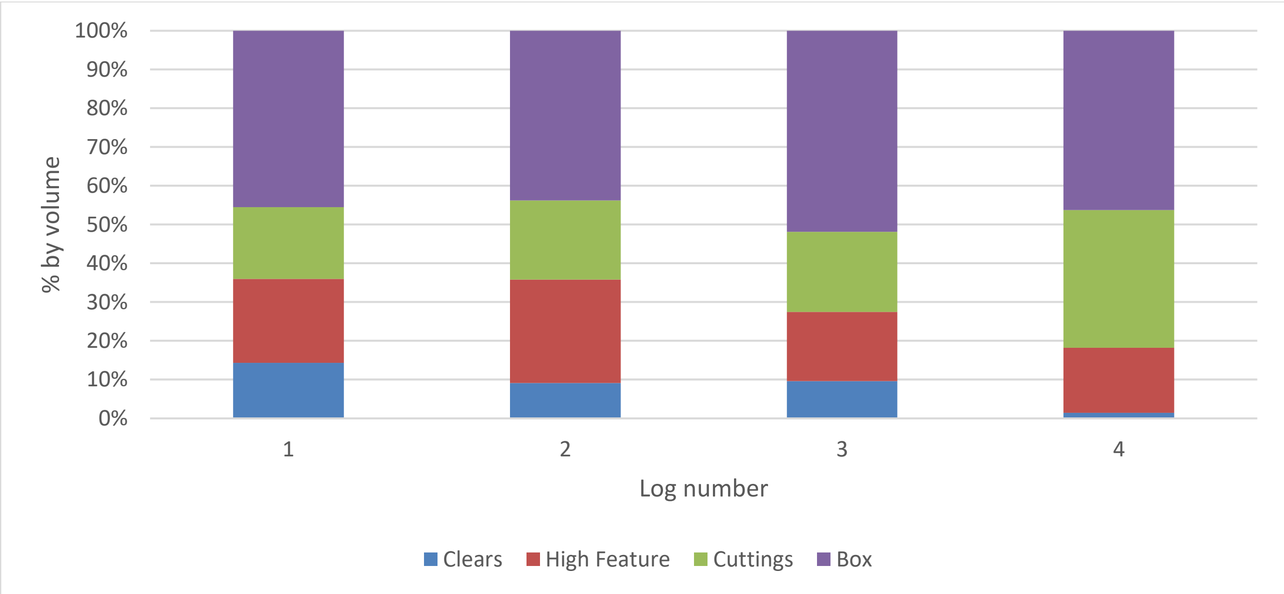

Figure 5. Proportions of boards achieving each grade within each log number.

The boards that were docked and assessed for checking and collapse were generally in very good condition with only 8% of boards having within-ring internal checks, and 2% with ring shakes (tangential splitting along latewood bands). 19% of boards had kino veins, with this often being a resin-rich band following a single growth ring (Figure 3). This proportion of kino veins is lower than what was seen in the overall grading results, but it only assesses one end of the board, and kino veins were often only present for part of the board length. Some boards had larger gum pockets, but this was less common. Previous studies found variable incidences of kino e.g. in Jones, et al. (2010) only 6% of boards were affected, but they referenced other studies where 35-40% of boards were affected.

Figure 3. End grain and one face of a board with a typical kino vein.

Because only a subset of the logs were sawn, and these were not selected randomly from all the logs harvested, relating the volume of sawn timber to the stand area is only possible for a scenario where the logs are peeled where possible, and only logs unsuitable for peeling are sawn. For this situation, the expected yield of the different grades of sawn timber, and different stiffness classes of veneer are shown in Table 3.

Table 3. Expected yields of veneers plus sawn timber per hectare of planted forest.

Veneer	**MOE < 9.1**	**9.1 < MOE < 10.5**	**MOE >10.5**
m^3/ha	1	4	62

Sawn timber	**Clears**	**High feature**	**Cuttings**	**Box**
m^3/ha	3	7	7	14

A high-level estimate of the value per hectare of the different log grades and products is shown in Table 4. This uses log and product prices from Hall, et al. (2019), and veneer prices from Altaner (2020). This shows that for logs with a value of ~$77k/ha there is a return of ~$60k/ha from the finished products plus the value of the pulp logs ($15.5k/ha). Increasing the recovery of sawn timber would go some way towards improving the value of the products, but finding markets for the lower grade logs that were not suitable for this study would have a larger impact on the economic viability of this species.

Table 4. Yields of logs and wood products, plus an estimate of their value

Product	**Volume**	**% recovery of total log volume**	**Vol m^3/ha**	**Value $/ha**
Peeler logs	14.5	34	172	$37,026
Sawlog	11.4	27	135	$24,052
Pulp/firewood	16.1	38	209	$15,670
Veneer	5.8	14	67	$27,489
Green timber	3.9	9	45	$16,549
Dry timber	2.7	3	16	$16,730

CONCLUSION

The MOE values measured by the Metriguard are comparable to those measured at Scion. This confirms that the *E. fastigata* veneers are, on average, significantly stiffer than radiata pine (average stiffness of 14.1GPa, compared to 9.9GPa for radiata pine). The density measurements from the Metriguard were significantly lower than those measured at Scion (average 560kg/m^3, compared to 600kg/m^3 measured at Scion). From a manufacturing point of view density measurements are probably not as critical as MOE measurements.

For the sawn timber, crook was a major defect, downgrading over 50% of the boards. Because the logs that were sawn had higher than average growth strain, it is not surprising that the boards developed crook during drying. It is also possible that the sawing pattern used increased the likelihood of crook formation (D. Satchell *pers comm*). The next most common defect was kino veins and gum pockets. Knots were not as common as expected, with only around 30% of boards having knots. Where knots were present they tended to be fairly isolated live knots with long clear lengths between them, rather than the overall knotty appearance that might be expected from unpruned logs, or from the knotty core of pruned logs. Undersized and damaged boards only made up a small proportion (~10% of the boards), but improved sawing patterns and careful handling would potentially reduce this proportion further.

If crook was ignored 20% of the boards were clears grade, and 55% High Feature Flooring grade. The high feature boards tended to only have one or two features per board, so did not have the rustic featured appearance that had been expected for this grade.

A high-level economic analysis of the logs and wood products from this trial suggest that significant value needs to be added to the logs or products to make this species viable. Improving the recovery from the sawing would go some way towards improving this but identifying higher value markets for the logs that were not suitable for this study would have a substantial positive impact on the economic viability.

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