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Pruned Plantation-Grown *Eucalyptus nitens*: Effect of Thinning and Conventional Processing Practices on Sawn Board Quality and Recovery

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Abstract

Thinned and pruned plantation-grown *Eucalyptus nitens* (H.Deane & Maiden) Maiden has potential to supplement native forest 'ash' eucalypt logs for the Tasmanian sawmilling industry. Processing methods developed for native forest eucalypts were applied to logs from 22-year-old pruned stands thinned at age six years to 100, 200, 300, 400 stems/ha and unthinned control stands with a stocking of 700 stems/ha at harvest.

Consistent with existing industry requirements for the two sawing methods, 42 trees with diameter at breast height over bark (DBHOB) < 43 cm were selected for back-sawing (flat-sawing), and 39 trees with DBHOB > 43 cm for quarter-sawing. For each sawing method, sets of trees were selected to provide trees evenly distributed across the target diameter range and, as near as possible, with sets matched across thinning treatments for size. From each tree two sawlogs, nominally 2.7 m in length, were cut from the pruned part of the stem. Both logs from individual trees were either back-sawn or quarter-sawn with single-saw log breakdown and re-saw systems. The boards were dried, dressed and graded to meet the requirements of Australian Standard AS 2796. Potential value-limiting defects were recorded, recovery calculated and measurements made of docked volume due to board end splits, flitch deflection, shrinkage and other processing related characteristics.

Thinning treatment affected some shrinkage traits but for all other measures of processing performance was not significant, for logs of matched size. Likewise, a basal area measure of localised competition experienced by individual trees had no significant effect on processing performance. This indicates that the thinning intensity was not critical for processing with either a back-sawing or quarter-sawing strategy in conventional sawmills, as trees of equivalent size grown under different competitive regimes did not differ substantially in their processing performance.

Quarter-sawn logs had lower total recovery, but higher recoveries of select and standard grades, than back-sawn logs. Upper logs produced higher recoveries of select and standard grades than butt logs for both sawing methods. These differences were primarily due to the severity of drying-related defects and the volume of wood docked to eliminate board end-splits. For both sawing methods the total recoveries from all logs, and the recoveries of select and standard grades from the upper logs, were similar to recent comparable studies in native forest sawlogs. However, the recoveries of select and standard grades from the butt logs were lower. Poor sawing accuracy contributed to the high occurrence of surface checking and product under-sizing for both sawing methods. Together with improved material handling during drying, greater sawing accuracy has the potential to improve not only recoveries but also product quality from both the butt and upper logs.

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Introduction

From the early 1980s, Forestry Tasmania established silvicultural trials testing spacing, thinning and fertiliser treatments for a number of species of eucalypts. These trials assessed the potential of eucalypts to be grown in plantations and ultimately supplement the supply of logs from the native forests to the Tasmanian hardwood processing industry. Of the species used in the trials, *Eucalyptus nitens* proved to be the most suited, with good growth rates and adaptability to the Tasmanian climate. The wood produced from *E. nitens* also has similarities to Tasmanian native forest *E. delegatensis* R.T. Baker and *E. regnans* F Muell., which make up a large proportion of the log supply from native forests.

There are doubts about the ability of conventional hardwood processors to process logs from unmanaged plantations because of excessive growth stresses, tension wood and the presence of knots and other branch-related defects (Nolan et al., 2005). These authors concluded that plantation-grown eucalypts should be pruned and thinned if logs are to be produced for the conventional hardwood industry. However, recent processing trials with pruned logs have produced varying results. Washusen et al. (2004) found acceptable results from both back-sawing and quarter-sawing strategies from pruned logs from Western Australian-grown 22-year-old *E. globulus* Labill., which has some similar attributes to *E. nitens*. Washusen et al. (2006) also obtained good drying results for quarter-sawn boards from pruned 16-year-old *E. nitens* from south-eastern Australia, although defects associated with insect attack were common. In contrast, McKenzie et al. (2003) found that pruned and thinned 17-year-old *E. nitens* in New Zealand produced low recoveries of high quality products due to prevalent drying-related defects. The variation in results between these studies is at least partly due to differences in processing methods, particularly differences in product thickness and application of uncontrolled air-drying. Other factors that may contribute to variation are: site effects; genetic differences; and the intensity and timing of thinning.

One of the oldest of Forestry Tasmania's *E. nitens* trials is a thinning and pruning trial testing the impact of thinning intensity. This trial is located at Goulds Country in northeast Tasmania. At the time of the research reported here, it was 22 years old, and the thinned treatment plots had produced logs of an average size acceptable to the existing industry for processing both back-sawn and quarter-sawn timber. The aim was to assess the effect of the silvicultural treatments on wood quality, product recovery and processing performance, using both back-sawing and quarter-sawing strategies. This assessment was conducted using conventional native forest eucalypt sawing and wood drying methods to yield products that could meet existing market demands for appearance products. The trial was intended as a first step in understanding the critical log- and wood-quality issues that may limit the potential for conventional processing of plantation-grown *E. nitens* and identify potential areas for improvement in growing and processing methods.

Materials and Methods

The silvicultural trial was located 27 km northwest of St. Helens (northeast Tasmania) in the Goulds Country block (41° 05´ S, 148° 06´ E) at an elevation of 120 m a.s.l. The site was originally native forest, dominated by *E. regnans* and *E. obliqua* (G.Frost.) L'Hér. The soils were yellow podsols formed over adamellite granites (Gerrand et al., 1997a). Mean annual rainfall for the nearest meteorological station at St. Helens was 776 mm and mean daily maximum and minimum temperatures were 18.4 °C and 7.4 °C respectively. Mean prevailing wind direction at 0900 h and 1500 h was northwest (Australian Bureau of Meteorology, 2006). Gerrand et al. (1997b) estimated annual rainfall at the trial site to be in the order of 1000 mm, and temperatures would be slightly lower than at St. Helens.

The site was cleared, broadcast-burned and windrowed and then planted in 1984 with *E. nitens* (Toorongo, Victoria provenance) tube stock seedlings spaced at approximately 3.5 x 2.5 m (1143 stems/ha). The site received a routine fertiliser application viz. 235 g/tree of nitrogen (N)-phosphorus (P) fertiliser (N : P ratio 11 : 5) in the first year after establishment. No cultivation or weed control was carried out and understorey shrub species competed vigorously with the planted *E. nitens* (Gerrand et al., 1997a).

The silvicultural trial (Table 1) was established in November 1990, six years after planting. The trial was a randomised complete block design including four replicates of five thinning treatments: thinned to 100; 200; 300; or 400 stems/ha; or unthinned. Following the initial measurement and tree selection in December 1990, thinning treatments (thinning to final stocking) were applied motor-manually. Thinning was from below to remove small and defective trees, which resulted in uneven spacing

TABLE 1: Summary of experimental details.

Variable	Details
Plantation age (2006)	22 years
Thinned	6 years
Pruned	6 years (single lift)
Thinning treatments	100, 200, 300, 400 trees/ha and unthinned (~ 700 trees/ha at harvest)
Plots	0.1 ha; 25 x 40 m
Replicates	2 pruned and 2 unpruned

within the treatments. Each plot was 25 × 40 m (0.1 ha) in size, with a buffer row thinned to the same stocking.

In June 1991, two of the four replicates of each treatment were pruned to 6.4 m in a single operation using pruning saws. At this time, the height to the first green limb was, on average, 5.6 m. Each plot was surrounded by a two-row buffer and the buffers were thinned to an average of the two adjacent treatments. For this processing research only the pruned treatments were sampled.

Tree selection

The differences in stocking produced a tendency for trees to have a larger DBHOB (diameter at breast height over bark) at lower stocking densities. This presented a number of sampling issues because log diameter: (i) has a major bearing on the selection of processing strategies; (ii) influences processing performance and product characteristics; and (iii) is inversely related to the size of the defect core i.e. smaller logs have a proportionally larger defect core.

The most important aspect of log diameter is its influence on product recovery as a consequence of growth stress release (Jacobs, 1938; Boyd, 1950; Chafe, 1979). As log diameter declines, the release of a given magnitude of longitudinal growth stress at the log periphery during sawing, combined with the radial gradient in stresses within the log, results in greater: (i) board deflection; (ii) log, flitch and board end-splitting; and (iii) difficulties in maintaining product sizing accuracy.

Most conventional sawmills processing ash-type eucalypts apply a quarter-sawing (as opposed to back-sawing) strategy as standard procedure. Quarter-sawing increases the radial dimension of boards and, hence, for logs with a given longitudinal growth stress level, the differential in stresses across the radial dimension is increased. This results in greater board deflection and reduced ability to straighten the deflection. Quarter-sawing also produces a larger percentage of narrow and, therefore, low-value boards in small diameter logs. For these reasons most conventional sawmills prefer logs with mid diameter of greater than 40 cm for quarter-sawing. For smaller logs, down to a minimum of about 25 cm small-end diameter, back-sawing strategies are normally applied to increase or maintain recovery and increase average board width. However, back-sawn boards, being more difficult to dry because of greater (tangential) shrinkage across the board face, produce more surface checking and cupping, potentially limiting product value (Campbell & Hartley, 1984).

For the study reported here, it was recognised that a random selection of trees from each treatment would largely reflect diameter-driven effects and it was decided to apply a stratified sampling strategy that attempted to control these effects. The intention was to conduct parallel processing trials on different sets of logs appropriately sized for the two sawing methods, and to investigate the effects of tree size and thinning treatment within each sawing method. Samples were selected to meet the existing diameter requirements of conventional sawmills for the two different sawing strategies.

To obtain the two samples, trees were selected for either back-sawing or quarter-sawing (i.e. the two logs within each tree were to be sawn by the same method) based on an estimate of the small-end diameter under bark (SEDUB) of the pruned part of the stem. This simplified the log segregation process at the mill and allowed a comparison between butt and upper logs within the tree for each sawing strategy. It was anticipated that SEDUB for quarter-sawing would be approximately 35-45 cm and for back-sawing 25-35 cm. Respectively, these sizes approximated the established minimum and range in SED for quarter-sawing and back-sawing strategies employed in conventional hardwood mills in south-eastern Australia. The two sets of trees were selected based on an estimate of the DBHOB required to produce logs of the selected SEDUB after allowing for taper and bark thickness. A stratification and accrual selection strategy was applied. The stratum cells were thinning treatment by DBHOB class (30-42.9 cm DBHOB for back-sawing, and 43-60 cm DBHOB for quarter-sawing), with the target number of trees for each stratum cell being 10. It was not possible to fill either the 400 stems/ha or control treatments cells in the 43-60 cm DBHOB range or the 100 stems/ha treatment cell in the 30-42.9 cm DBHOB range. Where it was possible to fill the stratum cells, the trees were selected so that each stratum cell had trees evenly distributed across the diameter range. Out of the targets of 50 trees per sawing method, 42 butt logs and 42 upper logs were back-sawn while 39 butt logs and 38 upper logs were quarter-sawn.

This selection strategy has important implications for the analysis and interpretation of data in that the samples of trees selected for some stratum cells were not truly representative of the respective thinning treatment. Given variation in localised competition between trees within treatment plots, there might be a tendency to sample trees that were not representative of the average level of competition in a thinning treatment. To check this, a competition index for each tree was calculated using the pre-felling assessment data collected in 2006. This was the sum of the basal area of all trees which had their stem centre located within the 10 x 10 m square plot centred on each of the sampled trees. Using this data, it was possible to model, as a covariate, the effect of the local competition index for each individual tree that was processed.

Standing-tree assessment and harvesting

Prior to harvest, each selected tree was inspected in the field and eliminated from the trials if it was defective for the following reasons: (i) if it was estimated that the tree would produced logs with sweep that exceeded 20% of log DBHOB over any 2.4 m length; and (ii) if the tree had stem damage of sufficient severity that would qualify as a defective quarter using the Victorian Forest Service log grading rules (i.e. the defect width or combined defect width exceeded 33% of surface width of the log quarter on which it was located). Where a defective tree was located, it was replaced with a tree with a similar DBHOB at January 2006 from the same treatment.

In May 2006, the selected trees were harvested by mechanical harvester. To reduce the impact of the felling on log end-splitting, the fallers did not use excessive force on the tree with the harvester boom to fall it in a selected direction.

After felling, a number of disks and logs were taken from the lower stem. The aim was for the lower end of the first sawlog to be 500 mm above ground level, after two 40 mm thick disks below the log had been removed. Because of difficulties in positioning the harvesting head in a few trees this height varied by up to ±150 mm.

Immediately after felling, the butt ends of the trees were end-sealed with Technimul® (Dussek Campbell Pty Ltd, Sydney, Australia) wax emulsion, tagged, numbered and gang nail plated to prevent extension of end-splits. They were cross-cut at a minimum length of 5.7 m, debarked and the top end sealed, gang nail plates applied and tagged and numbered as for the butt end. In late May 2006, the full-length bush logs were transported to the McKays Timber sawmill in St. Helens and placed under water sprays.

Log preparation and measurement

At the sawmill, the logs were cross-cut to produce two 2.7 m long sawlogs. Disks (5 cm in thickness) were cut below the first and second logs, and above the second log for other studies. Immediately after the logs were cross-cut, the southwest location and log identification number were marked on the large end. Log length, the smallest and largest diameters at both ends of the logs, log end split radial lengths on the log ends and extension of the splits up the stem were recorded.

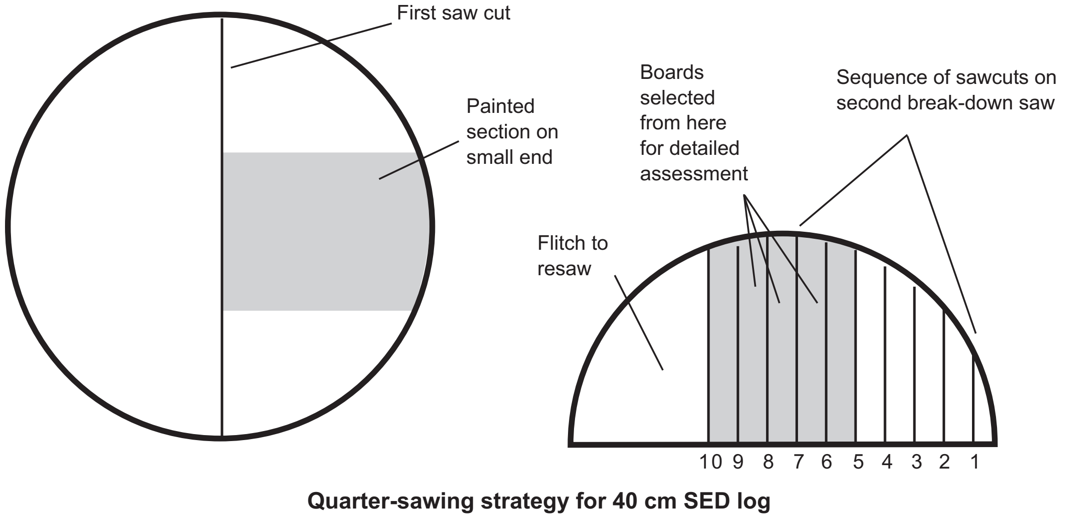
$$V = \left[\frac{D_1 + D_2 + D_3 + D_4}{4} \times \frac{1}{2}\right]^2 \times \pi \times L \qquad [1]$$

where:
V = log volume (m^3);
D_1 = largest small end diameter 1 (m);
D_2 = smallest small end diameter 2 (m);
D_3 = largest large end diameter 1 (m);
D_4 = smallest large end diameter 2 (m); and
L = log length (m).

From the measurements of splits, the Log End Split Index-2 (Yang, 2005) was calculated as the sum of individual split indices for each log end. To match board identity to log origin, the large-ends of the logs were painted using a sequence of eight colours. On the small end, the position of a cant on the southwest side of the log was marked with yellow paint to identify boards for intensive study.

Sawing methods

The sawing line consisted of two single-saw log breakdown units and a single-saw two-man bench for re-sawing flitches and slabs. The first breakdown saw was used to halve logs for quarter-sawing or produce a flat side to stabilise the logs for back-sawing. During sawing on the second breakdown saw only two dogs were used and there was no line-bar to provide a reference for sizing. Face cutting was employed to eliminate deflection in the log when necessary. This strategy was often required during quarter-sawing



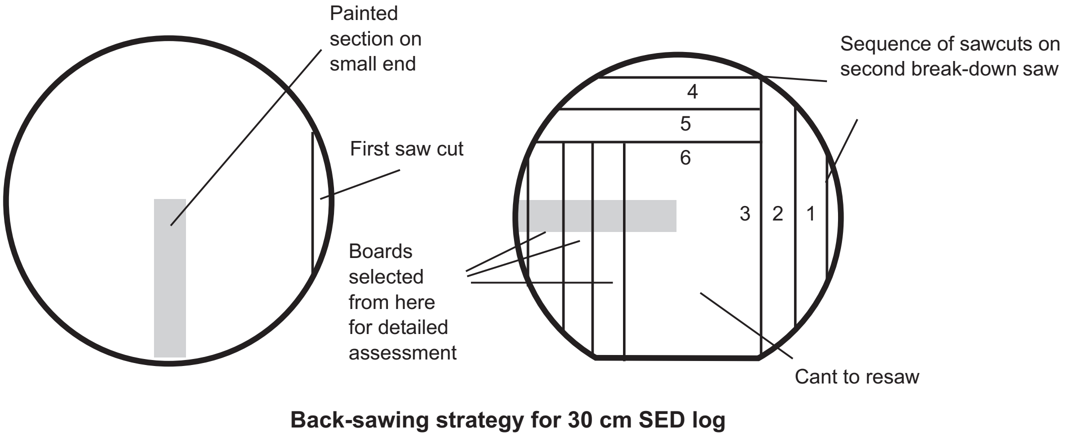


FIGURE 1: Quarter-sawing and back-sawing strategies employed

because each log half was sawn without turning in a partial 'through-and-through' pattern. Also, with this quarter-sawing pattern, the first boards produced (boards from cuts 1, 2 and 3 in Figure 1) are effectively back-sawn as the tangential surface makes up the wide face. During back-sawing, the logs were rotated using the "one third" rule. That is, the logs were rotated after boards equivalent to about one third of the diameter had been removed (Figure 1). During back-sawing the logs were turned 90º three times to complete the sawing and produce a centre cant for re-sawing.

For both sawing strategies, before the first cut was made the logs were either aligned so that the painted cant was horizontal (for quarter-sawing) or the painted line was vertical (for back-sawing), as shown in Figure 1. Boards were selected from this zone for detailed assessment after the sawing was completed.

During quarter-sawing, deflection was measured on two occasions. The first measurement was made on each log half (the southwest and northeast halves) on the conveyors immediately after the logs were halved. The second measurement recorded the amount of spring on the central slab from each log half just prior to re-sawing. Both measurements were used to assess differences between thinning treatments and butt/upper logs, and a comparison was made between the two measurements to determine if there was a change in the magnitude of deflection as the sawing process progressed.

The sawing strategy for both back-sawing and quarter-sawing aimed to produce nominal 25 mm thick dried boards and the widest board possible. For back-sawing, the nominal widths for dried boards were: 50; 75; 100; 125; 150; 175; 200; or 225 mm. For quarter-sawing, the widths were: 50; 75; 100; 125; 150; or 175 mm.

Board identification and green measurements

After completion of sawing, each board was identified by writing a code that identified the colour painted on the large end of the log and the sequence in which the log entered the mill. This enabled tracking each board back to the log of origin during and at the conclusion of processing. The boards were immediately block-stacked and wrapped in plastic. Those boards in the marked cants of the quarter-sawn logs that were perfectly quarter-sawn, and those in the marked cants of the back-sawn logs that were perfectly back-sawn were selected for intensive study. This gave from two to nine boards per log for intensive study, representing the south-west radius of the log. These boards were given the log code and also a unique board number and marked as follows: (i) the length of the longest end-split was permanently marked with a black water-proof pen to indicate end-split length prior to drying; and (ii) marks were placed at 25% of the board length from each end of the full-length board and at mid-board length. At these three points, the green width and thickness was measured to determine sawing accuracy. Spring and bow were measured with boards resting on their wide face on a flat surface. Shrinkage in width and thickness were also calculated after repeating the measurement at conclusion of drying.

Pre-drying and kiln drying

All boards were wrapped in plastic and transported to Launceston for drying in June 2006. The back-sawn boards selected from the painted cants were processed separately because of insufficient kiln space and so they could be randomly distributed within one drying stack. They were distributed randomly across the width and height of a stack and pre-dried in a small kiln at the University of Tasmania using a schedule in which relative humidity was progressively lowered from 90% to 60% and dry bulb temperature increased from 20 to 25 °C over a two-month period. Kiln air-speed was set at 0.5 m/s. Pre-drying was continued until average moisture content was below 20% as indicated by sample boards and confirmed by using a resistance moisture meter. The quarter-sawn boards and the remainder of the boards from the back-sawn logs were initially pre-dried using similar conditions to those used for the sub-set of back-sawn boards selected from the painted centre cants. Due to the volume of material for drying, some wood had a period of air-drying prior to reconditioning and final drying. Weighting of drying stacks was minimal.

Once pre-drying was completed, all of the boards were reconditioned and kiln dried at ITC Timbers Ltd, Launceston. During reconditioning and kiln drying the boards were stacked with native forest ‘ash’ of similar dimensions. Due to commercial constraints the kiln schedules cannot be reported, but are considered to be representative of current Tasmanian industry practice.

Dry board assessment and grading

The dried boards were transported to the McKay Timber drymill in Hobart. The boards from the marked cant were re-measured for: thickness and width at the three marked locations; end split length before and after drying; spring; bow; and cupping.

The boards were planed on the face and back with an Opticut 200 moulder (Weinig) and defects docked. The boards were graded by McKay Timbers graders in consultation with research staff to meet the requirements of Australian Standard AS 2796.1 (1999). The grades produced were select, standard (medium feature grade) and utility grade (high feature or common grade). The surfaces of select and standard grades were free of surface checking in line with the requirements of the ‘ash’ eucalypt market.

Board volumes were calculated using nominal dry dimensions in line with standard procedures for the Australian hardwood industry. These dimensions were 25 mm thickness and a width of 50; 75; 100; 125; 150; 175; 200 or 225 mm. The board volumes for each grade were tallied for each log to determine recoveries of select and standard grades (the higher-value products) and total recovery.

All of the defects present on graded surfaces and edges were recorded for each board. The defects included green and dead knots, surface checking, under-sizing, kino pockets, insect damage, sapwood and decay. The percentage of all utility grade boards affected by each of the major grade-limiting defects of surface checking, under-sizing, kino pockets and sapwood was calculated (some boards had more than one defect). After grading, the boards used for detailed assessment were docked at 25% and 75% of board length and the number of internal checks measured at each location.

A random sample of two boards per log (the first two boards from each log identified after sorting and after eliminating the intensively measured boards) was used for stiffness, strength and hardness measurement at the Launceston laboratory of the Timber Research Unit of the University of Tasmania. Stiffness and strength were measured as described by Mack (1979) and specified by Australian Standard AS/NZS 2878 (2000) on short clear sections, of dimension 20 × 20 × 300 mm (radial × tangential × longitudinal) cut from near the middle of each board. Janka hardness was measured on radial and tangential faces of clear specimens of dimension 25 × 50 × 150 mm according to the procedure defined by Mack (1979).

Statistical analysis

As sawing method and tree DBHOB were confounded (trees of less than 43 cm DBHOB were back-sawn and the larger trees quarter-sawn) it was appropriate to fit sawing method as the first explanatory factor in the statistical analysis, or to conduct separate statistical analyses for the quarter-sawn and back-sawn boards. The first approach was taken for analysis of overall recovery traits, and the second for analyses of processing traits for the intensively studied boards, where substantial differences were anticipated between back- and quarter-sawn boards for most traits. Univariate analyses were carried out separately for the sets of back-sawn and quarter-sawn logs to analyse the impact of DBHOB, thinning, log position and tree identity on product recoveries. Linear mixed models of the type shown in Equation [2] were fitted:

$$Y = \mu + DBHOB * THINNING + TREE + LOG * DBHOB * THINNING + RESIDUAL \qquad [2]$$

where:

Y is a vector of observations of the response variate;
μ is the overall mean;
DBHOB, *THINNING* and *LOG* are the tree DBHOB, thinning treatment and log position effects fitted as fixed factors;
TREE is an individual-tree effect within thinning treatment fitted as a random factor; and
RESIDUAL is the vector of residual errors.

For processing traits measured on the intensively studied boards, the data sets for back-sawn and quarter-sawn boards were analysed separately using the same model.

To test the impact of variation in competition experienced by individual trees, as opposed to thinning treatment, THINNING was replaced by COMPETINGBA in Equation [2], where COMPETINGBA is the sum of the basal area (BA) of competing trees located within a 10 x 10 m plot centred on each selected tree.

Analysis was conducted using the Genstat 9.0 software package (VSN International). Plots of residual versus fitted values were used to test for heteroscedasticity and identify outlying data values. Although error distributions were not normal for some of the variates, there were no genuine outlying values that needed to be removed from the data sets. The significance of fixed factors was tested using Wald tests and that of random factors was tested using the Z-test. Models that included replicate as an additional random term were also analysed, but replicate differences were not significant, so the replicate effect is omitted here to simplify presentation of the results.

Square root transformations improved the normality of distributions of residuals for some variates and were, therefore, used for testing explanatory factors for these variates. Poisson distributions with a log link function were appropriate for some other variates, while conversion to category data was required for others. Category response variates were analysed using a binomial distribution and a log link function. Use of Poisson and binomial (0, 1) distributions gave an analysis of deviance (as opposed to an analysis of variance) and chi-squared probabilities for potential explanatory factors.

Results

Effects of Thinning

Characteristics of the selected trees and logs

Mean DBHOB of harvested trees and the level of competition experienced by individual trees, as indicated by competing basal area, are given in Table 2. The numbers of logs and mean and range in diameters of logs are given in Table 3.

Considering separately the sets of back-sawn and quarter-sawn trees, mean tree DBHOB of selected trees varied relatively little across the five thinning treatments, although it tended to increase slightly at the lower stockings. Thus, the selection strategy delivered sets of smaller logs for back-sawing and larger logs for quarter-sawing, matched on diameter across thinning treatments. This contrasted with the mean DBHOB of all trees in the treatments (Table 2), which showed a clear trend of increasing DBHOB with increasing intensity of thinning, from 24.5 cm in the unthinned control treatment to 50.1 cm in the 100 stems/ha treatment.

Considering the competing basal area in the 100 m^2 area centred on each selected tree, from Table 2 it can be seen that: (i) the 100 and 200 stems/ha thinning treatments had lower levels of competition; (ii) trees in the 400 stems/ha thinning treatment experienced the highest levels of competition; and (iii) the smaller trees selected for back-sawing had higher levels of competition (mean of 33 m^2/ha) than the larger trees selected for quarter-sawing (mean of 24 m^2/ha). Fixed-effect analysis of variance showed that both thinning treatments and sawing methods differed significantly ($p<0.001$ and $p<0.05$ respectively) in the levels of competing basal area around the selected individual trees. Thus, despite the selection of trees across specified diameter ranges, the trees selected from the different thinning treatments had experienced significantly different levels of competition, at least in

TABLE 2: Mean tree DBHOB (diameter at breast height over bark) of all trees in pruned plots of five thinning treatments, mean DBHOB of trees selected for back-sawing and quarter-sawing, and the mean and range of basal area of competing trees in the 100 m^2 area centred on each selected tree.

	All Trees	**Back-sawn trees**		**Quarter-sawn trees**	
Thinning treatment (tree/ha)	**Mean DBHOB of all trees in pruned plots (cm)**	**Mean DBHOB of selected trees (cm)**	**Mean and [range] of competing basal area for selected trees (m^2/ha)**	**Mean DBHOB of selected trees (cm)**	**Mean and [range] of competing basal area for selected trees (m^2/ha)**
100	50.2	40.9	12 [0 - 23]	51.9	13 [0 - 32]
200	44.1	37.0	20 [0 - 37]	49.6	20 [0 - 49]
300	37.7	37.0	38 [12 - 84]	49.2	29 [2 - 62]
400	33.8	37.1	48 [24 - 84]	47.2	36 [3 - 79]
Control	24.5	36.3	30 [17 - 49]	45.7	34 [30 - 38]
Mean	38.0	37.0	33	49.5	24

the later years of stand growth. The level of competition experienced by individual selected trees in each thinning treatment varied widely (Table 2). The overall linear relationship between DBHOB and basal area of the trees in the surrounding 100 m^2 area was negative and significant (p=0.05), although it accounted for only 3.6% of variance in the DBHOB of the selected trees.

Effects of Sawing Strategy

Small-end diameters of back-sawn upper logs averaged about 4-5 cm smaller than those of back-sawn butt logs, the corresponding difference for quarter-sawn logs being about 6 cm (Table 3). For those stratum cells (sawing method x thinning treatment x log position).

TABLE 3: The number of logs sawn, mean, minimum and maximum SEDUB (log small-end diameters under bark, in cm) for each thinning × sawing method × log position combination

Log group	**Variable**	**Thinning treatment (trees/ha)**					
		100	**200**	**300**	**400**	**Control**	**Total**
Back-saw / Butt log	Number	2	10	10	10	10	42
	SEDUB Mean	38.6	33.1	34.7	33.8	32.9	
	SEDUB Min.	37.3	28.3	29.9	27.4	28.1	
	SEDUB Max.	39.9	38.4	39.5	39.6	37.4	
Back-saw / Upper log	Number	2	10	10	10	10	42
	SEDUB Mean	32.1	29.0	30.8	29.1	28.5	
	SEDUB Min.	31.6	23.1	26.0	24.6	24.5	
	SEDUB Max.	32.6	34.5	35.9	35.1	33.1	
Quarter-saw / Butt log	Number	10	11	10	6	2	39
	SEDUB Mean	46.4	44.4	45.2	42.7	42.3	
	SEDUB Min.	41.6	38.5	40.2	39.2	42.3	
	SEDUB Max.	53.0	51.3	57.1	47.5	42.3	
Quarter-saw / Upper log	Number	9	11	10	6	2	38
	SEDUB Mean	40.3	38.6	39.3	37.5	36.4	
	SEDUB Min.	35.1	34.4	34.0	35.1	35.9	
	SEDUB Max.	45.3	45.9	49.5	41.6	37.0	

TABLE 4: Log end-splitting index prior to sawing

Log group	Logs to be back-sawn	Logs to be quarter-sawn
Butt log butt end	0.31	0.37
Butt log top end	1.26	1.80
Upper log butt end	1.49	2.48
Upper log top end	2.67	4.13

where 10 logs were available for sawing, the range in small-end diameter between the smallest and largest log was substantial, ranging from 9 to 17 cm (Table 3).

Log end-splitting

Log end-splitting index showed a progressive and significant increase with stem height from the lower end of the butt log to the upper end of the second, upper log (Table 4). Logs selected for quarter-sawing had a higher end-splitting index than those selected for back-sawing, and there was a significant (p<0.05) effect of tree DBHOB, end-splitting index values increasing with DBHOB.

Half log and slab deflection during quarter-sawing

Slabs distorted more than half-logs (Table 5). This indicates that deflection increased as the sawing process continued. There was significantly more (p<0.01) deflection in the half-logs and slabs from the upper log than for those from the butt log.

Effect of thinning treatments on processing performance

As reported in detail below for individual variates, thinning treatment had little effect on processing performance for either back-sawing or quarter-sawing for the sets of sampled trees, which were matched as far as possible for tree DBHOB across the thinning treatments. Only board width shrinkage of back-sawn logs was significantly affected (p<0.05, Table 6). Neither thinning, nor the interaction between thinning treatment and other explanatory factors, affected any other processing variates. As DBHOB was included in the statistical model, the impact of tree diameter on processing performance, within the sets of sampled trees, can be examined. Tree DBHOB significantly affected volume loss from end splits, cupping and internal checking in both back-sawn and quarter-sawn logs (Table 6). Only bow in dry back-sawn boards and spring in green quarter-sawn boards displayed significant interaction between tree DBHOB and thinning treatment (Table 6). The possibility that the competitive environment of individual trees might affect their processing performance was further investigated by modelling competing basal area in place of thinning treatment as an explanatory variable in Equation [2]. This analysis showed that competing basal area of individual trees had no significant effect on processing outcomes (statistical tests not presented).

Board end-split severity

The mean percentage loss of board volume ranged from 4.2% in the quarter-sawn boards from the lower logs to 9.5% for back-sawn boards in the upper logs (Table 7). The difference between butt and upper log was significant for back-sawn logs but not for quarter-sawn logs (Table 6). Percentage volume loss increased with increasing tree DBHOB.

Variation in green board width and thickness

Mean green board thickness and width were, on average, 0.2 to 0.4 mm less at the 25% and 75% of board length positions than at the mid-point of the boards (Table 7). The only significant factor influencing variation in thickness was log position, with the quarter-sawn boards from butt logs having significantly (p<0.001) less variation than the upper logs.

Additional information on sawing accuracy is given in Figure 2, which shows the range and frequency distribution of measurements of board thickness from the approximately 1700 measurements made on the intensively studied green boards. The standard deviations of board thickness were 0.83 mm and 0.84 mm for quarter-sawing and back-sawing respectively.

TABLE 5: Mean half-log and slab deflection during sawing in quarter-sawn logs

Log group	Slab deflection (mm)	Half log deflection (mm)
Butt log / SW side	9.3	4.9
Butt log / NE side	11.3	5.9
Upper log / SW side	14.1	7.8
Upper log / NE side	14.8	7.2

TABLE 6: Significance[1] of explanatory factors for board traits in intensively studied cants of back-sawn and quarter-sawn logs, showing distributions modelled or transformations applied in statistical analysis.

Dependent variable	**Explanatory factor**							**Distribution/ transformation**
	DBHOB	**Thinning**	**DBHOH x Thinning**	**Tree**	**Log position**	**Log position x DBHOB**	**Log position x thinning**	
a) Back-sawn logs								
Board end-splitting								
% of boards with splits	n.s	n.s	n.s	n.s	*	n.s	n.s	binomial
Volume loss from splits	**	n.s	n.s	***	**	n.s	n.s	sq. root
Bow, spring and cup								
Bow in green boards	n.s	n.s	n.s	***	***	*	n.s	sq. root
Bow in dry boards	n.s	n.s	*	n.s	*	n.s	n.s	sq. root
Spring in green boards	n.s	n.s	n.s	n.s	n.s	n.s	n.s	sq. root
Spring in dry boards	n.s	n.s	n.s	n.s	n.s	n.s	n.s	sq. root
Cup/cm board width	*	n.s	n.s	n.s	n.s	n.s	*	normal
Board shrinkage								
Thickness (mean of 3 positions)	n.s	n.s	n.s	***	**	n.s	n.s	normal
Width (mean of 3 positions)	n.s	*	n.s	**	*	n.s	n.s	normal
Surface checking								
% of boards with surface checks	n.s	n.s	n.s	n.s	***	n.s	n.s	binomial
Length/m^2 of graded surface	n.s	n.s	n.s	n.s	**	n.s	*	poisson
Internal checking								
% of boards with internal checks	n.s	n.s	n.s	*	***	n.s	n.s	binomial
Number of internal checks/board	*	n.s	n.s	n.s	***	n.s	n.s	poisson
b) Quarter-sawn logs								
Board end-splitting								
% of boards with splits	n.s	n.s	n.s	**	n.s	n.s	n.s	binomial
Volume loss from splits	*	n.s	n.s	***	n.s	n.s	n.s	sq. root
Bow, spring and cup								
Bow in green boards	n.s	n.s	n.s	n.s	n.s	n.s	n.s	sq. root
Bow in dry boards	*	n.s	n.s	n.s	n.s	n.s	n.s	sq. root
Spring in green boards	n.s	n.s	*	n.s	n.s	n.s	n.s	sq. root
Spring in dry boards	n.s	n.s	n.s	***	**	**	n.s	sq. root
Cup/cm board width	*	n.s	n.s	n.s	n.s	n.s	n.s	normal
Board shrinkage								
Thickness (mean of 3 positions)	n.s	n.s	n.s	***	n.s	n.s	n.s	normal
Width (mean of 3 positions)	n.s	n.s	n.s	***	n.s	n.s	n.s	normal
Surface checking								
% of boards with surface checks	n.s	n.s	n.s	**	n.s	n.s	n.s	binomial
Length/m^2 of graded surface	n.s	n.s	n.s	*	n.s	n.s	n.s	poisson
Internal checking								
% of boards with internal checks	n.s	n.s	n.s	***	n.s	n.s	n.s	binomial
Number of internal checks/board	*	n.s	n.s	n.s	n.s	n.s	n.s	poisson

[1] n.s.= not significant, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$

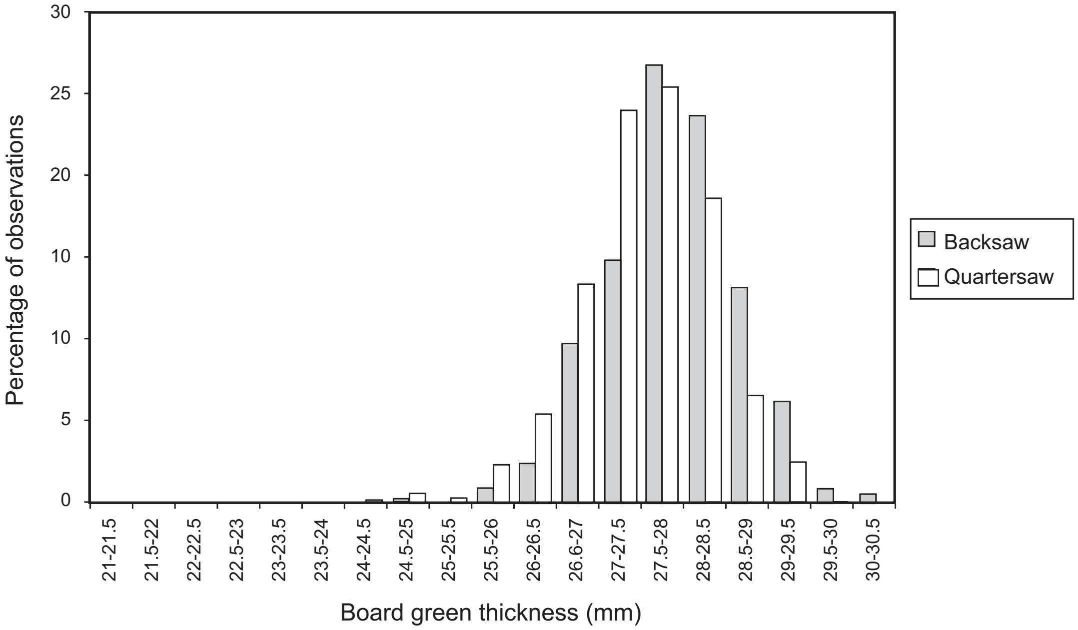


FIGURE 2: Distribution of product thickness measurements for back-sawing and quarter-sawing.

Board spring, bow and cupping

Bow was greater for back-sawn than for quarter-sawn boards, while sawing method produced little difference in spring (Tables 6 and 7). Spring and bow worsened during drying (Table 7).

Cupping in back-sawn logs was more than double that in quarter-sawn logs (Table 7), averaging over 2 mm. When cupping was expressed in mm/cm of board-width, it was still much greater in back-sawn boards, although the difference was less pronounced because back-sawn boards were, on average, about 30% wider than quarter-sawn boards. There was little difference between butt and upper logs for bow and spring in dried boards, while for quarter-sawn boards cupping was significantly ($p<0.001$) greater in butt logs than upper logs (Table 6). Increasing tree DBHOB was associated with a significant ($p<0.05$) reduction in cupping for both sawing methods.

Checking of dried boards

Surface checking was significantly more severe on back-sawn boards than on quarter-sawn boards, and was more severe on the butt logs than upper logs for both sawing methods (Tables 6 and 7). Internal checking was also common but rarely a grade-limiting defect because it generally remained unexposed after planing. The number of internal checks per board was greater for back-sawn boards than quarter-sawn boards, as well as there being significantly more checks in the boards from the butt logs than the upper logs for both sawing methods (Tables 6 and 7). Increase in tree DBHOB was associated with a significant ($p<0.05$) increase in number of internal checks per board, for both sawing methods.

Shrinkage

Quarter-sawn boards displayed lower percentage shrinkage in board-width than back-sawn boards for both butt and upper logs (Table 7). This is to be expected given that the magnitude of tangential shrinkage is typically about double that of radial shrinkage in eucalypts (Kingston & Risdon, 1961). Back-sawn boards from the upper log had significantly greater shrinkage in board thickness than back-sawn boards from the butt log, but significantly lower shrinkage in board width, while quarter-sawn boards from the upper logs had significantly greater shrinkage in width than those from butt logs (Table 6).

Mechanical properties

Mechanical properties were determined on only two boards per log. Boards from butt logs had significantly lower ($p<0.05$) stiffness (MOE) and strength (MOR) than those from upper logs, whereas there was no significant effect of log position for Janka hardness (Table 8).

TABLE 7: Means of board traits for intensively studied board cants in butt and upper logs processed by back-sawing and quarter-sawing

Board Trait	**Back-sawn**		**Quarter-sawn**	
	Butt log	**Upper log**	**Butt log**	**Upper log**
Volume docked for end splits (% of green volume)	5	9.5	4.2	4.7
Mean board width (mm)	146	136	115	98
Board thickness variation (mm)[1]	-0.36	-0.43	-0.19	-0.33
Board width variation (mm)[1]	-0.22	-0.36	-0.31	-0.41
Bow in green boards (mm)	6.1	9.1	1.1	1.7
Bow in dry boards (mm)	9	11	3.4	2.3
Spring in green boards (mm)	3.29	4.16	3.82	2.31
Spring in dry boards (mm)	6.48	5.75	5.91	6.28
Cup (mm)	2.27	1.99	1.01	0.23
Surface check (length in mm/m^2 board surface area)	1110	440	120	80
Internal checks (number/board)	7.58	1.99	4.1	0.74
Board thickness shrinkage (%, mean of 3 positions)	5.03	5.68	5.96	6.1
Board width shrinkage (%, mean of 3 positions)	6.62	6.09	3.86	4.34

[1] mean of measurements at 25% and 75% relative to that at 50% of board length

Product recovery and value-limiting defects

Total recovery and the recoveries for combined select and standard grades as a percentage of log volume for each sawing method and log height are shown in Table 9, which also gives comparable recoveries from recent investigations into recoveries from native forest regrowth logs in other sawmills where back-sawing and quarter-sawing strategies were applied There were higher total recoveries for back-sawn logs than quarter-sawn logs (Table 9). In contrast to total recovery, there were higher recoveries of the higher-value select and standard grade boards for quarter-sawn logs than for back-sawn logs. There was also significantly ($p<0.001$) higher recovery of select and standard grades for upper logs compared to butt logs for both sawing methods. Total recovery increased significantly with increasing tree DBHOB ($p<0.05$) for both sawing methods, but the recovery of select and standard grades was not significantly affected. The grade-limiting defects are shown for utility grade boards only, because of the large gap in product value between select and standard grades and utility grade. Surface checking was the most important grade limiting defect (Table 10). It was more prevalent in back-sawn and butt logs (Table 7), and was the major reason for differences in recoveries of select and standard grades between the four log groups. Under-sizing was common on quarter-sawn utility grade boards, with 22%-35% of boards affected. Under-sizing, in this case, was the result of un-recovered collapse, normal shrinkage or cupping that individually, or in combination, reduced board dimensions or parts of boards below final target size.

TABLE 8. Mean board stiffness, strength and hardness

Board Trait	**Back-sawn**		**Quarter-sawn**	
	Butt log	**Upper log**	**Butt log**	**Upper log**
MOE (GPa)	12.0	13.2	11.4	12.7
MOR (GPa)	99.0	108.1	97.3	104.2
Janka Hardness (tangential surface) (kN)	4.5	4.4	5.3	4.8
Janka Hardness (radial surface) (kN)	5.0	5.0	5.2	4.9

TABLE 9: Total recovery, and recovery of combined select and standard grades, for pruned *Eucalyptus nitens* and comparable recoveries from sawing studies on logs from native forest *Eucalyptus* species in southern Australia.

Species	Planting/ Regeneration Date	Source	Log quality	Recovery (% log volume)		Sawing method
				Total	Select & standard	
E. nitens[1]	1984	Goulds Country	Pruned butt logs	29.8	2.5	Back-sawn
E. nitens[1]	1984	Goulds Country	Pruned upper logs	31.2	9.1	Back-sawn
E. nitens[1]	1984	Goulds Country	Pruned butt logs	26.9	6.8	Quarter-sawn
E. nitens[1]	1984	Goulds Country	Pruned upper logs	27.9	14.3	Quarter-sawn
E. sieberi[2]	unknown and 1957	re-growth	Victorian B grade	31.9	3.4	Back-sawn
E. diversicolor[3]	unknown	re-growth	Western Australia Grade 1	28.2	9.7	Back-sawn
E. regnans[4]	1934	re-growth	Tasmanian Category 3	30.8	23.3	Quarter-sawn
E. regnans[5]	1939	re-growth	Victorian B/C grade	25.8	14.3	Quarter-sawn

[1] present study
[2] Washusen et al., (2007a)
[3] Washusen et al., (2007b)
[4] Washusen et al., (2007c)
[5] Washusen et al., (2007d).

Discussion

This study evaluated the silvicultural and processing factors that affected a range of outcomes, particularly the recovery of higher-value select and standard grade boards and the causes of board down-grade, that influence the profitability of sawmilling systems. The results show that the existing industry could process logs from any of the thinning treatments with a given sawing strategy without any disadvantage. This was because, for logs matched for size across thinning treatments, there were no major differences in processing performance resulting from the thinning treatments, and no influence of local competition as indicated by the competing basal area around individual trees on log processing performance. A residual stocking of 300 stems/ha following thinning at 6 years, examined in this study, is very similar to the sawlog growing regime currently followed by Forestry Tasmania for sawlog plantations, with commercial thinning for pulpwood at age 8-10 years and residual stocking of about 300 stems/ha. Therefore, it appears that, for logs of any given size, there would be no processing advantage in growing these logs under a regime with early, pre-commercial thinning to reduce levels of competition early in the rotation, as has been recommended for *E. grandis* by authors such as Shield (2004).

However, thinning regimes of course affect the log volume per hectare and the log diameter distributions produced from plantations. Heavy thinning at age 6 years enabled development of higher mean DBHOB at the stand level, with mean DBHOB of all plot trees

TABLE 10: Major grade limiting defects on utility grade boards as a percentage of boards affected.

Log Group	Total number of boards samples	Surface check	Undersize	Sapwood	Kino pockets
Back-sawn/butt	258	68	9	2	10
Back-sawn/upper	134	51	8	3	7
Quarter-sawn/butt	201	35	35	15	4
Quarter-sawn/upper	71	22	22	17	4

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at harvest increasing progressively from 24.5 cm in the unthinned control treatment to 50.1 cm in the 100 sph treatment (Table 2). With heavy thinning, a higher proportion of the log volume produced on 25-30 year rotations on sites comparable to Goulds Country would be of logs with DBHOB greater than 43 cm, suitable for quarter-sawing in conventional sawmills. Recoveries of select and standard grade boards from the (smaller) back-sawn logs were very poor (less than 6% of total log volume) primarily due to the frequent presence of surface checking. This would have a major impact on sawmill profitability because, in Australian markets, select and standard-grade boards fetch three to four times the unit price of utility grade boards. The recovery of select and standard grade boards from the larger quarter-sawn logs was substantially higher, and was within the range reported for native forest ash eucalypts (Table 9).

Log position (butt versus upper log) had an important influence on many processing outcomes including: log- and board-end-splitting; bow and thickness variation in green boards; cup; surface and internal checking in dried boards; recoveries of select and standard grade boards; and board stiffness. In general, the upper logs posed fewer processing problems than did the butt logs, with the important exception of greater volume losses due to end-splitting in quarter-sawn boards from the upper logs. For both sawing methods, tree diameter was a further significant influence on log and board end-splitting, cup and the number of internal checks per board. Higher tree DBHOB was associated with significantly increased total recovery, but did not significantly influence recovery of select and standard grade boards, for the relatively narrow range of tree DBHOB processed in each sawing study. The TREE effect in Equation [2] was highly significant for several growth stress-related and drying defects in both back- and quarter-sawing (Table 6). This may indicate genetic differences in processing performance within the Toorongo provenance of *E. nitens*, but as family identity of individual trees was not retained in the trial, the magnitude of such genetic effects cannot be assessed.

End-splitting was an important defect, requiring docking and loss of significant merchantable volume. The volume lost may have been inflated because of the requirement to orientate the marked centre cants to a specified direction on the log breakdown saws; operators would normally orient the log to minimise such losses. Alteration of processing methods to accommodate longer length logs may be a simple way of reducing losses due to end-splitting (Washusen 2007) because the end-split length as a percentage of log length tends to decline as log length increases. However, there is a trade-off resulting from potentially greater losses due to sawing inaccuracy with longer logs, as discussed below.

While there is little that can be done about spring, the failure to remove bow during drying is surprising. Normally it would be expected that bow would reduce during drying in correctly weighted and stickered drying stacks. However, this may well be a consequence of board thickness variation where the boards were thinner at the ends relative to mid-length. The consequence of this is that the stack will tend to curve as it is built up so that boards towards the top bow slightly. An alternative cause would be that the stacks were insufficiently weighted, which was the case for the back-sawn boards from the marked centre cant that were pre-dried in the small University of Tasmania kiln.

The analysis of board thickness indicates that despite straightening cuts being applied, log and flitch deflection during both quarter- and back-sawing led to the production of boards that were on average wider and thicker at mid-length than at the ends. This variation arose partly from deflection in the log and flitches, and partly from inaccuracies in the sawing equipment. Had the width and thickness measurements been taken closer to the board ends this effect would have been even greater than indicated in Table 7. This variation is evidence that the sawing equipment and sawing strategies typically applied for native forest eucalypts are not suited to this plantation resource.

The quarter-sawn half-log deflection due to release of growth stresses was less (10 mm for 2.7 m logs) than for quarter-sawn *E. nitens* logs in New Zealand (32 mm for 4 m logs, McKenzie et al., (2003). This does not mean that deflection would be less had we processed logs of comparable length, as piece length is a critical element along with radial differential in strain in determining the level of deflection.

The sawing accuracy achieved was poor by modern standards. For example, some manufacturers of sawing equipment guarantee a standard deviation of 0.5 mm, and the actual performance may be 0.2-0.3 mm (K. Westermark, Viesto Oy, Finland, personal communication). With a target green thickness of 27.5-28.0 mm, the standard deviation of 0.83-0.84 mm reported in this study meant that boards at the lower end of the distribution would be approaching 25 mm thickness before drying commenced, and with a thickness shrinkage on drying of 5-6%, equating to about 1.5 mm reduction in thickness, some 20% of dried boards would be below 25 mm in thickness before dressing. The consequences are that there is reduced opportunity to plane boards after drying to remove cupping and surface checking and produce select and standard grade boards at a nominal 25 mm thickness. In addition, excessive width variation would require docking and ripping of boards to smaller dimensions, leading to reduced product recovery and lower unit prices for smaller boards.

The substantial cupping recorded provides further indication that the conventional processing strategies employed were inappropriate for plantation-grown *E. nitens.* The degree of cupping may well be the consequence of inadequately weighted drying stacks or, alternatively, ineffective or poorly timed steam reconditioning. To illustrate the extent of this problem the cupping of back-sawn butt logs had a mean of over 2 mm. To remove this level of cupping during processing, planers would need to be set to remove approximately 5 mm of wood to expose clean surfaces on the face and back of boards, leading to major loss of merchantable volume.

Both surface and internal checking (when exposed on the board surface through machining) on graded surfaces are important value-limiting defects in current markets. Many mills in Australia, as a result, require select and standard grade surfaces to be free of surface checks. The severity and prevalence of surface checking and under-sizing was influenced by the processing methods. Poor sawing accuracy, insufficient weighting of the drying stacks leading to cupping and possibly ineffective steam reconditioning contributed to production of boards close to or below the final target size. The consequence of this was that planing prior to grading often failed to remove shallow surface checking and collapsed regions, hence they were down-graded to utility grade.

The lower total recovery from quarter-sawing was a consequence of the removal of spring in boards and deflection in logs and flitches. A major source of this loss of recovery was through the frequent application of face cuts during log breakdown. Unlike back-sawing where the logs were rotated, face cutting was the only strategy available during quarter-sawing to remove deflection in logs as a consequence of growth stress release. Modification of the log carriage and saw would eliminate the need for many of the face cuts. The most important modifications would be to: (i) ensure that three dogs were employed (as opposed to two); (ii) incorporate a line-bar ahead of the saw to provide a board thickness reference; and, (iii) incorporate independent hydraulic operation of dogs to ensure that the sawn face of the logs was always in contact with the line-bar. These three modifications would eliminate the need for many face cuts, and they would give the added advantage of improving overall sawing accuracy.

The shrinkage values determined in this study, while useful in determining green board dimensions, should be reassessed if new drying strategies are developed in which reconditioning is conducted at higher moisture content than generally accepted by the Australian ash processing industry, leading to greater collapse recovery (Blakemore & Langrish, 2007).

The MOE, MOR and Janka hardness (combined tangential and radial surface) reported for *E. regnans* by Bolza and Klute (1963) was 16.4 (GPa), 110.0 (MPa) and 4.89 (kN), respectively. The Janka hardness of *E. nitens*, ranging from 4.4 to 5.3 kN is, therefore, approximately equivalent to that of native forest *E. regnans,* which is an important native forest species. However, MOE and MOR of *E. nitens* were approximately 76% and 93% of the native forest *E. regnans* values, indicating that new markets may need to be developed for plantation-grown *E. nitens.* Such markets have already been developed by one company for structural applications, using a unique grading system (Cannon & Innes, 2008).

Conclusions

Neither thinning treatment nor a localised measure of tree competition had significant impact on processing performance and sawn board quality and recovery, for the logs processed in this study. This indicates that the current post-thinning stocking rate target for management of *E. nitens* sawlog plantations in Tasmania of 300 trees/ha is acceptable from a processing perspective and there appears to be no processing advantage in either adopting the lower post-thinning stocking rates of 100 and 200 stems/ha investigated in this research, or carrying out pre-commercial thinning. Important defects were: surface- and internal-checking; log-and board-end-splitting; under-sizing; un-recovered collapse; and cupping. There were a number of shortcomings identified in the conventional processing practices applied which contributed to these defects. Poor sawing accuracy with both quarter-sawing and back-sawing contributed to these defects by limiting the potential for planing to remove shallow surface checking and other drying defects. Appropriate weighting of drying stacks, careful material handling to limit drying in uncontrolled ambient conditions and application of steam reconditioning treatments at optimum mean moisture content are all likely to improve results.

Clearly, more work is required to develop processing practices for plantation-grown *E. nitens*. It appears that the conventional industry (which is currently focussed on sawing native-forest logs) will require significant re-tooling, and both sawing and drying strategies need to be improved. This will be most critical if back-sawing is attempted for processing pruned *E. nitens* to produce conventional sawn appearance products. Despite the problems in processing performance, the recoveries were still comparable to those obtained in other processing trials on native forest sawlogs which are currently used by the Australian industry.

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