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PROCESSING YOUNG PLANTATION-GROWN *EUCALYPTUS NITENS* FOR SOLID-WOOD PRODUCTS. 1: INDIVIDUAL-TREE VARIATION IN QUALITY AND RECOVERY OF APPEARANCE-GRADE LUMBER AND VENEER

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ABSTRACT

A New Zealand stand of *Eucalyptus nitens* (Deane & Maiden) Maiden was pruned up to height 8 m and grown for 15 years at low stocking to 57 cm diameter at breast height. This stand provided 15 trees, preselected for a range of wood density. Lumber and veneer were cut from the 5-m butt logs, veneer was peeled from the second logs from height 7 to 13 m, and each tree was evaluated for production of appearance-grade lumber and rotary-peeled veneer.

Butt-log quality was good as pruning had effectively restricted the knotty core, and there was little decay from branches in either butt logs or veneer billets. Longitudinal growth stresses varied widely among trees, resulting in log end-splitting and sawlog flitch movement during sawing (spring), which led to crook in sawn timber, substantially reducing timber conversion in some trees. Collapse and internal checking were prevalent in air-dried lumber, and numbers of checks varied widely among trees. Face-checking was found in boards from all trees after kiln-drying and reconditioning, and even those with very few face checks had internal checks.

Veneer thickness varied unacceptably, caused probably by incorrect knife- and pressure-bar settings. Veneer splitting also varied among trees, and was worse in butt-log than in second-log veneers. Unsatisfactory pre-heating of billets before peeling may have exacerbated splitting. Knots severely downgraded structural plywood veneer grades, <8% of sheets from the second logs being acceptable compared with 87% of sheets from the pruned butt logs. Stiffness of veneer sheets was successfully measured using a sonic device (Pundit™) to sort veneers for manufacture of laminated veneer lumber.

Keywords: sawing; timber; veneer; growth stress; checking; stiffness; *Eucalyptus nitens*.

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INTRODUCTION

Eucalyptus nitens is a fast-growing, cold-hardy species grown in plantations in south-eastern Australia, New Zealand, Chile, and South Africa. This species is used mainly for pulping. However, logs from natural stands have been sawn in the past for framing, flooring, panelling, and joinery (Miller *et al*. 1992; Turnbull & Pryor 1984), and in Tasmania *E. nitens* is being grown in plantations for appearance-grade sawn timber and veneer (Wardlaw & Neilsen 1999).

In New Zealand, *E. nitens* was not planted commercially until the late 1980s because *Paropsis charybdis* Stål beetles had previously caused severe defoliation. The introduction of a parasitic wasp, *Enoggera nassaui* (Girault) (Forest Research Institute 1990), has now controlled *P. charybdis* to the extent that *E. nitens* is grown commercially in Bay of Plenty/Taupo and Southland regions for kraft pulp and for export wood chips. *Eucalyptus nitens* is subject to severe infection by leaf-spot fungi, such as *Mycosphaerella cryptica* (Cooke) Hansf., *M. nubilosa* (Cooke) Hansf., and *Phaeophloeospora eucalypti* (Cooke & Massee) F.A.Crous *et al*., particularly on sites with a warm and humid summer such as Northland and coastal Bay of Plenty. This may limit its planting to colder sites in future (Gadgil & Dick 1983; Shelbourne *et al*. 2000; Hood *et al*. 2002).

Wood properties, chemistry, kraft and chemi-mechanical pulping, and fibre and handsheet properties have been intensively researched in New Zealand for this species at the individual-tree level (Downes *et al*. 1997; Kibblewhite *et al*. 1998; Jones & Richardson 1999; Kibblewhite & Riddell 2000; Kibblewhite & Shelbourne 1997).

Eucalypts are generally difficult to saw because of growth stresses, and are also difficult to dry without degrade. Poor "sawability", caused largely by high longitudinal growth stresses in the outside growth layers of the stem, is a problem that is common to many hardwoods, particularly eucalypts (Page 1984; Jacobs 1979 p.27). The distribution of the stress causes the log to split when cross-cut, and the log and flitches to bend longitudinally when rip-sawn. This longitudinal bending or "spring" is caused by the outside portion of the log being in longitudinal tension and the core in longitudinal compression. This results in bending of the flitch, requiring a straightening cut of the log face and leading to crook in the quarter-sawn boards and losses in conversion. Further movement when the flitch is cut leads to more losses as extra straightening cuts are required (Haslett 1988a). Moderate growth stresses have been reported to affect the sawing of 30-year-old *E. nitens* (Haslett & Young 1992). Waugh & Yang (1994) and Yang & Waugh (1996) compared log end-splitting in an extensive study of a total of 15 plantations in Tasmania and Victoria, four trees per plantation, ranging in ages from 15 to 45 years, including *E. nitens*, *E. regnans* F.Mueller, and *E. globulus* Labill. ssp. *globulus*, and found least in the *E. nitens* logs. McKimm (1985) found significant differences in microstrain measurements in standing trees between *E. nitens* provenances, with levels similar to those in *E. regnans*.

Internal checking is often associated with collapse, which is an "excessive or irregular form of shrinkage during drying … which occurs above fibre saturation point when liquid is removed by drying from cells. … On the radial face, collapse shows as a 'washboard' or fluted surface and on the tangential or back face it shows as heavy open checks with distortion of the surface as well" (Jacobs 1979 p.257). Collapse and checking can be partially reversed by steam reconditioning, but the final drying usually leads to surface checks reopening (Campbell & Hartley 1984). Chafe *et al*. (1992) suggested that when reference is made to collapse, what is meant generally is "recoverable" collapse, calculated as:

$$\text{Collapse} = S_v - S_r$$

where

S_v = shrinkage before steam reconditioning

S_r = shrinkage after reconditioning.

High levels of internal checking after drying were reported in discs taken at height intervals from 20 trees of *E. nitens* aged 15 years grown in Kaingaroa Forest, New Zealand, and in corresponding sawn boards from basal 1.4-m billets (Lausberg *et al*. 1995). Number of checks decreased to near zero above height 11.4 m. Checking was also widespread in breast-height discs of 9- to 10-year-old trees, sampled from six New Zealand sites, from latitudes 36° to 46°S. Checking was much more prevalent on the sites with higher mean annual temperatures and poor crown health. Extreme low wood density was associated with nutrient-rich sites and high rainfall (Shelbourne *et al*. 2002). Checking, measured in height-6-m discs of ten 11-year-old trees of *E. nitens, E, globulus*, and *E. maidenii* Labill., was found in all trees of *E. nitens*, one tree of *E. globulus*, and none of *E. maidenii* (McKinley *et al*. 2002). Haslett & Young (1992) found large numbers of checks, as well as collapse, in quarter-sawn-boards of 30-year-old *E. nitens*, even though timber was carefully air-dried before being kiln-dried. Yang & Waugh (1996) simulated a similar drying schedule for timber from 15-, 25-, and 29-year-old *E. nitens*, and also recorded high levels of internal checking. Waugh & Yang (1994) in the previously-mentioned study reported that *E. regnans* showed the worst drying degrade, followed by *E. nitens* and *E. globulus*, in terms of number and length of surface checks and percentage of boards with >5 surface checks. However, checking was assessed after steam-reconditioning which may cause many checks to close and become invisible. Timber from a Victorian study of 20-year-old trees of *E. nitens* showed minimal internal checking (McKimm *et al*. 1988). The wide range of pre-kiln-drying treatments employed to reduce degrade include wrapping or coating timber, drying in sheds with restricted airflow, and pre-steaming or pre-drying with fairly constant equilibrium moisture content (Vermaas 2000).

Twisting of boards on drying was another a serious problem in Haslett & Young's (1992) New Zealand study of 30-year-old *E. nitens*. Knots were a major source of degrade in unpruned plantation-grown trees. Pruning can eliminate or reduce the number of knots, but decay associated with pruning wounds is an important factor in plantation-management of *E. nitens* in Tasmania (Wardlaw & Neilsen 1999).

There could be a wider role for *E. nitens* in New Zealand, if fast-grown plantation trees can produce good-quality solid-wood products. The study reported here was of fifteen 15-year-old trees of *E. nitens*, in which 10 pruned butt logs were sawn and five pruned butt logs and all second logs were rotary-peeled. The first objective (reported in this paper) was to evaluate the recovery, grade, and quality of lumber and veneer by individual trees. The second objective (McKenzie *et al*. 2003) was to evaluate ways of predicting characteristics of the logs, sawn timber, and veneer, from standing tree, disc, and 1-m-billet sampling. The third objective was to evaluate laminated veneer lumber (LVL) made from the unpruned second log (Gaunt *et al*. 2003), and veneer sliced from butt-log boards (Roper & Hay 2000).

MATERIAL AND METHODS

Tree Selection

The stand of *E. nitens* utilised for this study was planted in 1983 at Golden Downs Forest, Nelson (lat. 41°24´S, long. 172°48´E) at an altitude of 230 m. The seed originated from the Toorongo Plateau in central Victoria. The *E. nitens* were planted as rows, 6 m apart and 2 m within rows, to provide a nurse crop for *Acacia melanoxylon* R.Br. which was planted the following year. By 1999 the acacias had formed a suppressed understorey, about a third of the height of the eucalypts. The *E. nitens* were thinned from an initial stocking of 833 stems/ha to 170 stems/ha at age 4 years, and then to 100 stems/ha at age 6. Pruning was done in four lifts to 2, 4, 6, and about 8 m at ages 2, 3, 4, and 6 years. A permanent sample plot (PSP), established in the stand in 1991 to assess growth, was re-measured in 1994 and 1997 (Table 1).

Forty trees in the stand were numbered and sampled for outerwood density at breast-height using 5-mm increment cores. They were classified into low-, medium-, and high-density groups, and five trees were then selected from each group, giving a total of 15 trees. These were required to have a minimum diameter of 30 cm at 11 m height for rotary peeling of second logs.

TABLE 1–Summary of *E. nitens* growth data, Cpt 101, Golden Downs

Age (years)	Stocking (stems/ha)	Mean dbh (cm)	Mean height (m)	Total volume (m^3/ha)
7.5	93	32.2	22.3	66.8
11	93	44.7	26.9	149.8
15.7	93	56.1	35.3	303.2

Tree and Log Assessment

Longitudinal growth stress was measured as tensile microstrain at two diametrically opposed positions at breast height on each of the 15 numbered trees, using the simplified version of the Nicholson (1971) method.

Diameter at breast height (dbh), total tree height, and height to first branch were measured, and 1.4-m height and the north direction were marked on each stem. After felling, bark, mature leaves, flower buds, and mature capsules from all trees were collected to confirm species identity. The health of each tree was assessed by examining the stump for the presence of any decay and by taking samples of leaves from the crown for subsequent examination.

Trees were felled and log ends were sealed with a water-based paint; gang-nail plates were fixed to each end to reduce end-splitting in transit. For 10 of the 15 trees (from the base upwards), a 5.5-m butt log, intervening discs, a 1-m billet, and then a 5.5-m second log were cross-cut (Fig. 1). For the other five trees, the 5.5-m butt logs were destined for rotary peeling and, as for the first 10 trees, discs and a 1-m billet were collected. Second logs of all 15 trees were destined for rotary peeling for veneer. The discs and 1-m billet were used for further wood property and sawtimber studies (McKenzie *et al.* 2003)

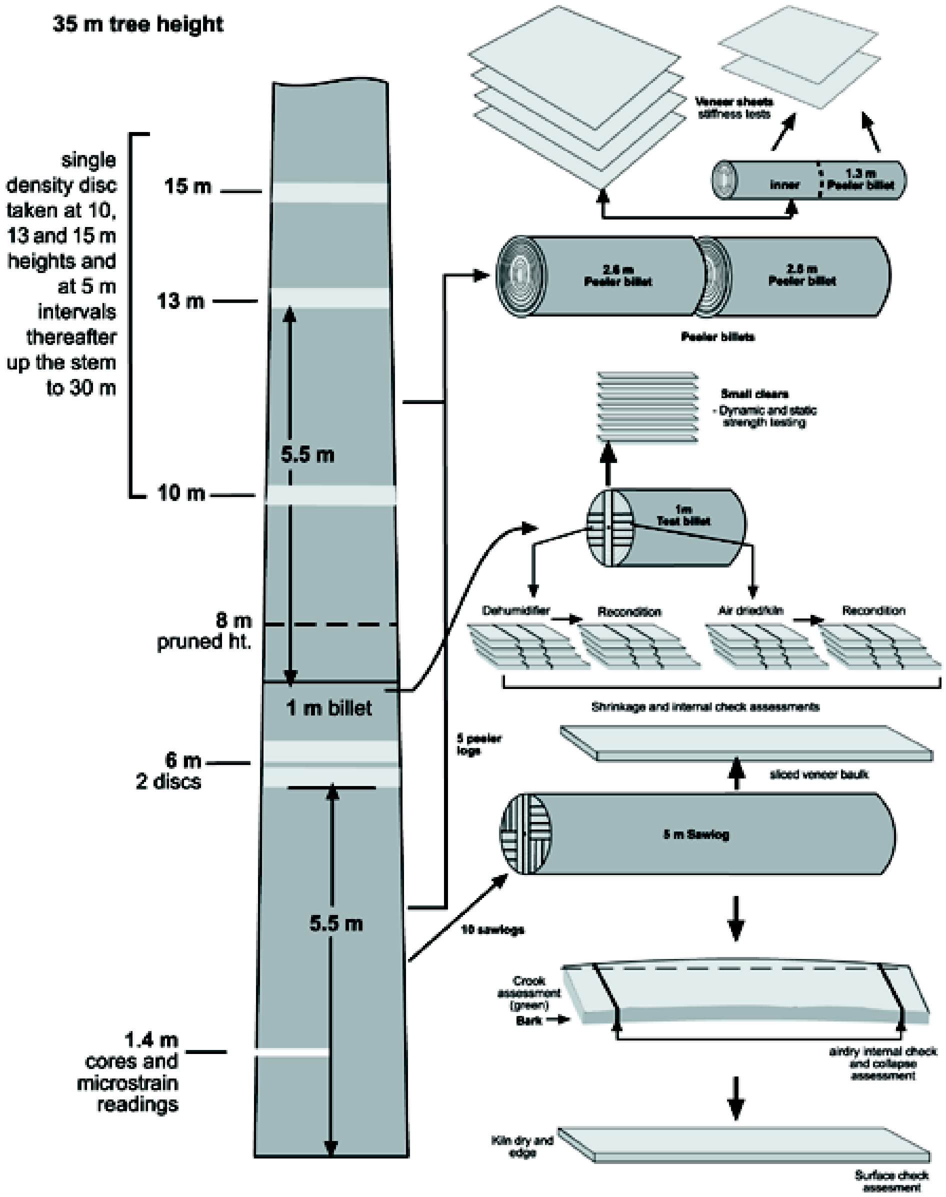

FIG. 1–Position of samples in relation to tree height and processing of logs and billets

Length, diameters at large end (l.e.d.) and small end (s.e.d.), and presence of decay were recorded for each sawlog. The radial extent of log-end splits was assessed immediately before they were peeled or sawn, which was 8–15 days after felling for peeler logs and 16 days after for sawlogs. The summed length-of-split/log-diameter ratio for all splits at each end was calculated as the "log splitting index" for each log. The diameter of the largest branch stub in four quadrants of each peeler log was averaged to give "branch index" (BIX).

Sawing

Each pruned butt log, cut to 5 m length, was sawn on a Woodmizer bandsaw mill to maximise production of 40-mm-thick quarter-sawn timber, with the residue as 25-mm boards (Fig. 2). Separation of the flitch from the log (spring) when the first saw-cut had reached a 4-m length was measured at the log end (Fig. 3), and the sawing pattern and board numbers were recorded for each log. Straightening cuts were made to remove the growth-stress-induced bow in the flitch, which otherwise would cause variable thickness of resulting boards (Fig. 2). However, losses due to straightening cuts were not quantified.

One fresh-sawn, defect-free board per tree was removed at this stage for manufacture of sliced veneer (Roper & Hay 2000).

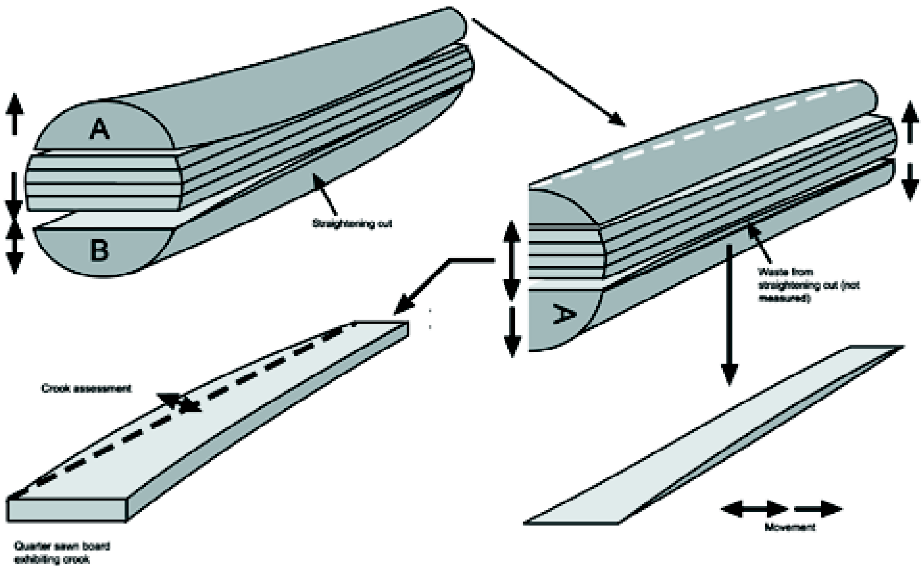

FIG. 2–Sawing pattern to produce quarter-sawn boards, and crook assessment method.

The diameter of each knot in the green boards was measured and the knot classified as either “sound”, “stained” (but wood was still hard), “soft decay”, or “decayed within the knot and in adjacent stem wood”.

Crook, a deflection in the plane of the board’s edge as it comes off the saw, was measured on those boards with a sawn edge (boards cut from flitches A and B, Fig. 2) according to NZS 3631:1988.

Boards were placed in filleted stacks in an open barn, and were wrapped in shade cloth and air-dried for 13 months to 17% moisture content (m.c.). Internal checking was then assessed by cutting 30 cm from upper and lower ends of each board, and the numbers of checks in the heartwood, sapwood/heartwood transition, and sapwood zones were recorded separately. Ring collapse severity (wash-boarding) was scored subjectively at the same points, from 0 (no collapse), 1 (slight collapse), 2 (moderate collapse), to 3 (severe collapse).

FIG. 3–Assessment of spring occurring at the first saw cut in Tree 24.

The boards were then kiln-dried, using a schedule of 70°C wet-bulb/55°C dry-bulb, for 95 hours. This was followed by kiln reconditioning involving steaming for about 2 hours and then slowly reducing humidity. The kiln-dried boards were cross-cut into two 2.2-m boards, and ripped to remove wane and knots, to nominal board widths of 50, 75, 100, 125, 150, and 200 mm.

The following characteristics were measured or recorded for each board:

Length (docked for end-splitting), nominal width, and thickness
Pinhole, kino, and decay
Cumulative surface-check length on each edge and face (the major defect)
Internal checks (on cut end)
Twist (evident in only two boards, so no assessments were undertaken).

Face checking, evident after reconditioning, was measured as total length of checks on each face and edge of the boards. The impact of these checks on grade was assessed by assigning boards to three classes using the allowances for face checking for Clears, Dressing, and Building grades (NZS 3631:1988):

- Class “C”: Clear on all edges and faces, or three face checks, not more than 0.5 mm wide or 50 mm long
- Class “D”: Clear (as for “C”) on at least one face and one edge
- Class “B”: Boards not meeting the requirement for D.

Nominal volume of each board was calculated, giving total volume for each class, by log. Recovery of timber volume was calculated as a percentage of log volume. The log volume was adjusted for the 10 boards used for making sliced veneer, and using an *E. nitens* volume/taper equation (M.Budianto & A.E.Hay unpubl. data) to account for a length of 30 cm, removed from each board end for the internal checking assessment.

Veneer Peeling and Drying

A preliminary study (I.Simpson & J.Sole unpubl. data) showed that much less drying degrade occurred in veneer that was peeled from heated logs. Therefore, 14 second logs and five butt logs were soaked overnight in hot water, to achieve a temperature of 55°C in the centre of the log (near 70°C on the outside). One second log (Tree 24) with severe end-splitting (Fig. 4) was not peeled. Some veneer logs were not completely submerged in the tank and their identity was recorded. The five butt and 14 second logs were then each cut into two 2.6-m billets which were peeled on a rotary peeler lathe to a core diameter of 180 mm to produce sheets 2.6 mm thick, 1.2 m wide, and 2.4 m long. Residual 180-mm cores were each cross-cut into two 1.3-m billets and then peeled to 90 mm diameter on a smaller lathe. Sheets were numbered in sequence from the outside of the log. Dried sheets varied a lot in thickness and moisture content, with an average of 18%, and a range of 6–60% (mould occurring on some sheets). Thickness, measured on each side of the sheet, varied both between and within sheets — average thickness 2.5 mm (standard deviation (s.d.) 0.14 mm), and average within-sheet range 0.15 mm.

FIG. 4–End-splitting in peeler log (left) and sawlog (below) of Tree 24.

Grading and Stiffness Assessment of Veneer Sheets

All rotary-peeled veneer sheets were visually graded, as for structural plywood (AS/NZS 2269:1994), into grades A, B, C, or D (Table 2). Sheets that failed to meet these grades were assigned a grade of "E". Other defects such as splits, stain, mould, and kino were recorded but not used in the grading. Each end of each sheet was categorised as having ≤5 or >5 end splits, and the longest split per sheet end was measured. The first appearance of knots in the sequence of sheets from the butt logs was noted in order to assess the size of the defect core.

TABLE 2–Knot and kino allowances for veneer grades AS/NZS 2269

Grade	Intergrown knots (size, number*)	Aggregation permitted† (mm)
A	<4 mm, <4/sheet	45
B	<25 mm, <4/sheet	45
C	<50 mm	75
D	No limit	75

* The measurement of the knot defect includes disturbed grain associated with the knot.
† Across any 300-mm-sheet width

Each sheet's dimensions were measured and it was weighed to estimate density. Sound velocity was also measured electronically on each sheet using a Pundit™ (R.Booker unpubl. data). Stiffness (modulus of elasticity, MoE) was predicted by the product of basic wood density × sonic velocity^2.

Statistical Analysis

Statistical analysis of the individual-tree values for recovery and quality of sawn timber and veneer were mostly restricted to calculation of overall means, ranges, standard deviations, and coefficients of variation. Radial checking at log ends was further analysed by a simple within- and among-tree analysis of variance.

RESULTS AND DISCUSSION

Tree Growth and Health

Eucalyptus nitens grew well and was well adapted to this site. The morphology of the leaves and buds of Trees 24 and 89, and of leaves only of Trees 45 and 68 (no buds present) were of *E. denticulata* I.O.Cooke & P.Y.Ladiges type (Cook & Ladiges 1991). They therefore appear to have originated from the *E. nitens*/*E. denticulata* mixed stands known to occur on the Toorongo Plateau in central Victoria. These trees may have been *E. denticulata* or a hybrid between this species and *E. nitens* as the leaf glands were not as well expressed as in typical *E. denticulata* from the Errinundra Plateau in eastern Victoria. The other 11 trees were typical *E. nitens*. By chance, butt logs of three of the four trees with some *E. denticulata* parentage were not sawn, but were peeled. One tree, 24, was sawn and showed very low conversion and highest growth stress of all trees. Numbers of trees of this type were too small to differentiate them from the rest, which were all *E. nitens*.

The rapid growth in diameter (mean dbh 57 cm, s.d. 4.2 cm) and height (mean 36.3 m, s.d. 2.1 m) resulted from the low stocking (93 stems/ha) (Table 1) as well as the fertile site, previously part of a tree nursery. The height to the first branch ranged from 7.8 to 11.2 m, above which were deep crowns of healthy foliage. One tree had a small amount of decay in the stump but it did not extend into the butt log. There was evidence of pinhole (*Platypus* spp.) attack on the bark of some trees and damage was later observed in the sawn timber.

Sawing and Sawn Timber Properties

The mean volume of the 10 butt logs sawn was 1.40 m^3 (s.d. 0.145 m^3) with a mean small-end diameter of 480 mm. Growth stress, measured on the standing tree as “microstrain”, was highly variable within and among trees (Table 3). Splits that opened at the pith during logging and log end-splitting index, measured just before processing, showed large among-tree variation for butt logs, varying from 0.50 (Tree 90) to 5.0 (Tree 24) (Table 3), and from 1.05 to 5.0 for the same trees in the second log. There was considerable stress in some of the logs when they were milled, as indicated by flitch movement which was measured as the size of the opening created by the first saw cut (Fig. 2 and 3); this showed wide tree-to-tree variation, ranging from 1 mm to 170 mm (Table 3). Crook, the curvature from the plane of the board’s edge, is also evidently caused by longitudinal growth stress and tree mean values varied from an average of 27 mm (Tree 30) to 93 mm (Tree 24) (Table 3). Six boards, mainly from Tree 24, were discarded due to shattering near the pith.

TABLE 3–Growth stress-related log and timber variables.

Tree No.	Butt log end-splitting (index)	Second log end-splitting (index)	Flitch movement (mm)	Timber crook (cm)	Log timber conversion (%)*	Breast-height growth stress (tensile microstrain)
7	3.50	4.00	100	53.0	50.9	928
8†	4.15	3.75				462
22	4.75	3.00	150	47.0	44.3	559
24‡	5.00	5.00	170	93.4	37.1	1685
30	2.25	2.25	1	26.6	52.5	234
35	1.68	2.38	80	30.5	52.4	205
38	1.25	1.50	50	27.9	50.9	303
42	3.50	2.50	80	37.9	54.2	558
45†	3.35	1.75				390
68†	3.38	3.50				469
78	2.90	3.00	80	45.0	47.0	470
86†	3.80	3.25				460
87	1.15	1.00	40	29.2	55.5	302
89†	3.90	3.25				719
90	0.50	1.05	60	30.3	55.9	317
Mean	3.00	2.75	81.1	42.1	50.1	537
CV%	45.1	41.1	61.7	48.1	11.6	68.7

* Log volume adjusted to compare with reduced length boards
† Butt logs peeled, not sawn
‡ Second log not peeled due to splitting

Overall mean recovery of knot-free timber after kiln drying and steam reconditioning averaged 50% (Table 3). Conversion was inflated by the cutting of each initial 5-m board into two 2.2-m boards, followed by ripping. It varied widely from 37% (Tree 24) to 56% (Trees 87 and 90) and was closely and inversely related to end-splitting, crook, and microstrain (Table 3). The relationship of this important wood property to other traits which determine the "sawability " of a tree was examined by McKenzie *et al.* (2003).

Butt Log Sawn-timber Defects

Knots varied in number from 40 to 116 per tree (mean 87, s.d. 24.1) (not tabulated) and all trees, except Tree 35, had some stained knots. Soft decay was observed in knots from five trees, spreading vertically 15 to 78 cm but not radially. Stain had also spread a few centimetres vertically from increment-core holes made several years before felling. Decay of knots after pruning can be a serious problem in management of plantation eucalypts (Wardlaw & Neilsen 1999), but in this stand it was minimal.

After the boards were air-dried (but before kiln-drying and reconditioning) there were an average of twenty 5-m boards per tree for assessment of collapse and checking. Collapse was scored at upper and lower ends of each board (0 = none to 3 = severe). The tree-mean collapse score (Table 4) at the upper (small) end varied from 0 to 2.9, and five out of 10 trees had collapse scores of over 1.2. Collapse was bad for Trees 35 and 22 (scores 1.5 and 2.9). Collapse was far worse at the lower ends of the boards, averaging 2.36 overall *vs* 1.11 for the upper ends.

Trees varied widely in the amount of internal checking in the butt log after air drying (Table 4). Checking in the heartwood was less frequent than in the sapwood. Trees 24 and

TABLE 4–Collapse and checking in sawn boards

Tree No.	Air-dried boards						Reconditioned boards	
	Collapse score (0 (no collapse) to 3 (severe collapse))		Total No. of checks (checks/ cm^2)		No. of checks in heartwood (checks/ cm^2)		Length of face checks (mm/ cm^2)	End checks (% C class boards)
	small end	large end	small end	large end	small end	large end		
7	0.82	2.84	0.013	0.035	0.007	0.014	0.059	2.5
22	2.91	2.96	0.116	0.079	0.057	0.038	0.286	0
24	0.00	0.74	0.000	0.002	0.000	0.000	0.06	0
30	0.71	1.86	0.021	0.021	0.007	0.003	0.062	4.3
35	1.50	2.94	0.073	0.052	0.011	0.023	0.082	17.5
38	1.47	2.82	0.037	0.043	0.020	0.022	0.029	18.9
42	1.21	2.65	0.033	0.046	0.008	0.011	0.051	14.3
78	0.13	2.00	0.001	0.007	0.000	0.002	0.038	9.1
87	1.12	1.88	0.040	0.071	0.005	0.011	0.046	13.5
90	1.24	2.94	0.041	0.083	0.007	0.025	0.05	17.1
Mean	1.11	2.36	0.038	0.044	0.012	0.015	0.0767	9.7
CV%	73.5	30.9	93.8	64.6	135.9	81.8	97.8	77.1

78 had no internal checking visible at the upper ends of boards, and other trees varied from 0.01 to 0.12 checks/cm^2. End-splitting of boards (not tabulated) was confined to near the pith in the near-diametrical boards (Numbers 1–4, Fig. 2) except for Tree 24 which had more extensive end-splitting.

There were an average of forty 2.2-m-long boards per tree for grading and further assessment, but unfortunately the reconditioning period used (2 hours) was less than the recommended 4 hours for 40-mm-thick timber (Haslett 1988b). Face checking, occurring after reconditioning, was measured on all faces and edges of the 2.2-m boards as total length of checks/board area (Table 4). Trees varied in the length of face checking per square centimetre of board surface from 0.029 mm/cm^2 (Tree 38) to 0.286 mm/cm^2 (Tree 22).

Boards were classified as “C”, “D”, and “B” on the sole basis of face-checking criteria for Clears, Dressing, and Building grades, resulting in 35% of timber volume classified as C, 41% as D, and 23% as B (Table 5). Trees varied in percentage of C class (minimal face checking) from 5% to 59%, again showing high among-tree variability in this characteristic. Cross-cutting some of the face checks showed that they were the same defect as internal checks, occurring as part of a series of checks in a growth ring which were exposed on the surfaces of boards. Internal checking was observed in the uncut ends of 9.7% of C class boards (Table 4), suggesting that some boards, apparently free of checks, may have internal checks which will be exposed during manufacturing. Trees 22 and 24 showed no such end checks, but in five out of 10 trees over 13% of the C class boards had end checks.

Drying distortion was essentially absent, with twist noted in only two boards. There was no apparent cause, such as knots or damage, for the very small pockets of kino found in six boards from three trees. Pinhole was present in boards from six trees, the worst having 40% of boards affected (Table 5).

TABLE 5–Volume of sawn timber in each face checking class and number of boards affected by pinhole

Tree No.	Timber volume in class* (%)			Boards with pinhole (% total boards)
	C†	D	B	
7	34.5	50.0	15.4	7.5
22	5.4	16.5	78.1	2.1
24	42.2	32.2	25.6	16.2
30	25.7	57.8	16.5	2.2
35	25.5	41.5	33.1	0
38	49.0	46.6	4.4	0
42	24.4	47.3	28.3	0
78	59.4	34.4	6.3	6.1
87	48.1	45.1	6.8	40.5
90	40.7	41.9	17.3	0
Overall mean	35.48	41.33	23.18	7.5

* Classes based only on face checking allowances for Clears, Dressing, Building grades (NZS 3631)
† Including sliced-veneer flitches.

Peeler Log, Veneer Recovery, and Quality

Butt logs of five trees were cross-cut into two billets with average small-end diameters of 503 mm (s.d. 27 mm) and 477 mm (s.d. 27 mm) respectively. The 14 second logs were also cut in half and resulting billets had average small-end diameters of 441 mm (s.d. 26 mm) and 408 mm (s.d. 23 mm) respectively. Overall recovery of full- and part-sheets of veneer was 59% of the total log volume of 16.9 m^3. The recovery by billet was not related to log size and varied from 40% to 65%. Large hollows in the stem, associated with large branches, led to some veneer being discarded during initial "round-up" of seven logs. One of the second logs had stain spreading vertically from an unpruned branch, and another had a very large decayed branch. Further reduction in recovery was caused by excessive breakage of sheets near the centre of one log, and core breakage occurred in the butt log of Tree 89, so that peeling was abandoned at 280 mm diameter. The second log from Tree 24 (Fig. 4) had such severe end-splitting that it could not be peeled at all.

Manufacture of LVL is a continuous process and so, although small splits are not a problem, sheet breakage is unacceptable. In this study, sheet breakage at time of peeling was not recorded but fragments of veneer accounted for 4% of the volume. Veneer splits, which gave an indication of the tendency to breakage, were expressed as the mean longest split in each sheet, and as the percentage of veneer sheet edges having more than five splits. The mean length of the longest split per sheet for second logs (Table 6) varied from 144 mm for Tree 38 to 483 mm for Tree 45, and from 319 mm to 612 mm for the butt logs. Some veneer splitting may have resulted from uneven heating of some logs which had not been

TABLE 6–Mean veneer-sheet splitting and stiffness values

Tree No.	First log: mean longest veneer split/sheet (mm)	Second log: mean longest veneer split/sheet (mm)	Veneer sheets with more than five splits (%)	Pundit™ modulus of elasticity (GPa) (both logs)
7		334	76.7	14.5
8	486	204	38.6	15.3
22		295	52.8	15.2
24		Not peeled		
30		352	76.6	17.3
35		362	38.6	14.9
38		144	13.9	15.3
42		246	67.9	15.3
45	612	483	78.3	14.1
68	402	250	62.5	15.4
78		219	31.8	16
86	319	433	67.0	18.5
87		387	43.2	13.1
89	380	194	55.8	15.8
90		296	36.4	12.4
Mean		300	52.9	15.2
CV		32.5	37.2	10.0

fully submerged in the hot water bath prior to peeling. A one-way analysis of variance suggested that splitting was indeed significantly worse for these logs. The proportion of veneer edges with more than five splits in partially submerged logs was 67% *vs* 45% in the fully submerged logs ($F_{1,12} = 5.85$; $p = 0.03$), while the mean longest split per sheet was 363 mm *vs* 265 mm ($F_{1,12} = 3.95$; $p = 0.07$).

There were massive differences in structural veneer grade recovery between the pruned butt and unpruned second logs (Table 7). This was to be expected because of the large branch stubs of 8 to 13.5 cm diameter recorded in the second logs (mean BIX 5.8 cm, s.d. 1.9 cm, for the first billet; 7.0 cm, s.d. 1.7 cm, for the second billet). This led to most of the second-log sheets being outside the acceptable grades (i.e., "E" grade). More than half the sheets from the pruned butt logs were graded A, and a quarter B. Knots were present in the last one or two sheets for three butt logs, indicating a knotty core diameter of 18 cm or less for the five logs.

TABLE 7–Percentages of veneer sheets in each structural grade AS/NZS 22269

Peeler log type	Grade A	Grade B	Grade C	Grade D	Grade E*
Butt	52.5	24.4	1.1	9.2	12.8
Second log	0	0	0.1	7.3	92.5

* Unacceptable

Mean tree stiffness of veneer sheets, measured acoustically by Pundit™ (Table 6), varied from 12.4 to 18.5 GPa. In an associated study (Gaunt *et al*. 2003), the sheets were sorted by these values into three stiffness classes (high, medium, and low) and manufactured into sheets of LVL. The sorting was very successful, resulting in corresponding increased stiffness of LVL.

CONCLUSION

Growth of *E. nitens* on this northern South Island site was very rapid, with an average dbh of 57 mm and height of 36 m at age 15 years, and timely pruning had adequately restricted the size of the knotty core. There was only very localised decay in the stubs of pruned branches in the butt log and some decay was associated with dead branches in some of the second logs.

Butt logs showed highly variable amounts of end-splitting, which was gross in only one tree but serious in two-thirds of the trees. Second logs (for veneers) showed similar amounts of end-splitting and ranked, by trees, similarly to the butt logs. Longitudinal growth stress, measured as microstrain at breast height on standing trees, was the apparent cause of flitch spring during sawing and of crook in boards. Ripping eliminated the crook but reduced timber conversion. Average conversion was 50%, but varied widely between trees from 37% to 56%.

The two main drying defects were collapse and checking. Twist, an important defect in a previous study, was negligible. Bad collapse was present in two trees out of 10 and was far worse at the lower end of the butt-log boards. The frequency of internal checking of butt-log boards after air-drying was highly variable among trees, and in three of the 10 trees it was negligible. Face checking, visible after kiln drying and reconditioning, occurred in boards from all 10 trees. Ten percent of the boards with minimal face checking (within the limits for Clear grade) had internal checks exposed at the cut ends and more internal checks were likely to be exposed in boards during remanufacturing. Checking in the butt logs was a major source of degrade, which impacted seriously on the utility and value of dried appearance-grade lumber of this species.

Successful processing of veneer logs evidently depends on preheating logs evenly and using appropriate settings for the lathe. The knots in the second logs made veneer unacceptable for structural plywood when graded visually, but sonic assessment of stiffness led to effective sorting of veneers into stiffness classes for LVL.

There was wide tree-to-tree variation in important sawn-timber and veneer properties. This may be able to be exploited by breeding programmes to improve product quality and recovery.

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