Low-rainfall eucalypts as a potential plantation resource in south-eastern Australia for sawn appearance products

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Summary

Four eucalypt species were evaluated for their potential to produce sawn appearance products when grown in the low rainfall (400–600 mm y^{-1}) region of south-eastern Australia. The species were selected on the basis of their suitability for the region and the availability of sawlogs in existing plantations. The sampled trees were about 40 y-old with a minimum diameter at breast height over bark of 30 cm. A butt log 3.1 m long was harvested from ten or eleven trees of each of the following species: *Eucalyptus astringens* (Maiden) Maiden (brown mallet), *E. cladocalyx* F.Muell. (sugar gum), *E. leucoxylon* F.Muell. (yellow gum) and *E. occidentalis* Endl. (flat-topped yate). The logs were back-sawn with a conventional sawing system to produce boards mostly of 100 mm x 40 mm (nominal) cross-section.

The recovery of green boards that met high-value appearance grades was poor. The recovery of select grade or better boards ranged from only 0.9% of log volume for *E. leucoxylon* to 8.1% for *E. astringens*. The poor recoveries were mostly attributable to the small diameter of logs and the lack of silvicultural treatment in the stands from which they were cut.

The results highlight the difficulties of growing high-value sawlogs in this region, without suitable silviculture. At best, given the expected long rotations, the economics of growing high-value sawlogs are likely to be marginal, and profitability will depend on other land management benefits provided by the trees. Improved genetic stock and appropriate silviculture will be critical if green recoveries (select grade and better) of at least 30–35% are to be achieved. Green recoveries of this magnitude are likely to be required for a viable sawn timber industry to be established in this region.

Use of a conservative air-drying schedule resulted in little drying degrade, surface checking being the main drying defect observed. Given the level of surface checking found, in the absence of other defects 85% of boards would still have made select grade or better. Nevertheless, careful drying practices will be required to minimise surface checking in back-sawn boards of each of these species.

Keywords: forest plantations; sawnwood; yields; productivity; dry conditions; arid climate; amelioration of forest sites; *Eucalyptus*

Introduction

There are various reasons for farmers and regional communities to establish plantations in the low-rainfall (400–600 mm y^{-1}) regions of south-eastern Australia. Primary amongst these is the need to improve agricultural systems and ameliorate serious broad-scale environmental degradation, such as dryland salinity. Other considerations include provision of wind-breaks and stock shelter, enhancing local and regional aesthetics, and increasing biodiversity.

In the study region, uncertainty about the wood quality and processing characteristics of candidate species is a major constraint to plantation establishment. This study provides data on the recovery of green appearance-grade products from four eucalypt species in existing plantations (grown with minimal management) to evaluate their potential to produce solid-wood appearance products. Basic observations on the drying properties of these species are also reported.

Materials and methods

Species selection

An initial survey of 30–60-y-old plantations in the predominantly winter rainfall region (400–600 mm y^{-1}) of south-eastern Australia assessed basic growth characteristics (growth rate, tree form, and site and climate suitability) and identified species with at least 20 trees (to allow some freedom to select the 10–11 trees to be evaluated) meeting the following criteria for the sawmill study:

- about 40 y-old
- a minimum diameter at breast height over bark (DBHOB) of 30 cm
- a clean, straight bole to height of at least 3.5 m (sufficient to harvest a butt log 3.1 m long).

Diameters were measured with a diameter tape, tree height with a Suunto clinometer and 30 m tape, and the point basal area with a factor 1 or 2 wedge depending on size and distribution of surrounding stems. Table 1 summarises the plantation and log information for each of the four species sampled. All the plantations were located north of Horsham in western Victoria (<450 mm y^{-1} rainfall) and harvesting was carried out in February 2000.

Table 1. Summary of species and log details: mean (and standard error in parentheses)

Details	Species			
	E. occidentalis	*E. cladocalyx*	*E. leucoxylon*	*E. astringens*
Plantation	Barrett	Wail	Wail	Glen Lee
Latitude	36°25'S	36°31'S	36°30'S	36°16'S
Longitude	142°19'E	142°05'E	142°04'E	141°50'E
Age at harvest (y)	42	29	44	41
No. trees	11	10	11	11
DBHOB (cm)	41.3 (2.3)	35.1 (0.8)	36.5 (1.2)	34.6 (1.2)
Range	30.1–52.9	31.0–39.0	30.5–44.5	30.9–45.2
Tree height (m)	20.8 (0.5)	19.3 (0.4)	21.2 (0.8)	18.0 (0.5)
Range	18.3–23.0	17.2–21.6	17.2–25.2	16.1–21.3
Point basal area (m^2 ha^{-1})	20.8 (1.0)	22.1 (1.7)	17.8 (0.9)	17.0 (1.6)
Large-end diameter (cm)	38.7 (0.9)	31.6 (1.0)	35.8 (1.2)	36.1 (1.5)
Small-end diameter (cm)	33.6 (0.7)	26.6 (0.5)	28.8 (0.8)	30.0 (1.0)
Log volume‡ (m^3)	0.330 (0.013)	0.209 (0.010)	0.259 (0.016)	0.272 (0.019)
Taper (cm m^{-1})	1.6 (0.1)	1.6 (0.2)	2.2 (0.2)	2.0 (0.3)
Large-end sapwood width (mm)	16.7 (0.7)	19.3 (1.4)	21.6 (1.6)	15.9 (0.8)
Small-end sapwood width (mm)	17.9 (0.6)	21.0 (1.5)	19.9 (0.7)	15.2 (0.8)

‡Log volume calculated using Smalian’s formula from the large- and small-end diameters.

Log preparation and sawing

Immediately upon cross-cutting and trimming to length, the ends of all logs were coated with a wax emulsion (‘PARACOL’ 855N: Hercules Chemicals Australia) to prevent end-drying and checking. After transport to the sawmill the logs were stored, with the bark left on, under water spray. In the days preceding sawing, logs were debarked and, after ends were trimmed square, measured for length. End diameters and sapwood width were measured on the longest and perpendicular axes. Log taper was calculated as the difference between the large- and small-end diameters divided by the log length. Sawing was conducted at the Timber Industry Training Centre, Creswick, using a conventional back-sawing strategy. A sizing carriage and 72-inch-diameter ‘Salem’ vertical band-saw were used for primary log breakdown. A Grey one-man circular-saw bench was used for re-sawing and sizing boards to dimension. The sawing strategy involved cutting a central cant 105 mm wide that was aligned with the north–south orientation of the logs in the plantation (Fig. 1). Boards 43 mm thick were taper sawn from the cant and wings, and smaller-dimension products were also cut where possible. To enable the sawyer to identify the north–south axis of the logs, three lines of different colours were applied to the large end of each log to indicate the north, south and west axes respectively. The lines later enabled the relative positions of the boards in the log to be determined (the paint can be seen on ends of boards in Fig. 2b).

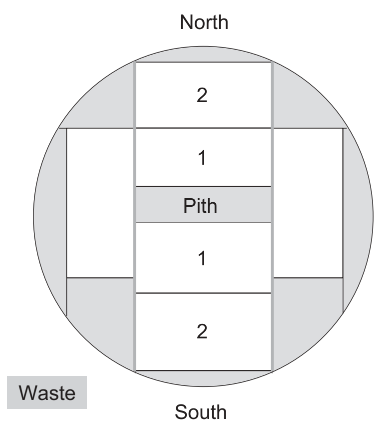

Figure 1. Basic sawing pattern (view of small end). A central cant, 105 mm wide (indicated by light lines), was cut in the north–south alignment and then boards 43 mm thick were taper sawn.

Green grading and recovery calculations

All boards were visually graded to CSIRO appearance-grading rules (Waugh and Rozsa 1991). The grades and a brief description of the uses of each grade are provided in Table 2. Boards were notionally docked where an upgrade of two grades could be achieved within the length restrictions listed in Table 2.

Green recoveries were determined using nominal board sizes and notional docked lengths. The nominal board sizes were 100 mm x 40 mm, 100 mm x 25 mm, 100 mm x 12 mm, 70 mm x 40 mm, 70 mm x 25 mm, 70 mm x 12 mm, 50 mm x 40 mm and 50 mm x 25 mm. Log volumes were calculated using Smalian’s formula. To simplify the interpretation of the green grade recoveries, the following measures of recovery were calculated:

- sawn recovery — total recovery of all products plus reject, as a percentage of log volume. This is an indicator of the efficiencies of the sawing systems and strategies used rather than of the quality of wood sawn.
- product recovery — recovery of all sawn products less reject, as a percentage of log volume. Cutting grades (Table 2) were allotted to polishing and moulding grades.
- target recovery — recovery of cover grade and better, as a percentage of log volume. Products 100 mm x 12 mm or 50 mm x 25 mm in size and less than 1.8 m in length were rejected, as they are not sizes preferred by industry.

Table 2. Brief description of CSIRO-developed appearance grades (Waugh and Rozsa 1991)

Grade	Brief description of uses
Polishing	Wood used for highly decorative purposes. Graded on all faces and used for high-value furniture, wood turning and trim items. Minimum length 1.8 m.
Moulding	Also used for highly decorative purposes. Graded on all faces and used for furniture and trimmings. Minimum length 1.8 m.
Select	Graded on the best face and both edges. Examples of uses are lining boards, strip flooring and shelving. Minimum length 2.4 m.
Standard	Graded on the best face. Example uses are lining boards and strip flooring. Minimum length 2.4 m.
Utility	Graded on the best face. Example uses are industrial shelving, strip flooring, and industrial lining boards. Minimum length 2.4 m.
Cutting grade 1	Short lengths equivalent to polishing grade cut from lower-grade boards. Minimum length 1.2 m.
Cutting grade 2	Short lengths equivalent to moulding grade cut from lower-grade boards. Minimum length 1.2 m.
Cover	Graded on the worst defect. Stiffness is of prime importance as the products are used for strength within furniture. Not strictly a structural product because the tolerances for machining and distortion are finer than specified for structural products. Minimum length 2.4 m.
Case	Graded on the worst defect. Used for low-grade pallets or chipped if price is not right. Minimum length 2.4 m.
Reject	No use as solid wood; possible use as fuel wood or chips

- select recovery — recovery of select grade and better, as a percentage of log volume. The same restrictions on product dimensions apply as for the target recovery.

Lyctid-susceptible sapwood is not permitted, or at best is restricted to the limits for wane, in the CSIRO appearance-grading rules. *E. astringens* is known to have lyctid-resistant sapwood (Bootle 1985), while *E. cladocalyx* and *E. leucoxylon* are known to have lyctid-susceptible sapwood (Standards Australia 2000). The susceptibility of *E. occidentalis* is unknown, but it may be resistant as it is closely related to *E. astringens*. Regardless, in this study it was assumed for all species that even if the sapwood was susceptible, it would be chemically treated and thus permissible. Without treatment the recoveries for *E. cladocalyx* and *E. leucoxylon*, and possibly *E. occidentalis*, would be further reduced.

Drying

No drying schedules for back-sawn material of these species, 40 mm thick, were given in Rozsa and Mills (1991). To minimise drying degrade, all boards in the present study were dried conservatively under mild conditions of controlled air-drying. Boards 40 mm thick were deliberately targeted for the drying study, as drying problems are more pronounced in such thick boards. If these boards can be dried successfully, it should be possible to dry thinner boards with less degrade and in a shorter time.

To monitor drying rates and degrade, one sample board was prepared from each of the trees in the study. In each case, the board selected for sampling was from the north–south cant (Fig. 1); preferably from the outer heartwood. The sample boards were 600 mm long and cut from the butt end of the board. A section 20 mm long was cut for determination of moisture content (MC) accordance with the oven-dry (OD) method outlined in AS/NZS 1080.1:1997 (Standards Australia 1997). At the completion of drying, additional sections were cut from the middle of the sample boards to determine final MC and to re-estimate more accurately the OD weight of these boards. The boards from each species were kept separate in four discrete stacks; the sample boards were distributed across two layers within each species stack (Fig. 2). The stacks were arranged in two pairs, one member of each pair being on top of the other.

Prior to the sample boards being cut, all boards were left block stacked and wrapped in plastic for six weeks. When the sample boards were prepared the boards were stickered out and the stacks re-covered with plastic. After a further 11 weeks the plastic was removed from the long sides of the stacks and replaced with hessian. After a further five weeks the hessian was removed from the long sides of the stacks. The stacks then were placed in front of a drying fan-wall to improve uniformity of drying. The fan-

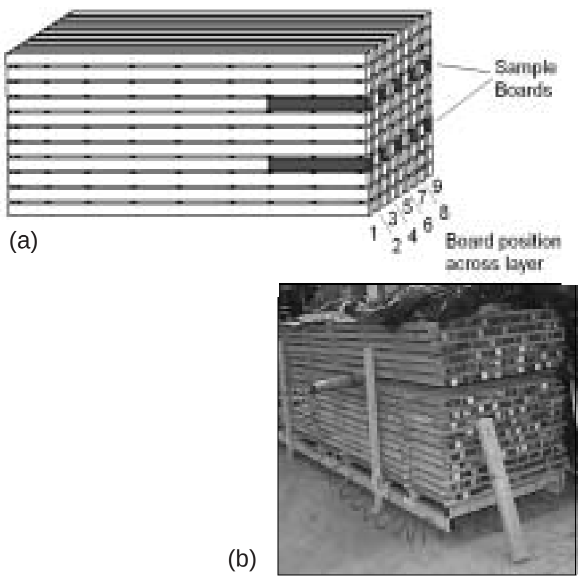

Figure 2. (a) Diagram of placement of sample boards: boards from each species were placed in two layers. (b) A sample board of *E. astringens* removed from stack for weighing.

Table 3. Comparison of log features (log volume, small-end diameter (SED) and taper) and the various green recovery figures from this study (400–600 mm y^{-1}) with those from the butt logs only in the Washusen *et al*. (2000) study (580–750 mm y^{-1}) (Rk = rank)

Species	Count	Log volume		SED		Taper		Sawn recovery		Product recovery		Target recovery		Select recovery	
(location, age)		Mean	Rk	Mean	Rk	Mean	Rk	Mean	Rk	Mean	Rk	Mean	Rk	Mean	Rk
	Rainfall zone: 400–600 mm y^{-1}														
E. cladocalyx (Wail, 29 y)	10	0.209	9	26.6	10	1.59	6	40.0	7	32.0	5	18.1	8	1.0	9
E. astringens (Glen Lee, 41 y)	11	0.272	6	30.0	7	1.96	3	39.9	8	32.5	4	22.9	6	8.1	5
E. leucoxylon (Wail, 44 y)	11	0.259	8	28.8	8	2.25	1	35.9	10	22.0	10	7.4	10	0.9	10
E. occidentalis (Barrett, 42 y)	11	0.330	2	33.6	3	1.63	5	43.0	3	26.4	9	14.0	9	5.2	8
Combined	43	0.269		29.8		1.86		39.7		28.1		17.7		3.9	
	Rainfall zone: 580–750 mm y^{-1}														
E. cladocalyx (Earlston, 40 y)	5	0.304	4	33.2	4	1.54	7	43.3	2	35.1	2	32.6	2	20.6	2
E. cladocalyx (Bandiana, 36 y)	5	0.297	5	32.4	5	1.82	4	42.8	5	34.5	3	29.6	4	18.9	3
E. globulus (Oxley, 15 y)	10	0.208	10	27.5	9	1.30	9	42.9	4	27.0	8	20.6	7	6.5	7
C. maculata (Lake Hume, 40 y)	10	0.411	1	38.1	1	2.17	2	44.1	1	39.4	1	37.0	1	28.0	1
E. sideroxylon (Lake Hume, 40 y)	5	0.314	3	34.2	2	1.39	8	42.2	6	31.0	6	30.6	3	13.7	4
E. sideroxylon (Tarrawingee, 26 y)	5	0.264	7	31.5	6	1.06	10	36.0	9	27.9	7	25.0	5	8.0	6
Combined	40	0.302		32.8		1.59		42.3		32.7		29.1		16.3	

wall monitored ambient conditions to draw air through the stacks (<0.5 m s^{-1}) when the temperature was <30°C and relative humidity >60%. At all times the top and ends of the stack remained covered with plastic.

Steam reconditioning was applied for 6 hours when the average board MCs were about 15–18%. At this stage, an electrical moisture meter (‘Delmhorst’ RC1C) was used to check that core MCs were below 25%. After reconditioning, the boards were kiln-dried to 10% MC. The final drying schedules took 2 weeks, with conditions set at 60/50°C (dry bulb/wet bulb) for 7 days, equalised at 70/50°C for 4 days and finally conditioned at 70/65°C for 2–3 days. Air flow through the kiln was 1–1.5 m s^{-1}. The steam reconditioning and final drying were undertaken in a pilot-scale kiln with a capacity of 4 m^3.

Results and discussion

Recovery of green appearance products

Table 3 shows the various recoveries for each species. For comparison, the equivalent recoveries, from the butt logs only, have been extracted from the study by Washusen *et al.* (2000) and included in this table. One difference in grading between the two studies was that sapwood was graded as wane in the Washusen *et al.* study. This was mostly due to the strong colour difference between heartwood and sapwood in *E. sideroxylon*, which usually makes sapwood unsuitable in appearance products. The recoveries for the other species in the Washusen *et al.* study, which have lighter colours and less contrast between heartwood and sapwood, would be slightly higher than shown in this table if the assumption used in this study had been applied; that is, that the sapwood would be chemically treated against lyctid borer.

Table 3 clearly shows that the recovery of appearance products in the present study was poor compared with that in the Washusen *et al.* study. This is partly due to the smaller diameter and greater taper of the logs sawn in this study. This is most apparent with *E. cladocalyx*, where the small-diameter logs had much lower recovery of the higher-quality grades (mostly due to wane and pith, as shown in Fig. 3) than was obtained from the larger logs sampled by Washusen *et al.* (2000).

The obvious exception is *E. occidentalis*, which had the second-largest logs of either study with only average taper. While it had the third-greatest recovery of sawn products, the recovery of target and select grade products was very poor. This was mostly due to extensive decay columns from large dead knots that were not apparent in the standing trees. Figure 3 shows that decay was in fact the major cause of boards being rejected for most species in this study. Wane, pith and green knots were the other main grade-limiting defects, restricting a high proportion of the boards to the lower-value products of cover grade, case grade or reject grade. Termite galleries were a problem only with *E. leucoxylon*.

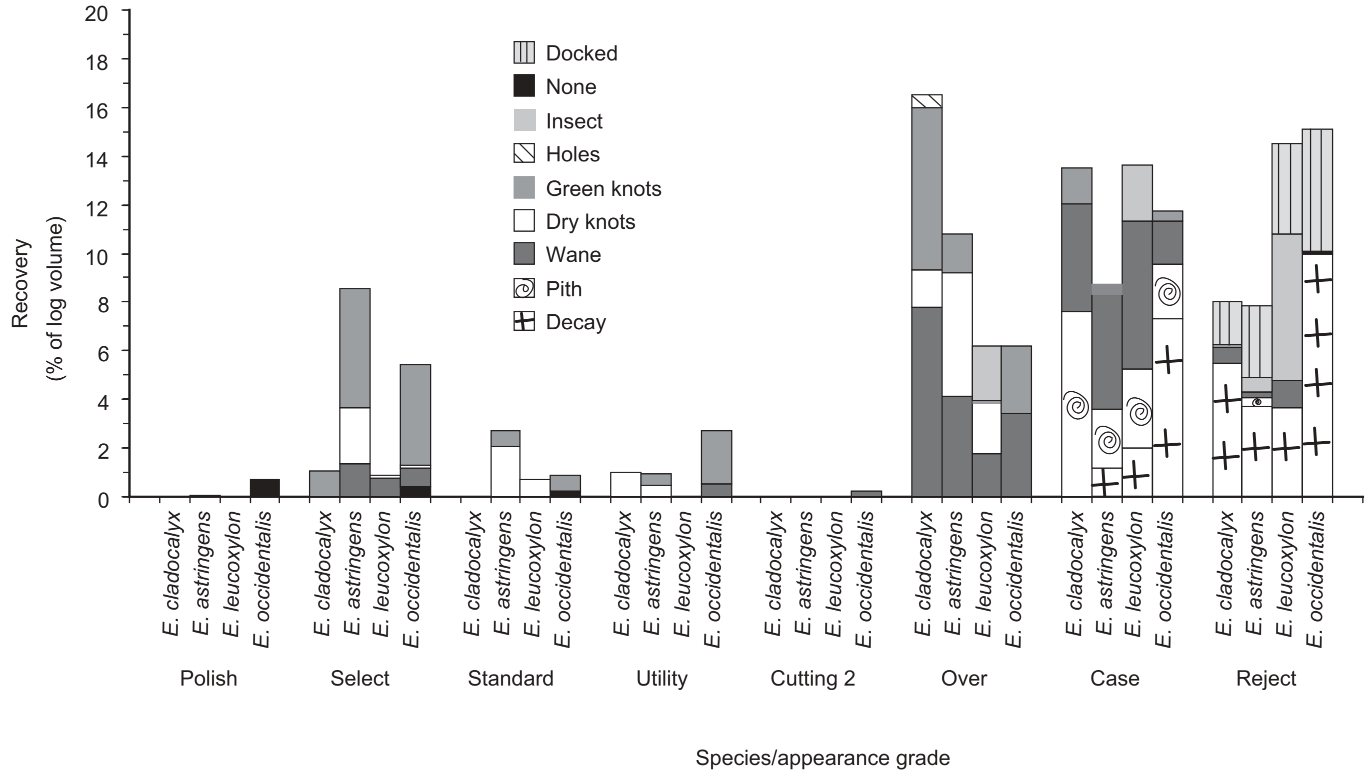

Figure 3. Grade-limiting defects and consequent recovery of appearance grades for each species

Intuitively, small-end diameter (SED) has an effect on recovery of appearance grades, as anything that increases the corewood zone (pith, juvenile wood and inner knotty zone) will significantly reduce the proportion of outer clear mature wood that can be sawn into high-grade products. Figure 4 shows, by position in the central cant (Fig. 1), the proportion (fraction of volume) of boards that met the target grade criteria (cover grade or better). As expected, the fraction of boards that meet the target grade criteria clearly increases with the distance of the origin of the board from the pith. The yields in positions 1 and 2 are notably low for *E. leucoxylon* and *E. occidentalis*. *Eucalyptus leucoxylon* had the poorest form; wandering or irregular pith is likely to be the main problem with this species.

Efforts to minimise the amount of irregular pith, and knotty and decaying corewood, through genetic improvement, silviculture and mechanical pruning will be important for these two species in particular if recoveries are to be improved.

Work on improving characteristics such as stem form and branching is already being undertaken by the Australian Low Rainfall Tree Improvement Group (ALRTIG). Early provenance testing with *E. occidentalis* suggests that significant improvements in form and height to crown break should be readily achieved through selection of appropriate seed (Chris Harwood, CSIRO Forestry and Forest Products, *pers. comm.*).

Drying rate and degrade

Figure 5 shows the mean MC of the sample boards for each species during drying. While *E. cladocalyx* started out with the highest mean MC, it also dried most rapidly. The opposite situation occurred with *E. astringens*, which started with the lowest mean MC but dried most slowly. The drying rates shown in this figure are likely to reflect both the inherent drying properties of each species and the position of the species in the two composite stacks. Boards of *E. cladocalyx* were at the top of its stack while *E. astringens* boards were at the bottom of its stack, closer to the colder moister air that settles at ground level.

While wrapped in plastic and hessian, only minor surface checking occurred, toward the ends of the boards. After the hessian was removed, some small fine checks became evident, especially in *E. occidentalis*. New checks continued to be initiated and existing checks lengthened over the following three months. Checks mostly occurred on boards that were on the edge of the stacks or on boards that came from positions close to the pith.

Cross cuts made through the sample boards at the conclusion of drying revealed only two or three boards with any internal checks. In these cases, the checks were restricted either to material from close to the pith or within localised areas with unusual patterns (wide or non-concentric) of growth rings. Distortion was a minor problem, being mostly isolated occurrences of spring.

Despite the conservative drying conditions, some fine surface checking remained on some boards of all species after they were machined to 90 mm x 35 mm. Table 4 shows how surface checking would have limited the grades of the boards in the absence of all other defects. About 75% of boards had no surface checking, while most boards with surface checks would still meet the criteria for select to utility grade. Overall, surface checking was the grade-limiting defect for about 12% of the boards. Boards of *E. cladocalyx* had the worst instances of surface checking, but

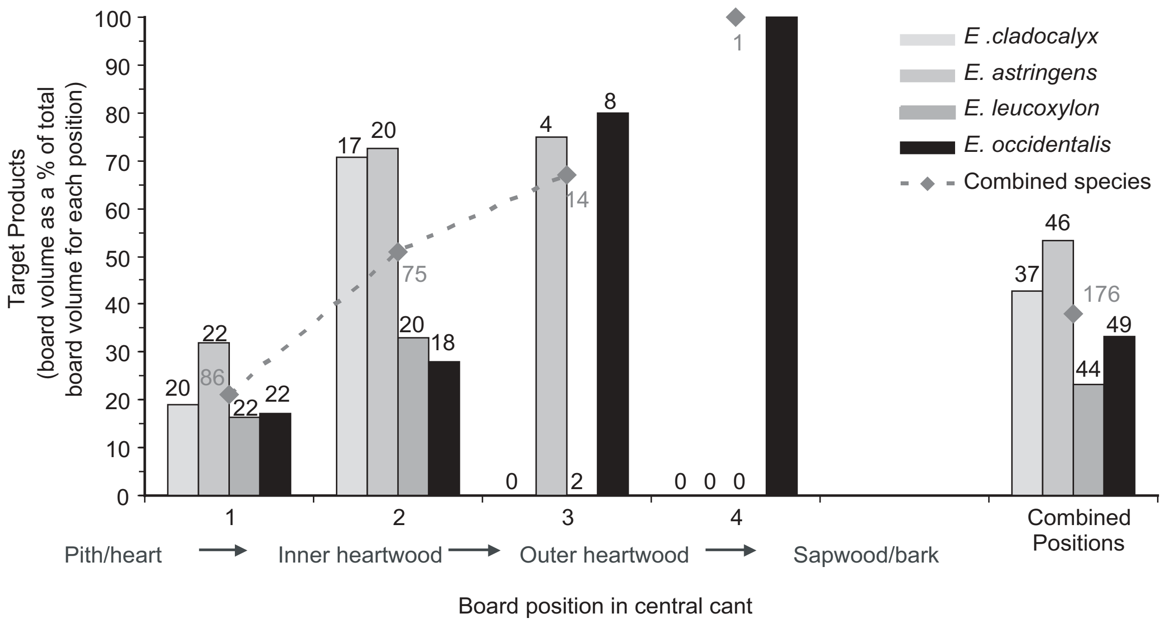

Figure 4. Volume of target products (cover grade and better) expressed as a percentage of the volume of all boards for each board position from the north-south cant only. Numbers above columns indicate the total number of boards recovered from each position. Numbers on the y-axis indicate the position of boards on the log cross-section (Fig. 1).

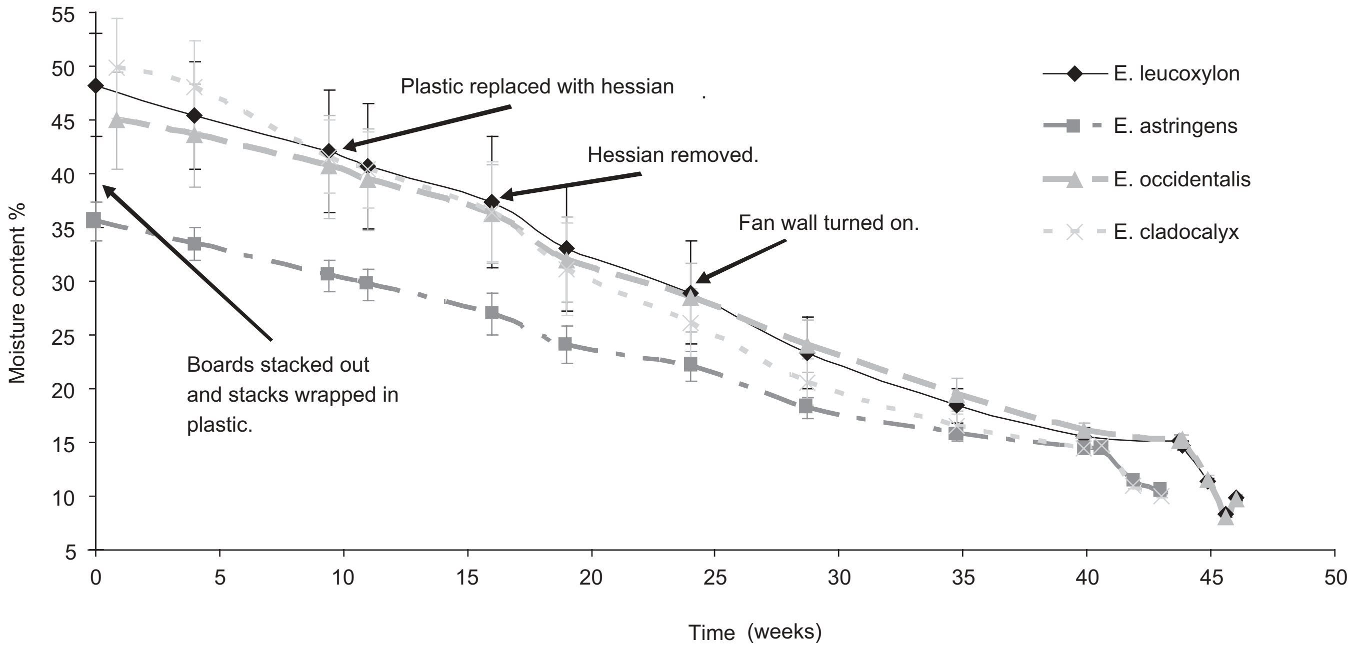

Figure 5. Mean moisture content of the sample boards for each species over time during drying; error bars show 95% confidence intervals for the mean sample board

Table 4. The appearance grades (% of boards) the boards would have achieved if all defects other than surface checks had been ignored. The final two columns show the number of boards where surface checking was the grade-limiting defect. Sample boards are included in this table.

Species	Appearance grade (%)					Count	Grade-limiting defect	
	Polish	Select	Standard	Utility	Cover		Number	Fraction (%)
E. cladocalyx	67	6	0	28	0	54	2	4
E. astringens	70	18	0	12	0	74	14	19
E. leucoxylon	93	5	2	0	0	59	3	5
E. occidentalis	69	12	1	13	4	98	14	14
Combined (%)	74	11	1	13	1	100	33	12
Combined (count)	211	31	2	37	4	285		

these were rarely the grade-limiting defect — probably because of the high percentage of these boards with pith and green knots (Fig. 3) due to the small diameter of the logs. Boards of *E. leucoxylon* had the lowest incidence of surface checking, with 93% of them being check free.

Conclusions

The recovery of appearance products from the four species sampled was poor compared with the recovery from other species in a similar study by Washusen *et al*. (2000). The main inherent defects contributing to the poor recovery were decay, green knots, dead knots, wane and pith. The impact of these defects was significant, confining a high proportion of sawn boards to the low-value grades of cover and case, as well as causing a similarly high proportion of boards to be rejected. These defects were a result of the poor form and small diameter of the logs sawn (with the exception of larger-diameter *E. occidentalis* logs).

Despite the conservative air drying, surface checking still occurred in all species, although internal checking and distortion problems were negligible. In most cases the surface checks appeared to be fine, long and deep. Some of the surface checks were removed in the machining process, but in the absence of all other defects about 15% of the boards would have been limited to select grade or lower by checking. Pre-drying could possibly bring the drying time for 43 mm back-sawn boards to 60–120 days with acceptable levels of surface checking. This observation is partly based on the previous experience of drying from green a number of medium- to high-density species (including *E. cladocalyx*) evaluated by Washusen *et al*. (1998). Drying problems and times should also be significantly less when drying thinner products.

Despite the poor result in this study, *E. cladocalyx* shows good potential in the lower-rainfall zone as it appears to have comparatively better growth rates (Anderson 2000; Stewart *et al*. 2000) than other species considered for the low-rainfall region, and recoveries from older, larger trees were promising (Washusen *et al*. 2000). The potential of *E. occidentalis* and *E. astringens* also appears to be good, provided that stem form and branching characteristics can be significantly improved. *Eucalyptus leucoxylon* appears to have little potential for high-value solid wood products unless its form can be significantly improved, and it might be considered only on sites unsuitable for the other species. In its favour, *E. leucoxylon* did have the least surface checking during drying.

At best, given the expected long rotations, the economics of growing high-value sawlogs in the low-rainfall region are likely to be marginal, and overall merit of planting candidate species will depend on other land management benefits. A detailed evaluation of the economics of growing these species in the low-rainfall region has not been attempted here. Nevertheless, it is felt that a viable sawing industry based on such a resource would need to achieve green recoveries of target products (cover grade or better) of at least 35–40% of log volume, and recovery of appearance products (select grade or better) of at least 30–35% of log volume. To achieve these figures, trees will probably need to be at least 40 cm DBHOB to maximise the volume of clear outer heartwood. Recent work (Washusen, unpublished) suggests that it may be possible to recover 35% of log volume as polish and moulding grades from large-diameter (≥40 cm) pruned trees, providing that drying degrade can be minimised. An ability to cut out defects and produce shorter boards would also help to achieve these levels of recovery.

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