Recovery of dried appearance grade timber from *Eucalyptus globulus* Labill. grown in plantations in medium rainfall areas of the southern Murray-Darling Basin.

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Summary

The potential of 40 mm-thick, back-sawn boards of 15-year-old *Eucalyptus globulus* Labill. subsp. *globulus* to produce dried appearance products was assessed. Two samples of boards from plantation grown logs described in Washusen et al. (2000) representing (i) the cross-section through each log (Sample 1), and (ii) outer heartwood boards (Sample 2) were dried to 12% moisture content. Sample 1 was dried using sheltered air-drying followed by kiln-drying. Sample 2 was kiln-dried from green without preliminary air-drying. Dried recovery results were poor in both samples and extensive degrade substantially reduced the recovery of undried boards graded select and better that were reported by Washusen et al. (2000). The dried recovery of select grade and better represented reductions of 69% and 60% for Sample 1 and 2 respectively, and based on Sample 1 the final recovery was estimated to be less than 2% of the original log volume. Tension wood was identified as one of the causes of drying degrade in boards from the outer heartwood. The results suggest that the species has little prospect for the production of high-quality solid wood products from unpruned logs from plantations in the southern Murray-Darling Basin unless there can be significant improvement in drying performance.

Introduction

The potential for undried product recovery from unthinned and unpruned, 15-year-old plantation grown *E. globulus* subsp. *globulus* from a medium rainfall area (680 mm mean annual rainfall) of the southern Murray-Darling Basin was reported by Washusen (1998) and Washusen et al. (2000). The recoveries show that defects primarily relating to the branching characteristics of the species prevent good recoveries of high quality appearance products. However, it was also suggested that mechanical pruning may improve recovery. This is in line with the conclusions of Waugh and Yang (1993) for Tasmanian plantation grown trees and findings of Moore et al. (1996) from 13-year-old wide-spaced *E. globulus* from Busselton in Western Australia.

Despite this optimism, drying-degrade is still a considerable problem for the species and varied results have been reported in the literature. Recent studies by Northway (1996), Northway and Blakemore (1996) and Bekele (1995) have reported considerable drying degrade, and problems have been suggested in other studies including those of veneer from butt logs (Moore et al. 1996), and veneer drying trials (Shedley 1997) based on Western Australian grown trees.

This study assessed the effects of drying on the undried recovery reported by Washusen et al. (2000) for this plantation. Specifically the aim was to:

- Assess the effect on product quality of two drying treatments (i) a combination of sheltered air-drying followed by kiln drying and (ii) kiln-drying alone.
- Determine the effect of drying by sheltered air-drying followed by kiln-drying on the undried recoveries, and estimate final recovery.
- Assess the extent of surface checking, internal checking, discoloration, distortion, splitting and undersizing on timber dried by both schedules.

Methods

The plantation, log selection and undried recovery

The logs in this study were taken from the lower 7.5 m of 10, 15-year-old trees grown on deep alluvial soils at 680 mm mean annual rainfall near Oxley in North East Victoria, in the southern Murray-Darling Basin. The selected trees were from an unmanaged plantation with a stand density of 920 trees/ha and a mean tree height 29.0 m, and where there had been no thinning or pruning conducted. After falling, a disc was removed from each tree at breast height (1.3 metres above ground) and the remaining log was cut into two to produce a total of 20, 3-metre long logs. The mean log diameter was 27.8 cm. The logs were sawn by a conventional back-sawing strategy suited to small diameter logs. Examples of the sawing methods employed are shown in Figure 1. Immediately following sawing each board was given a number that identified the log and tree it came from. All boards were graded green and recovery of undried products determined as described in Washusen et al. (2000). Drying was conducted on two samples of boards.

The board samples

The first sample (Sample 1) comprised 40 x 100 mm nominal section boards which made up the complete cross-section (shown in Figure 1) from sapwood to sapwood through the pith. During grading of the undried (green) products each board was identified with the numbered sequence shown in Figure 1 depending on their location relative to the pith and the cardinal direction in the standing tree. The lettering identified boards from the pith (C) or from the north (N) or south (S) side of the tree. This numbering sequence identi-
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Figure 1. Sawing methods used for a 35 cm small end diameter log and 25 cm small end diameter log with the lettering system used to record the location of boards in the log and select boards for Sample 1. The shaded area represents the location where Sample 2 was selected.

Fied boards from the inner and outer heartwood and, together with the numbers that identified the tree and log boards, could be matched to make comparisons between inner and outer heartwood.

The second sample (Sample 2) was selected from the remaining 40 x 100 mm back sawn boards from each log (see shaded area in Figure 1). They were all outer heartwood boards located at greater than 50 mm from the pith because of the way Sample 1 was selected.

**Drying methods**

Currently there is no established kiln-drying schedule for back-sawn products from immature eucalypts (Rozsa and Mills 1991). Consequently both Sample 1 and 2 were dried to 12% moisture content using less severe drying conditions than those suggested by Rozsa and Mills for mature trees. The conditions were carefully controlled during drying to minimise degrade. Sample 1 was subject to a slow period of sheltered air-drying prior to final kiln-drying and Sample 2 was dried directly using conventional methods in a kiln at CSIRO, Clayton, Victoria. In both cases schedules were adjusted to minimise drying degrade when excessive defect was evident, either by reducing temperature, delaying setting higher temperatures or reducing the air-flow. With Sample 1, inner and outer heartwood boards were placed at random across the block-stacks. Dry-bulb temperature, wet-bulb temperature and air speed were recorded for each kiln-drying run.

**Sheltered air-drying and kiln drying of Sample 1 boards**

After sawing and grading of undried boards, Sample 1 was immediately block-stacked and wrapped in plastic. Prior to commencement of drying, basic density and moisture content were determined for a selection of inner and outer heartwood boards. The inner heartwood boards were selected from the S and N series of boards (Figure 1) as S1 and N1, and the outer heartwood as the highest number in the series (e.g. either S2 or S3). From these boards two 20 mm wide specimens were taken 30 cm from each end of the board. These specimens were trimmed and volume determined by the immersion method. The specimens were oven-dried at 103 ± 2°C until constant mass and the undried moisture content calculated. These boards were weighed periodically during drying to monitor the drying rates.

Following moisture content and basic density determination, all boards were placed back together and racked out for

| Days | Dry /Wet bulb °C | Air Speed (m/sec) | Comments | Mean MC % of sample boards |
|------|------------------|-------------------|----------|---------------------------|
| 0    | NA               | NA                | Sheltered air-drying under plastic | 91.6 |
| 17   | NA               | NA                | 89.8     |
| 33   | NA               | NA                | 83.1     |
| 45   | NA               | NA                | 72.2     |
| 67   | NA               | NA                | 61.3     |
| 76   | 45/43            | 1-1.5             | Exposed air-drying commenced / plastic removed | 35.5 |
| 112  | NA               | NA                | 44.5     |
| 161  | 45/43            | 1-1.5             | Kiln drying commenced | 26.5 |
| 163  | 45/42            | 1-1.5             | 26.0     |
| 164  | 50/45            | 1-1.5             | 23.3     |
| 166  | 55/50            | 1-1.5             | 21.1     |
| 168  | 60/53            | 1-1.5             |          |
| 170  | 60/52            | 1-1.5             |          |
| 174  | 60/52            | 1-1.5             | Distortion common | 16.0 |
| 175  | 70/60            | 1-1.5             | Steamed (5 Hours) | 10.8 |
| 177  | 70/64 and 70/62  | 1-1.5             | Drying recommenced |
| 179  | Run stopped      |                    |
| 188  | Boards weighed out |                   |

1 Moisture content distribution determined for selected samples.
drying under plastic in an enclosed warehouse. The sample boards were 2.4 m long after removal of samples. All remaining boards were docked to 2.8 m from the lower end to fit the available kiln. Boards with known density and moisture content were placed in the centre of the stack to monitor the moisture content of boards during air-drying and later kiln-drying and these were weighed regularly to monitor drying rates. The drying schedule used is summarised in Table 1 with observations and measurements recorded during drying.

**Kiln-drying schedule for Sample 2 boards**

Sample 2 was block-stacked and wrapped in plastic following sawing and grading and immediately transported to the kiln for drying. Before stacking in the kiln, moisture content was determined for randomly selected boards by the methods described for Sample 1. At the centre of each stack a row of boards was used to monitor drying rates using these moisture content values. The drying schedule is summarised in Table 2. With both drying samples, once boards reached a moisture content of less than 12%, there was a period of conditioning (3 days) and moisture content samples were taken to ensure that moisture distribution was even at completion of drying.

**Grading dried products and recovery calculations**

Following drying and prior to grading the board identification was copied from the face of boards to the edge, and the wide faces of each board were dressed to the product thickness of 36 mm to remove shallow surface checking and assist the identification of undersizing and distortion.

All boards were graded on all defects and the grade for each defect recorded on grading sheets using the appearance grading criteria applied to the undried boards (Washusen 1998, Washusen et al. 2000). However, defects that were not attributed to drying, such as knots, kino and decay, were given the same grade that was recorded for the undried boards. This was done because with removal of wood during dressing, defects often changed appearance from the undried condition. Also the docking to remove specimens and shorten boards for the kiln may have removed some defects. These changes to the samples were of little consequence because the main objective of this study was to determine the effect of drying and the drying characteristics of the products from different locations relative to the pith, and with different drying schedules. By adopting this method the original board lengths and green defects could be used to give final recovery figures.

**Table 2. The schedule for drying *E. globulus* subsp. *globulus* Sample 2; and moisture content of the boards.**

| Days | Dry/Wet bulb °C | Air Speed (m/sec) | Comments | Mean MC % |
|------|----------------|------------------|----------|-----------|
| 0    | 30/28          | First fan 0.6    | Run started (no fan reversal) | 85.1      |
| 3    | 30/28          | As above         | Some surface checking         | 83.9      |
| 4    | 35/33          | As above         | Collapse evident              | 80.4      |
| 5    | 30/28          | As above         | Surface checks common         | 72.4      |
| 7    | 35/33          | Second fan 0.6   | Surface checks common         | 66.7      |
| 11   | 35/33          | As above         |                                      | 65.0      |
| 14   | 35/33          | First fan 0.6    |                                      | 61.3      |
| 17   | 40/38          | Both fans <1     | Surface checks starting to close | 56.3      |
| 19   | 40/37          | As above         | Checks continue to close       | 47.7      |
| 21   | 40/37          | As above         | Checks continue to close       | 46.6      |
| 24   | 45/42          | As above         | Checks continue to close       | 43.2      |
| 25   | 45/42          | As above         |                                      | 39.9      |
| 26   | 45/42          | As above         |                                      | 36.0      |
| 28   | 50/45          | As above         |                                      | 33.0      |
| 31   | 50/45          | As above         |                                      | 29.6      |
| 33   | 55/50          | 1.0              |                                      | 25.4      |
| 35   | 55/50          | As above         |                                      | 21.8      |
| 38   | 60/52          | 1.5              |                                      | 16.5      |
| 40   | 60/50          | As above         |                                      | 14.2      |
| 42   | 60/50          | As above         |                                      | 12.8      |
| 45   | 70/60          | As above         |                                      | 10.4      |
| 47   | 70/60          | As above         |                                      | 9.4       |
| 49   | 70/65          | As above         |                                      |           |
| 2    |                |                  | Kiln stopped                     |           |
| 3    |                |                  |                                    |           |
| 4    |                |                  |                                    |           |
| 55   | 80/74          | Both fans 2.5    | Drying recommenced               |           |
| 58   | 80/75          | As above         | Final conditioning               |           |
| 59   | 80/76          | As above         |                                      |           |
| 60   | Run finished   |                  |                                      |           |

*Table 2. The schedule for drying *E. globulus* subsp. *globulus* Sample 2; and moisture content of the boards.*
The additional defects that were associated with drying were surface checks and splitting, internal checks on the ends of boards, discoloration, distortion and end-splitting. No product docking was employed and any board with end-splitting was rejected.

The volume of graded recovery was determined for each drying sample before and after drying within the constraints outlined above. Recovery was calculated for select grade and better and target products as a percentage of grade recovery, and for final dried recovery as select grade and better as a percentage of log volume. Target products are defined in Washusen et al. (2000). They are products of cover grade or better and with cross sectional dimensions and product lengths that are preferred by industry.

Assessment of drying defects

Degrade from drying was assessed and compared between samples. The assessment involved determining firstly, the severity of surface checks and splits; secondly the distortion and splitting, and thirdly the internal checks. The two drying samples were not directly comparable because of the inclusion of inner heartwood boards in Sample 1. However, comparisons can be made between outer heartwood boards from Sample 1 with boards from Sample 2, both being a similar distance from the pith.

The drying defects were quantified by calculating the proportions of boards affected by surface checks, distortion and splitting, and the results calculated as the number of boards in each grade expressed as a percentage of the total number in the sample.

Surface checks

The occurrence and severity of surface checking was further analysed and comparisons made between inner and outer heartwood and between drying samples. This was achieved by allotting each board to a category derived from the grade attributed to surface checks alone according to CSIRO criteria (Waugh and Rozsa 1991). The categories were: 1 polishing grade; 2 moulding grade; 3 select grade; 4 standard grade and 5 other grades. The degree of surface checking for each grade is given in Table 3. Central boards were excluded from analysis and boards were allotted to the inner and outer heartwood zone where matched sets of boards were available.

| Tolerance for checks | Category |
|----------------------|----------|
|                      | 1        | 2        | 3        | 4        | 5        |
| Width (mm)           | <1       | <1       | <1       | <1       | no limit |
| Depth (mm)           | <2       | <3       | <3       | <5       | no limit |
| Sum of check length mm/1.0m² | <250      | <300      | <1000    | <2000    | no limit |
| Number of checks     | <1/0.04m² | <1/0.02m² | no limit | no limit | no limit |

Internal checking

The extent and severity of internal checking was determined from specimens that were removed at selected intervals along the board. They were used as a means of quantifying differences in drying degrade between Sample 1 and Sample 2 and heartwood location. The boards used were selected from each tree where possible, and as a matched pair of inner and outer heartwood boards from one side of a log from Sample 1 and by random sampling for Sample 2. In the case of Sample 1 it was not possible to obtain matching inner and outer heartwood boards from 2 of the 10 trees because of diameter restrictions.

From the selected boards 100 mm sections were removed at 30 cm from the lower end of each board (the end closest to ground level in the standing tree). The sections were examined and the number of internal checks counted on the lower end of each section. Where internal checks were found with visual assessment, 2 mm sections were cut from the lower end, and the sample number and board identification number were transferred to the face of these sections. The 2 mm sections were measured using image processing where the number and area of internal checks were determined according to the method developed by Ilic (1999).

Results and Discussion

Graded recovery and assessment of defects

The change in product quality with drying is given in Table 4. This shows the percentage decline in quantity of select grade and better and target products between the undried recoveries reported by Washusen et al. (2000) and dried material for each sample. Degrade was severe for both methods of drying with a greater reduction in recovery of select grade and better in Sample 1 (69.2%) than Sample 2 (60.0%). The estimated final recovery for select grade or better using the result for Sample 1 was very low at 1.8% (% of log volume). Reductions were also evident with the recovery of target products (Sample 1; 19.5% and Sample 2; 47.7%).

The type of degrade varied between samples with more surface checking in Sample 1 and a greater amount of distortion and splitting in Sample 2 boards. Surface checking was severe enough to potentially prevent 46% of boards making select grade in Sample 1 and distortion and splitting was severe enough to reject 39% of boards in Sample 2. This high
Table 4. Decline in the recovery of select grade and better and target products expressed as percentage of recovery before drying following application of the two drying schedules, and final recovery of select grade and better as a percentage of log volume.

| Drying Sample | Decline in recovery of Select grade and better (% of grade recovery) | Decline in recovery of Target products (% of grade recovery) | Estimated final recovery of select grade and better (% of log volume) |
|---------------|---------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------------|
| Sample 1      | 69.2                                                                | 19.5                                                        | 1.8                                                              |
| Sample 2      | 60.0                                                                | 47.7                                                        |                                                                  |

incidence of distortion and splitting was the major reason for the large reductions of target products for Sample 2 boards discussed above and shown in Table 4.

While these results indicate that extensive defects developed during drying, many boards were found to have sections where drying was relatively good. These sections were shorter than the minimum length restrictions imposed by the CSIRO criteria and had secondary processing been employed the recoveries would be higher.

Surface checking

The surface check categories for inner and outer heartwood boards of Sample 1, and for the two drying methods are compared in Figure 2. In Sample 1 there was a tendency for a worsening of surface checking in the outer heartwood which is evident by the smaller percentage of boards from the outer heartwood in grade 1 and 3 and the higher percentage of boards in grade 4. This was unexpected as the inner heartwood boards were close to the pith where extensive drying degrade could be expected in juvenile wood. Figure 2 also shows that most of the boards from Sample 2 were in grade 1 indicating that there was less severe surface checking with Sample 2 boards than the outer heartwood boards of Sample 1. The difference in surface checking may have been the result of better control of conditions in the kiln during the early stages of drying of Sample 2 and harsher ambient conditions during air-drying of Sample 1. This result suggests that surface checking might be contained with good control of the drying conditions.

Internal checking

The assessment of internal checking is given in Table 5. This shows the percentage of samples where internal checks were observed, and the number and area of checks from the image processing. The results show that internal checking was a greater problem in the outer heartwood than the inner heartwood in Sample 1 boards, and this was an even greater problem in the outer heartwood in Sample 2 boards where 58% of sample sections had checks.

General drying results and tension wood

The result show that both methods of drying resulted in a substantial degrade of the timber despite the slow drying schedules used. The reason for this was not fully investigated. However, tension wood bands were identified in several samples from the outer heartwood. The location of the tension wood is shown in Figure 3. This shows a 50 mm wide radial strip taken from a disc at the lower end of one of the logs (breast height at 1.3 m above ground). It was dried to 12% moisture content and reconditioned in steam at 100°C for 30 minutes. The severe transverse shrinkage near the sapwood is in a zone of tension wood. This occurrence of tension wood accounts for some of the drying degrade and may explain the poor results in the outer heartwood of Sample 1 boards and the increased internal checking in Sample 2 boards. Tension wood appears to be a common problem in young plantation-grown *E. globulus*. Recently

Table 5. Number and area of internal checks from sample sections.

| Drying Sample               | No. of samples sections | % of samples with checks | Mean No. of checks per sample | Mean area of checks (mm²) |
|-----------------------------|-------------------------|-------------------------|------------------------------|--------------------------|
| Sample 1 Inner heartwood    | 20                      | 20%                     | 0.7                          | 3.4                      |
| Sample 1 Outer heartwood    | 20                      | 45%                     | 1.9                          | 6.8                      |
| Sample 2                    | 40                      | 58%                     | 3.5                          | 19.6                     |
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Figure 3. Radial strip taken from a breast height disc showing excessive shrinkage in the outer heartwood and sapwood.

tension wood was found to be common in 10-year-old trees grown in the Mt. Gambier region of South Australia by Washusen and Ilic (2000). In this study tension wood was located in the outer heartwood and sapwood with a distribution similar to that shown in Figure 3. Tension wood has also been suspected to cause drying degrade in studies by Northway and Blakemore (1996), Northway (1996) and Bekele (1995). These observations suggest that future research should investigate either the role that tension wood plays in the degrade of timber during drying or how to reduce its occurrence in standing trees.

Conclusions

The drying degrade in the form of either surface checking, internal checking or distortion and splitting or combination of these defects was severe and led to serious degrade under both drying regimes. The result was to further reduce the already low recoveries of undried timber reported by Washusen (1998) and Washusen et al. (2000). The results are similar however, to other studies of 40 mm thick back-sawn boards conducted by CSIRO from trees grown in plantations in Tasmania, Gippsland and irrigated areas of northern Victoria (Waugh and Yang 1993, Northway 1996, Northway and Blakemore 1996). The similar difficulties in drying 40 mm thick boards from the southern Murray-Darling Basin indicates a need to either further investigate drying, particularly the role that tension wood may play in the drying characteristics of the species, or investigate drying of thinner sectioned material.

The time taken to kiln-dry boards from undried material was also unacceptably long (61 days) and a period of sheltered air-drying may be necessary to reduce drying costs. Even so, the time taken for air-drying in this study would be costly to industry.

One of the notable aspects of this study was the variability in wood quality and drying degrade within logs. Short sections of many boards dried successfully, particularly when air-dried followed by kiln-drying. The cause of this variability needs to be determined. The rapid growth rates of the species, its suitability for pulp production and higher basic density than radiata pine are attributes of the species which warrant further investigation of its potential for use as solid wood.

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