



High value, solid wood products

from low rainfall (450-650mm/yr)
farm forestry

**A report for the RIRDC/Land & Water
Australia/FWPRDC
Joint Venture Agroforestry Program**

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Foreword

There are numerous reasons for farmers and regional communities to support plantation establishment. The primary reason, especially in regions of lower rainfall, is to improve agricultural systems and their sustainability by ameliorating serious broad-scale environmental degradation, such as dryland salinity. Secondary considerations include enhancing local and regional aesthetics, enhancing biodiversity and providing wind-breaks and stock shelter. In some cases, wood production may be a low priority, but for most a commercial return is essential to justify the investment in time and money establishing and managing plantations. The focus on ‘high-value’ solid-wood products in this project is to compensate for the anticipated slow growth rates and high establishment, management, harvesting, transport and processing costs for sawlog production in this zone.

In the study zone, uncertainty about the viability of wood production is a major limitation to plantation establishment. The 400-600 mm/yr rainfall zone is well below what has been considered acceptable for industrial forestry, which is normally restricted to the >750 mm/yr rainfall zone. This project investigates the opportunities for producing high-value wood products from plantations in the 400-600 mm/yr rainfall zone of the southern Murray-Darling Basin by sampling existing plantations of four species with potential suitable for growing in the region.

This project was funded by the Natural Heritage Trust, through the FWPRDC and the Joint Venture Agroforestry Program (JVAP). The JVAP is supported by Rural Industries, Land & Water Australia, Forest and Wood Products and the Murray Darling Basin Commission.

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Simon Hearn

Managing Director

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1 Executive Summary

1.1 Objectives

This study is intended to assist farm forestry growers select species for high-quality solid-wood production in lower rainfall areas. The objectives were to identify the potential of a minimum of four species of plantation grown trees to produce high value solid-wood products. The species evaluated were from existing plantations in the 400-600 mm rainfall zone of the southern Murray-Darling Basin.

1.2 Key Results

- The limited range of species and number of plantations with enough trees of sufficient size for sawlog assessment restricted the choice of species. The species selected for the sawing study were *Eucalyptus occidentalis*, *E. cladocalyx*, *E. astringens* and *E. leucoxylon*.
- In all the plantations inspected, low crown breaks limited the length of the logs that could be harvested from the trees. A 3m butt log from 10 trees of each species was back-sawn mostly into 105 x 43 mm dimension boards using a similar strategy to previous studies by Washusen *et al* (1996).
- The recovery of green appearance grade products (measured either as Appearance recovery – select grade and better, or Target recovery – Cover Grade and better) from the sampled trees was extremely poor and highlights the difficulties of growing high-value sawlogs in this region.

<i>Species</i>		Appearance Recovery	Target Recovery	Sawn Recovery
% of log volume				
<i>E. occidentalis</i> (Swamp Yate)	– 42 y.o.	5.2	14.0	43.0
<i>E. cladocalyx</i> (Sugar Gum)	– 29 y.o.	1.0	18.1	40.0
<i>E. astringens</i> (Brown Mallet)	– 41 y.o.	8.1	22.9	39.9
<i>E. leucoxylon</i> (Yellow Gum)	– 44 y.o.	0.9	7.4	35.9

- The major defects, in varying degrees for each species, contributing to the poor recoveries were:
 - decay
 - knots (both green and dead)
 - pith,
 - wane
- The poor recoveries were at least partially attributable to the small diameter logs sampled in this study. This is best shown by comparing the low recovery of Appearance products for *E. cladocalyx* (1.0%), with that achieved from older and larger trees of the same species (20.6%) in a previous study by Washusen *et al* (1996). A minimum DBH of 40cm will be required for sawlog production to maximise the volume of clear outer heartwood.
- Using a conservative air-drying schedule, in the absence of other defects, only 15% of the dried boards still had surface checks that would have been limited to below select grade. The other 85% would have made select grade or better.
- Because of the high densities of the species grown in the lower rainfall zone, careful drying practices will be required to minimise surface checking problems in back-sawn boards.
- Despite the poor recovery of appearance products in this study, the review of growth data and the good recovery in the previous study by Washusen *et al* (1996) suggests that *E. cladocalyx* has the best potential for producing high-value solid-wood products in the lower rainfall zones. *E. occidentalis* and *E. astringens* followed closely behind, providing poor form and branching characteristics can be improved in the later two species. *E. leucoxylon* has little potential unless significant form improvements could be made which has affected recoveries.

- These results highlight the critical importance of improved genetic stock and appropriate silviculture to achieve green recoveries of Appearance products (select grade and better) of at least 30-35% (of log volume) for a viable solid wood industry to be established.

1.3 Application of Results

These results highlight the importance of improved genetic stock and appropriate silviculture to produce high-value wood products. It is essential for the Australian Low Rainfall Tree Improvement Group (ALRTIG) to reduce poor branching and canopy crown habits through breeding, to minimise the proportion of knotty inner corewood. Silvicultural practices will need to allow for wide spacings to minimise competition and maximise diameter growth whilst undertaking pruning to reduce knot size.

The outcomes of this study are being discussed on an ongoing basis with CSIRO FFP members of ALRTIG as well as with many of the Agroforestry and private forestry networks. A joint field day with the University of Melbourne will be conducted in the second half of 2001 to disseminate and discuss the results of the two farm forestry projects.

1.4 Further work

This study is the first step in utilising low rainfall tree species for high-value solid wood products. Much more work is needed to characterise the wood properties and product potential of these species, and to develop pre-drying practices and schedules to reduce drying times, while keeping surface checking within reasonable limits. Species properties such as colour, hardness, stiffness and stability require investigation so that the market opportunities and acceptability of these properties, including acceptable variability, can be tested.

2 Introduction

This project investigates the opportunities for producing high-value wood products from plantations in the 400-600 mm/yr rainfall zone of the southern Murray-Darling Basin. A commercial return from plantations established on private land is necessary if extensive plantation establishment is to be realised, as envisaged in the 2020 vision (Plantation 2020 Vision Implementation Committee, 1997)¹ of trebling Australia's plantation estate (in 1996) by the year 2020. The more specific objective for low rainfall farm forestry is that "30% of farmers are engaged in farm forestry by 2020 with at least 10% of land area and 10% of farm revenues coming from farm forestry" (Department of Agriculture, Fisheries and Forestry Australia, 2000)²

In the study zone, uncertainty about the viability of wood production is a major limitation to plantation establishment. The 400-600 mm/yr rainfall zone is well below what has been considered acceptable for industrial forestry, which is normally restricted to the >750 mm/yr rainfall zone. There are however, numerous reasons for farmers and regional communities to support plantation establishment. The primary reason, especially in this lower rainfall zone, is to improve agricultural systems and their sustainability by ameliorating serious broad-scale environmental degradation, such as dryland salinity. Secondary considerations include enhancing local and regional aesthetics, enhancing biodiversity and providing wind-breaks and stock shelter. In some cases, wood production may be a low priority, but for most a commercial return is essential to justify the investment in time and money establishing and managing plantations. The focus on 'high-value' solid-wood products is to compensate for the anticipated slow growth rates and high establishment, management, harvesting, transport and processing costs for sawlog production in this zone.

Research in this zone on species selection, site matching, genetics and breeding, and silvicultural management is currently focused through the Australian Low Rainfall Tree Improvement Group (ALRTIG)³. This study is complementary to that research in trying to identify the species with most potential for high value solid-wood products. This work is also an extension of a similar study in the 600-700 mm rainfall zone of South Eastern Australia (Washusen *et al*, 1996).

3 Objectives

3.1 Project objectives

The objectives of this project were to identify the potential, of a minimum of four species, of plantation grown trees to produce high value solid-wood products. The species evaluated were from existing plantations in the 400-600 mm rainfall zone of the southern Murray-Darling Basin. This is intended to assist species selection, for wood production, for farm forestry in this region.

The research was conducted in collaboration with the University of Melbourne, which conducted an independent but related project looking at on-farm sawing systems.

¹ Web page: <http://www.affa.gov.au/docs/forestry/plantations/2020.html>

² Web Page: http://www.affa.gov.au/docs/forestry/farm_forestry/rainfall/index.html

³ Web Page: www.ffp.csiro.au/alrtig/

4 Methodology

4.1 Outline of work undertaken

The area investigated covers the drier inland areas of the Great Dividing Range. Extending from the South Australian border it includes the Horsham, St Arnaud, Bendigo and Shepparton regions of Victoria and continues north up to the Wagga Wagga region of New South Wales. Close collaboration with local farm forestry groups, regional plantation committees (RPC's), State Government agencies and industry was instrumental in locating representative plantings during the early part of the project.

The approach followed was to:

- Determine land areas suitable for different commercial tree species, based on existing data regarding rainfall and temperature using software developed by CSIRO Forestry and Forest Products.
- Carry out field inspections of existing plantations to establish the most appropriate species for study of wood product potential. Examine tree growth, form and wood quality characteristics from core samples where appropriate (determine density profiles and incidence of defects).
- Harvest representative trees and remove sample logs from a minimum of four species to examine the potential for the production of sawn products, including green product recoveries and drying performance. Evaluate critical performance criteria for suitability for high-value appearance uses. Examine the effect of knots, kino and other defects on sawn product appearance. Additional trees were harvested for one of these species to meet the processing needs of an associated study being carried out by the University of Melbourne evaluating the effectiveness of on-farm small-scale sawing systems for handling this resource.
- Back-saw logs to maximize the recovery of nominal 40 mm thickness products for drying performance studies. A sawing strategy common to different sized logs was adopted.
- Carry out an evaluation of the effect of defects on product recovery. Make comparisons with other product recovery studies conducted by CSIRO Forestry and Forest Products, which used similar sawing and product evaluation methods.
- In collaboration with the University of Melbourne, evaluate the effectiveness of different sawing systems.
- Dry a minimum of four pieces from each sawlog. Monitor drying conditions, moisture contents and the progression (if any) of drying degrade as the wood is dried. Following machining, a final evaluation of drying degrade will be carried out.
- Prepare a final report and adopt a technology transfer strategy through presentations to potential tree growers and processors. A field day will be held in latter half of 2001 in conjunction with the University of Melbourne to present the results from this study and the study investigating the effectiveness of different sawing systems. It is also envisaged that a joint press release between CSIRO FFP and FWPRDC will be issued once the final report has been accepted. Results from this study have been partially presented at:
 - the Murray Riverina Farm Forestry R&D Committee Meeting (May 2001 at Wagga Wagga);
 - AFFA – Farm Forestry Program Seminar Series on Current and Future Farm Forestry initiatives (June 2001 in Canberra)

5 Results and discussion

5.1 Climate map

The 400-600 mm/yr (predominantly winter) rainfall zone is shaded lightly in Figure 1. The map was produced from a major revision of the 'Australian climatic mapping program' (Jovanovic and Booth, 2000, pers. comm.), details of the original program can be found in Booth (1996).

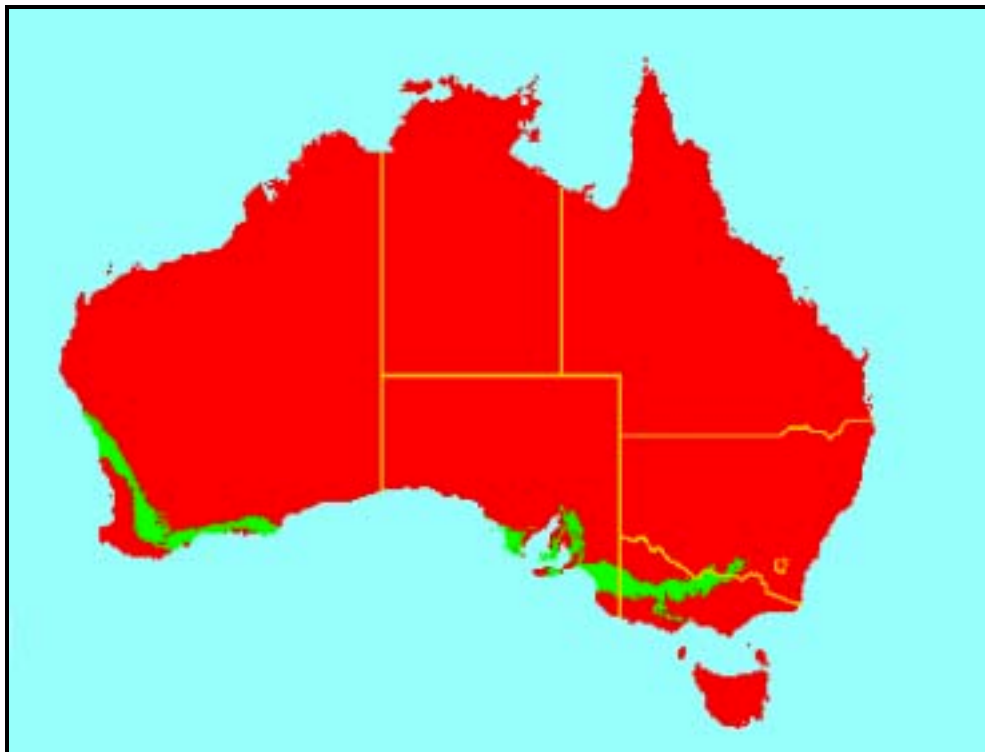


Figure 1: Map of the 400-600 mm/yr annual (pre-dominantly winter) rainfall climate zone (lighter colour)

5.2 Species selection

5.2.1 Plantation inspections

Numerous small community and roadside plantations are scattered throughout the project region. The vast majority are poorly managed with extremely poor tree form and diameters of <25 cm, which are generally too small to be of interest for sawn timber production. Figure 2 shows an example of one of the more substantial plantations of *Eucalyptus occidentalis* in the You Yang's Regional Reserve. It is a good example of the typical form and size of trees encountered with many of the species inspected.

As with the plantation in Figure 2, most plantations (including windbreaks, amenity and community plantations) were established to supply either fuel wood, poles (telephone and others) or posts and fencing material for the local community, industries and farms. The poor tree form and vigour result from a number of problems including:

- poor quality seed source,
- low productivity soils and sites,
- poor matching of species/provenances to sites and
- lack of on-going silviculture.

Site and environmental conditions varied dramatically across the project region and critically affected species performance. This was most pronounced in the performance of exotic pines at different trial sites. A number of species performed well on one site and struggled on another and vice versa for other species.



Figure 2: Stand of *Eucalyptus occidentalis* (plantation estimated at between 20 - 30 y-o) in the You Yang's Regional Reserve.

Consultation with relevant community and government agencies in the project area identified only limited examples of different species in plantations and even fewer with trees suitable for sampling. This was particularly true for native species.

Various species and provenance trials of both hardwood and softwood species exist, with most effort currently being focused in the Australian Low Rainfall Tree Improvement Group (ALRTIG)¹. A number of the more promising trials were either too young to harvest or harvesting and sampling could not be co-ordinated to fit in with the management objectives of the trial plantations.

Given all the limitations and considerations of the existing plantations, a detailed evaluation and comparison of species performance and suitability for the region, as attempted in the previous study (Washusen *et al*, 1996), was not undertaken. This was also partly because in the Wimmera region around Horsham, which had the plantations of greatest potential for sampling in this project, growth data was already being collected and reported separately (Stewart *et al*, 2000).

¹ Web Page: www.ffp.csiro.au/alrtig/

Plantation evaluations were focused on identifying individual trees that met the selection criteria. This was to ensure adequate numbers of suitable trees were available for sampling. Ten trees of each species were required for this project, but the associated Melbourne University study decided to additionally sample 6 trees of 3 of the species instead of a larger number of one species. To allow some degree of random selection, and to overcome inevitable harvesting difficulties with some trees (e.g. tree leaning in an unsafe direction), a minimum of 20-25 suitable trees was required for a species to be considered. The Diameter at Breast Height Over-Bark (DBHOB), height and point based basal area (as a crude measure of competition) of potential sample trees were measured.

The general form of most trees in the stands was categorised using the descriptions in Table 1 and shown diagrammatically in Figure 3. Table 2 summarises the plantations that were inspected and rates their form and growth. Where a number of form categories were common each is listed. The general vigour (growth rate, mortality rates) of trees in the different plantations was subjectively ranked between 0 and 5 (0 = Extremely poor and 5 = Excellent). The largest diameter and tallest tree height is provided to crudely indicate the growth rates that might be achievable for the species on the site. Table 2 also lists the number of suitable trees that met the selection criteria. Figure 4 shows diagrammatically the location of the plantations which were inspected. For interest sake, the map used is a Bureau of Meteorology 3 year total rainfall (1 October 1997 to 30 September 2000) map that provides an indication of rainfall distributions in the project zone, as well as the fact that much of south-eastern Australia is currently experiencing below average rainfall.

Table 1: Categories and description of tree form

<i>Type</i>	<i>Description</i>
1	Mallee form or multi-stemmed coppice
2	Stunted and/or distorted growth
3	2 or more stems with low heavy branching
4	Curved single stem with low heavy branching
5	Straight stem with low heavy branching
6	2 or more straight stems
7	Curved lower stem with low heavy crown branching
8	Straight lower stem with low heavy crown branching
9	Curved single stem with light branching
10	Straight single stem with light branching (ideal for saw log).

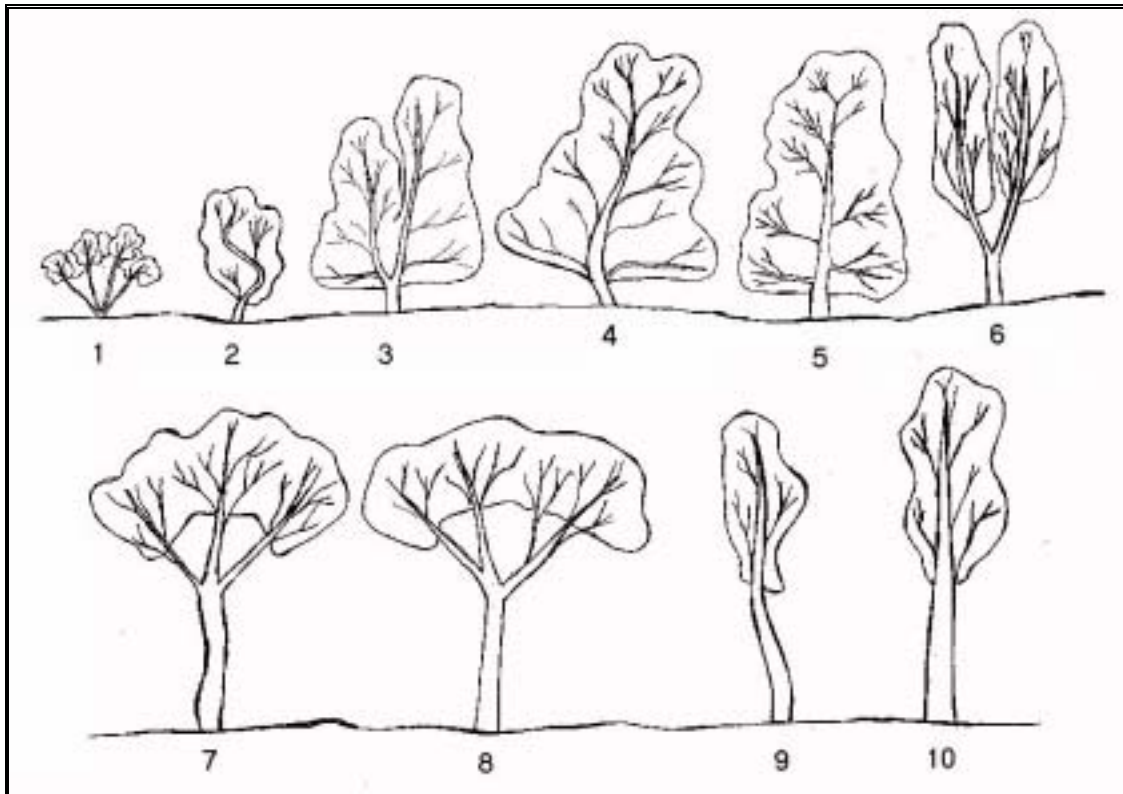


Figure 3: Diagrams of form categories

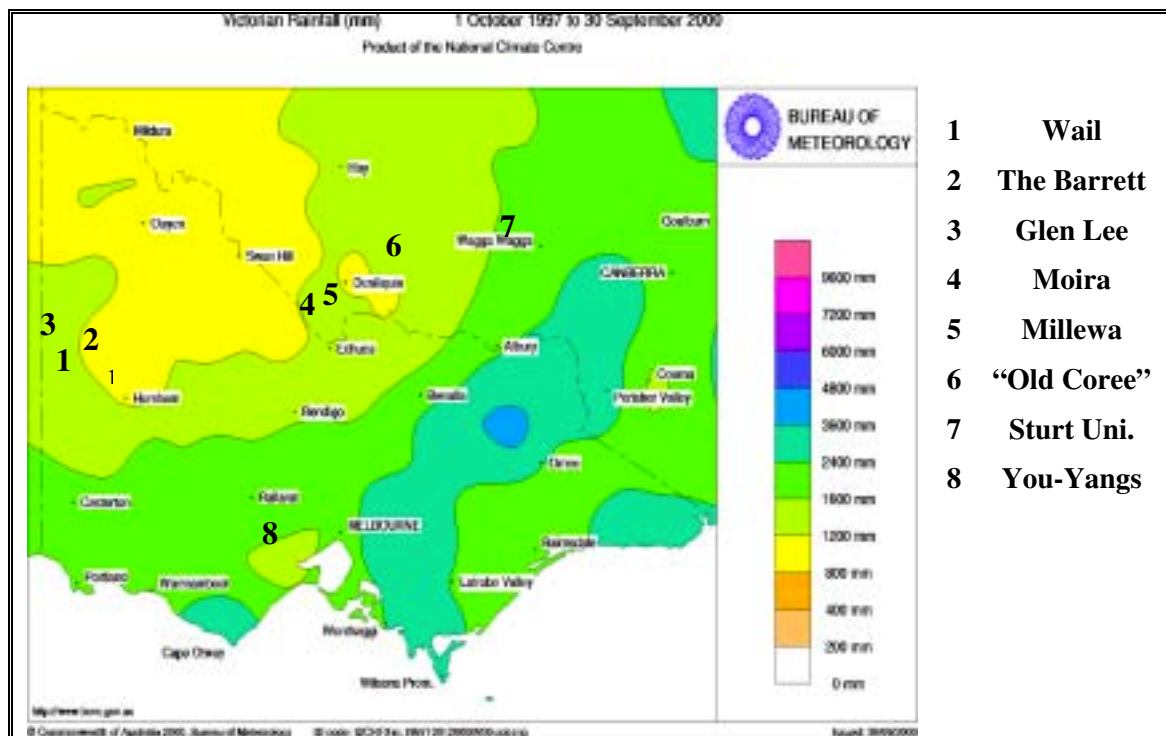


Figure 4: Location of inspected plantations shown on three year total (1 October 1997 to 30 September 2000) regional rainfall map (Bureau of Meteorology¹)

¹ <http://www.bom.gov.au>

Table 2: Summary of plantation inspections

Location	Species	Latitude	Longitude	Year Planted	Approximate Mean Annual Rainfall (mm/yr.)	Top height (m)	Largest Diameters (cm)	Vigour (x/5)	Form (x/10)	Numbers of trees which met criteria	Comments
Wail State Forest	<i>Eucalyptus cladocalyx</i>	360 31' S	1420 5' E	1971-73	425	22	40	4	9	13	Reasonable form and vigour.
	<i>Pinus brutia</i>	36° 31' S	142° 5' E	1945-50	425	16	44	3	5	4	Four remnant large and heavily branched trees from the original trial.
	<i>P. radiata</i>	36° 31' S	142° 5' E	1945-50	425	31	62	5	10	20 ¹	The <i>P. radiata</i> is vastly outgrowing and dominating the 2 rows of <i>P. brutia</i> within it, over 50% of which have died.
	<i>P. brutia</i>	36° 31' S	142° 5' E	1945-50	425	12	30	1	2,5	4	Small trial plot of up to 100 trees. Very variable height and diameter growth with a 20-30% mortality rate and only 4 trees meet DBH criteria. Most have straight stems but also have large spreading branches all the way to the base
	<i>E. leucoxylon</i>	36° 30' S	142° 4' E	1956-60	425	25	55	3	7	28	Branches occur very low and stem is often curved and elliptical at the base. Best growth on sites closer to river.
	<i>E. melliodora</i>	36° 30' S	142° 4' E	1956-60	425	20	38	1	6,9	2	One of the two trees is a large double leader at base. Mortality rate in the rows appears to be over 80%.
	<i>Callitris preissii</i>	36° 29' S	142° 3' E	1956-60	425	18	38	1	2,5	3	Mortality rate appeared to be over 50% and surviving stems were often stunted in growth. Best growth on sandier parts of site.
	<i>P. pinea/</i> <i>P. brutia/</i> <i>P. halepensis/</i> <i>Pinus spp?</i>	36° 30' S	142° 4' E	1959-60	425	14	38	1	2,5		Rows of different pines are distinct but species identification is difficult due to stunted growth and lack of cones on many trees. Growth is variable. Most stems look to be just surviving and growth is very poor. Local anecdotal evidence suggested stone pine was the major species planted.

¹ Many additional suitable stems existed, a selection of 20 of the biggest stems was considered adequate.

Location	Species	Latitude	Longitude	Year Planted	Approximate Mean Annual Rainfall (mm/yr.)	Top height (m)	Largest Diameters (cm)	Vigour (x/5)	Form (x/10)	Numbers of trees which met criteria	Comments
The Barrett Reserve	<i>E. occidentalis</i>	36° 25' S	142° 19' E	1958	425	24	66	4	8	31	31 trees were selected. Growth was good but branching usually occurred above about 4m. Most other species planted at this location are too young or too small to be of interest.
Glenlee State Forest	<i>E. astringens</i>	36° 16' S	141° 50' E	1959	400	21	46	3	3,7	42	Easily the best performing species on this site. There is one long block of trees and two other strips with two rows in each strip. Branching on most occurred at around 3m or lower (This was true with about half the 42 trees measured).
	<i>E. occidentalis</i>	36° 16' S	141° 50' E	1959	400			2	1,3		Almost all are multi-stemmed and bushy.
	<i>E. microcarpa</i> <i>various other eucalypts</i>	36° 16' S	141° 50' E	1959	400			1	1,3		Most of the unidentified trees appear to be either boxes or Western Australian gums and mallees. Most of the trees trialed have survived to various degrees (although some missing rows are apparent) but most form a multi branched canopy very low down on the bole and none were of adequately large DBH.
You Yangs	<i>E. occidentalis</i>	37° 57' S	144° 25' E	?	425			3	8	<10 ¹	Trees not available for harvesting. Largest stems are spread out along a drainage line. Various plantation and coppicing ages available but majority are small and multi-stemmed.
	<i>E. cladocalyx</i>	37° 57' S	144° 25' E	?	425			3	1,6,9		Various plantation and coppicing ages available but majority are small multi-stemmed coppice.
	<i>P. canariensis</i>	37° 57' S	144° 25' E	?	425			4	7	>50 ¹	Small stand of tall straight and lightly branched stems.
Millewa State Forest	<i>P. canariensis</i>	35° 49' S	144° 58' E	1929-31	400	30	48	4	10	-	Densely stocked plantation of tall straight trees with small branches. Surrounding red gum forest on clay soils suggests trees are utilizing flood water. This species has much better form and vigour than any other trialed on this site though.
	<i>P. halepensis</i> /	35° 49' S	144° 58' E	1929-32	400	18	20	3	3,4,9	-	Most were bent over with dense branching habits

¹ DBHOB, heights not measured as plantation age was unknown

Location	Species	Latitude	Longitude	Year Planted	Approximate Mean Annual Rainfall (mm/yr.)	Top height (m)	Largest Diameters (cm)	Vigour (x/5)	Form (x/10)	Numbers of trees which met criteria	Comments
	<i>P. pinanero/</i>	35° 49' S	144° 58' E	1931	400	18	40	4	4	-	In strip of trees 4 rows wide, most were large but correspondingly also had very large and extensive lower branching
	<i>P. radiata</i>	35° 49' S	144° 58' E	1929-30	400	25	40	3	5	-	Only a few large isolated trees with large branches and bushy spreading habit.
Moirā State Forest	<i>P. canariensis</i>	36° 1' S	144° 54' E	1918-66	425	21	40	4	5,10	-	Stands at various ages. Where spacings are more open, trees are shorter with greater taper and branching thickening up but still look good. On this site <i>P. canariensis</i> is the best formed and growth appears comparable or better than other species.
	<i>P. halepensis</i>	36° 1' S	144° 54' E	1922-51	425	15-20	30	3	4,5,9	-	Form not as good as <i>P. canariensis</i> . Growth rates appear OK.
	<i>P. radiata</i>	36° 1' S	144° 54' E	1918-59	425	15-20		3	5,9		Form poor and hard to judge growth/mortality rates.
	<i>P. pinaster</i>	36° 1' S	144° 54' E	1918-58	425	15-20		3	7,9		Form poor but most stands appeared to have been harvested or thinned and only odd isolated trees left.
	<i>C. glaucophylla</i>	36° 1' S	144° 54' E	1937-48	425	15-20		3	9	-	Appears to be particularly slow growing but healthy with good form.

Location	Species	Latitude	Longitude	Year Planted	Approximate Mean Annual Rainfall (mm/yr.)	Top height (m)	Largest Diameters (cm)	Vigour (x/5)	Form (x/10)	Numbers of trees which met criteria	Comments		
Wagga Wagga	<i>P. canariensis</i>	35° 3' S	147° 20 E	1930's	550	15	30	3	5	-	With the large spacing taper is prominent and branches are medium to large and spreading. Stems are still straight.	See Thomas and Borough (1997) for more detailed assessment	Trees not available for sampling
	<i>P. brutia</i>	35° 3' S	147° 20 E	1930's	550	20	50	4	9	-	Large well formed trees. Most had clean branchless stems up to 5-6 m or higher.		
	<i>P. halepensis</i>	35° 3' S	147° 20 E	1930's	550	20	50	4	5	-	Similar growth to <i>P. Brutia</i> except has numerous large branching to low down on the stems.		
	<i>P. radiata</i>	35° 3' S	147° 20 E	1930's	550	18	40	2	4	-	Number of large dead trees. Bushy habits due to wide spacing. Some of the remaining trees look to be dying, only 2 or 3 healthy trees left.		
Jerilderee	<i>P. brutia</i>	35° 26' S	145° 35 E	1968	450	15?	30	3	10	-	CSIRO FFP overseen trials. Numerous small plots of different provenances. Some have been thinned out. For more detailed earlier assessment see Spencer (1985).		
	<i>P. halepensis</i>	35° 26' S	145° 35 E	1968	450	15?	30	3	5	-			

5.2.2 Selection criteria

The selection criteria from the previous study (Washusen *et al*, 1996) were modified to accommodate the low crown branching form. The minimum DBHOB for the sawing study was 30 cm. To make up necessary numbers of potential sample trees, diameters down to 28 cm were considered for some of the species. Sampling was limited to one 3.1m long butt log, due to the low and heavy crown branching. Stems needed to have a clean bole with no branching to a height of 3.5-4.0m, to allow for some butt trimming and removal of buttressing. Potential sample trees were almost always edge trees (trees planted on the edge of block plantings).

The exotic pine trials at both Moira and Millewa State Forests consisted of numerous plantings of a range of species that had been planted out over a 45 year period and were up to 80 years old. The different permutations of species and age (and in some case thinning at unknown ages) were too great to obtain worthwhile data and so no attempt was made to measure individual trees.

5.2.3 Species selected

The four species selected, for the evaluation of their wood properties, were Swamp Yate (*E. occidentalis*), Brown Mallet (*E. astringens*), Sugar Gum (*E. cladocalyx*) and Yellow Gum (*E. leucoxylon*). All of these, except *E. cladocalyx*, are species that have not been evaluated previously by CSIRO FFP and show reasonable potential under the right conditions. *E. cladocalyx* was evaluated in the previous study (Washusen *et al*, 1996), but the opportunity was taken to sample material from a younger plantation grown under different conditions. Drying degrade, possibly reaction wood related with fast growth, might be a concern with *E. cladocalyx*. If it is a serious problem it should be most evident in young (~25 y.o.) plantation material. The sampled plantations were all from regional and state reserves around the Horsham region in Western Victoria.

Two of these species have been identified by the ALRTIG as key species for this region. The ALRTIG key species are Swamp Yate (*E. occidentalis*), Sugar Gum (*E. cladocalyx*), Red Ironbark (*E. sideroxylon*), Spotted Gum (*Corymbia maculata*), River Red Gum (*E. camaldulensis*), River Red Gum - Flooded Gum Hybrid, Maritime Pine (*Pinus pinaster*) and Brutian Pine (*P. brutia*). Yellow gum is closely related to Red Ironbark, which was evaluated by Washusen *et al* (1996) and, while its form was generally poor, was evaluated here to compare wood properties as it might be a viable alternative for some site conditions. Similarly, Brown Mallet, which is closely related to *E. occidentalis*, was included as it showed good growth and promise on the harsher sites where some of the other species appeared to struggle.

5.2.4 Sites species were sampled from

Figure 5 shows the *E. occidentalis* plantation at the Barrett reserve. Similarly, Figure 6 shows the *E. cladocalyx* plantation at Wail Nursery, Figure 7 an example of *E. leucoxylon* in the Wail plantation and Figure 8 the *E. astringens* at Glenlee



Figure 5: *E. occidentalis* plantation at 'The Barrat' Reserve. Shows large edge trees grading into smaller diameters toward the middle of the plantation.



Figure 6: *E. cladocalyx* plantation at Wail Nursery. In the foreground is an isolated tree with extremely poor branching characteristics. Most of the trees sampled were from the edge trees in the background.



Figure 7: Typical form of *E. leucoxylon* trees sampled at Wail. Curvature and twisting of the lower trunk and low crown branching was more pronounced on most non-sampled trees in the plantation.



Figure 8: Row planting of *E. astringens* at Glenlee Reserve.

5.2.5 Natural distributions

Figure 9 is a map showing the predicted distribution for *E. occidentalis* using the Genetic Algorithm for Rule set Production (GARP v. 0.51¹) model output. The model was run from the 'Environment Australia Online' web-pages². Black dots are recorded locations for the species. The dark shaded areas are predicted presence of the species and light shaded areas are predicted absence. Clear areas are areas where there is varying degrees of evidence for both presence and absence of the species. Figure 10, Figure 11 and Figure 12 provide the additional GARP distributions for *E. cladocalyx*, *E. leucoxylon* and *E. astringens* respectively.

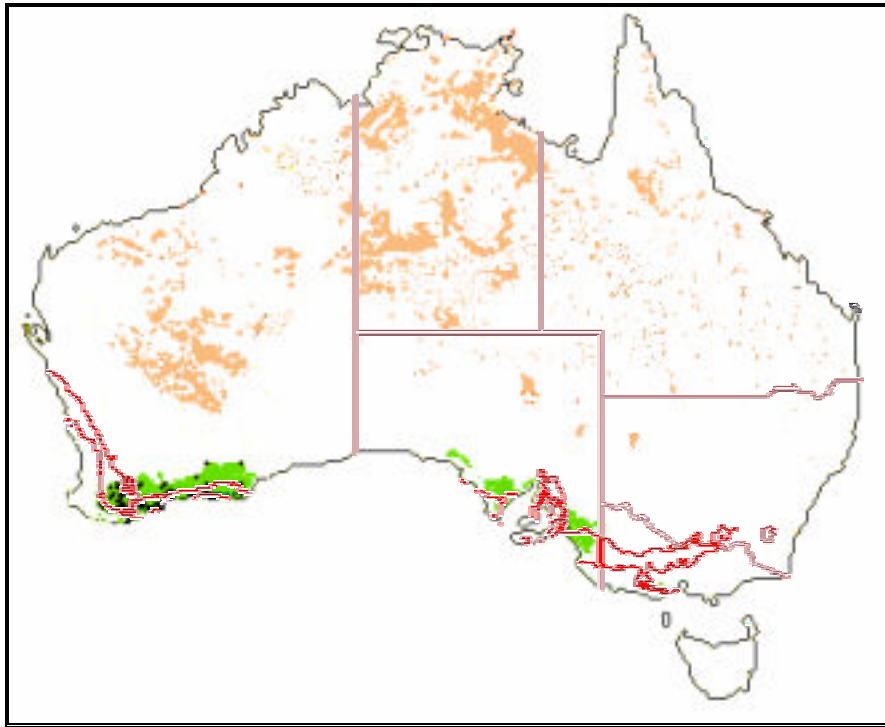


Figure 9: GARP model for predicted presence of *E. occidentalis* based on climatic and soil factors. Black dots are recorded locations for the species. The dark shaded areas are predicted presence of the species and light shaded areas are predicted absence. Clear areas are areas where there is varying degrees of evidence for both presence and absence of the species. State boundaries and outline of the 400-600 mm/yr project area (Figure 1) are superimposed.

¹ http://www.erin.gov.au/general/biodiv_model/ERIN/GARP/home.html

² <http://www.erin.gov.au/index.html>

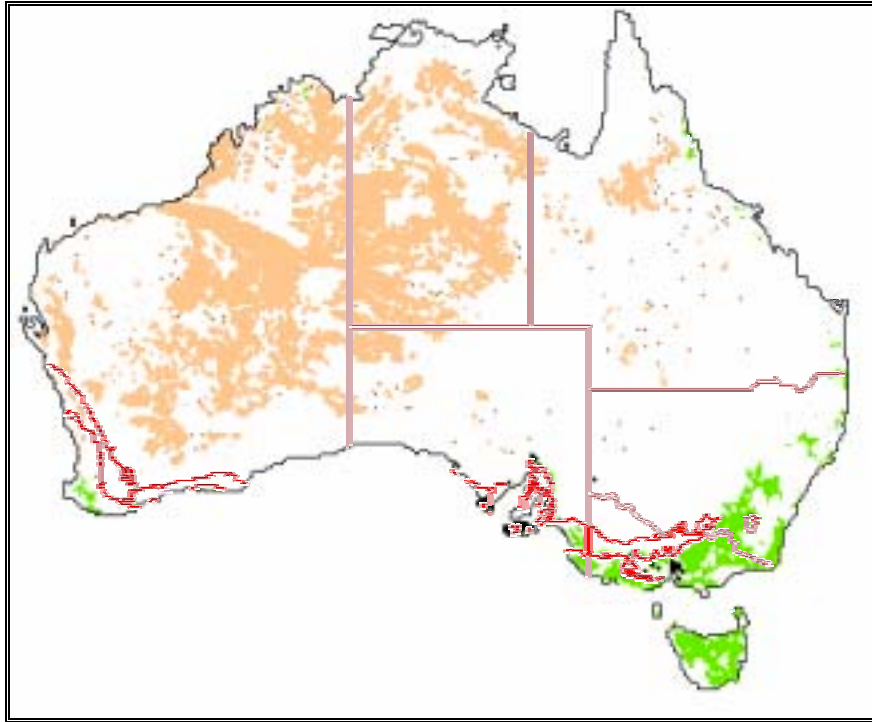


Figure 10: GARP model of predicted presence of *E. cladocalyx* based on climatic and soil factors. Black dots are recorded locations for the species. The dark shaded areas are predicted presence of the species and light shaded areas are predicted absence. Clear areas are areas where there is varying degrees of evidence for both presence and absence of the species. State boundaries and outline of 400-600 mm/yr project area (Figure 1) are superimposed.

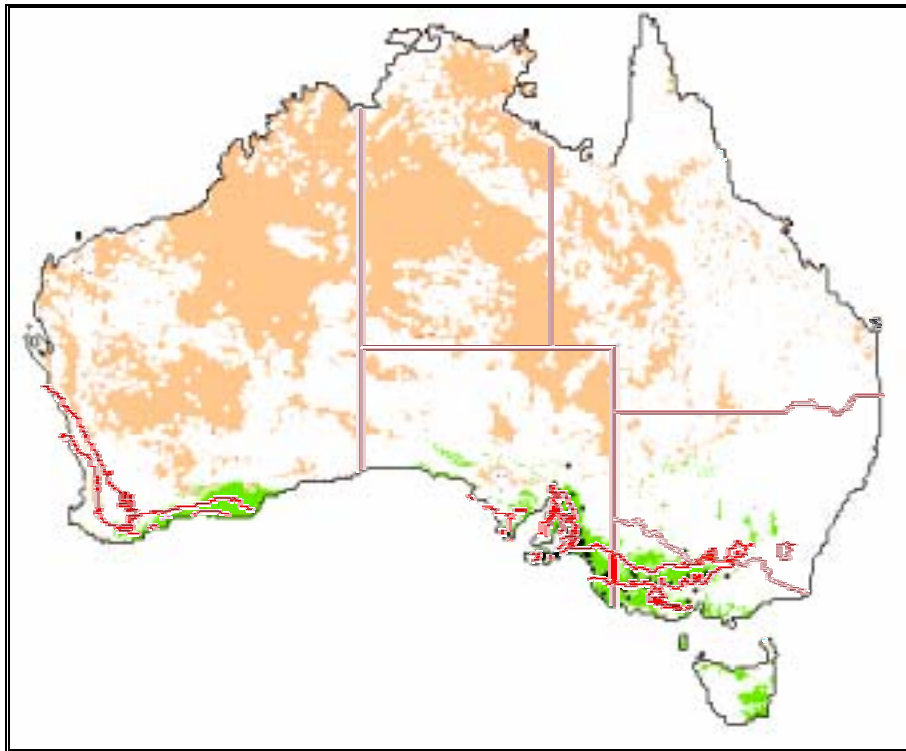


Figure 11: GARP model of predicted presence of *E. leucoxylon ssp leucoxylon* based on climatic and soil factors. Black dots are recorded locations for the species. The dark shaded areas are predicted presence of the species and light shaded areas are predicted absence. Clear areas are areas where there is varying degrees of evidence for both presence and absence of the species. State boundaries and outline of 400-600 mm/yr project area (Figure 1) are superimposed.

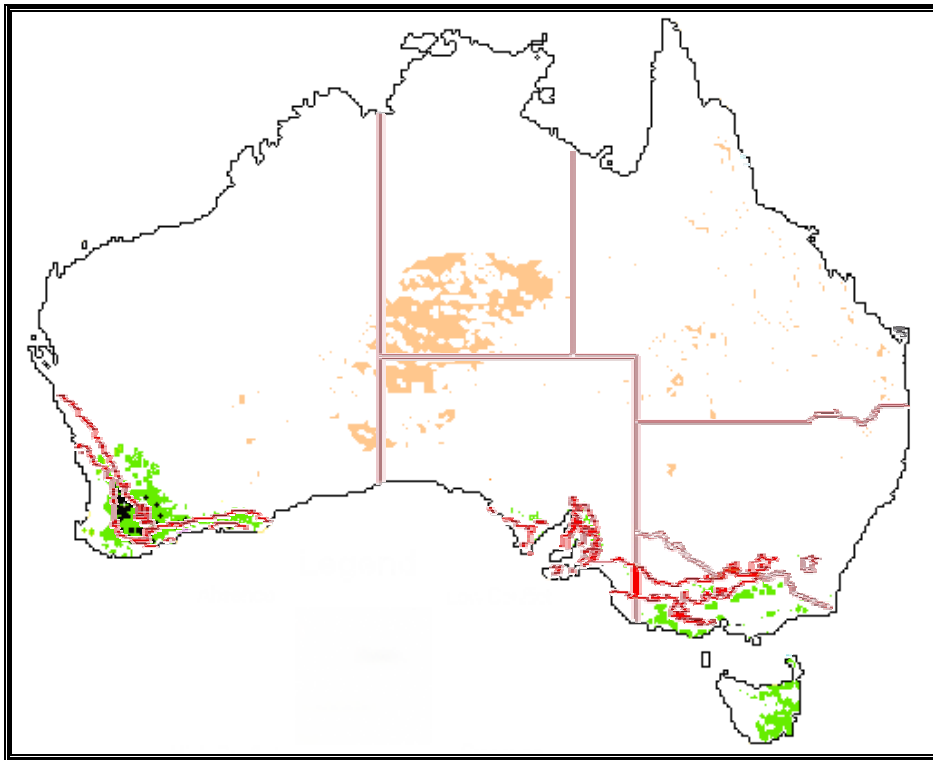


Figure 12: GARP model of predicted presence of *E. astringens* based on climatic and soil factors. Black dots are recorded locations for the species. The dark shaded areas are predicted presence of the species and light shaded areas are predicted absence. Clear areas are areas where there is varying degrees of evidence for both presence and absence of the species. State boundaries and outline of 400-600 mm/yr project area are superimposed.

5.2.6 Growth data

Stewart (2000) provides general growth data for the four selected species in the Wimmera region. The data was collected at a range of plantations, including those sampled in this study. Table 3 shows a summary of the locations with the best and worst basal area (BA) increments. As a comparison, Table 4 (Anderson, 2000) provides a similar summary of data collected for 3 of the same species grown at the You Yangs regional reserve. Again showing Stewart (2000) data, Figure 13 plots the height data for *E. cladocalyx* and *E. occidentalis* at various ages, with a growth curve fitted. Figure 14 shows the limited height data available for *E. leucoxyton* and *E. astringens*. Figure 15 shows the basal areas plotted against age for *E. cladocalyx* and *E. occidentalis*. This data suggests that *E. cladocalyx* has the fastest growth rates of the 3 species and the potential to be the tallest as well.

Table 3: Summary of growth data for the locations with the best and worst Basal Area (BA) increment for the 4 selected species in the Wimmera region. The values shown are the mean, with range shown in brackets, of the plots measured at each location, usually there were about 10 plots for each location. (Taken from Stewart, 2000).

Species	Location	Age	BA Increment (m ² /ha/yr)	Total Basal Area (BA) (m ² /ha)	Stocking (Stems/ha)	Estimated Diameter (cm)*	Height (m)	Estimated Mean Annual Increment (m ³ /ha/yr) §
<i>E. cladocalyx</i>	Best	23	0.63 (0.57-0.78)	14.4 (13.0-18.0)	1168 (987-1283)	13 (11-18)	13.9 (12.5-15.8)	2.9
	Worst	49	0.27 (0.23-0.31)	13.3 (11.4-15.2)	562 (464-722)	17 (14-20)	17.9 (16.6-20.3)	1.6
<i>E. occidentalis</i>	Best	34	0.47 (0.36-0.57)	15.9 (12.3-19.4)	485 (361-655)	18 (15-21)	16.5 (14.5-17.7)	2.6
	Worst	40	0.30 (0.14-0.37)	12.1 (5.6-14.9)	560 (191-792)	17 (9-19)	15.9 (13.5-17.8)	1.6
<i>E. astringens</i>	Best	33	0.39 (0.25-0.53)	13.0 (8.1-17.5)	575 (425-800)	14 (11-17)	17.1 (14.1-19.3)	2.2
	Worst	42	0.24 (0.16-0.33)	10.0 (6.8-13.7)	301 (203-447)	15 (14-20)	16.1 (15.4-17.0)	1.3
<i>E. leucoxylon</i>		34	0.35 (0.28-0.44)	12.0 (9.6-14.9)	570 (461-714)	16 (13-20)	13.7 (13.2-14.2)	1.6

* Mean diameter and range values were estimated from Stewart (2000) data using the equation below.

$$\text{Diameter} = \left(\sqrt{\text{BA}/\text{Stocking}/\pi} \right) \times 200$$

§ MAI was estimated using the formula below:

$$\text{MAI} = \left(\frac{1}{3} \times \text{B.A.} \times \text{Height} \right) / \text{Age}$$

Table 4: Summary of growth data for 3 of the species grown at the You Yangs regional reserve (Anderson, 2000).

Species	Age	BA Increment (m ² /ha/yr)	Total BA (m ² /ha)	Stocking (stems/ha)	Diameter (cm)	Height (m)	Estimated Mean Annual Increment (m ³ /ha/yr) §
<i>E. cladocalyx</i>	33	0.79	26	860-1000	18	19	5.0
<i>E. occidentalis</i>	41	0.39	16	1125	18	17	2.2
<i>E. astringens</i>	42	0.26-0.33	8.3-13.8	525-800	16-18	10-14	1.5

§ MAI was estimated using the formula below:

$$\text{MAI} = \left(\frac{1}{3} \times \text{B.A.} \times \text{Height} \right) / \text{Age}$$

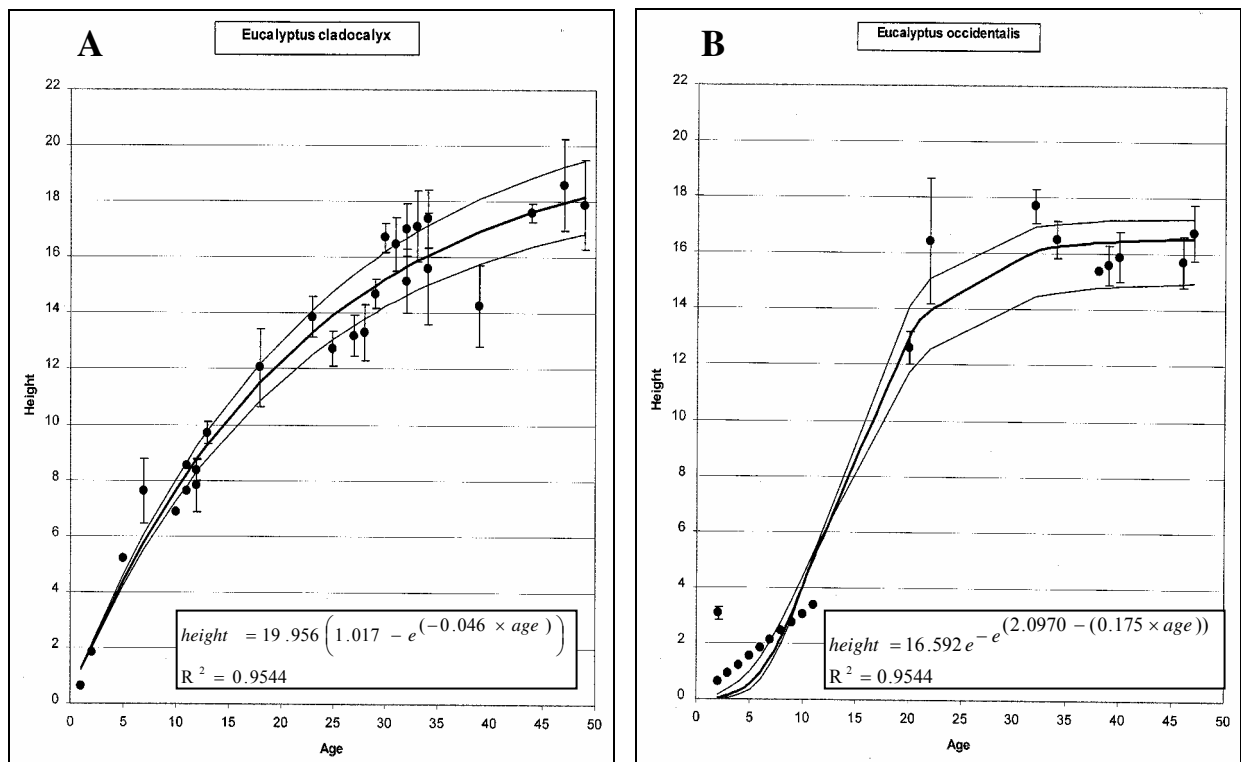


Figure 13: Height against age curve for (A) - *E. cladocalyx* and (B) - *E. occidentalis*. The solid line is the line of best fit for the data points shown. The error bars, where they occur, are $\pm 95\%$ confidence limits. The two lighter lines are best-fit upper and lower lines based on the mean data and confidence limits. (Taken from Stewart, 2000).

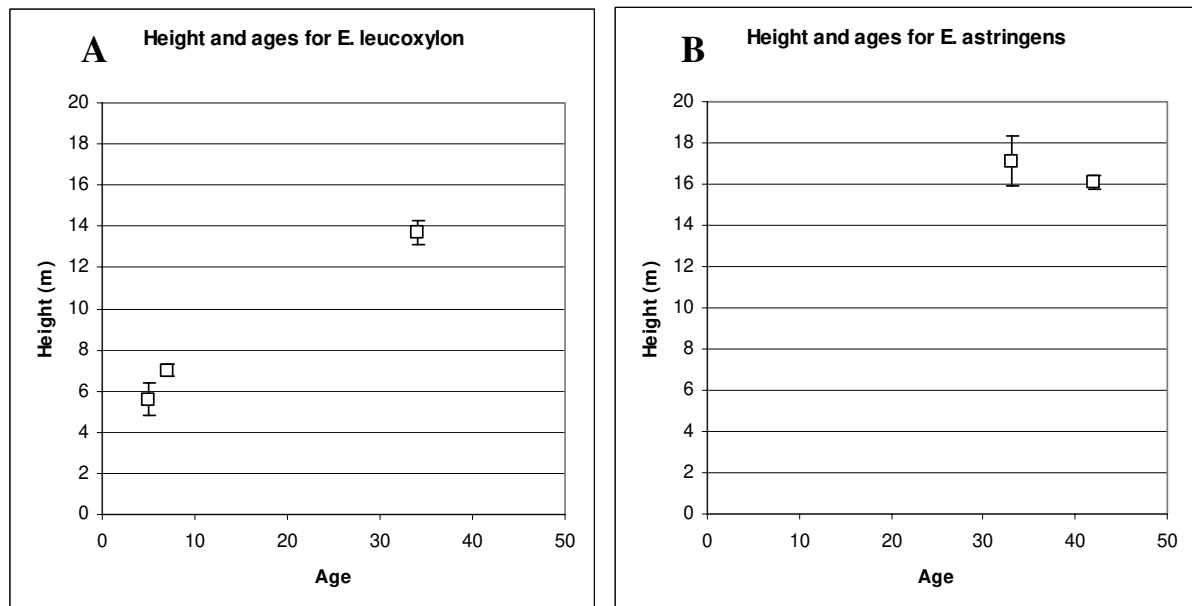


Figure 14: Height against age data for (A) - *E. leucoxylon* and (B) - *E. astringens*. The error bars are $\pm 95\%$ confidence limits. (Taken from Stewart, 2000).

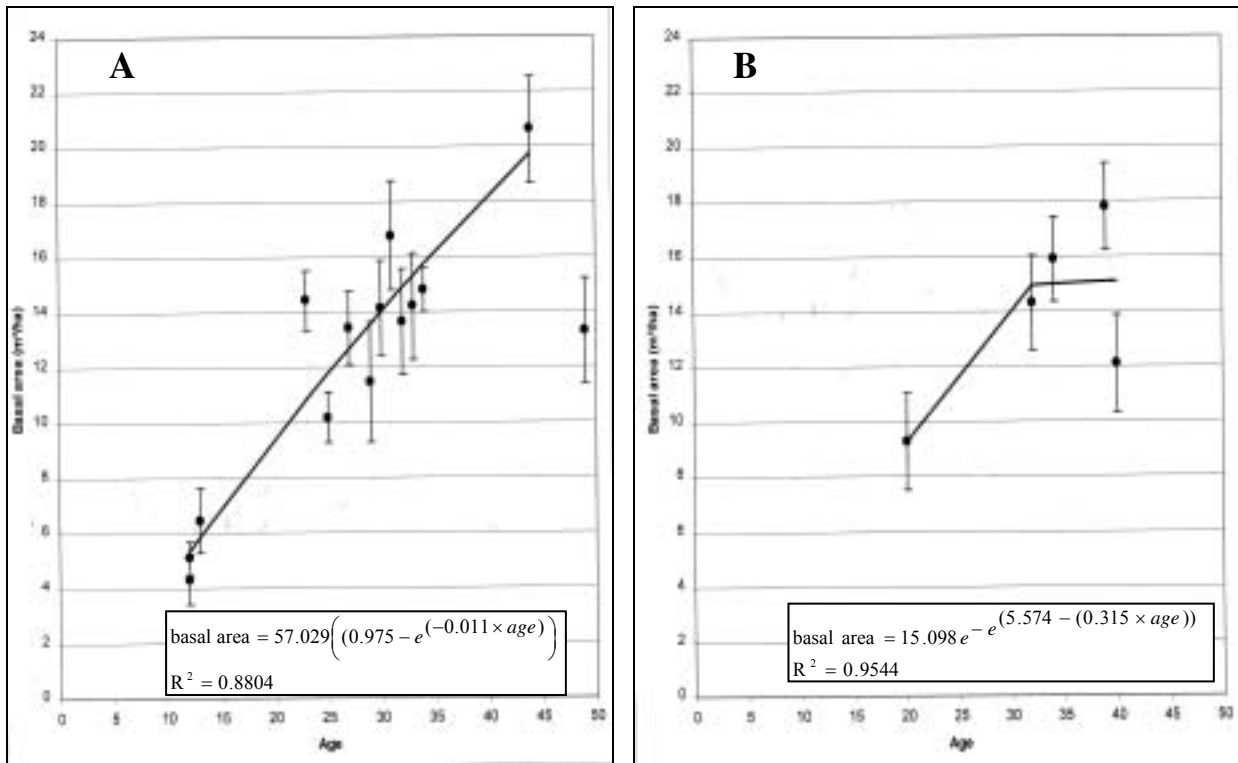


Figure 15: Basal area against age curve for (A) - *E. cladocalyx* and (B) - *E. occidentalis*. The solid line is the line of best fit for the data points shown. The error bars, where they occur, are $\pm 95\%$ confidence limits. In (A) the data point at the far right was excluded, as an outlier, from the line of best fit equation. (Taken from Stewart, 2000).

5.3 Sawing

5.3.1 Log harvesting, transport and defect recording.

Selected trees were harvested during the week commencing the 7/2/00. North direction was recorded on each log, by the placement of tags (with tree numbers), prior to felling. Upon cross-cutting all logs were end coated with a wax emulsion (PARACOL 855N: Hercules Chemicals Australia) and gang-nailed with 12.7 x 8.8 cm (5 x 3.5 inch) plates to prevent end splitting. Logs were progressively transported, within 2 days of falling, by the local Department of Natural Resources and Environment (NRE) fire crew to the Wail Nursery and stored under tarpaulin. All logs were transported to Creswick on the 19/2/00 and stored under water-spray with the bark left on. Debarking, log preparation and measurement was undertaken over the 11/4-14/4/00.

5.3.2 Tree and log details

Species and log details are summarised briefly in Table 5 below. It was intended to harvest 10 logs of each species for this study as well as supply 6 logs of the other species to the University of Melbourne. The University of Melbourne study had already undertaken a considerable amount of its preliminary sawing work with Sugar Gum. Thus, they only collected an additional 2 Sugar Gum butt logs plus a couple of short top logs or bigger branches. For three of the species 1 log of each, intended for the University of Melbourne study, was inadvertently included in this study.

Table 5: Summary of species and log details [mean (standard error)].

Details	Species			
	<i>E. occidentalis</i>	<i>E. cladocalyx</i>	<i>E. leucoxylon</i>	<i>E. astringens</i>
Plantation	Barrett	Wail		Glen Lee
Date planted	1959	1971-73	1956-60	1955
Count	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. (m2/ha)	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 (m3)	0.330 (0.013)	0.209 (0.010)	0.259 (0.016)	0.272 (0.019)
Taper (cm/m)	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)
Average of crook – depth (cm)	0.4 (0.4)	0.5 (0.3)	3.2 (1.2)	0.0 (0.0)
Average of butt sweep – depth (cm)	0.7 (0.5)	1.2 (0.7)	5.0 (1.5)	0.0 (0.0)

5.3.3 Sawing systems and strategy

Sawing was conducted at the Victorian Timber Industry Training Centre, Creswick on the 18th April, 2000. Primary breakdown was undertaken with a 72 inch Salem vertical band-saw. Cants and flitches were re-sawn on a Grey one-man circular-saw. Because of the short log lengths and assumed lack of growth stress, a conventional sizing strategy was employed despite the log carriage being equipped with a line-bar.

The sawing strategy was to cut a central 105mm wide cant from each log (Figure 16). The cant was always aligned with the north-south orientation of the logs. 43mm thick boards were then taper sawn from the cant. 105 x 43 mm boards were also cut from the wings, along with any other dimensioned products that could be recovered. 43 mm boards are thicker than what is required for most appearance products, but were targeted for the drying study. Thicker dimension products are generally harder to dry than thin as the moisture gradients and subsequent drying stresses which cause checks can be greater. Also, if the grade is poor the board is still of a useful dimension for products where strength is important (i.e. cover and case grade) or alternatively could still be ripped into thinner products if of a high enough grade.

The compass orientations were painted onto the large end of the logs prior to sawing (Figure 17). This enabled the sawyer to orientate the logs on the carriage. North was indicated with yellow paint, south with dark green and west with light green. The different colors also enabled board position in the cant to be determined.

To enable identification of all pieces sawn from each individual log, a sequence of colors was painted on the small end of logs. The sequence was; red, orange, green, blue, purple, black and white (Figure 17, inset). The subsequent logs with the same colour were given a sequential number. For example, a red log was denoted as R01, O01, G01,.....R02, O02, etc. The code number and a sequential board number were applied to boards as they came off the re-saw, eg R02-1, R02-2.....O02-1, O02-2.... (Figure 18).

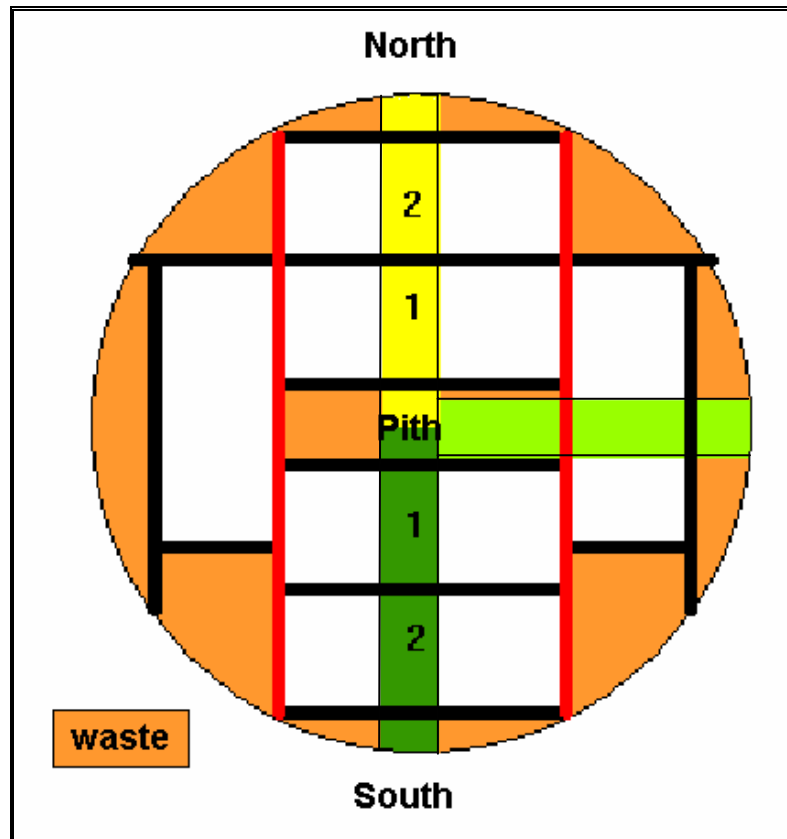


Figure 16: Basic sawing pattern (view of small end). A 105 mm wide central cant cut in the north-south alignment and 43 mm thick boards then taper sawn. Various dimension products were recovered from the wings with a focus on recovering 105 x 43 mm boards where possible.



Figure 17: North, south and west are indicated on the large end of logs for sawyer to align central cant with the north-south orientation. They are painted different colours. *Inset:* Color sequence applied to small end to trace boards back to logs.



Figure 18: Application of log color, log number and sequential board numbers to boards grouped (by log) off the re-saw bench.

5.4 Green appearance grading

To enable a comparison with the recoveries from Washusen *et al* (1996), all boards were visually graded using CSIRO-FFP developed Appearance Grading Rules (Waugh and Rozsa, 1991). The different grades and a brief description of the uses of each grade are provided in Table 6. In the interim between the two projects, new Australian Standards for hardwood grading were published (AS/NZS 2796.1:1999, AS/NZS 2796.2:1999 and AS/NZS 2796.3:1999). The main difference between the two grading systems is that the CSIRO-FFP rules are less strict on the defects allowed on the non-exposed face for select, standard and utility grade, but distinguishes 2 higher clear grades (Polish and Moulding grade) with tighter limits than set out in the Australian Standard for select grade. The Australian Standards also do not specify minimum lengths of boards. The minimum lengths of boards set out in the CSIRO-FFP grading rules (Table 6) are intended to allow the boards of that grade to be used in a variety of products. Industry is cutting or docking out more defects than is possible with the CSIRO-FFP appearance grade rules because of these minimum lengths, but this is for specific products and customers. Grading was undertaken on the round table (Figure 19). As well as recording grade limiting defects for each board, the grade of all non-limiting defects were also recorded.

To avoid loss of board end colours and identification, boards were only visually docked. The minimum lengths were 1.2 m for cutting grades, 1.8 m for polish and moulding grades and 2.4 m for all other grades. The visual docking strategy was only employed for green products where a board could be upgraded by at least 2 grades.

Table 6: Brief description of CSIRO developed appearance grades (Waugh and Rozsa, 1991)

Grades	Brief description of uses
(1) Polishing	<i>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 metres</i>
(2) Moulding	<i>Also used for highly decorative purposes. Graded on all faces and used for furniture and trimmings. Minimum length 1.8 metres</i>
(3) Select	<i>Graded on the best face and both edges. Examples of uses are lining boards, strip flooring and shelving. Minimum length 2.4 metres</i>
(4) Standard	<i>Graded on the best face. Example uses are lining boards and strip flooring. Minimum length 2.4 metres</i>
(5) Utility	<i>Graded on the best face. Example uses are industrial shelving, strip flooring, and industrial lining boards. Minimum length 2.4 metres</i>
(6) Cutting grade	<i>Short lengths equivalent to polishing grade cut from lower grade boards. Minimum length 1.2 metres.</i>
(7) Cutting grade	<i>Short lengths equivalent to moulding grade cut from lower grade boards. Minimum length 1.2 metres.</i>
(8) Cover	<i>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 metres</i>
(9) Case	<i>Graded on the worst defect. Used for low-grade pallets or chipped if price is not right. Minimum length 2.4 metres</i>
(10) Reject	No use



Figure 19: Appearance grading of green boards grouped by log on the round table as they come out from the re-saw.

5.4.1 Green recoveries

Green recoveries were determined using nominal board sizes and the visually docked lengths recorded on the grading sheets. The nominal sizes were 100 x 40 mm, 100 x 25 mm, 100 x 12 mm, 70 x 40 mm, 70 x 25 mm, 70 x 12 mm, 50 x 40 mm and 50 x 25 mm. Volume recoveries are expressed as a percentage of log volume, which were calculated using Smalian's formula (Eqn. 1).

$$Volume = L \frac{(A_L + A_S)}{2} \quad (\text{Eqn. 1})$$

$$\text{or} \quad Volume = \frac{L \pi (D_L^2 + D_S^2)}{8}$$

Where: L = Log length

A_L = Cross-sectional area of large end.

A_S = Cross-sectional area of small end.

D_L = Diameter of large end.

D_S = Diameter of small end.

The green off-saw recoveries for each of the species are shown in Figure 20. Total recovery is indicated by the dashes. Product recoveries are shown on the positive scale, docked and reject material are shown on the negative scale.

E. occidentalis had the highest overall recovery while *E. leucoxydon* had the lowest. *E. astringens* had the highest recovery of cover grade or better as well as the highest recovery of both standard and select grades. *E. cladocalyx* and particularly *E. leucoxydon* had poor recoveries of appearance products, even of the lesser value utility, or standard grades.

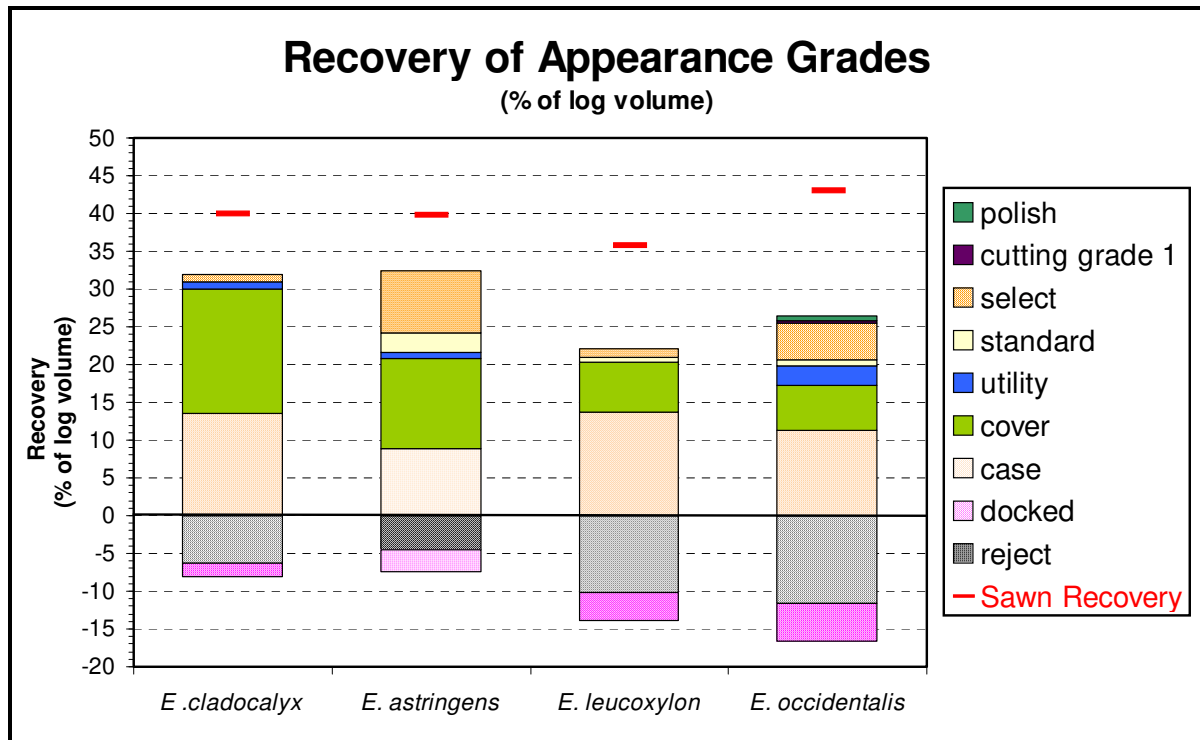


Figure 20: Overall recovery of sawn boards and appearance grades for the four species (based on nominal board dimensions).

5.4.2 Effect of defects on appearance recoveries

Figure 21 shows that decay was the major cause of boards being rejected for most species. This was most prevalent in *E. occidentalis*; the problem became apparent when debarking, which revealed large dead branch stubs (Figure 22) in a number of the logs. 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.

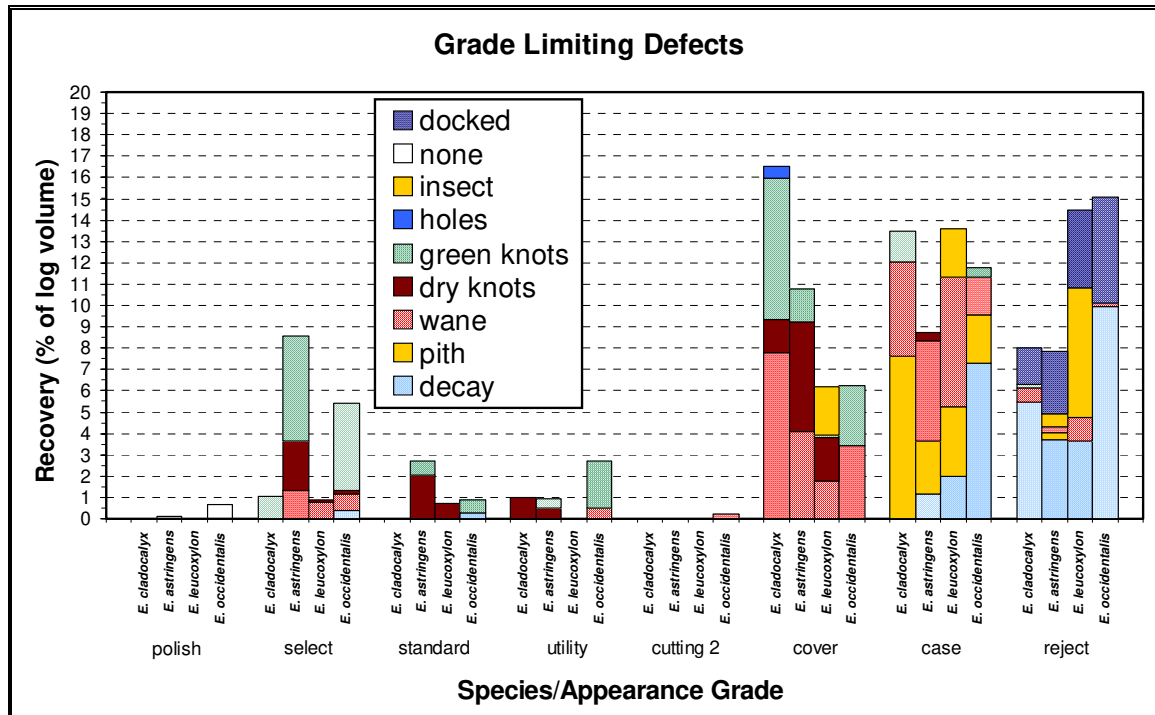


Figure 21: Recovery of different grades broken down by the grade limiting defects.



Figure 22: Example of badly rotten branch stubs in one of the *E. occidentalis* logs. This example also shows ribbing and other poor stem form attributes.

5.4.3 Recovery comparisons

The following measures of recovery were calculated and compared with those obtained in the earlier 600-750 mm/yr rainfall zone study (Washusen *et al*, 1996):

- Sawn recovery - total recovery of all products plus reject, as a % of log volume. This an indicator of the efficiencies of the sawing systems and strategies used rather than quality of wood sawn.
- Product recovery - recovery of all sawn products less reject, as a % of log volume. Cutting grades were allotted to polishing and moulding grades.
- Target recovery – recovery of cover grade and better, as a % of log volume. The product sizes of 100x12 mm, 50x25 mm and less than 1.8 m in length being rejected as they are not the product dimensions preferred by industry.
- Appearance recovery – recovery of select grade and better; firstly as a % of log volume; and secondly as a % of target recovery. The same restrictions on product dimensions apply as for the Target recovery.

It should be noted that in the earlier study by Washusen *et al* (1996) a slightly different calculation of log volume was used (Eqn. 2). The recovery figures were adjusted so that the same measure of log volume, as used in the present study (Eqn. 1), was used for all species.

	$V = \left(\frac{D}{2}\right)^2 \pi L$	(Eqn. 2)
Where:	$V =$ volume (m ³) $D =$ average diameter of large and small ends (m) $L =$ length (m)	

Table 7 provides the recoveries, and some limited log information for the different species, for both this study and the earlier study in the 600-750 mm/yr rainfall zone. Figure 23 is provided to make the comparison of recovery figures and the rankings clearer. Both clearly show that compared with the earlier study by Washusen *et al* (1996) the recovery of appearance products for the species in this study was poor. Part of the explanation is the smaller diameters and greater taper with the logs sawn in this study. This is most apparent with *E. cladocalyx*. The obvious exception is *E. occidentalis*. It had the second largest logs with only average taper. While it consequently had the third greatest recovery of sawn products, the recovery of target and appearance products was very poor. As discussed in section 5.4.1 this was mostly due to extensive decay of large dead knots.

Table 7 Comparison of log features (log volume, SED and taper) and the various green recovery figures from this study [400-600 mm/yr] with those from Washusen *et al* (1996) [600-750mm/yr]. The ranking of the various species are shown in brackets for each variable.

Rainfall zone mm/yr	Species (Location – Age at harvest)	Count	Log volume (m ³)		SED (cm)		Taper (cm/m)		Sawn recovery (% of log volume)		Product recovery (% of log volume)		Target recovery (% of log volume)		Appearance recovery (% of log volume)		Appearance recovery (% of target recovery)	
			Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
400-600	<i>E. cladocalyx</i> (Wail – 29 y.o.)	10	0.2087	[9]	26.6	[10]	1.59	[6]	40.0	[7]	32.0	[5]	18.1	[8]	1.0	[9]	5.0	[10]
	<i>E. astringens</i> (Glen lee – 41 y.o.)	11	0.2715	[6]	30.0	[7]	1.96	[3]	39.9	[8]	32.5	[4]	22.9	[6]	8.1	[5]	38.3	[5]
	<i>E. leucoxylon</i> (Wail – 44 y.o.)	11	0.2588	[8]	28.8	[8]	2.25	[1]	35.9	[10]	22.0	[10]	7.4	[10]	0.9	[10]	12.9	[9]
	<i>E. occidentalis</i> (Barrett – 42 y.o.)	11	0.3303	[2]	33.6	[3]	1.63	[5]	43.0	[3]	26.4	[9]	14.0	[9]	5.2	[8]	31.0	[6]
	Combined	43	0.2687		29.8		1.86		39.7		28.1		17.7		3.9		17.4	
600-750	<i>E. cladocalyx</i> (Earlston – 40 y.o.)	5	0.3044	[4]	33.2	[4]	1.54	[7]	43.3	[2]	35.1	[2]	32.6	[2]	20.6	[2]	62.3	[3]
	<i>E. cladocalyx</i> (Bandiana – 36 y.o.)	5	0.2965	[5]	32.4	[5]	1.82	[4]	42.8	[5]	34.5	[3]	29.6	[4]	18.9	[3]	64.6	[2]
	<i>E. globulus</i> (Oxley – 15 y.o.)	10	0.2084	[10]	27.5	[9]	1.30	[9]	42.9	[4]	27.0	[8]	20.6	[7]	6.5	[7]	26.6	[8]
	<i>E. maculata</i> (Lake Hume – 40 y.o.)	10	0.4109	[1]	38.1	[1]	2.17	[2]	44.1	[1]	39.4	[1]	37.0	[1]	28.0	[1]	75.8	[1]
	<i>E. sideroxylon</i> (Lake Hume – 40 y.o.)	5	0.3135	[3]	34.2	[2]	1.39	[8]	42.2	[6]	31.0	[6]	30.6	[3]	13.7	[4]	44.9	[4]
	<i>E. sideroxylon</i> (Tarrawingee – 26 y.o.)	5	0.2638	[7]	31.5	[6]	1.06	[10]	36.0	[9]	27.9	[7]	25.0	[5]	8.0	[6]	27.1	[7]
	Combined	40	0.3021		32.8		1.59		42.3		32.7		29.1		16.3		50.5	

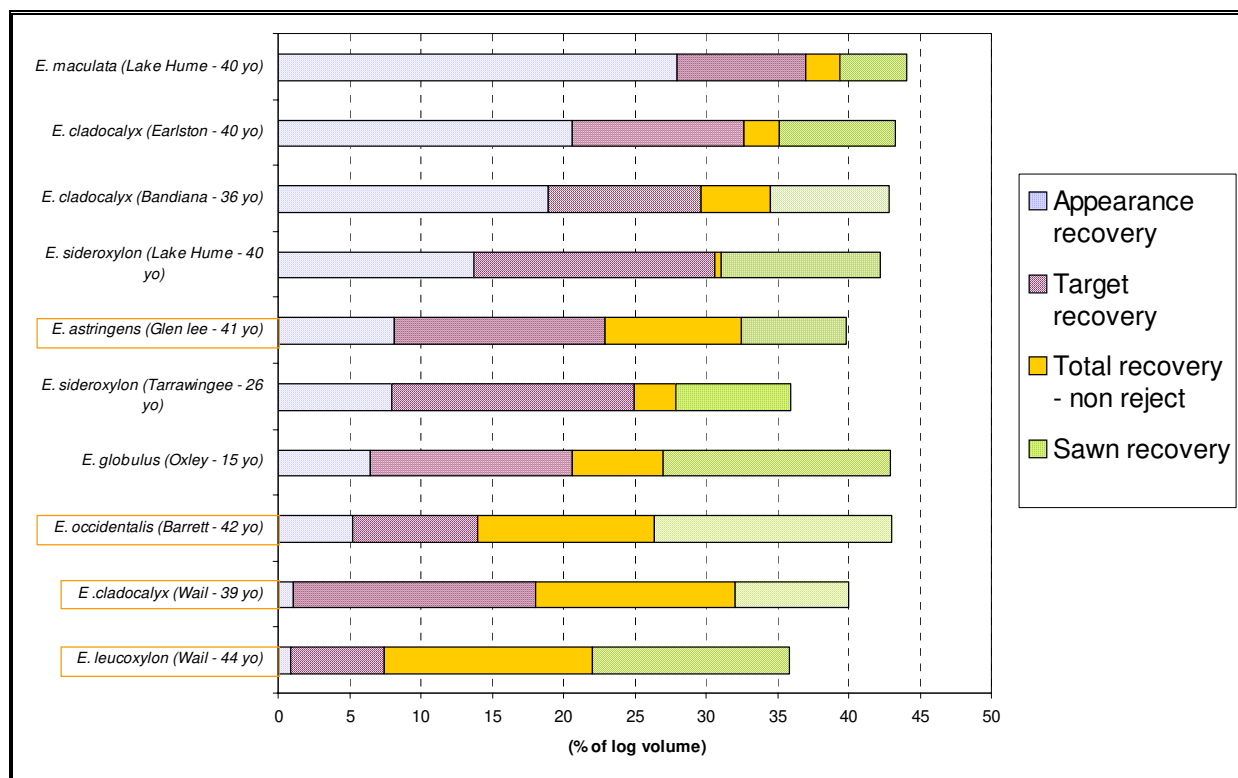


Figure 23: Green recoveries of the various species from this study and the earlier 600-750 mm/yr rainfall zone study (Washusen *et al*, 1996). The 4 species evaluated in this study are highlighted by a box around the species name. The species are arranged in order of Appearance recovery. Each recovery is inclusive of the recoveries to the left.

5.4.4 Relationships between log characteristics and recovery

The inter-relationships between the various log characteristics make it difficult to interpret how they are individually affecting sawn recovery. For example, Figure 24 and Figure 25 show the simple linear regressions between sawn recovery and two of the more important predictor variables in small end diameter and taper respectively. Only one of the relationships is significant (relating sawn recovery and SED for *E. cladocalyx*), and unexpectedly it indicates that sawn recovery decreased as SED increases. This relationship is only over a narrow range of SED but is reflected in the negative relationship for *E. leucoxylon* and *E. astringens*. These figures help illustrate why the application of these simple relationships is limited and their interpretation needs to be undertaken cautiously as the effects of other correlated variables, or even the correlation between taper and SED, are not being taken into consideration. Statistically analysing such inter-related variables is complex and, as it was not a central objective of this study, is not attempted here.

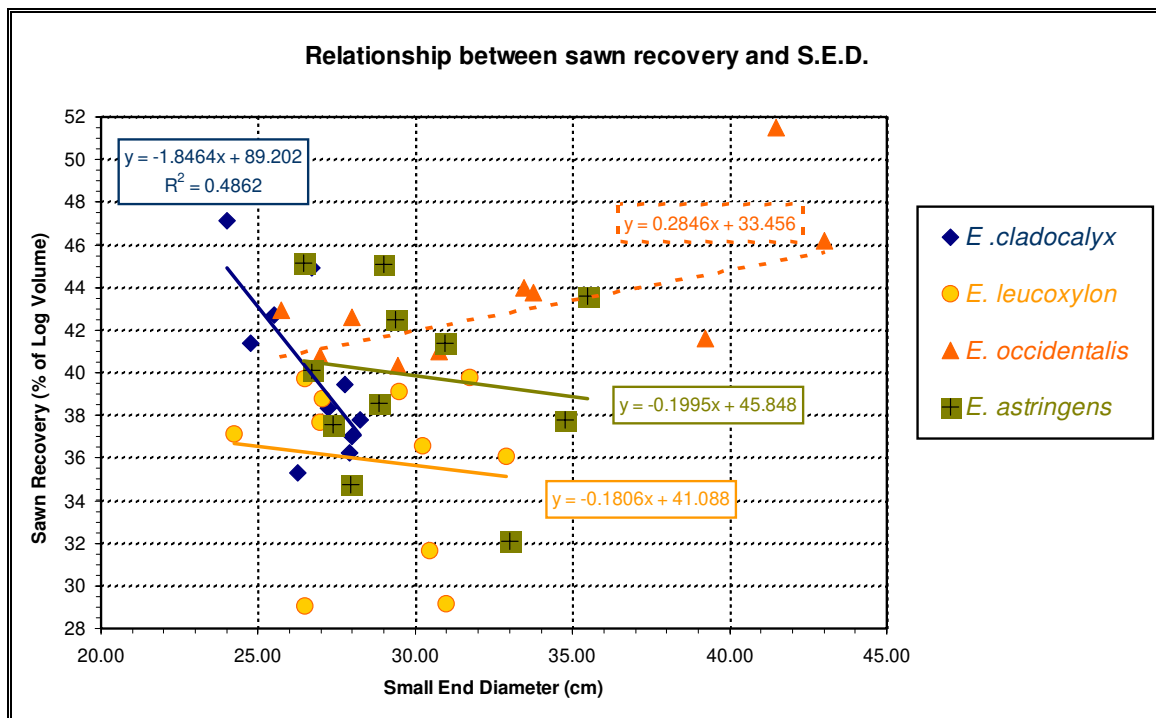


Figure 24: Linear regressions between sawn recovery and log small end diameter for the 4 species shown separately. R^2 values are only shown for significant relationships.

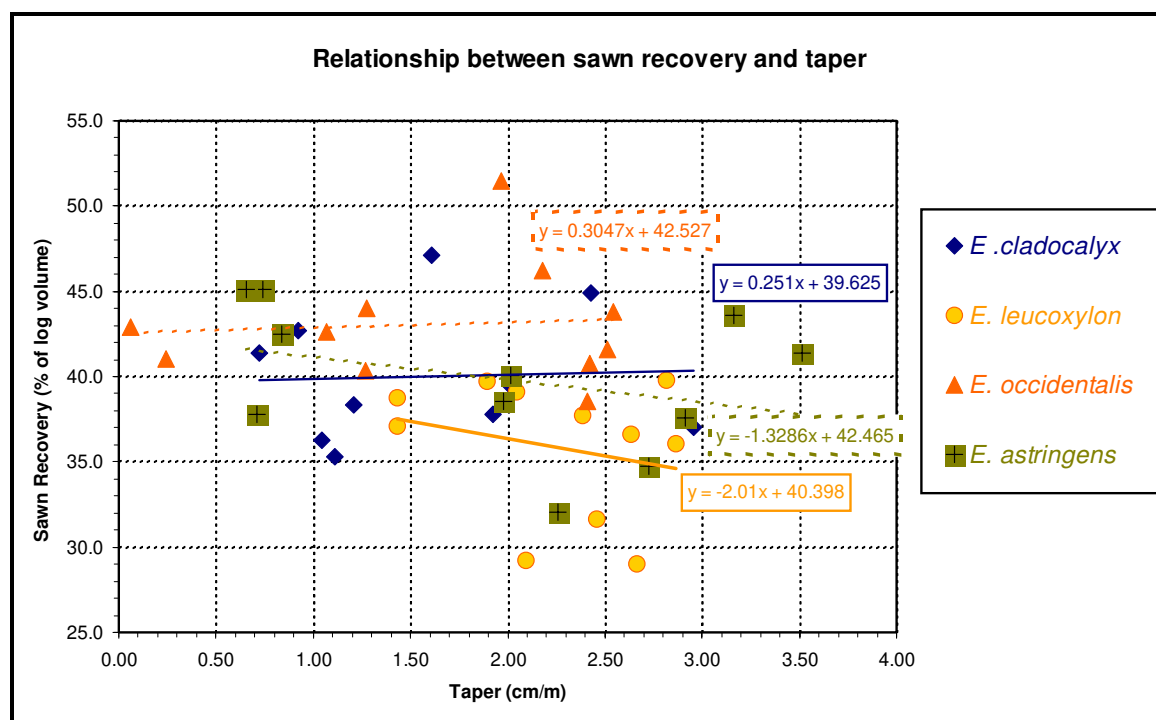


Figure 25: Linear regressions between sawn recovery and log taper for the 4 species shown separately. None of the relationships were statistically significant.

5.4.4.1 Effect of distance from pith on recovery of appearance products

As well as an effect on sawn recovery, intuitively SED should also have a strong effect on appearance recovery. Assuming that the diameter of the inner knotty core is roughly constant, smaller stem diameters reduce the proportion of outer clear wood in the stems.

To illustrate this point, and to see how important the effect is in the different species, Figure 26 shows the proportion (%) of boards (by volume) which meet the Target grade criteria (Cover grade or better) by position in the central north-south cant (Figure 16). This figure clearly shows an increasing percentage of boards met the criteria with increasing distance from the pith. This graph needs to be interpreted carefully, as the percentages for the outer positions are based on only a small number of boards recovered from the biggest logs. Similarly, an increasing proportion of boards met Appearance grade criteria with board position away from the pith (Figure 27). Interpreting these two figures in conjunction with Figure 21 highlights that knotty corewood and decaying inner heartwood problems were a significant problem with *E. leucoxylon* and *E. occidentalis*. This suggests that methods (genetic improvement, silviculture, mechanical pruning) to minimise the amount of knotty, decaying corewood will be particularly important for these two species. It also underlines the benefit of growing larger diameter trees to produce a large volume of clear outer heartwood.

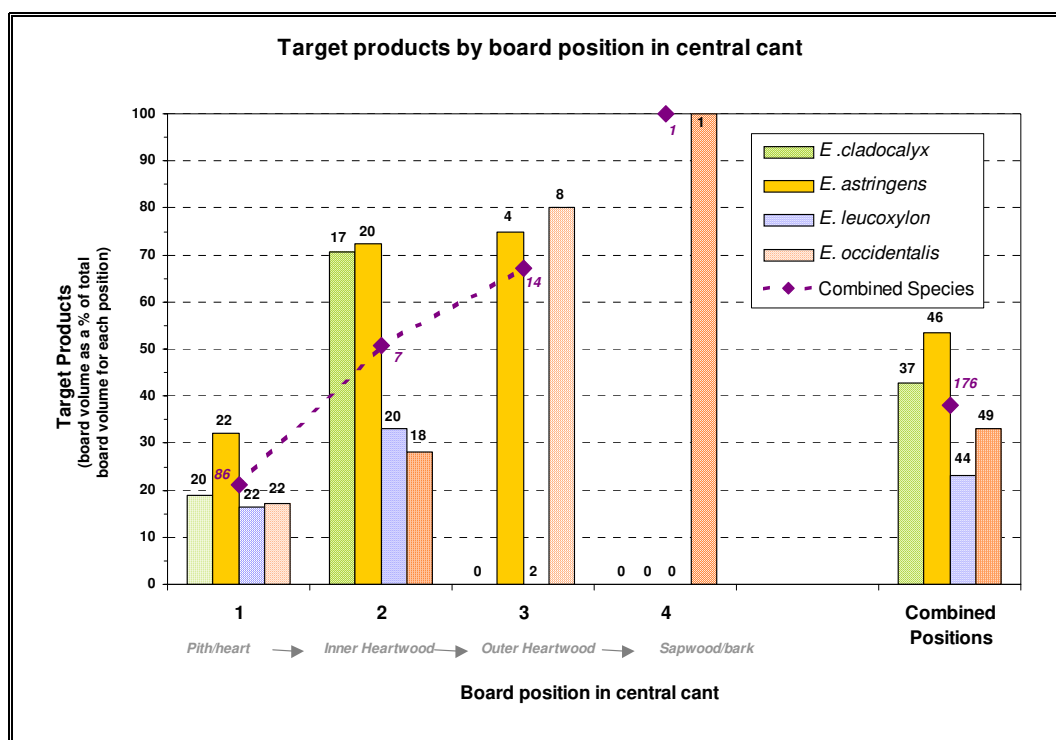


Figure 26: The volume of target products (cover grade and better) expressed as a percentage of the volume of all boards for each board position from the North-South cant only. Numbers above columns indicate the total number of boards recovered from each position.

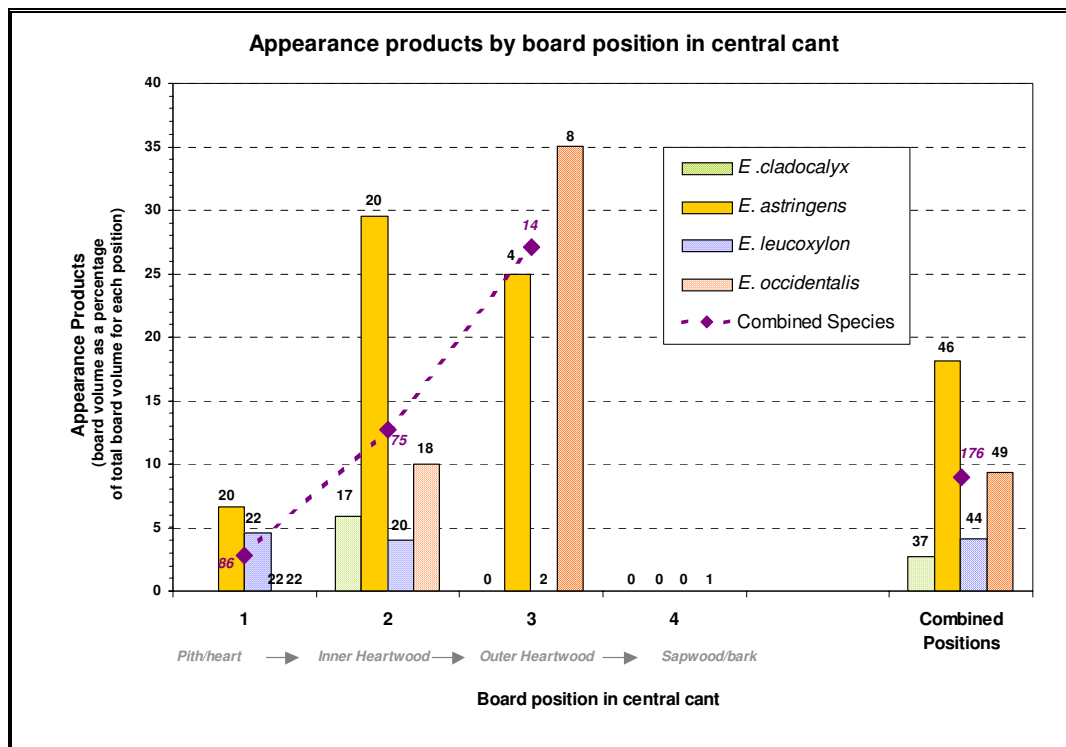


Figure 27: The volume of appearance products (select grade and better) expressed as a percentage of the volume of all boards for each board position from the North-South cant only. Numbers above columns indicate the total number boards recovered from each position.

5.5 Drying

To minimise drying degrade, all nominal 100 x 40 mm boards were dried conservatively under mild conditions of controlled air-drying. The 40 mm thick boards were deliberately targeted for the drying study, as drying problems are more pronounced in thicker boards. The reason thicker boards are harder to dry is that the drying gradient and the subsequent drying stresses in the board can be greater. If the drying stresses are too great surface checks will occur in the early stages of drying and internal checks in the latter stages. For a general discussion of drying stresses and degrade see Anonymous (1997). The mild drying conditions used in this study were intended to minimise the moisture gradient that develop through the thickness of the board. The rationale was that if 40mm thick boards can be dried successfully, then thinner boards should be able to be dried with less degrade and in less time. The only exceptions were a small number of nominally 100 x 40mm boards that were rejected as either severely decayed, broken or both. No other dimensions were dried as there were insufficient boards to reasonably draw conclusions on how the material would have dried. All drying was conducted inside a factory that houses CSIRO Forestry and Forest Product's pilot scale industrial kilns.

5.5.1 Sample board preparation

To monitor drying rates and degrade, one sample board (Figure 28) was prepared from each of the trees in the study. In every case, the board selected for sampling was from the north-south cant (Figure 16); the preference was to select outer heartwood boards. The length of the sample boards was 600 mm and was always cut from the butt end of the board. A 20 mm thick moisture content (MC) section was then cut and the MC% (Eqn. 3) and basic density (Eqn. 4) of this sample determined. The volume of the MC% sample was determined gravimetrically by the displacement in water method. The sample board was assumed to have been at the same moisture content as the MC% section, which allows the oven-dry mass of the sample board to be estimated from its initial green mass.

$$MC\% = \frac{(\text{Green mass}) - (\text{Oven dry mass})}{(\text{Oven dry mass})} \times 100 \quad (\text{Eqn. 3})$$

or

$$MC\% = \left(\left(\frac{\text{Green mass}}{\text{Oven dry mass}} \right) - 1 \right) \times 100$$

$$\text{Basic density} = \frac{\text{Oven dry mass (kg)}}{\text{Green volume (m}^3\text{)}} \quad (\text{Eqn. 4})$$

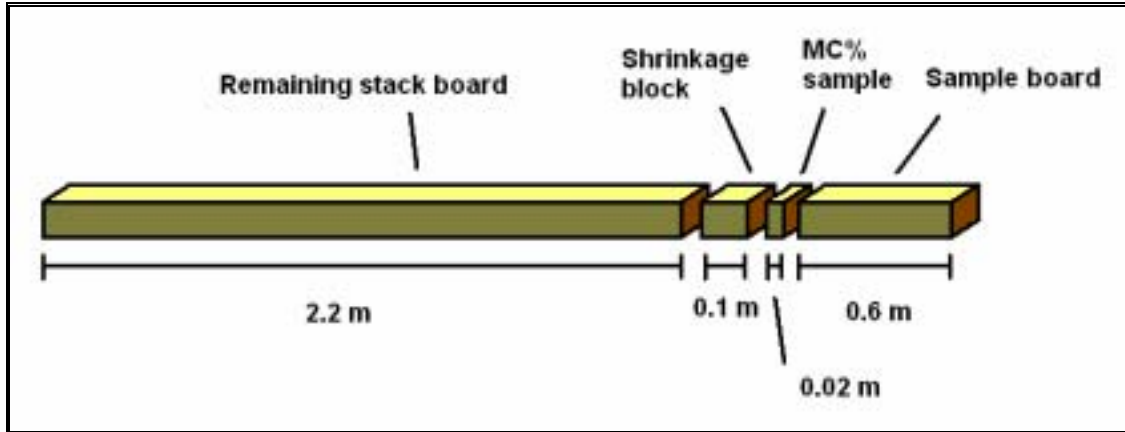


Figure 28 Diagram of sample board preparation

5.5.2 Air-drying stack preparation

Moisture Content (MC%) loss and drying degrade was monitored using the sample boards described in 5.5.1. The sample boards were distributed across two layers within each species (Figure 29). Two stacks were constructed in this way with two species, stacked separately but on top of each other, in each stack. End sample boards were used as it allows regular and safe monitoring of the sample boards with the use of a pneumatic lifter (Figure 29B).

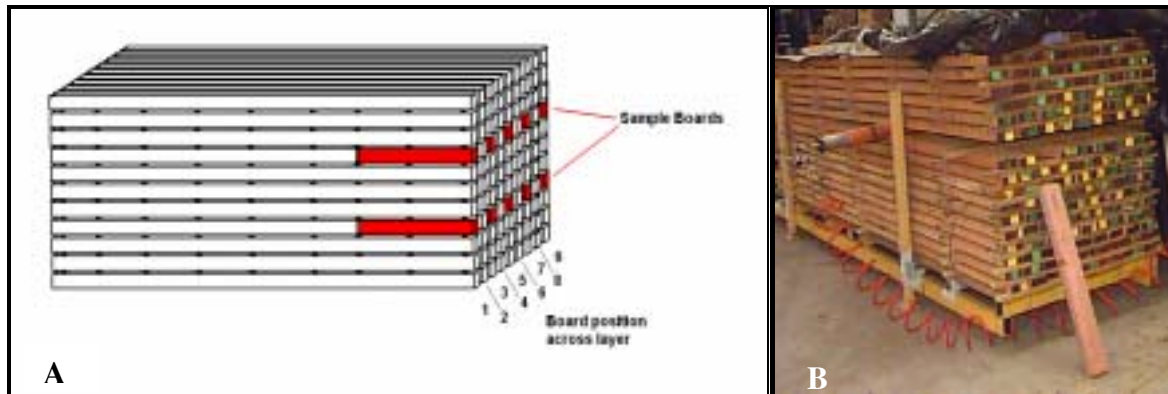


Figure 29 (A) Diagram of placement of sample boards, boards were placed in two layers for each species. (B) Picture showing a sample board (*E. astringens*) removed from stack for weighing.

5.5.3 Green MC% and Basic Density

Table 8 shows the mean green MC% and Basic Density for the four species. The means are comparable with previous published figures by Kingston and Risdon (1961). Typically for slow growing species, all the species are relatively dense with low green MC%. Figure 30 shows the strong negative correlation between green MC% and Basic Density for all of the species.

Table 8 Mean green MC% and Basic Density. Basic density data in blue shaded area is previous published data from Kingston and Risdon (1961).

Basic density	Species	Mean	SD	Count	Max	Min	95% CI for values	Mean	Count	95% CI for values
	Species	Mean	SD	Count	Max	Min	95% CI for values	Mean	Count	95% CI for values
Basic density	<i>E. astringens</i>	818.7	36.7	11	853.7	760.4	737 - 901	770	14	708-833
	<i>E. cladocalyx</i>	758.5	73.7	10	866.1	619.7	592 - 925	753	1	
	<i>E. leucoxylon</i>	795.1	37.2	11	845.7	707.8	712 - 878	811	16	607-1044
	<i>E. occidentalis</i>	775.6	44.5	11	851.4	700.9	676 - 875	-	-	-
Green MC%	Species	Mean	SD	Count	Max	Min	95% CI for values			
	Species	Mean	SD	Count	Max	Min	95% CI for values			
Green MC%	<i>E. astringens</i>	37.2	3.7	11	44.5	33.4	28.9 - 45.4			
	<i>E. cladocalyx</i>	50.4	8.4	10	67.2	41.5	31.4 - 69.4			
	<i>E. leucoxylon</i>	48.8	5.5	11	59.6	41.6	36.5 - 61.1			
	<i>E. occidentalis</i>	45.2	6.2	11	55.0	38.2	31.4 - 59.1			

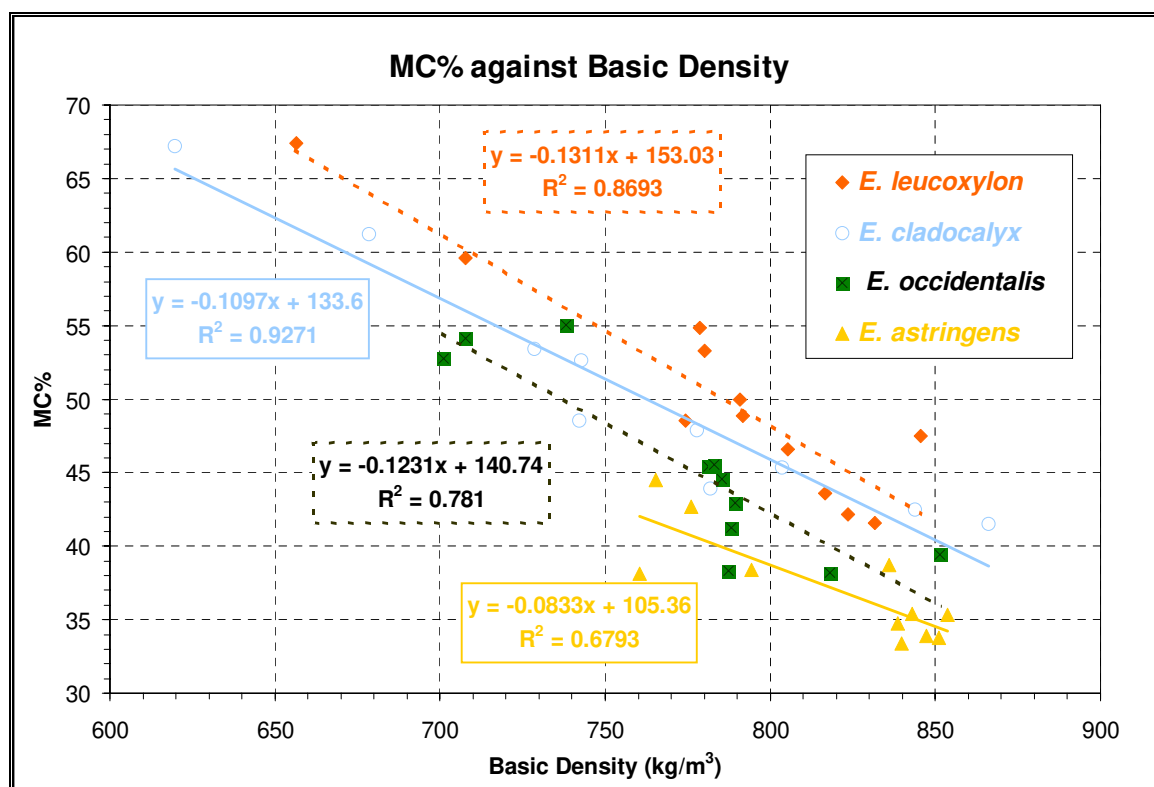


Figure 30 Plot of MC% against Basic Density which also shows the correlation coefficients for each of the species.

5.5.4 Air-drying

As an initial drying treatment, boards were left block stacked in the plastic for six weeks. On the 2/6/00 the *E. leucoxyton* and *E. astringens* boards were stacked out and the *E. occidentalis* and *E. cladocalyx* boards were stacked out on the 8/6/00. It was only at this stage of stickering that sample boards were prepared. The stickered stacks were initially left covered with plastic. On the 7/8/00 the plastic was replaced with hessian. The hessian was removed from the sides of the stacks on the 22/9/00, but the top and ends remained covered with plastic. To increase uniformity of drying through the stacks they were placed in front of a drying fan-wall on the 17/11/00. The fan wall monitors ambient conditions and was set to operate only when ambient temperatures were below 30°C and relative humidity was above 60%.

5.5.5 Final Kiln drying

Once confident that all core moisture contents were below 25% and that average board moisture contents were about 15-18%, stacks were reconditioned and final dried in a 4 m³ pilot scale kiln. The final drying schedules used are shown in Figure 31 and Figure 32 below.

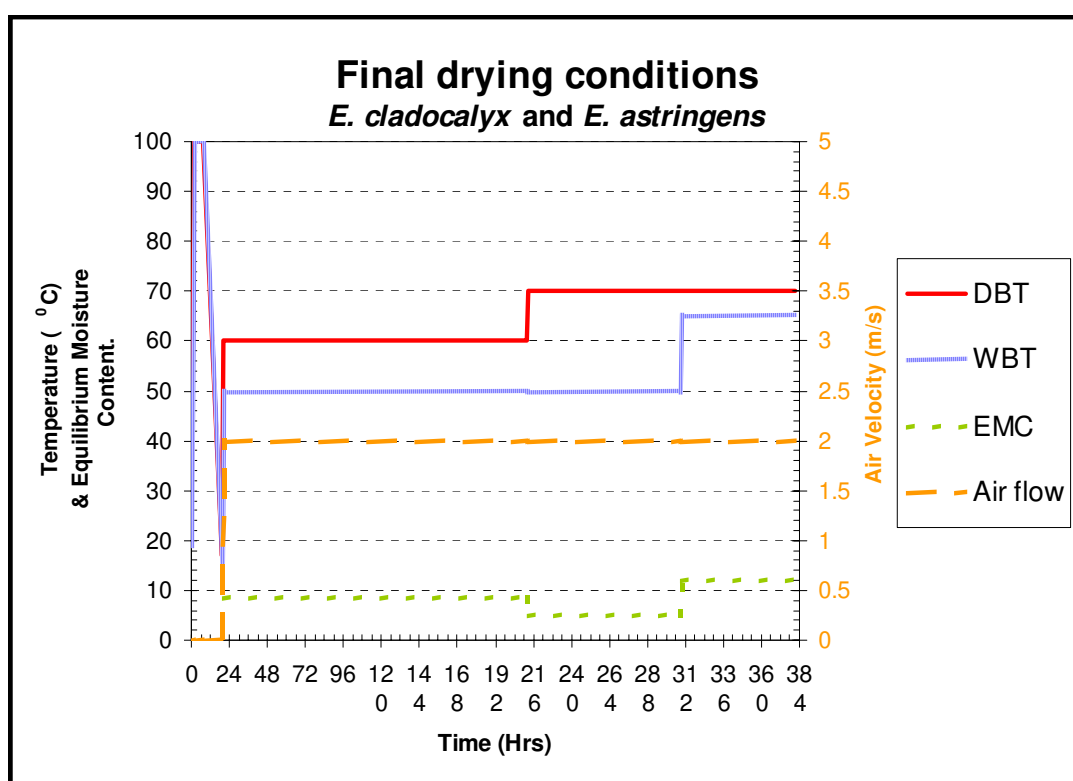


Figure 31 Final drying conditions used for *E. cladocalyx* and *E. astringens*.

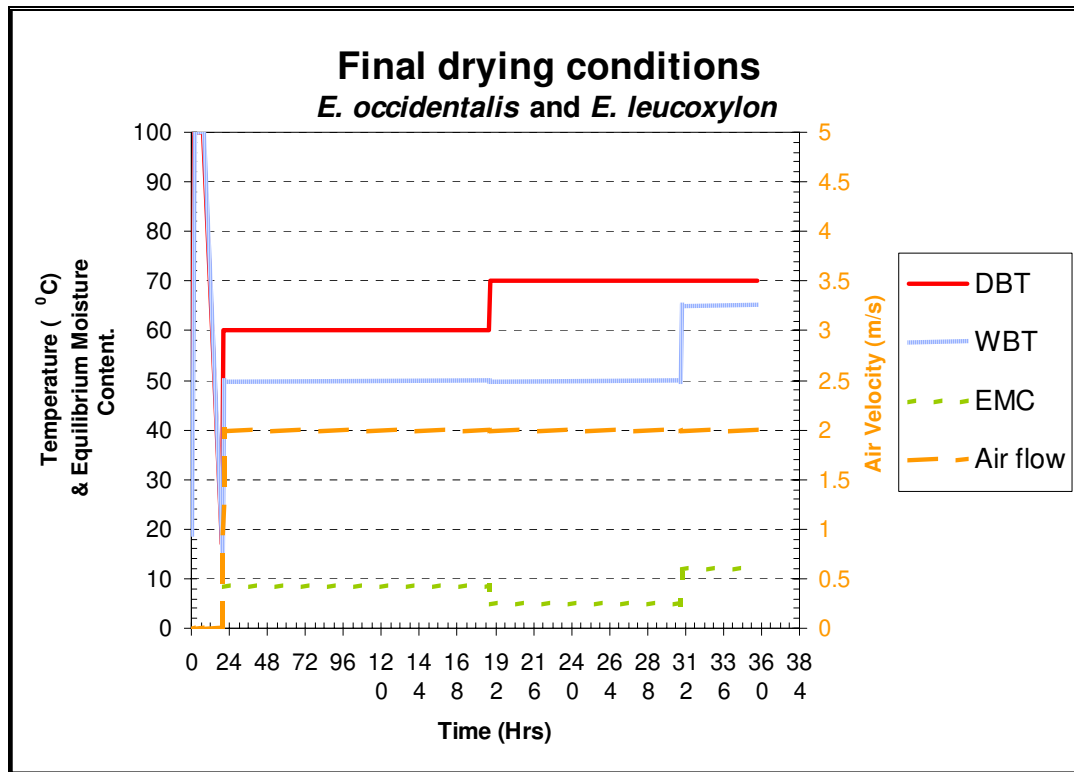


Figure 32 Final drying conditions used for *E. occidentalis* and *E. leucoxylon*.

5.5.6 Monitoring of Drying

5.5.6.1 Sample Boards

Figure 33 plots the mean MC% of the sample boards for each species against time. While *E. cladocalyx* started out with the highest mean MC% it also dried the fastest. The opposite occurred with *E. astringens* which started with the lowest mean MC%, but dried the slowest. The drying rates shown in this figure, partly reflect the inherent drying properties of the species and partly the position of the species in the stack. *E. cladocalyx* was at the top of its stack while *E. astringens* at the bottom of the stack closer to the colder moister air that settles at ground level.

While wrapped in plastic and hessian only minor levels of surface checking toward the ends of the boards occurred. After the hessian was removed, some small fine checks became evident on the 13/10/00, especially in the *E. occidentalis*. New checks continued to be initiated and existing checks lengthened over the next 3 months. Predominately checks occurred on edge boards or boards which came from close to the pith. Whilst the majority of checks remained fine and narrow, it was unclear how deep they went below the surface of the boards, and consequently, how big a problem they would be after machining.

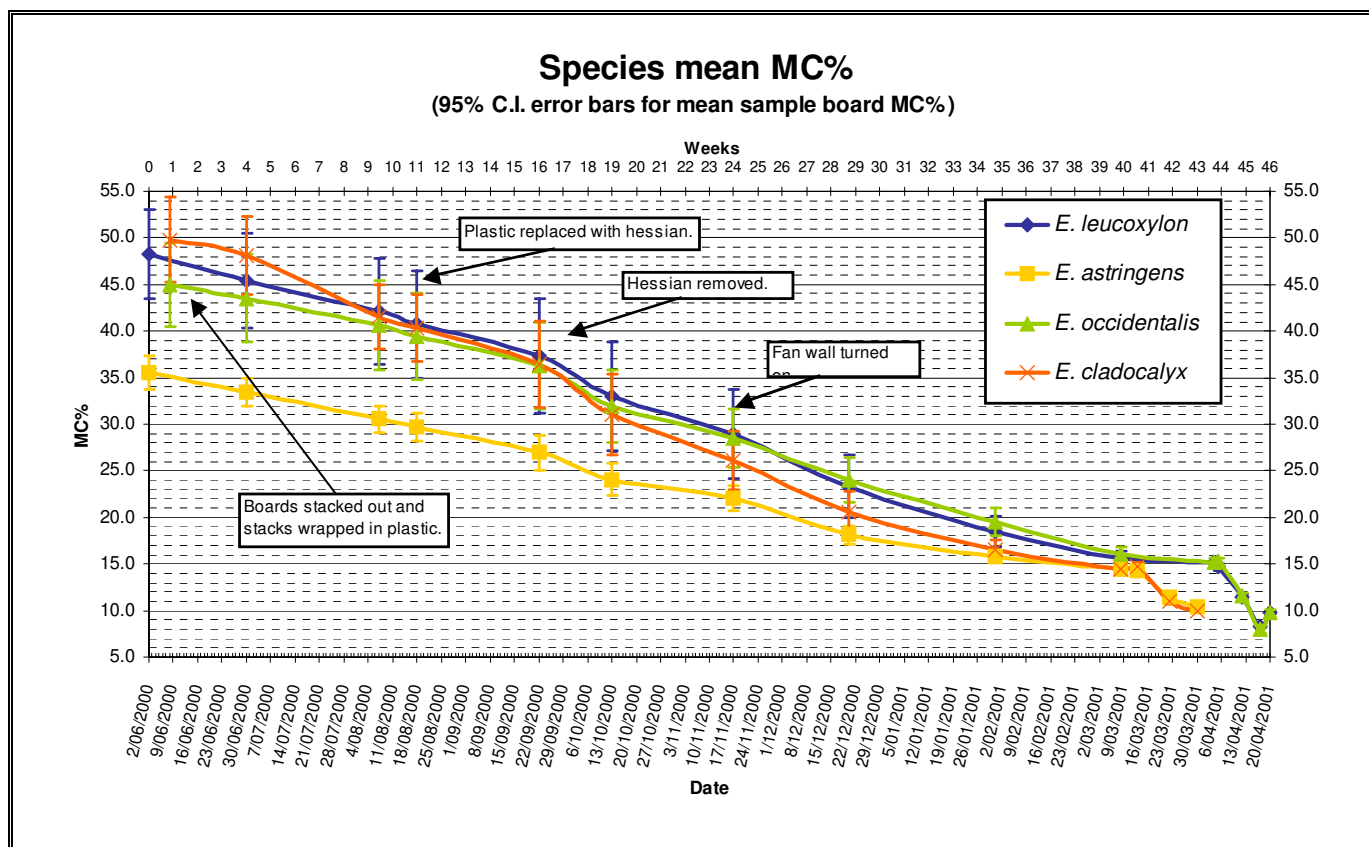


Figure 33 Mean MC% of the sample boards for each species plotted against date.

5.5.6.2 Resistance Moisture Meter

On the 8/3/01, as well as weighing the sample boards, a resistance moisture meter (Delmhorst RC – 1C) was used to measure the surface and core moisture content of both the sample boards and the main boards. Species corrections from the Australian Standard (AS/NZS 1080.1:1997) were applied for *E. leucoxylon* and *E. cladocalyx*. No published species corrections were found for *E. astringens* or *E. occidentalis*, so the corrections for *E. cornuta* (Yate) were used as a best guess approximation. The results of these measurements are summarised in Table 9. These measurements confirmed that the *E. astringens* and *E. cladocalyx* boards were ready for final kiln drying. Because of the handful of wet cores found in the *E. occidentalis* and *E. leucoxylon* boards it was decided that those two species required further air drying. At the completion of the first kiln drying run the wettest layer of *E. leucoxylon* boards and the wettest *E. occidentalis* board was remeasured with the meter to ensure the packs of these species were ready for final kiln drying. Table 9 also shows the results of measurements taken at the completion of final drying to initially check final moisture contents prior to oven dry sections being cut.

Table 9 Electrical moisture meter measurements of surface and core MC% on the 8/3/01

		Assessment at end of air drying.						Assessment at end of kiln drying.			
		8/3/01				4/4/01		3/4/01		20/4/01	
		Sample Board		Main Board		Main Board		Sample Board		Sample Board	
		Surface	Core	Surface	Core	Surface	Core	Surface	Core	Surface	Core
<i>E. leucoxydon</i>	mean	13.3	18.9	12.6	18.8	11.9	16.7			10.9	10.3
	max	15.4	28.0	16.1	35.5	13.9	24.3			12.0	11.6
	min	10.9	13.1	10.1	11.3	9.8	10.9			10.1	9.8
<i>E. astringens</i>	mean	9.4	11.8	9.2	12.4			9.4	9.1		
	max	10.3	14.1	11.0	16.0			9.9	9.5		
	min	8.8	10.3	8.4	9.5			9.1	8.4		
<i>E. occidentalis</i>	mean	10.6	16.2	10.1	16.9					9.3	8.7
	max	12.2	23.2	12.6	30.8	8.8	20.2			9.9	9.5
	min	9.1	11.0	9.1	11.0					8.8	8.0
<i>E. cladocalyx</i>	mean	10.6	14.8	11.5	15.1			10.6	9.5		
	max	13.4	18.8	13.0	19.2			11.8	10.1		
	min	8.9	10.1	9.3	10.9			9.7	8.9		

5.5.6.3 Oven Dry

Upon completion of final kiln drying, oven dry MC% sections were cut from the sample boards and the remainder of the original boards. An additional section from the longer remnant board was cut into layers to check for residual drying stresses and to measure moisture content gradients through the thickness of the board (Figure 34). Table 10 shows the results of these oven dry MC% measurements.

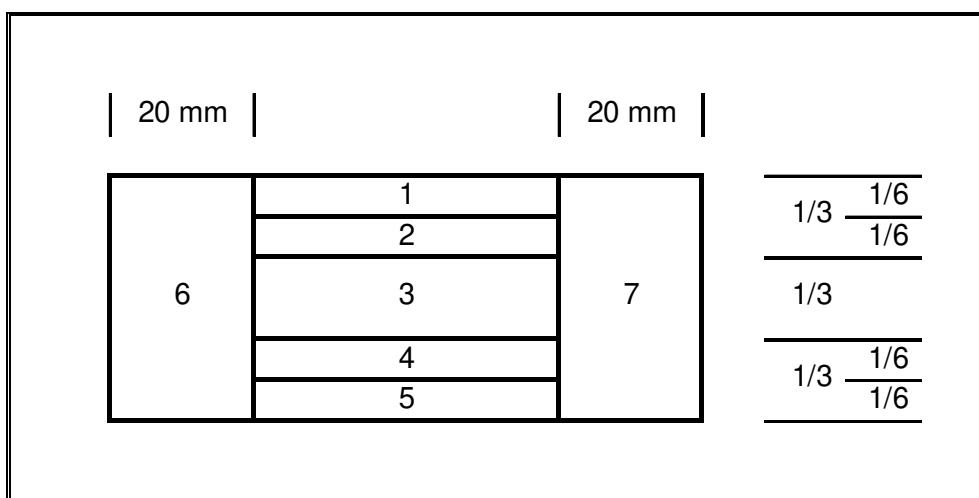


Figure 34 Diagram of sections cut to check for residual stresses and moisture content gradients through the thickness of the boards.

No residual drying stresses were evident in any of the boards and moisture gradients were negligible or at least within acceptable limits. Gradients were noticeable in the second kiln run where the final conditioning must not have been long enough to fully rewet the surface layers. However, as the outer layers of the boards will tend to pick up some moisture while stacked in the shed, restacking the boards in the kiln to extend this conditioning period was not considered necessary.

The MC% of the sections from the sample boards were also used to re-estimate the oven dry weight of the sample boards. The MC% based on these oven dry weights are shown in Figure 33.

Table 10 Oven dry MC% of sections cut at the completion of final drying.

		Sample Board	Main Board	Sections						
				1	2	3	4	5	6	7
<i>E. leucoxylon</i>	mean	9.8	9.8	8.7	9.8	10.1	9.8	9.3	8.8	9.3
	SD	0.23	0.51	0.72	0.64	0.93	0.87	0.41	0.52	0.45
	Max	10.3	10.9	9.4	11.1	12.2	11.8	10.3	9.9	10.2
	Min	9.5	9.3	6.9	9.1	9.1	8.9	8.6	7.9	8.6
	95% CI for values	9.3 - 10.3	8.7 - 11.0	7.1 - 10.3	8.4 - 11.2	8.0 - 12.2	7.9 - 11.7	8.4 - 10.3	7.7 - 10.0	8.3 - 10.3
<i>E. astrigens</i>	mean	10.4	10.3	10.0	10.2	10.3	10.1	10.0	9.9	9.9
	SD	0.14	0.20	0.20	0.39	0.44	0.35	0.17	0.19	0.18
	Max	10.7	10.6	10.3	10.8	10.9	10.8	10.3	10.2	10.2
	Min	10.1	10.0	9.7	9.5	9.6	9.7	9.9	9.7	9.6
	95% CI for values	10.1 - 10.7	9.8 - 10.7	9.6 - 10.5	9.3 - 11.1	9.4 - 11.3	9.3 - 10.9	9.7 - 10.4	9.5 - 10.3	9.6 - 10.3
<i>E. occidentalis</i>	mean	9.7	9.8	8.6	9.9	10.1	9.8	9.2	8.2	9.2
	SD	0.52	0.40	0.37	0.49	0.68	0.59	0.37	0.64	0.42
	Max	10.7	10.4	9.1	10.9	11.4	10.6	9.7	9.0	9.9
	Min	8.8	9.1	8.0	9.1	9.0	8.4	8.6	6.9	8.6
	95% CI for values	8.6 - 10.9	8.9 - 10.7	7.7 - 9.4	8.8 - 11.0	8.6 - 11.7	8.5 - 11.1	8.4 - 10.0	6.8 - 9.7	8.3 - 10.2
<i>E. cladocalyx</i>	mean	10.0	10.0	9.7	9.8	9.8	9.8	9.8	9.7	9.8
	SD	0.16	0.15	0.18	0.30	0.31	0.21	0.11	0.15	0.19
	Max	10.3	10.3	9.9	10.1	10.3	10.2	10.0	10.0	10.1
	Min	9.8	9.8	9.3	9.3	9.4	9.5	9.7	9.5	9.5
	95% CI for values	9.6 - 10.3	9.7 - 10.3	9.3 - 10.1	9.1 - 10.4	9.1 - 10.5	9.3 - 10.3	9.6 - 10.1	9.4 - 10.1	9.3 - 10.2

5.6 Dry Appearance Grading

5.6.1 Machining

Dry boards were square dressed using a four sided moulder to a final dimension of 90 x 35mm at the Timber Industry Training Centre in Creswick. Obvious reject boards were not machined. The dressed boards were regraded using the same grading rules as for the green appearance grading (Section 5.4). The main defect for the non-machined reject boards was also recorded.

5.6.2 Comparison of dry and green appearance grades.

Table 11 shows a comparison of dry and green appearance grades for most of the boards that were dried, this comparison excludes the sample boards. The table shows the numbers and percentages of boards that have improved, remained the same or worsened after drying and machining.

There are numerous reasons why dry board grades differ from the corresponding green grades. The most obvious being drying degrade; such as surface checking, internal checking and distortion, which will be discussed further in the following section (5.6.3). Machining is the other important factor as it changes the exposure of defects on the surface of boards. Some defects can be reduced or even removed, as might be the case with small green epicormic knots. In other cases, the opposite may occur for the same reason. Having a smooth machined surface also makes it easier to judge the extent of some defects. This is especially true in the case of discoloration or stain. For example, one of the *E. occidentalis* boards that was originally graded reject in its green state was re-graded as polish when after machining it became clear that the substantial amount of decay at one end was limited to that end and no discoloration extended into the remaining short length (1.8m long) of polish grade clear-wood as appeared to be the case when grading the board green. As the severity of a number of defects are assessed relative to the dimension of the face being graded, narrowing that dimension can also potential worsen the grade of a board, even if the size of the defect doesn't change.

With all of the species except *E. leucoxydon* a higher percentage of boards were of a lower grade after drying and machining than had improved their grade. Interpretation at a species level though, needs to be undertaken cautiously as the changes in grades are dependant on the original distribution of grades. For species which had a high percentage of lower grade boards there is more scope for boards being upgraded and vice versa.

Table 11 Change in appearance grade from green grading. Numbers in **shaded** cells show the number of boards that were the same when graded both green and dry. **Hatched** cells, to the left in the same row, show boards that have a better grade dry than green. **Light shaded** cells, to the right in the same row, show boards that have a lower grade dry than when green.

Species	Green Appearance Grade	Dry Grade							Green Total	% of boards that		
		Polish	Select	Standard	Utility	Cover	Pallet	Reject		Improved	Remained same	worsened
<i>E. cladocalyx</i>	Select					1			1 (2%)	0	0	100
	Utility					2			2 (4%)	0	0	100
	Cover			1	5	5	9	3	23 (51%)	26	22	52
	Pallet		1		1	1	1	9	13 (29%)	23	8	69
	Reject						1	5	6 (13%)	17	83	0
	Dry Total	0 (0%)	1 (2%)	1 (2%)	6 (13%)	9 (20%)	11 (24%)	17 (38%)	45 (100%)	22	24	53
<i>E. astringens</i>	Select		6	1	2	4	1	1	15 (23%)	0	40	60
	Standard		2	1		1	1		5 (8%)	40	20	40
	Utility		1			1			2 (3%)	50	0	50
	Cover		7	1	1	5	3	6	23 (36%)	39	22	39
	Pallet		2		1	2		7	12 (19%)	42	0	58
	Reject							7	7 (11%)	0	100	0
	Dry Total	0 (0%)	18 (28%)	3 (5%)	4 (6%)	13 (20%)	5 (8%)	21 (33%)	64 (100%)	27	30	44
<i>E. leucoxydon</i>	Select		1		1	1			3 (6%)	0	33	67
	Standard		1			1			2 (4%)	50	0	50
	Cover	1	5			3	2	2	13 (24%)	46	23	31
	Pallet		2	2		4	4	6	18 (33%)	44	22	33
	Reject						2	16	18 (33%)	11	89	0
	Dry Total	1 (2%)	9 (17%)	2 (4%)	1 (2%)	9 (17%)	8 (15%)	24 (44%)	54 (100%)	31	44	24
<i>E. occidentalis</i>	Polish	1	3						4 (5%)	0	25	75
	Select	3	6		3	1			13 (15%)	23	46	31
	Standard					2	1		3 (3%)	0	0	100
	Utility	1			1	2	1		5 (6%)	20	20	60
	Cover		1		2	3	3	2	11 (13%)	27	27	45
	Pallet		3		2	2	9	12	28 (32%)	25	32	43
	Reject	1	1				2	20	24 (27%)	17	83	0
	Dry Total	6 (7%)	14 (16%)	0 (0%)	8 (9%)	10 (11%)	16 (18%)	34 (39%)	88 (100%)	20	45	34
Combined	Polish	1	3						4 (2%)	0	25	75
	Select	3	13	1	6	7	1	1	32 (13%)	9	41	50
	Standard		3	1		4	2		10 (4%)	30	10	60
	Utility	1	1		1	5	1		9 (4%)	22	11	67
	Cover	1	13	2	8	16	17	13	70 (28%)	34	23	43
	Pallet		8	2	4	9	14	34	71 (28%)	32	20	48
	Reject	1	1				5	48	55 (22%)	13	87	0
Dry Total		7 (3%)	42 (17%)	6 (2%)	19 (8%)	41 (16%)	40 (16%)	96 (38%)	251 (100%)	25	37	38

5.6.3 Drying Degrade

Cutting the moisture content sections out of the sample boards revealed only 2 or 3 boards with any internal checks. In all of these cases, the checks were restricted to either material from close to the pith or within localised areas of unusual growth ring patterns. Distortion was a minimal problem with mostly isolated occurrences of spring being noted.

Despite the conservative drying conditions some fine surface checking was apparent amongst the boards of all species. Table 12 shows how surface checking would have limited the grades of the boards in the absence of other defects. About 75% of boards had no surface checking while the majority of boards with surface checks would have still met the select to utility grade descriptions. Overall, surface checking was the grade-limiting defect for about 12% of the boards. *E. cladocalyx* had the worst instances of surface checking, but they were almost never the grade limiting defect. This probably related to the high percentage of *E. cladocalyx* boards with pith and green knots in them (Figure 21) due to the smaller diameter logs. The pith or inner heartwood material was more likely to check, but the boards were low grade because of the pith or knotty corewood; hence the checking was not the grade limiting defect. *E. leucoxylon* had the lowest incidences of surface checking with 93% of the boards being check free.

Table 12 Shows the percentage of boards that would have been limited by surface checks if all other defects were 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	%
<i>E. cladocalyx</i>	67%	6%	0%	28%	0%	54	2	4
<i>E. astringens</i>	70%	18%	0%	12%	0%	74	14	19
<i>E. leucoxylon</i>	93%	5%	2%	0%	0%	59	3	5
<i>E. occidentalis</i>	69%	12%	1%	13%	4%	98	14	14
Combined	74%	11%	1%	13%	1%	100%	33	12
Count	211	31	2	37	4	285		

6 Conclusions

6.1 Inherent defects

The recovery of appearance products from the 4 species sampled was poor compared with the recoveries from other species in a similar study by Washusen *et al* (1996). The main inherent defects which contributed to the poor recoveries included decay, green knots, dead knots and pith. The impact of these defects was significant in limiting 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. With the exception of *E. occidentalis* however, the impact of these defects was partially related to the smaller diameter logs sampled in this study.

This study highlights the importance of good plantation management and silviculture and programs such as the ALRTIG to provide high quality seed and growing information for the various site conditions encountered in this region.

Improved stem form and branching characteristics should dramatically reduce the decay problems identified in this study, particularly the high levels that were encountered with *E. occidentalis*. Fortunately, early provenance testing with this species already suggests that significant form and crown break improvements should be readily achieved through appropriate selection (Chris Harwood¹, 2000 pers. comm.). Wide final spacings (<10m) and mechanical pruning are also likely to be important for growing large diameter logs in a reasonable rotation period for high value appearance products.

6.2 Drying characteristics

No established drying schedules existed for any of these species (Rozsa and Mills, 1991 in Anonymous, 1997). To ensure minimal drying degrade, a conservative and lengthy (<320 days) air drying regime was used. Despite this, surface checking still occurred in all species, although, internal checking and distortion problems were negligible. In most cases the surface checks appeared fine, long and deep. Some of the surface checks were removed in the machining process, but about 15% of the boards would still have been limited to below select grade in the absence of other defects. In other words, 85% of the boards would have made select grade or better.

As expected for slow growing hardwoods the wood of each species was dense (mean basic densities in the range of 760 -800 kg/m³) with low initial MC% (mean values ranging from 35 – 50%). Despite the problems with surface checks noted above, it is felt that pre-drying could be used to bring the drying time for 43mm back sawn boards to between 60-120 days with acceptable levels of surface checking. This is partly based on the previous experience with drying from green of the species (including *E. cladocalyx*) evaluated in the Washusen *et al* (1996) study. Drying problems and times should also be significantly less in drying thinner dimension products. Hopefully, being high density the wood should be high strength allowing finer sections to be used in applications like furniture and subsequently allowing thinner dimensions to be dried. Ozarska and Ashley (1998) found that for *E. cladocalyx* at least, the strength of 40 y.o. plantation grown material was equivalent to the high strength of mature wood, if slightly more variable.

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6.3 Implications of results

The poor recoveries achieved in this study highlight the difficulties of growing trees in this region for high-value appearance grade products. The recoveries from these unmanaged plantations are clearly too low to economically base an industry for producing high-value solid wood products. To establish such an industry in this zone, improved seed source and silviculture that grows large high-quality sawlogs will be critical. Given the expected long rotations, the economics of growing high value sawlogs are at best always going to be marginal and will depend on land management benefits. Lower land prices in the low rainfall zone should help. It is estimated that a viable sawing industry based on this 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 this, trees will probably need to be at least 40 cm DBH to maximise the volume of clear outer heartwood. Recent work suggests that it should be possible to recover 35% of log volume as polish and moulding grades from large diameter pruned trees, providing that drying degrade can be limited. The ability to cut out defects and produce shorter length boards, if a market exists, should also help achieve these sorts of recovery figures.

Despite the very poor result in this study, *E. cladocalyx* still shows the best potential in the lower rainfall zone as it had comparatively good growth rates in the region and recoveries from older larger trees were promising (Washusen *et al*, 1996). However, careful drying practices will be required to minimise surface checking degrade. The drying degrade from the young small diameter logs in this study was worse than for boards from the older larger logs of the other species in that it had the highest proportion of boards that would have been limited to below select grade because of surface checks in the absence of other defects.

The potential of *E. occidentalis* and *E. astringens* follow closely behind that of *E. cladocalyx*, providing that poor form and branching characteristics can be significantly improved. Again, because of the high densities and low permeabilities careful drying practices will be required to minimise drying degrade. *E. leucoxylon* would appear to have little potential for high-value solid wood products and might only be considered on sites unsuitable for the other species. Significant form improvements would be required. In its favour though, the timber did have the least difficulties with surface checking during drying.

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