



Vineyard Posts from Eucalypts Grown on Effluent Water

**A report for the RIRDC/Land & Water
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Foreword

The rapid expansion in eucalypt plantations has created a need to find new uses for the thinnings being generated through forest management. Some of those plantations are being grown to utilise effluent water so they may be harvested regularly to maximise wastewater uptake by young trees.

A number of the plantations are located in wine growing districts where there is high demand for vineyard posts. The posts most commonly used are copper-chromium-arsenic (CCA)-treated and creosote-treated pine, which at times are in short supply.

This publication investigates the use as vineyard trellis posts of thinnings from plantations of *Eucalyptus grandis*, *E. globulus* and *E. camaldulensis* grown on effluent water. The posts were treated with a safer creosote formulation called pigment emulsified creosote. This report also provides information on post strength, which is of major interest to grape growers due to the high cost of replacing posts broken during mechanical harvesting. A selection of posts has been installed at a winery in Mildura as demonstration to the industry.

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Our thanks are also due to Robert Kempton of Southcorp Wines Pty Ltd, for the demonstration site and installation of posts at their Karadoc (Lindemans) winery near Mildura. Our thanks are also due to Paul McClure, a grapegrower of Irymple South near Mildura who has installed 50 posts on his property.

Abbreviations

CCA =	copper chromium arsenic
HTC =	high temperature creosote or standard creosote
PEC =	pigment emulsified creosote
H4 =	hazard level four (in-ground exposure)
% m/m =	percent mass/mass

Contents

Foreword	iii
Acknowledgements	iv
Abbreviations.....	iv
Executive Summary.....	vi
1. Introduction.....	1
2. Objectives	4
3. Methods.....	5
3.1 Selection, Harvesting, Debarking and Drying	5
3.1.1 Selection of trees	5
3.1.2 Harvesting and debarking	5
3.1.3 Stacking and drying.....	6
3.2 Preservative Treatment	9
3.3 Bending Strength and Post Form	11
3.3.1 Strength tests	11
3.3.2 Evaluation of surface defects	11
4. Results.....	13
4.1 Selection, Harvesting, Debarking and Drying	13
4.1.1 Selection of trees	13
4.1.2 Harvesting and Debarking.....	14
4.2 Preservative Treatment	15
4.3 Bending Strength and Post Form	17
4.3.1 Strength tests	17
4.3.2 Evaluation of surface defects	19
4.4 Post Installation	20
5. Discussion	23
6. Implications.....	25
7. Recommendations	26
8. Appendix	27
9. References	33

Executive Summary

A number of eucalypt woodlots in the Mallee region and other areas of Victoria and New South Wales have been established to utilise industrial wastewater, treated sewage effluent or irrigation drainage water. These woodlots are grown for the safe disposal of wastewater, which would otherwise cause environmental degradation and water pollution. They have often been planted in wine growing regions, and as the wine industry continues to grow, the plantations could be used to supply posts to the local industry for use in grapevine trellises.

To test the suitability of eucalypt species as trellis posts, a number of trees from each species of *Eucalyptus grandis*, *E. globulus* and *E. camaldulensis*, fitting the diameter range for in-line posts, were harvested. Posts were seasoned by air-drying, and transported to Grafton for treatment with pigment emulsified creosote (PEC). Samples of treated posts were strength tested and examined for preservative penetration. The remaining posts were installed at several locations to demonstrate the product.

The key events and results were:

- Trees from eucalypt plantations can be successfully converted into vineyard posts. In the areas examined: Three-year old *E. grandis* from Deniliquin yielded the highest volume of posts with 60% of trees useful for this purpose. In comparison, five-year old *E. globulus* from Shepparton had 20% of trees suitable for posts, and seven year-old *E. camaldulensis* from Mildura had only 5% of trees suitable.
- Hand debarking the *E. grandis* and *E. globulus* posts was relatively easy, while debarking of the drier-site *E. camaldulensis* posts was laborious.
- The posts were slowly air dried under cover to reduce splitting and checking.
- A successful large-scale treatment trial on *E. grandis*, *E. globulus* and *E. camaldulensis* posts was conducted at Koppers Timber Preservation Pty Ltd in Grafton using PEC. Posts were treated with PEC and compared to the requirements of the current Australian Standard AS1604.1 2000.
- In all posts complete depth of sapwood penetration of PEC was visible. Sapwood accounted for a mean of 82-89% of the total volume of the trellis posts. Therefore, failure to treat the heartwood is of minor concern.
- *E. grandis* posts absorbed most PEC, with a mean retention of 33.2 % m/m creosote component. This value is well above the minimum H4 requirement of 10 % m/m creosote, suggesting there is scope for reducing the treatment cycle for *E. grandis* posts.
- *E. globulus* posts absorbed least creosote, with a mean retention of 15.4 % m/m. Five out of 30 posts were below the minimum requirement. However, a longer treatment cycle is likely to rectify this result.
- *E. camaldulensis* posts absorbed the appropriate amount of creosote with the treatment schedule employed.
- After treatment and air drying in bundles for three months, the surface condition of the PEC-treated posts appeared dry with little or no greasiness. The amount of surface affected by exudate (crud) was restricted to the edges of large checks and splits on a few *E. camaldulensis* posts.

- The mean bending strength of PEC-treated *E. globulus* posts was significantly higher than for the CCA- and creosote-treated pine posts and the two other eucalypt species. All eucalypt species tested were stronger than CCA-treated pine posts.
- Assessment of surface defects showed that no eucalypt post was rejected because of unacceptable knots; however, 10% of *E. camaldulensis* and 7% of *E. globulus* posts were rejected due to unacceptable splits. Posts made of *E. grandis* were uniform with no rejections arising from splitting.
- A demonstration site has been established at the Southcorp Wines Pty Ltd winery (Lindemans), Karadoc near Mildura. About 50 posts are also installed at a grower's property at Irymple South near Mildura. More posts are also in the process of being installed at this property. In addition 40 posts were taken to the Mildura Wastewater Treatment and Reuse Centre and installed as fencing in areas under flood irrigation with treated wastewater.
- Experienced post driving contractors who installed a set of posts at the demonstration site at Southcorp (Lindemans) winery described a number of advantages with the posts. They felt that manual handling of the PEC-treated posts was easier and safer than with creosote-treated pine posts, and that vapour emissions were reduced.
- From this study, *E. grandis* should be the preferred crop for producing commercial vineyard posts from plantations grown on effluent water. The plantations could be harvested within three years, and the majority of trees should be straight enough to yield posts. The species also suffered least from splitting (although it should be noted that pole-sized timbers of *E. grandis* have a reputation for excessive splitting). The sapwood was readily treatable, and indeed the treatment schedule used resulted in over-treatment. Therefore, shorter treatment times than the schedule employed should be possible.
- Plantations of the remaining species, *E. globulus* and *E. camaldulensis*, could also be used to produce posts. However, production would need to be coupled with alternative markets as well, such as wood pulp production for those trees not straight. Selection for provenances or silvicultural practices that yield a higher proportion of posts for these species could also be examined.
- The prime concern at wastewater treatment plants is to rapidly remove (transpire) wastewater. Therefore, the entire crop of *E. grandis* could be cleared for vineyard post production and a new plantation established to maintain a young vigorous crop that removes water efficiently.
- While we consider PEC to be the best preservative for eucalypt posts (based on resistance to soft rot, and resistance to checking), the commercial treatment plant is in Grafton, NSW. Transportation of posts to and from Grafton from the plantation sites examined is unlikely to be a commercial option.
- Immediate commercialisation of the results could occur if forestry organisations near Grafton treated their thinnings as vineyard posts. Posts could then be sold to the Hunter Valley or adjacent wineries to test market acceptance. The experience gained could be used to determine the feasibility of building a PEC treatment plant in the Sunraysia district.

1. Introduction

The Australian wine industry goes through periods of rapid expansion and consolidation. A major infrastructural component in vineyards is the trellis post, needed to support the growing vine. At times, the most frequently used 75-100 mm diameter posts have been in short supply due to the large number of new vineyard plantings and redevelopment. There is also a constant demand for replacement posts. The average life of a vineyard is between 25 and 35 years due to continuous improvement such as replanting with new grape varieties and replacing old trellis systems with improved ones. Old posts are generally not suitable for re-use. Also, a significant number of posts (as high as 15%) require annual replacement due mainly to breakage by mechanical harvesters (Figure 1), some fungal decay (Figure 2), and occasionally, wind damage.

Typically 500-800 posts per hectare of the preferred size are used as in-line posts for new and redevelopment vineyards. Australian vineyards require the construction of about 25,000-km of trellis using about 5.5 million posts per year. This places the market in the order of \$33 million per year. Australian vineyard posts produced today are 70% copper-chromium-arsenic (CCA)-treated *Pinus radiata* and 25% *Pinus radiata* treated with creosote. CCA is the world's best known and most widely used water-borne preservative while creosote, manufactured from coal tars, is the most well known member of the oil-borne preservatives. Treatment of small diameter posts is necessary to protect the sapwood from biodeterioration, as the sapwood of all species is non-durable. A small percentage of posts (less than 1%) are untreated cypress pine, however, as the sapwood of this species is also non-durable, problems from decay have been experienced except in those posts that have been selected for high heartwood content.

During periods of high demand for timber posts, growers and manufacturers have been forced to look for alternatives such as steel, concrete, recycled plastics etc. There is also an interest in using posts stronger than CCA-treated pine, so as to reduce damage during harvesting. While a new trellis post costs in the order of \$6-7 each, the cost of replacing a broken post within an established vineyard can range from \$30 to \$100 each. While posts should be strong, they should also not be excessively large in diameter, otherwise some grape bunches may be missed by the harvester if they lay within the 'shadow' of the post during harvesting.

Potential new sources of vineyard posts (and fence posts) are from the rapidly expanding eucalypt plantations being grown to reduce salinity, for carbon credits, wood pulp, and timber supply. In the Mallee region and other areas of Victoria and New South Wales a number of woodlots of various eucalypt species are being grown to utilise industrial wastewater, treated sewage effluent or irrigation drainage water (Figure 3). These woodlots are grown for the safe disposal of wastewater, which would otherwise cause environmental degradation and water pollution. They have often been planted in wine growing regions, and as the wine industry continues to grow they could be used to supply treated posts to the local industry for use in grapevine trellises. Young fast grown eucalypts need to be treated with preservative before they are suitable for this application.

The aim of this project was to research and demonstrate the potential for wood preservation treatment of eucalypts grown with effluent water and their subsequent use as vineyard trellis posts. The main plantation species in the Sunraysia region examined were *Eucalyptus grandis*, *E. globulus* and *E. camaldulensis*. Both trellis and strainer posts were produced.

In this project, the preservative chosen for treatment was pigment emulsified creosote (PEC), a cleaner creosote-based preservative. It was developed by CSIRO and Koppers Australia (now Koppers Timber Preservation Pty Ltd) (Greaves et al., 1986). PEC is a highly stable emulsion of creosote and is capable of withstanding much of the stressing that a preservative undergoes during its use for vacuum pressure impregnation of timber. PEC is less suited to hot and cold bath treatments (Brennan et al., 1996). It contains creosote, water, emulsifiers, stabilisers and a micronised pigment.

The pigment, which is dispersed through both the oil and water phases of the emulsion, locks the creosote component into the wood structure. In comparison, creosote (HTC) more often bleeds or exudes to the surface of the treated commodity. On the wood surface, some creosote components oxidise and/or polymerise to form pitch-like deposits known in the industry as 'crud'. PEC is most suited to hardwoods and is used to reduce crud and vapour emissions. This treatment would be desirable in vineyard trellis where the mechanical arms of harvesting equipment can become contaminated by exudates on the posts. PEC was also chosen instead of CCA, as CCA-treated timber can be susceptible to weathering, giving rise to checks, splits and dimensional changes. As some species of young eucalypt have a tendency to split, it was thought that the highest chance of producing suitable posts would be with PEC. A disadvantage is that there is only one commercial PEC plant, at Grafton, while there are about 130 CCA plants around the country.

There are many aspects to consider in determining the commercial viability of producing vineyard posts from eucalypts such as how best to harvest, debark, season, and transport posts. However, these aspects were outside the scope and resources of this project.

This report describes the harvesting, debarking, and drying of approximately 850 posts from three eucalypt species (*E. grandis*, *E. camaldulensis* and *E. globulus*) from Deniliquin, Mildura and Shepparton. After PEC treatment, a sample of posts was strength tested, and the remainder installed in vineyards for demonstration purposes.



Figure 1. A trellis post broken by a mechanical harvester.



Figure 2. Fungal decay is one of the reasons for post replacement.



Figure 3. Woodlot at Shepparton Wastewater Treatment Complex. Outer row is *E. grandis*, and inner rows are *E. globulus*.

2. Objectives

The objectives of this project were:

- To examine the potential of producing vineyard posts from eucalypt plantations grown to utilise sewage and winery effluent.
- Locate plantations and woodlots near Mildura and Benalla and assess whether they are suitable for the production of vineyard trellis posts.
- Carry out a large-scale trial with a major manufacturer of PEC-treated timbers to provide information on the treatability of the eucalypt species.
- Investigate strength and load-carrying capacity of treated round timbers as vineyard trellis posts. Particularly seek to identify advantages that eucalypt posts may have over competitors.
- To evaluate surface defects of eucalypt posts, in terms of splits and knots.
- Establish test/demonstration sites in wine growing regions to assist in the assessment and marketing of eucalypt posts.
- Provide local woodlot growers with information regarding tree species and quality requirements to assist planning and adoption of the most suitable silvicultural techniques for round timber production.

3. Methods

3.1 Selection, Harvesting, Debarking and Drying

3.1.1 Selection of trees

Trees were selected from *E. camaldulensis* woodlots in the Sunraysia\Riverland region of northwest Victoria (Mildura), *E. globulus* and *E. grandis* woodlots in northern Victoria (Shepparton) and an *E. grandis* woodlot in the Murray Riverina region of southern New South Wales (Deniliquin). Plantations were chosen on the basis that trees were of suitable diameter, rather than of the same age group.

Posts 2.7 metres in length and ranging in small end diameter from 75-100 mm were required as trellis posts. Approximately 260 posts of each species were needed. An additional 40 posts 3.0 metre in length and ranging in small end diameter from 125-150 mm were required as strainer posts. Both post types were cut 0.3 metres longer than required. The extra length was to give the opportunity to cut off split ends prior to preservative treatment if needed.

Trees fitting the diameter ranges above were marked with fluorescent paint and recorded on to a data sheet. It was important that trees selected were straight and free of major defects for the required length. The breast height diameter over-bark of each tree was measured and recorded on to the data sheets.

3.1.2 Harvesting and debarking

The marked trees were felled using a chainsaw and then docked to the required post length. Any branches were removed either by chainsaw or axe. The posts were then marked with an aluminium identification tag. Each identification tag contained the tree species (G, C or L for *E. grandis*, *E. camaldulensis* and *E. globulus* respectively), tree number and post number. The tree number and post number can differ as more than one post could be cut from some trees. If the post was a strainer an "S" was marked alongside the species code. The tag was nailed to the small end of each post. The contents of each tag were recorded on to the data sheet. The posts were then debarked by hand after bruising with the back of an axe (Figure 4). Mechanical harvesters and debarkers were not available to the project at the time.



Figure 4. Debarking an *E. grandis* trellis post

3.1.3 Stacking and drying

The posts were removed from the woodlots as soon as possible after debarking using a tractor and trailer. All posts were slow air-dried to minimise splitting and checking prior to preservative treatment.

E. grandis

The strainer posts harvested at Shepparton were removed from the woodlot and stacked in a pile nearby. Two large polytarps were used to cover the posts. Two weeks after harvesting the posts were transported to Benalla, where they were stacked under cover in an old shearing shed. Parts of the shed were open to the outside allowing sufficient air to circulate. Trellis posts harvested at Deniliquin were removed from the plantation immediately after being debarked. They were taken to a large machinery shed on the property, which had a back wall and side walls, while the front was open. The posts were stacked into two piles, with each row of posts perpendicular to the previous one (Figure 5). The stacks were then covered with hessian to further slow drying.



Figure 5. Cross-stacking *E. grandis* trellis posts.

E. camaldulensis

These posts were removed from the woodlots and stacked in two piles under cover in a small machinery shed on the complex. The shed had front and back walls but no side walls, thus sufficient air could circulate to promote drying. Hessian was used to slow drying.

E. globulus

The posts were removed from the woodlot and stacked into two piles just beside a nearby service road. As no suitable sheds were available on the treatment complex, a simple roofed structure with no walls was erected. Once again hessian covered the piles in an attempt to slow the drying process (Figure 6).



Figure 6. *E. globulus* strainer and trellis posts covered with hessian to slow drying

3.2 Preservative Treatment

After three months air drying, the posts were checked for moisture content at approximately half sapwood depth using a moisture meter. All posts sampled had dried below fibre saturation point and averaged around 12% moisture content. The posts were then transported to Koppers Timber Preservation Pty Ltd, Grafton, NSW. This is the only plant in Australia carrying out pressure treatment of timber using PEC. Prior to treatment a random sample of 30 posts of each species was weighed, and their outside and heartwood diameters at both ends measured along with their overall length (Appendix). The heartwood/sapwood boundary was found by brushing the cut ends with dimethyl yellow (warning: possible carcinogen) pH indicator. The measurements at each end were averaged in order to calculate the treatable volume as accurately as possible.

The posts were loaded in strapped bundles on to bogies and transported into the cylinder on August 26th 1999 (Figure 7). In order to achieve full sapwood penetration and minimum preservative retention requirements of Australian Standard AS 1604.1-2000 the following treatment cycle was used:

Initial vacuum at -90 kPa for 30 minutes,
hydraulic pressure at 1400 kPa for 180 minutes,
and final vacuum at -90 kPa for 60 minutes.

All 940 posts were treated in the one charge (charge included some posts additional to this project). The posts were removed from the cylinder (Figure 8) and the random sample of 30 posts of each species weighed the next morning, after hot fumes had dissipated, to determine the PEC and creosote-equivalent preservative retentions. Another reason for weighing posts the next morning is that it is more accurate to weigh posts at a similar temperature to their pre-treatment weighing. However, uptake of PEC may have been slightly underestimated due to some small reduction in mass overnight from surface evaporation of PEC. The raw data for each post is presented in the Appendix.



Figure 7. Untreated vineyard posts being loaded into the treatment cylinder at Koppers, Grafton



Figure 8. PEC-treated vineyard posts just after treatment

After impregnation with PEC, the treated posts were allowed to air dry in bundles in the Koppers exposure yard before being transported to Southcorp (Lindemans) winery, Karadoc, Mildura on October 6th 1999. At the Southcorp winery, the majority of posts remained in bundles to dry further until installation in May 2000. The random sample of 30 posts of each species was collected from Southcorp winery during October 1999 and taken to the Sunraysia Horticultural Centre for strength testing and evaluation of surface defects. The strength test measured the peak pulling force at breakage. The surface defects in terms of knots and splits of each post were also assessed using an ISO 9002 Work Procedure Manual of a post manufacturer.

After strength testing, the broken posts were sent to CSIRO for assessment of surface quality, preservative penetration patterns, and calculation of creosote retentions.

Cutting of PEC-treated timber at ambient temperature will mobilise the preservative. Smearing and bleeding of creosote on the cut surfaces will give an incorrect visual impression of the penetration and distribution of creosote. For example, the mobility of creosote over the heartwood face may give the impression that it has been treated. In an attempt to overcome this problem, all posts were first stored in a freezer for three weeks. The posts were then cross-sectioned with a bandsaw and a photograph of the penetration and distribution of PEC on the freshly cut surface taken as soon as possible after being cut.

3.3 Bending Strength and Post Form

3.3.1 *Strength tests*

After impregnation the posts were air dried in bundles. The sample posts being analysed in detail were removed from the bundles two months after treatment and evaluated for strength at the Sunraysia Horticultural Centre (SHC). The remaining posts were/will be installed in vineyard and fencing trials.

Posts were strength tested using a cantilever method that most closely simulates actual service conditions or forces placed on a vineyard post. A portable test rig was used with a fixed bed rig (post clamping facility installed in concrete) to measure the strength of individual posts. A chain equipped with a STC load cell, and connected to the hydraulic cylinder of the portable rig, applied horizontal pull (Figure 9). The post to be tested was placed at a depth of 0.6 m in the fixed bed rig and held firmly by the clamp. The portable rig was placed against the concrete bed and the end of the chain was tied to the post at 1.5 m above the clamp of the fixed bed rig. The hydraulic cylinder was activated through a tractor hydraulic system to apply the pull, which gradually increased until the post broke. The STC load cell in association with a digital indicator measured the peak pulling force at post breakage.

Before strength testing, the circumference of each post was measured at 600 mm from the thick end to calculate the diameter of the post at clamp. The diameter and breaking force were used in the calculation of bending strength.

3.3.2 *Evaluation of surface defects*

Surface defects, in terms of splits and knots, were evaluated for each post before strength testing. The ISO 9002 Work Procedures Manual of a vineyard trellis post manufacturer (Auspine Limited 1996) was followed to evaluate surface defects. Some of the grade description provided in the manual follows:

- Diameter of an individual knot shall not exceed 12.5% of post circumference at knot.
- Diameter of all knots over 150 mm length shall not exceed 50% of post circumference.
- Change in diameter due to presence of knot whorl shall not exceed 10 mm.
- No single end split shall exceed 8 mm width and the sum of the widths shall not exceed 19 mm.



Figure 9. A post being strength tested.

4. Results

4.1 Selection, Harvesting, Debarking and Drying

4.1.1 Selection of trees

E. grandis

Trellis posts were cut on 17 November 1998 from an irrigated eucalypt plantation situated on a farm northeast of Deniliquin. The trees were three years old. Trees of the required diameter and properties were easy to locate and a total of 280 posts were cut from 238 trees. Approximately 60% of trees looked at were marked as appearing straight enough to yield posts.

Strainer posts were obtained on 10 November 1998 from an irrigated woodlot situated at the Shepparton Wastewater Treatment Complex in northern Victoria. The trees were five years old. Trees of the required diameter and properties were easy to find in the woodlot and a total of 59 posts were cut from 44 trees felled. Once again around 60% of the trees in the plantation were useful.

E. camaldulensis

Both trellis and strainer posts were cut on 18 January 1999 from a number of woodlots at the Lower Murray Water Treatment Complex in Mildura. The trees were seven years old. Trees of the required properties were difficult to locate. Most trees were not straight enough to be of any use. Only 5% of all trees looked at on the complex were marked as useful (Figure 10). A total of 42 strainer posts were cut from 39 trees while 205 trellis posts were cut from 175 trees.



Figure 10. *E. camaldulensis* woodlot at the Lower Murray Water Treatment Complex in Mildura.

E. globulus

Strainer and trellis posts were cut on 22 January 1999 from an irrigated woodlot also situated at the Shepparton Wastewater Treatment Complex (Figure 11). The trees were five years old. Trees of the required properties were at times difficult to find due to a lack of straightness. Approximately 20% of all trees in the woodlot were marked as useful. More often than not multiple posts were obtained from each tree. On one occasion six trellis posts came from one tree. A total of 40 strainer posts were cut from 33 trees while 260 trellis posts came from 170 trees.



Figure 11. *E. globulus* woodlot at Shepparton Wastewater Treatment Complex

4.1.2 Harvesting and Debarking

E. grandis

Relatively few branches on *E. grandis* posts needed to be removed prior to debarking. Both the strainer posts (Shepparton) and trellis posts (Deniliquin) were simple to debark. The bark would readily spring away from the post when bruised with the back of an axe in a number of positions. Further minimal effort was required to fully remove the bark (Figure 4).

E. camaldulensis

Once again only a few branches on *E. camaldulensis* posts required removal prior to debarking. Debarking of *E. camaldulensis* trellis and strainer posts was extremely difficult. The bark was spongy and absorbed impact. Only after several blows in the same area would the bark separate from the post. This continual hitting would only spring the bark in the area being hit. Thus, a considerable amount of effort was required to debark the posts. More frequent irrigation of the woodlot may make bark removal easier.

E. globulus

Branches on *E. globulus* posts were abundant (Figure 11) and a substantial amount of time was taken to remove them prior to debarking. Trellis and strainer posts of *E. globulus* were relatively simple to debark, with only a few posing some difficulty. On most occasions the bark would spring from the post and be readily removed. However, in the drier areas of the woodlot debarking required considerable effort.

4.2 Preservative Treatment

Mean post dimensions and sapwood volumes of the random sample of 30 trellis posts of each species are provided in Table 1. The mean outer diameter of the posts examined was 96 mm for both *E. grandis* and *E. globulus*, and 106 mm for *E. camaldulensis*. The thickness of the sapwood band was relatively constant between species, ranging from a mean of 32 to 34 mm. Sapwood volume was therefore high, ranging from 82% for *E. camaldulensis* to 89% for *E. globulus*. The sapwood band is expected to be the treatable zone.

Table 1. Trellis post dimensions and sapwood volumes. Mean of 30 replicates.

Species	Large end diameter (mm)	Small end diameter (mm)	Outer diameter (mm)	Sapwood thickness (mm)	Sapwood volume (%)	Treatable volume (m ³)
<i>E. grandis</i>	108	83	96	33	86	0.0172
<i>E. globulus</i>	104	87	96	34	89	0.0178
<i>E. camaldulensis</i>	119	92	106	32	82	0.0200

All 940 posts (some additional to those used in this trial) were treated in the one charge with a total of 4710 kg of PEC being consumed. The random samples of 30 posts of each species were weighed before and after treatment to determine the PEC and creosote-equivalent preservative retentions. The raw data for each post is presented in the Appendix.

Figures 12-14 show the transverse penetration and distribution of PEC in each species. The results showed that all sapwood was treated and there appeared to be no distinct difference in the macro-distribution of PEC between each timber species. The majority of creosote viewed in posts from the end grain lies within the vessels. Therefore, in frozen sapwood, this makes the distribution of creosote appear uneven and patchy, as it largely reflects the distribution of vessels. As the sapwood begins to thaw, the creosote begins to bleed over the freshly cut surface so that after a short time all of the sapwood will appear black. This behaviour of creosote explains the penetration patterns in the figures. For example, Figure 12 shows *E. grandis* posts shortly after they were cut. The two centre posts in the photo appear to have a relatively thin band of PEC penetration. However, these posts were penetrated with PEC almost to their cores, but the PEC can only be seen in closer view because it is still mostly located within the frozen vessels. The dark outer bands are where the sapwood has begun to thaw, allowing creosote to bleed across the surface to give greater visual impact.



Figure 12. Transverse view of PEC penetration and distribution in *E. grandis* posts



Figure 13. Transverse view of PEC penetration and distribution in *E. globulus* posts



Figure 14. Transverse view of PEC penetration and distribution in *E. camaldulensis* posts

The percentage of sapwood volume indicating the presence of PEC was estimated visually immediately after the posts were cut (Table 2). This percentage is obviously related to the percentage area in the sapwood containing vessels. For *E. grandis*, a mean of 65.8% of the sapwood area was estimated to be black with creosote. For *E. globulus* the value was 73.0% and for *E. camaldulensis* 69.5%. However, not a lot should be made from these figures as indicated earlier. The key outcome for PEC penetration was that the majority of posts had full depth of sapwood penetration. In a few posts some penetration of heartwood was also evident. However, most of this penetration was along internal checks.

The mean preservative retentions of PEC, and their creosote equivalents, for each species are presented in Table 2.

Table 2. Creosote retentions in sapwood. Mean of 30 replicates.

Species	% of sapwood end grain with PEC	PEC retention (kg/m ³)	≡creosote retention (kg/m ³)	≡creosote* retention (% m/m)	Number of posts below creosote retention of 10 % m/m
<i>E. grandis</i>	65.8	218.5	142.0	33.2	0
<i>E. globulus</i>	73.0	136.5	88.6	15.4	5
<i>E. camaldulensis</i>	69.5	171.5	111.5	21.1	1

*Calculated from mean air dry density and creosote retention in kg/m³.

4.3 Bending Strength and Post Form

4.3.1 Strength tests

The mean bending strength for posts are presented in Table 3. As expected, there was an increase in breaking force with increasing diameter of post, regardless of post type (Figure 15). In theory, the breaking force of a round post is proportional to its diameter cubed. Analysis showed that the increase in post breaking force was proportional to the diameter of the post cubed (Figure 15), agreeing with the theory. Therefore, the actual diameter of a post is a good predictor of breaking force. Note that results for pine posts were collected in studies previous to this work.

The breaking force of CCA-treated *P. radiata* and PEC-treated *E. globulus* was significantly different from the breaking force of the other posts (Figure 15), reflecting the respective bending strengths (Table 3). The mean bending strength of *E. globulus* was significantly (at 5% level) higher than for pine posts and the two other eucalypt species (Table 3). All eucalypt species tested were stronger than CCA-treated pine posts, and at least as good as creosote-treated pine posts (Table 3).

Table 3. The bending strength of different trellis posts. Mean and standard deviation of 30 replicates.

CCA-treated <i>P. radiata</i>		Creosote-treated <i>P. radiata</i>		PEC-treated <i>E. grandis</i>		PEC-treated <i>E. camaldulensis</i>		PEC-treated <i>E. globulus</i>	
Mean (MPa)	sd (MPa)	Mean (MPa)	sd (MPa)	Mean (MPa)	Sd (MPa)	Mean (MPa)	sd (MPa)	Mean (MPa)	sd (MPa)
47 a	12	59 b	18	57 b	9	59 b	14	77 c	14

Note: Means in each column followed by the same letter are not significantly different at 5% level of significance

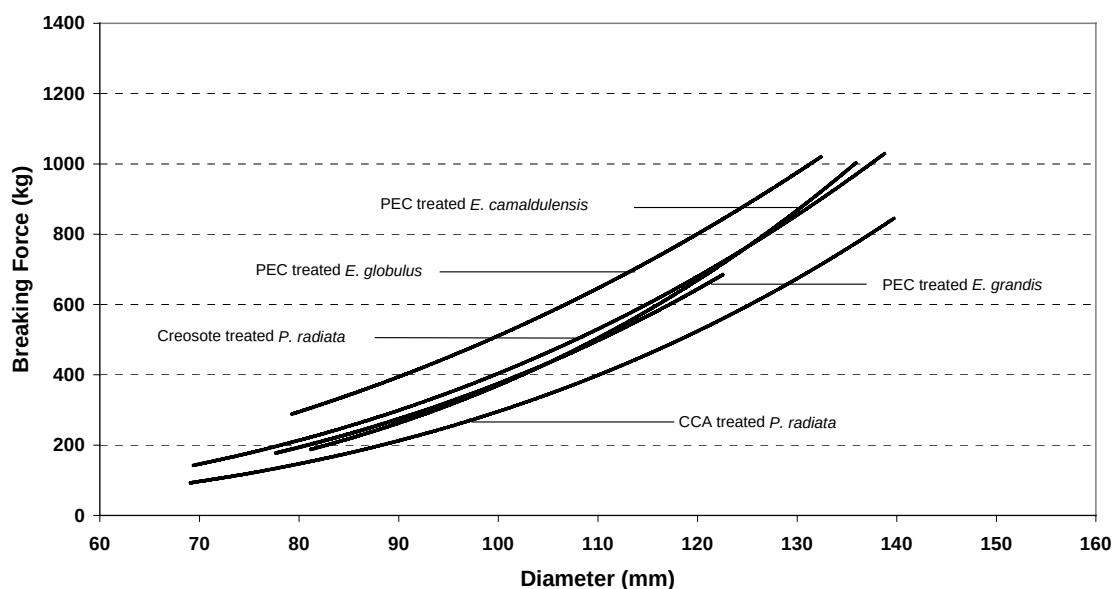


Figure 15. The relationship between post diameter and post breaking force.

None of the eucalypt posts tested snapped into two pieces, rather they broke by the fracture of outer grains (Figure 16). Typically, 15-20% of the CCA-treated radiata pine posts snapped under load.

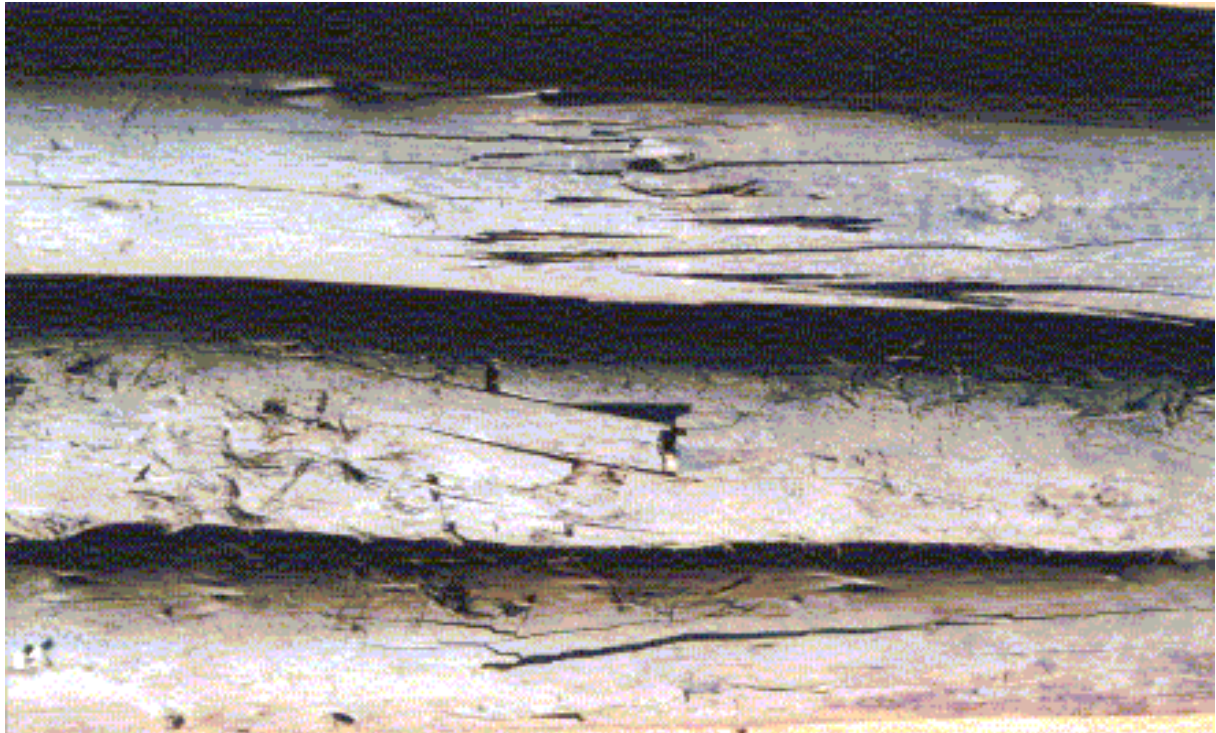


Figure 16. Fractured outer grains of PEC-treated eucalypt posts (a post from each species).

4.3.2 Evaluation of surface defects

The surface condition of each post was visually assessed. The posts appeared dry with little or no greasiness present on the surface. However, gloves should still be worn while handling PEC-treated posts. The amount of surface affected by exudate was restricted to only a couple of *E. camaldulensis* posts. A dry and shiny crud deposit along large checks and splits was seen on these posts.

Assessment of surface defects showed that no eucalypt post would be rejected because of unacceptable knots. This was despite the abundant branching noted on *E. globulus* posts during harvesting, indicating that the branches involved were of small diameter. However, 10% of *E. camaldulensis* and 7% of *E. globulus* posts (Figure 17) would be rejected due to unacceptable splits. The strength test on these posts showed no sign of weakness due to splits. Posts made of *E. grandis* were uniform with no rejections arising from splitting.



Figure 17. Unacceptable split in *E. globulus* trellis post.



Figure 18. An *E. grandis* post ideal for trellising.

4.4 Post Installation

Grapevine trellises were constructed from 290 posts, consisting of 245 trellis posts and 45 strainer posts, at a demonstration site located next to the wine tasting and sales area at Southcorp (Lindemans) winery, Karadoc. Contractors, using an auger attached to the back of a tractor, drilled the postholes (Figure 19). While drilling, a jet of water was squirted into the hole to create a slurry. The post was positioned in the hole and then rammed into place until the required depth was obtained (Figure 20). A total of 12 rows, comprising four consecutive rows of each species, were installed (Figure 21). Posts were installed large end down.



Figure 19. Trellis post hole being drilled and water squirted into hole to create a slurry

The posts were installed in May 2000 and the temperature on the day in Mildura reached 25°C. The surface of the posts was relatively dry and no sticky or greasy exudate was present. Feedback from the installation contractors was encouraging. They felt manual handling of the PEC-treated eucalypt posts was easier compared to the standard creosote-treated pine posts which they mentioned are wet and oily on the surface all year round. In addition, they felt the vapour emissions associated with PEC were less than those associated with creosote-treated pine posts.



Figure 20. Eucalypt trellis post being rammed into position



Figure 21. First row of PEC-treated posts next to the wine tasting and sales area at Southcorp (Lindemans) winery.

The remaining posts were transported to a local vineyard at Irymple South near Mildura. A total of 50 posts have been installed for grapevine trellising at this site. More posts are in the process being installed.

A further 40 posts were taken to the Mildura Wastewater Treatment and Reuse Centre. These posts were installed as fencing in areas under flood irrigation with treated wastewater (Table 4).

Table 4. Identification tags of posts for installation as fencing by the Mildura Wastewater Treatment and Reuse Centre

Deniliquin <i>E. grandis</i>		Shepparton <i>E. globulus</i>		Mildura <i>E. camaldulensis</i>	
Strainer	Post	Strainer	Post	Strainer	Post
G8/9A	G69/87	LS8/10A	L1/1A	CS4/4	C25/25
G16/20A	G128/162	LS17/22	L61/129A	CS10/10	C56/162
G26/34A	G136/173	LS22/27A	L83/178A	CS23/24	C117/135
	G184/223		L84/181A		C119/138A
	G191/230		L87/189B		C154/181
	G196/235		L89/194B		C155/182
	G204/243		L94/203A		C156/183
	G222/263		L98/210A		C163/191A
	G226/268		L99/213		C167/197
	G230/273A		L104/220		C174/204

5. Discussion

The eucalypt species with highest proportion of trees straight enough for vineyard posts was *E. grandis*, with 60% of trees suitable. In comparison, around 20% of *E. globulus* and only 5% of *E. camaldulensis* trees were acceptable. However, other plantations of the latter two species may yield more posts, as tree form can vary significantly with provenance and growing regimes. For example, Watkins and Waugh (1996, unpublished) estimated some plantations of *E. camaldulensis* to have 50-70% of trees suitable for posts.

Posts of suitable size had also been reached fastest by *E. grandis*, with a plantation three years old suitable for trellis posts, while the *E. globulus* plantation was five years old and *E. camaldulensis* seven years old. Another factor to consider when assessing a plantation for post production is the reason for growing the plantation. If a plantation is being grown for pulpwood, then straight trees could be harvested for posts. However, if the aim is to produce sawlogs then straight trees would be left standing. The plantations harvested in this study were grown to use effluent water. Therefore, clear felling and coppicing at a young age to produce posts is feasible as the aim is to have a continuous rotating crop of vigorously growing trees that transpire water.

Due to various timing and financial constraints in this project, trees were harvested by hand. In commercial operations this would not be feasible, and methods of mechanical debarking should be examined in other studies. Debarking by hand was relatively easy with *E. grandis* and *E. globulus* posts. However, trees growing in drier areas (some *E. globulus* trees and all *E. camaldulensis* trees) were difficult as the bark clung tightly to the timber. The results suggest that debarking would be easier during wetter or cooler times of the year (if access is still possible), or soon after tree irrigation.

Drying will also have a major impact on commercialisation. Posts in this study were air dried under cover. This decision was based on some earlier work on *E. grandis* posts by Watkins and Waugh (1996, unpublished), who examined three drying methods: air drying outside, air drying under cover, and kiln drying. In that study, posts dried exposed and outside suffered worst splitting and cracking, followed by those kiln dried. Least degrade was suffered by posts air dried more slowly under cover. The other option for hardwood posts, successfully applied in pine posts, is to steam condition the green post just prior to preservative treatment. However, this process is generally unsuccessful for eucalypts, increasing checking and collapse (Kohli and Kumar, 1988; Cookson et al., 1996; T. Hawkins, pers. comm., 1999). Another possibility is the use of microwaves to hasten the drying of posts (Torgovnikov and Vinden, 2000). McKimm (1984) obtained only minor degrade of *E. grandis* posts seasoned under tree cover in plantations. Care also needs to be taken to convert and treat eucalypt posts relatively quickly, to reduce the potential damage that could be caused by beetle attack. For example, bostrychid and lyctine borers can attack sapwood during or after timber seasoning. The three eucalypt species examined here all have lyctine susceptible sapwood, although susceptibility is rarer for *E. grandis* (Fairey, 1975).

The degree of splitting in posts was not assessed before treatment. Posts were originally cut 0.3 m longer (2.7 m) than intended (2.4 m), with the thought that if end splitting was severe this length could be removed to improve the post. However, the dominant drying defect that occurred was large splits (cracks) that extended almost the length of the post, so that docking a small amount from an end would achieve little. Therefore, the posts were not docked (docking is not used by commercial manufacturers) but left as 2.7 m lengths. Splitting was assessed after treatment. Least splitting occurred in *E. grandis*, while most occurred in *E. camaldulensis*. Posts were air dried adjacent to their plantations, rather than in the one place at the same time as would be required in more rigorous comparative drying experiments. While *E. grandis* dried best, the larger diameter strainer posts suffered more defect (not quantified), and pole sized *E. grandis* has a reputation for excessive splitting so is generally not used for poles (T. Hawkins, pers. comm.). The *E. grandis* posts also had higher sapwood content, and indeed were nearly all sapwood, whereas *E. camaldulensis* had higher heartwood content. Splitting needs to be limited in vineyard posts, mainly so that staples for wire will take to the post.

Assessment of surface defects showed that no eucalypt post was rejected because of unacceptable knots. Knots are generally more prevalent in pine posts.

The posts were treated with PEC in one charge using a commercial treatment schedule. Preservative retention was determined by measuring sapwood volume, and weighing posts before and after treatment. This approach was considered more accurate than chemical analysis, as Dean Stark extractions of a disc or plug can give variable results. That is, some natural extractives will come through as 'creosote'. For example, untreated karri can sometimes be extracted and pass the creosote retention requirements.

The treatment requirement for hardwoods in H4 exposure (outside in-ground) as specified in Australian Standard 1604.1-2000 is 10 % m/m creosote in the treated (sapwood) zone. The standard also requires that when a sample of ten posts is taken for analysis, all posts should contain this minimum preservative retention. All *E. grandis* posts were treated to H4 retentions, with a mean creosote retention of 33.2 % m/m. Indeed, *E. grandis* was probably over-treated, and in a commercial operation a lighter treatment schedule should probably be used. High retentions will improve resistance to decay, however, as most breakage is due to mechanical harvesters rather than decay, treatment to lower retentions may be more cost effective. Apart from varying treatment schedules, another way to reduce preservative absorption in *E. grandis* is to treat the posts at higher moisture content than used in this study, thereby reducing the duration of seasoning and saving drying costs. For *E. camaldulensis*, all but one of the 30 posts was treated to minimum requirements. The exception contained 9.6 % m/m creosote, so its inclusion in a commercial bundle of posts should be of minor concern. *E. globulus* absorbed least PEC, although the majority of posts were still treated above the minimum requirement, with a mean retention of 15.4 % m/m creosote. Five of the 30 *E. globulus* posts failed to meet the minimum requirement, suggesting that a slightly extended treatment schedule would be necessary in the commercial treatment of this species.

Even though PEC is largely contained within the vessels and rays, creosote based preservatives generally protect eucalypt sapwood from soft rot better than CCA (Greaves, 1977). This is probably due to the maintenance of a degree of mobility of creosote within the wood, both in liquid and vapour form. This feature appears to provide protection to the whole of the sapwood volume over a long period of time.

The majority of a post's strength is in the outer zone. For example, a 125 mm diameter post has 67% of its strength in a 15 mm sapwood band (Tamblyn, 1984). The mean sapwood thickness in the posts examined here were 32-34 mm, so that sapwood (treatable) volumes were 82-89%. Therefore, the inability to treat the narrow inner cylinder of heartwood should not be a major concern. Even if that heartwood was to deteriorate during service to decay and termite attack, the post should remain serviceable.

Strength was tested by a cantilever method most relevant to vineyard posts. PEC-treated *E. globulus* posts were stronger than similarly treated *E. grandis* and *E. camaldulensis* posts in this study, and creosote-treated *P. radiata* posts examined in earlier work. All of these posts were stronger than the most often used CCA-treated *P. radiata* post. Bariska *et al.* (1988) showed that CCA treatment causes partial acid hydrolysis of the holocellulose and lignin fractions of the wood structures, resulting in a weaker zone at the interface of the growth rings. McKimm (1984) found that bending strength (MOR) of treated eucalypts was stronger than similar sized *P. radiata* posts. Regardless of the type of posts tested, increasing diameter of posts resulted in an increase in breaking force, which agrees with the previous studies by Mollah *et al.* (1995 and 1997).

Radiata pine trellis posts used in Australian vineyards are mostly treated with CCA as growers prefer them to creosote-treated posts that bleed in hot weather. PEC-treated eucalypts largely overcome the problems associated with using creosote (Greaves *et al.*, 1985). The surface condition of the PEC-treated posts was dry, and feedback in relation to manual handling from contractors installing the posts at a demonstration site at Southcorp (Lindemans) winery, Mildura, was encouraging.

6. Implications

The results from this work show that *E. grandis*, *E. globulus*, and *E. camaldulensis* harvested from woodlots grown with effluent water can be adequately treated with PEC. Full sapwood penetration was achieved in the posts after air drying. All posts were treated in the same charge, resulting in over-treatment of *E. grandis* (which can be rectified by reducing treatment time), adequate treatment of *E. camaldulensis*, and slight under-treatment of *E. globulus* (which may be rectified by longer treatment times).

The PEC-treated eucalypt posts were stronger than similar sized CCA-treated *P. radiata* posts, and is an important marketing advantage. Growers tend to prefer CCA- to creosote-treated *P. radiata* posts because they are dry and easier to handle. However, PEC produces a cleaner creosote treatment in eucalypts.

To make the production of PEC-treated eucalypt posts cost competitive, the seasoning and transportation issues would need to be addressed. Air drying is a common practice in the hardwood industry, so the need to air dry posts for several months may be acceptable. It may be possible to shorten the seasoning time by examining if it is possible to treat the eucalypts at higher moisture contents than in the current study.

While treated pine vineyard posts are sometimes transported from Queensland to Sunraysia, shorter transportation distances would be needed. Plantation owners in the Grafton region, taking advantage of the local PEC treatment plant, could attempt immediate commercialisation and market acceptance of these results in adjacent vineyards such as the Hunter Valley.

7. Recommendations

Considering its fast growth rate, high percentage of straight trees, low degrade upon seasoning, treatability and strength, *E. grandis* seems to be the most suitable eucalypt species for vineyard trellis posts amongst those tested. *E. globulus* is suitable for the production of higher strength posts. Difficulties were experienced with *E. camaldulensis* due to a higher rejection rate from splits and cracks.

Commercialisation of the current research could proceed by treating thinnings from forests in the Grafton region at the local PEC treatment plant, and marketing those posts to the Hunter Valley or Sunraysia vineyards. This process would improve various aspects of commercialisation and test market acceptance.

The posts installed should continue to be monitored at the demonstration sites for performance. As with any treated timber product near crops, questions inevitably arise about whether the preservative leaches from timber at a harmful rate. Periodic analysis of soil and vine samples adjacent to the posts could be conducted in an effort to produce data that might circumvent these concerns.

Since starting the project, there has been a great deal of interest in the concept of producing vineyard posts from plantation grown eucalypts. Further work should investigate a wider range of plantation species for the production of vineyard posts. CCA treatments should also be examined, as there are more CCA treatment plants in the country than PEC plants.

This second stage should also compare and correlate the strength testing methods favoured by the vineyard industry (as used in this study), and the four point bending method favoured by the timber industry.

Information on the comparative decay resistance of the various treated posts could also be obtained using CSIRO's 'Accelerated Field Simulator'.

8. Appendix

E. grandis (G) trellis posts harvested 17th November 1998 at Deniliquin

Tag no.	End 1 (mm)		End 2 (mm)		Length (mm)	Treatable volume (m ³)	Initial weight (kg)	Pick up (kg)	Retention (kg/m ³)	
	φ	H φ	φ	Hφ					PEC	≡HTC
G49/65A	13 0	10 5	105	60	2.695	0.0141	14.892	5.570	395.7	257.2
G52/70	11 0	45	95	10	2.700	0.0201	11.115	4.773	236.9	154.0
G53/71	11 0	45	85	15	2.730	0.0183	11.826	3.472	189.7	123.3
G63/81	10 5	50	65	15	2.695	0.0133	7.328	2.852	215.2	139.9
G64/82	90	40	55	0	2.690	0.0101	5.915	1.615	160.5	104.3
G78/97	11 0	55	80	20	2.690	0.0159	10.003	3.425	215.1	139.8
G79/98	95	40	65	0	2.700	0.0124	6.304	1.314	106.4	69.1
G85/105	12 0	60	100	25	2.710	0.0215	12.790	5.037	234.6	152.5
G86/106	12 5	50	90	20	2.685	0.0220	10.242	4.863	221.5	144.0
G88/108	10 0	80	75	10	2.700	0.0097	8.521	4.289	443.3	288.1
G95/118B	90	20	70	10	2.685	0.0132	7.346	3.716	281.9	183.3
G118/145A	13 0	90	95	35	2.695	0.0176	13.202	2.953	168.1	109.3
G124/155B	10 0	25	70	10	2.690	0.0150	7.552	3.032	202.5	131.6
G126/159B	95	20	70	10	2.695	0.0142	6.545	3.641	256.3	166.6
G134/171	13 0	50	105	15	2.695	0.0267	13.332	5.442	204.1	132.6
G149/186	12 0	35	100	20	2.700	0.0241	12.906	3.666	151.8	98.7
G151/188	10 0	40	70	0	2.710	0.0142	7.820	1.853	130.9	85.1
G153/190	95	25	70	0	2.700	0.0141	6.649	2.101	149.0	96.8
G162/199	11 0	60	80	25	2.695	0.0151	9.412	2.874	190.2	123.7
G163/200	95	30	75	0	2.690	0.0145	8.142	3.340	229.9	149.5
G167/204	10 5	45	90	10	2.700	0.0180	9.927	3.398	188.5	122.5
G171/209	11 0	40	85	10	2.710	0.0188	11.745	3.409	181.7	118.1
G176/204	10 0	25	75	0	2.710	0.0160	7.106	2.718	170.3	110.7
G181/220B	10 5	20	85	10	2.705	0.0189	9.395	5.074	269.1	174.9
G199/238	12 0	45	90	25	2.710	0.0211	10.177	4.185	198.1	128.8
G217/256	11 0	35	85	30	2.685	0.0181	8.905	4.551	250.9	163.1
G219/259A	12 5	50	110	40	2.680	0.0249	16.098	5.127	206.2	134.0

G225/267	11 5	50	90	20	2.710	0.0196	10.978	3.404	173.6	112.8
G242/289B	11 0	30	85	30	2.685	0.0185	10.133	6.084	329.3	214.0
G257/310B	10 5	30	80	10	2.730	0.0176	9.414	3.607	204.8	133.1
Mean	10 8	44	83	16	2.6992	0.0172	9.857	3.713	218.5	142.0
S.D.	11	19	13	13	0.48	0.0041	2.59	1.178	70.4	45.8

***E. grandis* (G) trellis posts harvested 17th November 1998 at Deniliquin**

Tag no.	Initial weight (kg)	Post volume (m ³)	Air-dry density (kg/m ³)	Oven-dry density (kg/m ³)	Retention (%m/m)	
					PEC	≡HTC
G49/65A	14.892	0.0296	503.9	443.4	89.2	58.0
G52/70	11.115	0.0224	496.2	436.7	54.3	35.3
G53/71	11.826	0.0207	570.8	502.3	37.8	24.5
G63/81	7.328	0.0161	454.0	399.6	53.8	35.0
G64/82	5.915	0.0118	503.3	442.9	36.2	23.6
G78/97	10.003	0.0195	511.9	450.4	47.7	31.0
G79/98	6.304	0.0140	448.7	394.9	26.9	17.5
G85/105	12.790	0.0260	492.6	433.4	54.1	35.2
G86/106	10.242	0.0250	409.4	360.3	61.5	40.0
G88/108	8.521	0.0166	514.3	452.6	97.9	63.7
G95/118B	7.346	0.0137	535.9	471.6	59.8	38.9
G118/145A	13.202	0.0274	481.2	423.4	39.7	25.8
G124/155B	7.552	0.0157	479.8	422.2	48.0	31.2
G126/159B	6.545	0.0147	444.1	390.8	65.6	42.6
G134/171	13.332	0.0296	451.1	397.0	51.4	33.4
G149/186	12.906	0.0259	498.9	439.0	34.6	22.5
G151/188	7.820	0.0159	493.2	434.0	30.2	19.6
G153/190	6.649	0.0148	450.3	396.3	37.6	24.4
G162/199	9.412	0.0196	480.7	423.0	45.0	29.2
G163/200	8.142	0.0155	526.1	463.0	49.7	32.3
G167/204	9.927	0.0203	489.5	430.8	43.8	28.4
G171/209	11.745	0.0206	571.1	502.6	36.2	23.5
G176/204	7.106	0.0166	427.3	376.1	45.3	29.4
G181/220B	9.395	0.0194	484.6	426.5	63.1	41.0
G199/238	10.177	0.0239	425.0	374.0	53.0	34.4
G217/256	8.905	0.0204	437.0	384.6	65.3	42.4
G219/259A	16.098	0.0292	551.7	485.5	42.5	27.6
G225/267	10.978	0.0227	483.7	425.7	40.8	26.5
G242/289B	10.133	0.0204	497.3	437.6	75.2	48.9
G257/310B	9.414	0.0187	503.9	443.5	46.2	30.0
Mean	9.857	0.0202	487.3	428.8	51.1	33.2
S.D.	2.59	0.0050	40.0	35.2	15.9	10.3

***E. globulus* (L) trellis posts harvested 22nd January 1999 at Shepparton**

Tag no.	End 1		End 2		Length (mm)	Treatable volume (m ³)	Initial weight (kg)	Pick up (kg)	Retention	
	φ	Hφ	φ	Hφ					PEC	≡HTC
L9/14B	90	20	80	10	2.700	0.0148	12.866	1.684	113.4	73.7
L16/26	11	30	95	20	2.705	0.0211	14.746	2.451	116.4	75.7
L20/32B	10	30	85	10	2.715	0.0173	11.695	2.172	125.6	81.6
L30/52A	12	50	11	40	2.725	0.0253	22.817	1.494	59.1	38.4
L32/57A	12	50	10	35	2.705	0.0244	17.130	2.714	111.4	72.4
L41/80	11	30	90	20	2.700	0.0200	12.158	3.462	172.8	112.3
L42/82B	12	25	90	0	2.670	0.0229	13.710	1.590	69.3	45.1
L50/100B	95	40	85	25	2.690	0.0148	13.157	2.054	138.6	90.1
L54/109A	13	60	12	50	2.695	0.0267	21.805	3.713	139.2	90.5
L55/117C	95	15	75	10	2.690	0.0151	9.084	1.662	109.8	71.4
L59/125B	80	40	60	0	2.695	0.0089	7.259	1.652	185.8	120.8
L67/141A	12	20	95	30	2.695	0.0234	16.550	3.081	131.6	85.5
L67/142B	95	35	80	10	2.715	0.0150	12.236	2.06	137.0	89.1
L69/148C	10	40	85	25	2.710	0.0160	13.580	1.480	92.7	60.3
L74/160A	11	50	95	20	2.755	0.0197	14.870	3.023	153.3	99.7
L78/168B	11	20	85	10	2.695	0.0199	13.471	1.779	89.3	58.0
L79/171B	10	25	90	0	2.720	0.0187	12.320	1.464	78.4	51.0
L84/182B	10	45	90	10	2.715	0.0170	12.844	3.219	189.0	122.8
L84/183C	90	30	70	10	2.690	0.0127	8.595	2.101	165.7	107.7
L91/200C	10	30	80	0	2.730	0.0166	11.025	1.614	97.1	63.1
L93/202	90	50	80	35	2.745	0.0116	11.474	2.054	176.8	114.9
L95/205	11	50	90	15	2.735	0.0188	13.835	4.095	218.2	141.8
L98/212C	90	20	70	0	2.705	0.0134	9.020	1.640	122.5	79.6
L113/235A	12	60	10	35	2.720	0.0209	16.877	1.757	84.0	54.6
L114/237	90	45	70	20	2.720	0.0113	8.980	1.786	158.1	102.8
L115/238	10	50	80	25	2.695	0.0140	11.406	2.519	179.3	116.5
L116/239	14	60	11	40	2.710	0.0282	19.285	3.901	138.3	89.9
L120/246B	95	35	75	10	2.685	0.0140	9.067	2.976	211.8	137.7
L122/250B	10	40	85	20	2.670	0.0160	13.552	2.098	131.4	85.4
L125/259C	10	50	85	10	2.695	0.0155	12.525	2.472	200.2	130.1
Mean	10	38	87	18	2.7065	0.0178	13.265	2.346	136.5	88.8
S.D.	14	13	13	13	0.0193	0.0047	3.95	0.777	42.1	27.3

***E. globulus* (L) trellis posts harvested 22nd January 1999 at Shepparton**

Tag no.	Initial weight (kg)	Post volume (m ³)	Air-dry density (kg/m ³)	Oven-dry density (kg/m ³)	Retention (%m/m)	
					PEC	≡HTC
L9/14B	12.866	0.0154	836.9	736.4	15.4	10.0
L16/26	14.746	0.0224	657.1	578.3	20.1	13.1
L20/32B	11.695	0.0184	636.8	560.4	22.4	14.6
L30/52A	22.817	0.0297	769.1	676.8	8.7	5.7
L32/57A	17.130	0.0283	605.1	532.5	20.9	13.6
L41/80	12.158	0.0214	567.7	499.5	34.6	22.5
L42/82B	13.710	0.0236	581.1	511.4	13.6	8.8
L50/100B	13.157	0.0172	766.5	674.5	20.6	13.4
L54/109A	21.805	0.0331	658.3	579.3	24.0	15.6
L55/117C	9.084	0.0155	587.0	516.5	21.3	13.8
L59/125B	7.259	0.0106	685.9	603.6	30.8	20.0
L67/141A	16.550	0.0248	667.6	587.5	22.4	14.6
L67/142B	12.236	0.0164	744.0	654.7	20.9	13.6
L69/148C	13.580	0.0183	740.8	651.9	14.2	9.2
L74/160A	14.870	0.0229	650.6	572.6	26.8	17.4
L78/168B	13.471	0.0205	658.7	579.6	15.4	10.0
L79/171B	12.320	0.0193	637.2	560.8	14.0	9.1
L84/182B	12.844	0.0193	665.6	585.7	32.3	21.0
L84/183C	8.595	0.0137	625.9	550.8	30.1	19.6
L91/200C	11.025	0.0176	627.1	551.8	17.6	11.4
L93/202	11.474	0.0156	734.1	646.0	27.4	17.8
L95/205	13.835	0.0217	637.7	561.2	38.9	25.3
L98/212C	9.020	0.0138	653.2	574.8	21.3	13.9
L113/235A	16.877	0.0261	647.6	569.8	14.7	9.6
L114/237	8.980	0.0139	646.7	569.1	27.8	18.1
L115/238	11.406	0.0174	657.2	578.3	31.0	20.2
L116/239	19.285	0.0337	571.7	503.1	27.5	17.9
L120/246B	9.067	0.0154	587.0	516.5	41.0	26.7
L122/250B	13.552	0.0181	750.4	660.3	19.9	12.9
L125/259C	12.525	0.0182	687.1	604.6	33.1	21.5
Mean	13.265	0.0201	664.7	584.9	23.6	15.4
S.D.	3.95	0.0056	64.1	56.4	7.8	5.1

***E. camaldulensis* (C) trellis posts harvested 18th January 1999 at Mildura**

Tag no.	End 1		End 2		Length (mm)	Treatable volume (m ³)	Initial weight (kg)	Pick up (kg)	Retention	
	φ	Hφ	φ	Hφ					PEC	≡HTC
C1/1	13	90	80	40	2.725	0.0146	15.036	1.955	137.1	89.1
C4/4	10	60	60	35	2.700	0.0104	9.895	1.710	164.6	107.0
C9/9	12	70	90	50	2.720	0.0174	17.295	2.234	128.1	83.3
C11/11	11	40	70	30	2.700	0.0154	9.136	3.145	204.6	133.0
C13/13	95	35	60	15	2.710	0.0119	9.490	2.553	214.7	139.5
C27/27	12	70	95	20	2.705	0.0193	13.393	4.961	257.7	167.5
C37/38A	14	80	11	50	2.700	0.0254	19.700	5.890	232.2	150.9
C37/39B	11	50	10	20	2.700	0.0204	14.379	3.989	195.9	127.4
C38/42B	11	30	11	25	2.725	0.0255	18.024	4.113	161.5	105.0
C50/55	14	50	11	40	2.740	0.0297	20.263	4.161	140.1	91.1
C51/56	12	50	90	30	2.695	0.0215	15.430	2.643	122.9	79.9
C52/58B	12	45	10	35	2.695	0.0224	18.969	4.623	206.5	134.2
C54/60	13	65	11	30	2.720	0.0269	19.483	4.395	163.3	106.1
C62/68	10	35	85	15	2.705	0.0178	10.350	4.866	272.7	177.2
C68/74A	12	50	10	25	2.680	0.0248	21.975	6.932	280.0	182.0
C73/81	10	40	90	20	2.710	0.0171	10.696	3.448	201.2	130.8
C76/86B	90	10	75	0	2.710	0.0145	8.247	2.398	165.4	107.5
C79/90	12	60	80	20	2.710	0.0179	12.510	2.760	154.4	100.3
C80/91	13	75	11	40	2.710	0.0232	21.150	2.883	124.4	80.9
C109/126B	80	10	70	0	2.710	0.0119	7.300	1.260	105.7	68.7
C110/128B	12	40	10	20	2.705	0.0238	20.060	3.222	135.4	88.0
C113/131	12	75	90	40	2.710	0.0176	15.140	1.754	99.9	64.9
C138/161A	13	85	11	40	2.685	0.0227	19.752	3.370	148.7	96.6
C140/165B	12	45	90	40	2.720	0.0202	18.818	3.212	159.3	103.6
C146/172	13	10	11	40	2.710	0.0200	18.940	4.568	228.0	148.2
C152/179	13	50	10	40	2.700	0.0242	19.085	2.110	87.3	56.7
C157/184	11	50	80	30	2.705	0.0172	9.752	2.826	164.0	106.6
C164/193A	14	60	11	40	2.715	0.0283	19.280	4.142	146.6	95.3
C170/200	11	50	90	30	2.700	0.0178	10.500	3.041	170.7	111.0
Mean	11	54	92	29	2.708	0.0200	15.312	3.421	171.5	111.5
S.D.	15	22	16	13	0.012	0.0050	4.59	1.306	50.12	32.58

***E. camaldulensis* (C) trellis posts harvested 18th January 1999 at Mildura**

Tag no.	Initial weight (kg)	Post volume (m ³)	Air-dry density (kg/m ³)	Oven-dry density (kg/m ³)	Retention (%m/m)	
					PEC	≡HTC
C1/1	15.036	0.0249	603.0	530.7	29.3	19.0
C4/4	9.895	0.0155	638.1	561.5	29.3	19.0
C9/9	17.295	0.0253	682.5	600.6	21.3	13.9
C11/11	9.136	0.0180	506.9	446.0	45.9	29.8
C13/13	9.490	0.0134	706.3	621.6	34.5	22.4
C27/27	13.393	0.0249	538.2	473.6	54.4	35.4
C37/38A	19.700	0.0348	566.0	498.1	46.6	30.3
C37/39B	14.379	0.0234	613.6	540.0	36.3	23.6
C38/42B	18.024	0.0271	665.1	585.3	27.6	17.9
C50/55	20.263	0.0341	594.1	522.8	26.8	17.4
C51/56	15.430	0.0251	614.5	540.8	22.7	14.8
C52/58B	18.969	0.0258	734.6	646.4	32.0	20.8
C54/60	19.483	0.0324	601.5	529.3	30.8	20.1
C62/68	10.350	0.0194	533.9	469.8	58.0	37.7
C68/74A	21.975	0.0280	783.5	689.5	40.6	26.4
C73/81	10.696	0.0193	555.3	488.6	41.2	26.8
C76/86B	8.247	0.0146	564.6	496.9	33.3	21.6
C79/90	12.510	0.0221	565.2	497.3	31.0	20.2
C80/91	21.150	0.0309	685.3	603.1	20.6	13.4
C109/126B	7.300	0.0120	607.0	534.2	19.8	12.9
C110/128B	20.060	0.0259	774.0	681.1	19.9	12.9
C113/131	15.140	0.0252	599.6	527.7	18.9	12.3
C138/161A	19.752	0.0320	617.7	543.6	27.3	17.8
C140/165B	18.818	0.0240	783.0	689.0	23.1	15.0
C146/172	18.940	0.0335	565.9	498.0	45.8	29.8
C152/179	19.085	0.0285	669.1	588.8	14.8	9.6
C157/184	9.752	0.0208	467.8	411.7	39.8	25.9
C164/193A	19.280	0.0338	570.5	502.0	29.2	19.0
C170/200	10.500	0.0214	490.2	431.4	39.6	25.7
Mean	15.312	0.0247	617.1	543.1	32.4	21.1
S.D.	4.59	0.0064	84.0	73.9	10.9	7.1

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