



Australian Government

Forest and Wood Products
Research and Development
Corporation

The In-ground Natural Durability of Australian Timbers





© 2004 Forest & Wood Products Research & Development Corporation
All rights reserved.

**Publication: *The In-ground Natural Durability of Australian
Timbers***

The Forest and Wood Products Research and Development Corporation (“FWPRDC”) makes no warranties or assurances with respect to this publication including merchantability, fitness for purpose or otherwise. FWPRDC and all persons associated with it exclude all liability (including liability for negligence) in relation to any opinion, advice or information contained in this publication or for any consequences arising from the use of such opinion, advice or information.

This work is copyright and protected under the Copyright Act 1968 (Cth). All material except the FWPRDC logo may be reproduced in whole or in part, provided that it is not sold or used for commercial benefit and its source (Forest and Wood Products Research and Development Corporation) is acknowledged. Reproduction or copying for other purposes, which is strictly reserved only for the owner or licensee of copyright under the Copyright Act, is prohibited without the prior written consent of the Forest and Wood Products Research and Development Corporation.

Project no: PN04.1001

Researchers:

L. J. Cookson

CSIRO FFP

Private Bag 10, Clayton South, Vic 3169

Final report received by the FWPRDC in August 2004

Forest and Wood Products Research and Development Corporation

PO Box 69, World Trade Centre, Victoria 8005

Phone: 03 9614 7544 Fax: 03 9614 6822 Email: info@fwprdc.org.au

Web: www.fwprdc.org.au

The In-ground Natural Durability of Australian Timbers

Prepared for the

**Forest & Wood Products
Research & Development Corporation**

by

L. J. Cookson

*The FWPRDC is jointly funded by the Australian forest and wood products industry
and the Australian Government.*

EXECUTIVE SUMMARY

Objective

The objective of this study was to conduct a final inspection of the in-ground natural durability field trial exposed at five sites in Australia. Originally, 77 timber species were installed.

Key Results

- The best performing timber at each test site was CCA-treated *Pinus radiata*. All but one replicate (from Innisfail) was still serviceable after 33 to 36 years exposure. The test stakes had been treated to a retention of 12 kg CCA salt/m³.
- The next best performing timber at each test site was K.55 creosote treated *P. radiata*. The test stakes had been treated to a retention of 175-210 kg K.55 creosote/m³.
- Timber species with greatest natural durability in the outer heartwood were raspberry jam (*Acacia acuminata*), red box (*Eucalyptus polyanthemos*), wandoo (*E. wandoo*), tallowwood (*E. microcorys*), bull oak (*Allocasuarina luehmannii*), grey ironbark (*E. paniculata*), yellow box (*E. melliodora*), Gympie messmate (*E. cloeziana*), grey box (*E. moluccana*) and white mahogany (*E. acmenoides*).
- Based upon these results, revised natural durability ratings in Australian Standard 5604 are suggested for some species.

Application of Results

The trial demonstrates that CCA and creosote treated timbers can perform better than the best of the naturally durable timbers. Nevertheless, many untreated timbers will provide useful service lives, and this trial provides the best comparison available in Australia of 77 species. Based on these results, the natural durability ratings given in Australian Standard 5604 should be revised for some species. Future research that aims to produce an organic wood preservative would do well to examine the extractives of the most naturally durable timber species identified in this project.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
Objective.....	1
Key Results	1
Application of Results	1
TABLE OF CONTENTS	2
INTRODUCTION.....	3
RECOMMENDATIONS AND CONCLUSIONS.....	3
RESULTS AND DISCUSSION	3
ACKNOWLEDGEMENTS	8
MATERIALS AND METHODS	9
Timber Species, Treatment and Specimen Details	9
Test Site, Site Hazards and Exposure Details.....	9
Method of Inspection.....	10

INTRODUCTION

In 1968-69, Australia's largest in-ground natural durability trial was established over a range of climatic conditions at five test sites. The progress of this trial has been reported in a series of articles^{1,2,3}. The latest inspection before this report was in 1999 after 31 years exposure⁴.

Interest in natural durability is growing, partly due to concerns about the chemicals used to make non-durable timbers durable. An Australian Standard devoted to the subject was produced in 2003⁵. It broadens the traditional information available on in-ground natural durability, to other end uses such as termite resistance indoors (H2) and outside above ground natural durability (H3). Plantation species with higher natural durability generally attract higher prices, and may be easier to treat according to Australian Standards when only the sapwood needs to be penetrated due to the presence of naturally durable heartwood. Some of the species examined in this report are no longer available in commercial quantities. However, the search for more environmentally friendly organic wood preservatives also benefits from a greater understanding of those timbers found by evolution to be durable and the chemicals that confer that durability.

The in-ground natural durability trial was removed from exposure after 33-36 years, as some sites were to be redeveloped or closed. This report provides the final inspection results.

RECOMMENDATIONS AND CONCLUSIONS

After 33-36 years of exposure in ground, the best performing timbers were preservative treated. CCA-treated *Pinus radiata* performed best, with all but one replicate still serviceable at the five test sites. The next best performing timber was K.55 creosote treated *P. radiata*. The best performing naturally durable timbers were raspberry jam (*Acacia acuminata*), red box (*Eucalyptus polyanthemos*), wandoo (*E. wandoo*), tallowwood (*E. microcorys*), bull oak (*Allocasuarina luehmannii*), grey ironbark (*E. paniculata*), yellow box (*E. melliodora*), Gympie messmate (*E. cloeziana*), grey box (*E. moluccana*) and white mahogany (*E. acmenoides*). The in-ground natural durability ratings given in AS 5604 for some species should be reconsidered based on these results.

The surviving test stakes are currently stored at the Clayton laboratory. While this trial has ended, future work should include the chemical analysis of the CCA-treated *P. radiata* stakes, to determine the extent of leaching.

RESULTS AND DISCUSSION

The median ratings for each timber species at each of the five test sites after more than 33 years exposure are shown in Table 1. During inspections, test stakes were rated separately for decay and termite attack on a scale of 8-0, where 8 is sound and 0 destroyed. However, in Table 1, the worst rating from either biodeteriogen was used in the calculation of the median. The specimen life for each replicate stake was taken as midway between the inspection when the specimen first rated 3, and the previous inspection (when it rated 4 or higher).

¹ Thornton, J.D., Walters, N.E.M. and Saunders, I.W. (1983). An in-ground natural durability field test of Australian timbers and exotic reference species. I. Progress report after more than 10 years' exposure. Mater. Org. 18: 27-49.

² Thornton, J.D., Johnson, G.C. and Nguyen, N.-K. ((1994). Specimen life statistics and mean rates of biodeterioration for untreated heartwood timbers exposed in-ground for 23 years. Proc. Pacific Timber Engineering Conf., Gold Coast, Australia, July 11-15 1994, 10 pp.

³ Johnson, G.C., Thornton, J.D. and Nguyen, N.-K. (1996). An in-ground natural durability field test of Australian and exotic reference species. XI. Results after more than 25 years' exposure. Mater. Org. 30: 219-230.

⁴ Thornton, J.D., Johnson, G.C., Nguyen, N.-K. and McConalogue, A.S. (1999). Rates of biodeterioration and their upper bounds for use in the reliability-based durability design method. Results after 31 years of exposure. CSIRO FFP Client Report No. 637.

⁵ Australian Standard 5604-2003. Timber – Natural durability ratings. Standards Australia, Sydney.

Table 1: Median specimen life (years) for timber species at each test site after the 33.4 to 36 year final inspections

Timber species	Brisbane 36.0 years	Innisfail 36.0 years	Sydney 35.3 years	Walpeup 35.7 years	Melbourne 33.4 years
Eucalypt/Corymbia hardwoods					
<i>Corymbia calophylla</i> (marri)	3.1	5.2	11.9	12.4	10.9
<i>C. maculata</i> and <i>C. citriodora</i> (spotted gum)	8.5	8.5	15.0	18.1	>33.4
<i>E. acmenoides</i> (white mahogany)	19.8	21.9	27.6	>35.7	>33.4
<i>E. amygdalina</i> (black peppermint)	3.1	3.2	10.3	8.8	6.3
<i>E. astringens</i> (brown mallet)	8.5	5.2	21.9	15.9	27.6
<i>E. bosistoana</i> (coast grey box)	19.8	8.5	21.9	19.8	>33.4
<i>E. botryooides</i> (southern mahogany)	6.9	4.2	11.9	18.4	14.0
<i>E. camaldulensis</i> (river red gum)	8.5	11.9	15.7	21.9	>33.4
<i>E. capitellata</i> (brown stringybark)	5.2	1.1	8.6	8.8	12.3
<i>E. cladocalyx</i> (sugar gum)	19.1	22.8	33.1	27.6	>33.4
<i>E. cloeziana</i> (Gympie messmate)	23.9	13.8	25.0	>35.7	>33.4
<i>E. considianiana</i> (yertchuk)	8.5	3.2	16.2	22.8	16.7
<i>E. cornuta</i> (yate)	18.1	3.2	15.7	12.4	>33.4
<i>E. cypellocarpa</i> (mount. grey gum)	4.2	1.1	11.9	8.8	12.4
<i>E. diversicolor</i> (karri)	6.8	1.1	11.9	8.8	15.4
<i>E. dives</i> (broad-leaved peppermint)	5.2	2.2	10.3	14.8	10.9
<i>E. elata</i> (river peppermint)	1.0	1.1	4.7	5.3	4.3
<i>E. eugenioides</i> (white stringybark)	4.2	3.2	8.6	16.4	12.4
<i>E. eugenioides</i> (Wilkinson's str bk)	8.5	5.2	10.3	10.6	8.3
<i>E. fastigata</i> (brownbarrel)	4.2	1.1	8.6	8.8	4.3
<i>E. globulus</i> (Tasmanian blue gum)	6.9	1.1	11.9	8.8	12.4
<i>E. gomphocephala</i> (tuart)	19.8	4.2	21.0	18.4	>33.4
<i>E. goniocalyx</i> (long-leaved box)	8.5	3.2	10.3	21.4	15.4
<i>E. grandis</i> (rose gum)	6.9	6.9	8.6	14.8	8.3
<i>E. guilfoylei</i> (yellow tingle)	8.5	1.1	14.6	13.1	>33.4
<i>E. haemastoma</i> (scribbly gum)	5.2	2.2	11.9	19.4	14.0
<i>E. jacksonii</i> (red tingle)	3.1	1.1	8.6	7.0	10.9
<i>E. leucoxyton</i> (yellow gum)	15.0	10.2	8.6	26.9	>33.4
<i>E. longifolia</i> (woollybutt)	21.9	8.5	23.9	26.9	>33.4
<i>E. macrorhyncha</i> (red stringybark)	8.5	8.5	11.9	20.6	14.7
<i>E. maidenii</i> (Maiden's gum)	5.2	1.1	11.9	14.4	10.9
<i>E. marginata</i> (jarrah)	6.9	8.5	11.9	20.6	25.6
<i>E. megacarpa</i> (bullich)	6.9	1.1	8.3	8.8	13.8
<i>E. melliodora</i> (yellow box)	19.1	15.9	>35.3	33.3	>33.4
<i>E. microcorys</i> (tallowwood)	27.6	23.9	32.6	>35.7	>33.4
<i>E. moluccana</i> (grey box)	22.8	8.5	31.6	30.3	>33.4
<i>E. muelleriana</i> (yellow str bk)	5.2	1.1	8.6	14.8	15.4
<i>E. obliqua</i> (messmate)	3.1	1.1	8.6	8.8	8.3
<i>E. paniculata</i> (grey ironbark)	26.3	26.3	>35.3	26.9	>33.4
<i>E. patens</i> (WA blackbutt)	8.5	1.1	23.9	27.6	19.4
<i>E. pilularis</i> (blackbutt)	5.2	3.2	13.6	23.9	23.9
<i>E. polyanthemus</i> (red box)	25.0	26.9	>35.3	>35.7	>33.4
<i>E. radiata</i> (NSW messmate)	3.1	1.1	8.6	12.4	8.3
<i>E. regnans</i> (mountain ash)	2.1	1.1	8.6	5.3	6.3
<i>E. resinifera</i> (red mahogany)	11.9	8.5	13.3	24.4	>33.4
Timber species	Brisbane 36.0 years	Innisfail 36.0 years	Sydney 35.3 years	Walpeup 35.7 years	Melbourne 33.4 years

<i>E. rubida</i> (candlebark)	1.0	1.1	4.7	6.0	4.3
<i>E. saligna</i> (Sydney blue gum)	4.2	5.2	11.9	13.8	14.0
<i>E. salmonophloia</i> (salmon gum)	21.9	2.2	13.6	21.0	>33.4
<i>E. sideroxylon</i> (red ironbark)	22.8	26.3	25.5	27.6	>33.4
<i>E. sieberi</i> (silvertop ash)	5.2	1.1	11.9	13.8	13.1
<i>E. tereticornis</i> (forest red gum)	13.0	18.1	30.0	26.9	>33.4
<i>E. viminalis</i> (manna gum)	1.0	1.1	4.7	5.3	4.3
<i>E. wandoo</i> (wandoo)	33.4	27.6	>35.3	26.9	>33.4
Non-eucalypt hardwoods					
<i>Acacia acuminata</i> (raspberry jam)	26.9	15.9	34.2	>35.7	>33.4
<i>A. harpophylla</i> (brigalow)	26.3	21.9	21.9	22.8	>33.4
<i>Allocasuarina luehmannii</i> (bull oak)	>36.0	>36.0	>35.3	18.4	>33.4
<i>Anisoptera thyrifera</i> (garawa)	4.2	8.5	8.6	8.8	6.3
<i>Intsia bijuga</i> (kwila)	8.5	8.5	8.6	21.4	15.4
<i>Litsea reticulata</i> (bollywood)	3.1	5.2	8.3	12.4	8.3
<i>Lophostemon confertus</i> (brush box)	3.1	3.2	8.6	13.8	8.3
<i>L. suaveolens</i> (swamp box)	13.8	8.5	15.7	26.9	16.4
<i>Nothofagus cunninghamii</i> (myrtle beech)	1.0	1.1	6.6	2.2	8.3
<i>Syncarpia glomulifera</i> (turpentine)	10.3	8.5	11.9	26.9	27.6
<i>S. hillii</i> (satinay)	6.9	8.5	11.9	29.8	29.2
<i>Pterocarpus indicus</i> (New Guinea rosewood)	8.5	5.2	8.6	25.0	12.3
<i>Quercus alba</i> (American white oak)	2.1	1.1	8.6	8.8	4.3
<i>Tectona grandis</i> (Burmese teak)	11.9	10.2	12.8	33.3	>33.4
<i>Callitris glaucophylla</i> (white cypress pine)	10.3	8.5	11.9	24.4	27.6
<i>Lagarostrobos franklinii</i> (huon pine)	8.5	4.2	10.3	8.8	10.9
<i>Phyllocladus asplenifolius</i> (celery-top pine)	10.3	5.2	8.3	19.4	10.9
Softwoods					
<i>Agathis robusta</i> (kauri pine)	1.0	1.1	1.6	8.8	4.3
<i>Athrotaxis selaginoides</i> (King William pine)	6.9	8.5	8.6	>35.7	10.9
<i>Pinus radiata</i> (radiata pine)	1.0	1.1	1.6	1.0	6.3
<i>Prumnopitys amara</i> (black pine)	1.0	1.1	3.2	12.4	4.3
<i>Pseudotsuga menziesii</i> (Douglas fir)	3.1	1.1	4.7	3.3	8.3
<i>Sequoia sempervirens</i> (redwood)	5.8	5.2	8.6	>35.7	13.1
<i>Thuja plicata</i> (western red cedar)	6.9	5.2	8.6	19.1	10.9
12 kg CCA/m ³ treated <i>P. radiata</i>	>36	>36	>35.3	>35.7	>33.4
175-210 kg K.55 creosote/m ³ treated <i>P. radiata</i>	>36	33.4	>35.3	>35.7	>33.4

The second column in Table 2 provides the mean of the median ratings for all test sites. The best performing timber was CCA-treated *Pinus radiata*, with all but one replicate still serviceable at the five test sites. The next best performing timber was K.55 creosote treated *P. radiata*. The best performing naturally durable timbers were raspberry jam (*Acacia acuminata*), red box (*Eucalyptus polyanthemus*), wandoo (*E. wandoo*), tallowwood (*E. microcorys*), bull oak (*Allocasuarina luehmannii*), grey ironbark

(*E. paniculata*), yellow box (*E. melliodora*), Gympie messmate (*E. cloeziana*), grey box (*E. moluccana*) and white mahogany (*E. acmenoides*).

For untreated timbers, the mean service life values could be used to subdivide the various species into natural durability classes. According to AS 5604, timbers with service lives greater than 25 years belong in class 1, 15 to 25 years are class 2, 5 to 15 years are class 3, and 0 to 5 years are class 4. The wet tropical site at Innisfail has the highest rainfall and fastest decay rate of the test sites examined. If Innisfail is included in the analysis, several timbers that are normally considered class 2 timbers (15 to 25 year service life) fall into the lower class 3 category. Examples are, jarrah (*E. marginata*) with mean rating 14.7 and blackbutt (*E. pilularis*) with mean rating 14.0 that would become class 3 timbers. Similarly, forest red gum (*E. tereticornis*) and woollybutt (*E. longifolia*) would move from class 1 to class 2 timbers. If Innisfail is excluded from the analysis, these changes do not occur and the results appear to calibrate more similarly with the rate of deterioration accepted in the standard. Innisfail could then be seen as an accelerated decay site, rather than a site that contributes directly to the numbers given in the standard.

Table 2 shows the mean of the median specimen lives for the test sites excluding Innisfail (third column). The resulting values suggest the natural durability class for each timber species (fourth column). The natural durability classes given in the 2003 edition of AS 5604 are given in the fifth column, and generally agree with the results found in this trial. The similarity is not surprising, as earlier inspection results from this test have contributed to the development of the standard. Some changes are suggested by this latest comparison. Red box (*E. polyanthemos*) and brigalow (*A. harpophylla*) appear to be class 1 rather than class 2 timbers. Coast grey box (*E. bosistoana*) should remain a class 1 timber as its mean median specimen life was greater than 23.7 years. If the trial had continued, this species may have reached a 25 year specimen life. Timbers that should be upgraded from class 3 to class 2 are yellow gum (*E. leucoxydon*) and brown mallet (*E. astringens*). Turpentine (*S. glomulifera*) appears to be a class 2 rather than class 1 timber against decay and termites, and performs similarly to the closely related species satinay (*S. hillii*). The impression that turpentine is a class 1 timber may have arisen from its superior performance in the sea against marine borers. Swamp box (*L. suaveolens*) should also be considered a class 2 rather than class 1 timber. Species currently considered class 4 (non-durable) timbers, but showing class 3 natural durability, are celery-top pine (*Phyllocladus asplenifolius*), NSW messmate (*E. radiata*) and red tingle (*E. jacksonii*). The results suggest that a number of other species could be considered class 3 rather than class 4 timbers, namely black peppermint (*E. amygdalina*), garawa (*A. thyrifera*), brownbarrel (*E. fastigata*), American white oak (*Q. alba*) and mountain ash (*E. regnans*). However, it is probably advisable to retain these timbers in the class 4 category as a precaution. Candlebark (*E. rubida*) is clearly a class 4 and not a class 3 timber.

Table 2: Mean of median specimen lives from all sites, with or without the Innisfail results, and comparison with current AS 5604-2003 classification. Species order based on decreasing mean of median specimen lives, excluding Innisfail.

Timber species	Mean of median ratings from all sites	Mean of median ratings excluding Innisfail	Suggested rating	Current AS 5604 rating	Proposed change
Eucalypt/Corymbia hardwoods					
<i>E. polyanthemos</i> (red box)	>31.3	>32.4	1	2	1
<i>E. wandoo</i> (wandoo)	>31.3	>32.3	1	1	
<i>E. microcorys</i> (tallowwood)	>30.6	>32.3	1	1	
<i>E. paniculata</i> (grey ironbark)	>29.6	>30.5	1	1	
<i>E. melliodora</i> (yellow box)	>27.4	>30.3	1	1	
<i>E. cloeziana</i> (Gympie messmate)	>26.4	>29.5	1	1	
<i>E. moluccana</i> (grey box)	>25.3	>29.5	1	1	
<i>E. acmenoides</i> (white mahogany)	>27.7	>29.1	1	1	
<i>E. cladocalyx</i> (sugar gum)	>27.2	>28.3	1	1	

Timber species	Mean of median ratings from all sites	Mean of median ratings excluding Innisfail	Suggested rating	Current AS 5604 rating	Proposed change
<i>E. sideroxylon</i> (red ironbark)	>27.1	>27.3	1	1	
<i>E. longifolia</i> (woollybutt)	>22.9	>26.5	1	1	
<i>E. tereticornis</i> (forest red gum)	>24.3	>25.8	1	1	
<i>E. bosistoana</i> (coast grey box)	>20.7	>23.7	2	1	None
<i>E. gomphocephala</i> (tuart)	>19.4	>23.2	2	2	
<i>E. salmonophloia</i> (salmon gum)	>18.4	>22.5	2	2	
<i>E. leucoxylon</i> (yellow gum)	>18.8	>21.0	2	3	2
<i>E. resinifera</i> (red mahogany)	>18.3	>20.8	2	2	
<i>E. camaldulensis</i> (river red gum)	>18.3	>19.9	2	2	
<i>E. cornuta</i> (yate)	>16.6	>19.9	2	2	
<i>E. patens</i> (WA blackbutt)	16.1	19.9	2	2	
<i>C. maculata</i> & <i>C. citriodora</i> (spotted gum)	>16.7	>18.8	2	2	
<i>E. astringens</i> (brown mallet)	15.8	18.5	2	3	2
<i>E. guilfoylei</i> (yellow tingle)	>14.1	>17.4	2	2	
<i>E. pilularis</i> (blackbutt)	14.0	16.7	2	2	
<i>E. marginata</i> (jarrah)	14.7	16.3	2	2	
<i>E. consideniana</i> (yertchuk)	13.5	16.1	2	2	
<i>E. goniocalyx</i> (long-leaved box)	11.8	13.9	3	3	
<i>E. macrorhyncha</i> (red stringybark)	12.8	13.9	3	2	3
<i>E. botryoides</i> (southern mahogany)	11.1	12.8	3	3	
<i>E. haemastoma</i> (scribbly gum)	10.5	12.6	3	2	3
<i>E. muelleriana</i> (yellow stringybark)	9.0	11.0	3	3	
<i>E. saligna</i> (Sydney blue gum)	9.8	11.0	3	3	
<i>E. sieberi</i> (silvertop ash)	9.0	11.0	3	3	
<i>E. diversicolor</i> (karri)	8.8	10.7	3	3	
<i>E. maidenii</i> (Maiden's gum)	8.7	10.6	3	3	
<i>E. eugenioides</i> (white stringybark)	9.0	10.4	3	3	
<i>E. dives</i> (broad-leaved peppermint)	8.7	10.3	3	3	
<i>E. globulus</i> (Tasmanian blue gum)	8.2	10.0	3	3	
<i>E. grandis</i> (rose gum)	9.1	9.7	3	3	
<i>C. calophylla</i> (marri)	8.7	9.6	3	3	
<i>E. megacarpa</i> (bullich)	7.8	9.5	3	3	
<i>E. eugenioides</i> (Wilkinson's str.b.)	8.6	9.4	3	3	
<i>E. cypellocarpa</i> (mount. grey gum)	7.7	9.3	3	3	
<i>E. capitellata</i> (brown stringybark)	7.2	8.7	3	3	
<i>E. jacksonii</i> (red tingle)	6.1	7.4	3	4	3
<i>E. obliqua</i> (messmate)	6.0	7.2	3	3	
<i>E. amygdalina</i> (black peppermint)	6.3	7.1	3	4	3
<i>E. fastigata</i> (brownbarrel)	5.4	6.5	3	4	None
<i>E. regnans</i> (mountain ash)	4.7	5.6	3	4	None
<i>E. rubida</i> (candlebark)	3.4	4.0	4	3	4
<i>E. elata</i> (river peppermint)	3.3	3.8	4	4	
<i>E. viminalis</i> (manna gum)	3.3	3.8	4	4	
Non-eucalypt hardwoods					
<i>Acacia acuminata</i> (raspberry jam)	>29.2	>32.6	1	1	
<i>Allocasuarina luehmannii</i> (bull oak)	>31.8	>30.8	1	1	

Timber species	Mean of median ratings from all sites	Mean of median ratings excluding Innisfail	Suggested rating	Current AS 5604 rating	Proposed change
<i>A. harpophylla</i> (brigalow)	>25.3	>26.1	1	2	1
<i>Tectona grandis</i> (Burmese teak)	>20.3	>22.9	2	2	
<i>Syncarpia hillii</i> (satinay)	17.3	19.5	2	2	
<i>S. glomulifera</i> (turpentine)	17.0	19.2	2	1	2
<i>L. suaveolens</i> (swamp box)	16.3	18.2	2	1	2
<i>Pterocarpus indicus</i> (NG rosewood)	11.9	13.6	3	3	
<i>Intsia bijuga</i> (kwila)	12.5	13.5	3	3	
<i>Lophostemon confertus</i> (brush box)	7.4	8.5	3	3	
<i>E. radiata</i> (NSW messmate)	6.7	8.1	3	4	3
<i>Litsea reticulata</i> (bollywood)	7.5	8.0	3	3	
<i>Anisoptera thyrifera</i> (garawa)	7.3	7.0	3	4 for spp.	None
<i>Quercus alba</i> (American white oak)	5.0	6.0	3	4	None
Softwoods					
12 kg CCA/m ³ treated <i>P. radiata</i>	>35.3	>35.1			
175-210 kg K.55 creosote/m ³ treated <i>P. radiata</i>	>34.8	>35.1			
<i>Callitris glaucophylla</i> (white cypress pine)	16.5	18.6	2	2	
<i>Sequoia sempervirens</i> (redwood)	>13.7	>15.8	2	2	
<i>Athrotaxis selaginoides</i> (King William pine)	>14.1	>15.5	2	2	
<i>Phyllocladus asplenifolius</i> (celery-top pine)	10.8	12.2	3	4	3
<i>Thuja plicata</i> (western red cedar)	10.1	11.4	3	3	
<i>Lagarostrobos franklinii</i> (huon pine)	8.5	9.6	3	3	
<i>Prumnopitys amara</i> (black pine)	4.4	5.2	3	Not listed	4
<i>Pseudotsuga menziesii</i> (Douglas fir)	4.1	4.9	4	4	
<i>Nothofagus cumminghamii</i> (myrtle beech)	3.8	4.5	4	4	
<i>Agathis robusta</i> (kauri pine)	3.4	3.9	4	4	
<i>Pinus radiata</i> (radiata pine)	2.2	2.5	4	4	

ACKNOWLEDGEMENTS

With a field trial of such long duration, many people have had major involvement in the preparation, installation and reporting of this trial, until the final inspection when the author became involved. Dr John Thornton and Dr Gary Johnson have reported about and cared for this trial over the longest period. Thanks are also due to John for his help during the Walpeup inspection, and to Myron Cause who assisted during the Jolly's Lookout inspection. The provision of long term and secure test sites by the Department of Defence (Innisfail), Queensland Department of Primary Industries and Forestry, Forests NSW, PowerNet Victoria (Rowville) and the Victorian Department of Primary Industry (Walpeup) is also gratefully acknowledged. Thanks also to the FWPRDC for providing financial support for this work.

MATERIALS AND METHODS

Timber Species, Treatment and Specimen Details

At the beginning of this trial in 1968-69, 77 timber species were installed at five test sites. Test specimens were 450 x 50 x 50 mm, cut from the outer heartwood of the butt log. For comparison, *P. radiata* sapwood stakes (some stakes contained a proportion of heartwood) of similar dimensions were treated with K.55 creosote (vertical retort creosote) to 175-210 kg/m³, or copper chromium arsenic salt formulation to a retention of 12 kg/m³. Further details were given by Thornton *et al.*¹ Note that some specimens originally identified as *C. maculata* were collected from Queensland, and are therefore likely to be the closely related species *C. citriodora*.

Test Site, Site Hazards and Exposure Details

The test sites were described by Thornton *et al.*⁴, as follows: There were two test sites in Queensland; Jolly's Lookout (near Brisbane) with mean annual rainfall (mar) of 1500 mm, and in a wet tropical rainforest at Innisfail (mar 3500 mm). In NSW the test site was at Pennant Hills, Sydney (mar 950 mm). Two test sites were in Victoria; in the semi-arid Mallee at Walpeup (mar 340 mm), and at Mulgrave, Melbourne (mar 920 mm). The latter site was sold 18 years after the test was installed and the specimens were moved to a site less than 2 km away at Rowville.

These five sites were originally chosen because they were expected to provide a high termite hazard. However, after 27 years of experience at the sites, Thornton *et al.*⁴ graded the severity of in-ground decay and termite hazards within a range comprising very high, high, moderate, low and (for termites only) no hazard. On this basis, Jolly's Lookout has a very high decay hazard with low termite hazard, Innisfail high decay hazard with high termite hazard, Pennant Hills high decay hazard with low termite hazard, Walpeup moderate decay and termite hazard, and Mulgrave/Rowville moderate decay hazard and no termite hazard.

For most timber species, 10 replicates (two from each of five trees) were allocated to each site. At each site 740 specimens were installed. Specimens were installed in parallel rows in random order, with about 300 mm of the 450 mm length buried vertically in the ground (Figure 1), at four sites between May and July 1968, and at the Melbourne site in July 1969.



Figure 1. Natural durability test stakes on 23 September 2003 at Pennant Hills

Method of Inspection

Test specimens were previously inspected by Thornton *et al.* in 1999⁴. They were not inspected again until this final inspection, on 12 December 2002 for Rowville (after 33.4 years), 23 September 2003 for Pennant Hills (35.3 years), 30 March 2004 for Walpeup (35.7 years), 13 July 2004 at Brisbane (36 years), and 15 July 2004 at Innisfail (36 years). During the inspections, test stakes were withdrawn from the soil, and probed with a knife to determine the extent of decay or termite attack. Specimens were given a performance rating of 8-0 for each mode of attack (Table 3), with specimens rating 3 considered unserviceable⁶. The rating is based on the amount of cross-section lost (Figure 2).

Table 3: Rating scale used to assess replicates of the in-ground stake trial.

Rating	Cross-section lost	Minimum cross section remaining when attack is uniform, mm	Description of decay or termite attack
8	No loss, sound	50 x 50	None
7	Up to 15%	46 x 46	Light
6	15–30%	42 x 42	Light-moderate
5	30–45%	37 x 37	Moderate
4	45–60%	32 x 32	Moderate-heavy
3	60–75%	25 x 25	Heavy
2	75–90%	16 x 16	Severe
1	90–99%	5 x 5	Severe-destroyed
0	100%	0 x 0	Destroyed

⁶ Thornton, J.D., Johnson, G.C. and Nguyen, N-K. (1991). An in-ground natural durability field test of Australian timbers and exotic reference species. VI. Results after approximately 21 years exposure. *Mater.Org.* 26 (2): 145-155.



Figure 2. Example ratings for test stakes.

Disclaimer

CSIRO excludes all liability for any special, indirect or consequential damages arising out of the Client's use of or reliance on the information in this Report.

This report was prepared for the Client and its specified purposes. Accordingly, any person other than the Client uses the information in this report entirely at its own risk. CSIRO excludes all liability for any loss or damage suffered by any person other than the Client as a result of that person's reliance on or use of the information in the report, whether or not that loss was foreseeable.