Acacia heathii De Wild
Araucaria cunninghamii W.T.Aiton ex D.Don
Corymbia maculata – Spotted gums
Eucalyptus camaldulensis Dehnh.
Eucalyptus cladocalyx F.Muell.
Eucalyptus fraxinoides Deane and Maiden
Eucalyptus globulus Labill.
Eucalyptus delegatensis W.Hill ex Maiden
Eucalyptus occidentalis E.Mit.
Eucalyptus saligna Smith
Pinus pinaster Ait. ex D.Don
Pinus radiata D.Don

TREES FOR FARM FORESTRY: 22 PROMISING SPECIES
Foreword

Commercial farm forestry is an increasingly feasible business option for rural land in many parts of Australia. The interest generated by land owner groups and individuals and supported by government programs is being translated into on-ground action at a steadily expanding rate. The knowledge base supporting this on-ground action is only just keeping pace with the requirements of growers who are new to forestry activities in areas outside the conventional plantation forestry base.

This publication is one of a range of publications and advisory activities from the project ‘Seed and Information Support for Commercial Farm Forestry’, which was carried out by staff of CSIRO Forestry and Forest Products. The objective of the project was to enhance the economic and environmental benefits of commercial farm forestry through assisting farm forestry growers and investors to select and make best use of native and exotic species for the available sites and products required. This objective has been achieved through technology transfer, extension of the knowledge base and the use of enhanced genetic material.

Activities included:
- provision of high quality source identified seedlots for trial and demonstration plantings
- workshops on all aspects of establishing and monitoring trials to identify suitable tree species and provenances for sites and end uses
- publication of a manual for establishing field trials and demonstration plantings for farm forestry
- analysis and interpretation of trial data
- provision of the TREDAT tree performance database software, along with enhancements to the software for use with non-trial plantings, and training in its use
- establishment of a web-based national register of trials
- development of improved climatic profiles for a range of species
- assessment of the potential productivity of several of these species across a range of locations
- research into the suitability of a range of farm forestry species for pulpwood, cement board and oriented strandboard.

The other publications produced under the project are included in ‘related publications’ which follows the Introduction.

This project was funded by DAFF and the Natural Heritage Trust, the Joint Venture Agroforestry Program (JVAP) and CSIRO. JVAP is supported by three R&D corporations – Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia (L&WA), and Forest and Wood Products Research and Development Corporation1 (FWPRDC). The R&D corporations and the departments named are funded principally by the federal government.

This report is an addition to RIRDC’s diverse range of over 1800 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

Most of our publications are available for viewing, downloading or purchasing online through our website:
- purchases at www.rirdc.gov.au/eshop

Peter O’Brien
Managing Director
Rural Industries Research and Development Corporation

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1 Now Forest & Wood Products Australia (FWPA)
Acknowledgements

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Disclaimer

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Abbreviations

ALRTIG  Australian Low Rainfall Tree Improvement Group
ATSC   Australian Tree Seed Centre (part of CSIRO Forestry and Forest Products)
CALM   Conservation and Land Management of Western Australia
        (now Department of Environment and Conservation)
DBH    diameter at breast height i.e. measured at 1.3 metres up the bole of the tree from ground level
DNR    Queensland Department of Natural Resources (now split between DPI and NR&M)
DPI    Queensland Department of Primary Industries
dS m⁻¹  decisiemens per metre (units used to measure salinity levels. See ECₑ below for further information)
ECₑ    electrical conductivity of a saturated soil paste which is expressed in units of deciSiemens per metre. This has been found to be the best way to describe soil salinity. See glossary for ‘salinity classes’.
FPC    Forest Products Commission of Western Australia
ha⁻¹   per hectare
IBA    Indole-3-butyric acid (a hormone commonly used for rooting cuttings)
JVAP   Joint Venture Agroforestry Program
kcal   kilocalorie
m⁻³    per cubic metre
MAI    mean annual increment, a measure of the mean annual volume growth of a species expressed in cubic metres per hectare
MAR    mean annual rainfall expressed in millimetres
MAT    mean annual temperature expressed in °C
NPK    nitrogen, phosphorous and potassium fertiliser
DSE    Victorian Department of Sustainability and Environment
NR&M   Queensland Department of Natural Resources and Mines
QFRI   Queensland Forest Research Institute
Executive Summary

What the report is about

The selection of species for any planting program is a combination of science and inspiration. It requires a detailed knowledge of species variability and potential, gained either by research or experience, careful analysis of site factors and the way they impact on tree growth and an understanding of product requirements and yield potential.

Who is the report targeted at?

This publication addresses species selection, an area of uncertainty for growers and investors in commercial farm forestry in Australia.

Background

Other publications have looked at planting configurations, likely products and benefits, legislative, and social issues and drivers and economics. Most of these assume appropriate selection of species and planting material to deliver the required outcomes. Lack of information on suitable commercial production models is one of the key limiting factors to greater uptake of farm forestry. One of the greatest areas of uncertainty is associated with the selection of species that are not only bio-physically suited to the planting site, but also capable of delivering the right products and services for the available markets.

Aims/Objectives

This publication looks at 22 species which are suitable for a variety of planting conditions as well as having potential for commercial returns. It focuses primarily on native species although some commercially important exotic species are included for comparison.

This is not an exhaustive or necessarily definitive list, but the species listed here will be productive when planted in the right place using the correct silviculture.

The profiles also highlight the sort of information required to assess the useability of species against grower requirements and this sort of information should be gathered for any other species considered in a selection process.

Methods used

Much of the information provided here is the result of long term research and experimental trials. Some anecdotal information is included where this highlights a problem or issue that may be relevant to growers. Species trialling is an expensive process and, while desirable from the point of view of risk reduction, cannot be done at sufficient scale or intensity to provide definitive answers for all planting sites. Various techniques have been developed to try and attempt to extend the results of trials beyond their local area. Of these, the climate matching work has provided the greatest insight to date for a broad range of species.

Results/Key findings

Each of these species profiles contains a set of preferred climatic conditions and a comparison map showing where these types of conditions occur in Australia. This is a useful first cut but it then needs to be tempered with soil information and desired products and services. Information is included on general silviculture requirements appropriate to each species. The profiles also refer to the value and/or use of the pure species as a hybrid parent. Recommended further reading and references are given for each species.

Implications

While silviculture can modify the productive capacity of a plantation over time, the initial selection of planting material – species, provenance, seedlot or clone – is locked in for the full rotation. It pays growers and investors to select carefully and with the best available knowledge.
Introduction

Given the relatively long time from planting to harvest with forestry crops, it is difficult to carry out extensive trials to understand species potential at every site. It is necessary to establish experimental plantings on representative sites that are carefully designed to provide the highest quality information for the widest range of available operational planting sites. The tools available to assist the selection process are improving over time, particularly in regards to the understanding of genetic variation in tree species (e.g. Eldridge et al., 1993) and with better climate modelling capability for site analysis and mapping (e.g. Jovanovic and Booth, 2002).

These species profiles describe the characteristics of 22 species of actual or potential value for farm forestry in Australia. The information is derived from the available experimental sites and other assessments as well as some anecdotal information where this was considered useful for potential growers.

The species selected cover a range of climatic zones and include species about which little is known as well as several already in established production systems. The profiles also highlight the sort of information required for the process of selecting species against site and product objectives.

Selection of planting material

At the time of planting, an irrevocable choice is made about the genetic material to be used for the productive rotation. Certain growth characteristics can be modified during the rotation but careful selection of planting material is necessary to avoid costly failures. At this stage of farm forestry development, most planting material is coming from selected species and provenances. Breeding and improvement programs have commenced for a number of species (see individual species profiles) which will eventually provide improved planting material with known growth and product potential for a specified range of sites. Currently, species and provenance selection is about matching particular planting material to a particular site or range of sites. In order to do this we need information about both the planting material and the site in a form that allows comparison, such as if a species grows on sandy soils then it is less likely to be successful on a site with heavy clay soils.

The species profiles provide information on the known climatic and soil preferences for the species listed. Possible planting sites should be catalogued in a similar way. It is possible to use models to obtain estimates of climate at given points across Australia which can then be used to compare with the climate requirements of particular species. Soil information is more difficult and generally some form of soil analysis will be required. Analyses done for agricultural crops is rarely sufficient for tree crops and additional sampling work will be required to assess site capability. Ryan et al. (2003) provides a guide to site characterisation for assessing possible tree growth.

Knowledge of the biophysical requirements of species and provenances has been obtained from knowledge of their natural range and from cultivated stands. Generally, species will perform best on sites closely aligned with their natural environmental limits. However there are good examples (e.g. Pinus radiata and Grevillea robusta) where successful planting sites are found outside the natural environmental envelope. Wherever possible the profiles have been adjusted to include characteristics of known cultivated areas.

In general, knowledge of the biophysical requirements of species is more highly developed than the knowledge of product suitability and requirements. Many commercially available wood based products such as Medium Density Fibre Board and Oriented Strand Board have been developed around existing substantial raw material resources. They have reasonably specialised requirements for wood fibre as a raw material. Preliminary comparisons have indicated potential suitability for a range of the species listed here for a range of products (Hicks and Clark, 2001; Freischmidt et al., in review).

For a detailed discussion of species selection methods, see Boland (1997).
Why were these species selected for profiles?

The species included in this series of profiles were selected on the basis of their fledgling use in farm forestry, their potential based on performance in trial or other plantings and/or their suitability for different regions of Australia. The table below summarises their primary reasons for inclusion as follows:

- **Temperate/tropical** refers to the broad climatic region that the species is suitable for. Where both are listed, the species will have provenance and/or breeding programs applicable to both areas. Details are in the species profiles but the same material will, in general, NOT be suitable for both temperate and tropical locations.

- **Wet/dry** is a very general allocation to traditional higher rainfall forestry areas versus lower rainfall ‘new’ forestry areas. ‘High’ and ‘low’ rainfall is very subjective and absolute figures depend on where you are in Australia. Again, where both wet and dry are nominated for a species, it is likely that a different suite of genetic material will be applicable. The species profiles detail these differences.

- **Use/potential** relates to the current use of the species in Australian plantation programs or to the potential for use based on either superior growth rates or actual usage in overseas planting programs.

<table>
<thead>
<tr>
<th>Species</th>
<th>Temperate/tropical</th>
<th>Wet/dry</th>
<th>Use/potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia mearnsii</em></td>
<td>temp</td>
<td>wet/dry</td>
<td>potential</td>
</tr>
<tr>
<td><em>Araucaria cunninghamii</em></td>
<td>tropical/sub-trop</td>
<td>wet</td>
<td>in use</td>
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<tr>
<td><em>Eucalyptus benthamii</em></td>
<td>temp</td>
<td>wet/dry</td>
<td>potential</td>
</tr>
<tr>
<td><em>E. camaldulensis</em></td>
<td>temp/tropical</td>
<td>dry</td>
<td>potential</td>
</tr>
<tr>
<td><em>E. cladocalyx</em></td>
<td>temp</td>
<td>dry</td>
<td>potential+</td>
</tr>
<tr>
<td><em>E. cloeziana</em></td>
<td>tropical/sub-trop</td>
<td>wet/dry</td>
<td>potential+</td>
</tr>
<tr>
<td><em>E. dunnii</em></td>
<td>temp/sub-trop</td>
<td>wet</td>
<td>potential+</td>
</tr>
<tr>
<td><em>E. fraxinoides</em></td>
<td>temp</td>
<td>wet</td>
<td>potential</td>
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<td><em>E. globulus</em></td>
<td>temp</td>
<td>wet</td>
<td>use</td>
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<tr>
<td><em>E. grandis</em></td>
<td>temp/tropical</td>
<td>wet</td>
<td>use</td>
</tr>
<tr>
<td><em>C. maculata/henryii/citriodora subsp. variegata</em></td>
<td>temp/tropical</td>
<td>dry</td>
<td>use</td>
</tr>
<tr>
<td><em>E. nitens</em></td>
<td>temp</td>
<td>wet/dry</td>
<td>use (wet)</td>
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<tr>
<td><em>E. occidentalis</em></td>
<td>temp</td>
<td>dry</td>
<td>potential</td>
</tr>
<tr>
<td><em>E. pellita</em></td>
<td>tropical</td>
<td>wet</td>
<td>use</td>
</tr>
<tr>
<td><em>E. pilularis</em></td>
<td>sub-tropical</td>
<td>wet</td>
<td>potential+</td>
</tr>
<tr>
<td><em>E. saligna</em></td>
<td>temp/sub-tropical</td>
<td>wet</td>
<td>potential</td>
</tr>
<tr>
<td><em>E. sideroxylon/ E. tricarpa</em></td>
<td>temperate</td>
<td>dry</td>
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<td><em>E. smithii</em></td>
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<td><em>E. tereticornis</em></td>
<td>temp/tropical</td>
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<td><em>E. viminalis</em></td>
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<td>potential</td>
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<tr>
<td><em>Grevillea robusta</em></td>
<td>temperate/sub-tropical</td>
<td>wet</td>
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<tr>
<td><em>Pinus caribaea</em></td>
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<td>wet</td>
<td>use</td>
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<tr>
<td><em>P. pinaster</em></td>
<td>temperate</td>
<td>dry</td>
<td>use</td>
</tr>
<tr>
<td><em>P. radiata</em></td>
<td>temp</td>
<td>wet</td>
<td>use</td>
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</tbody>
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+ small but expanding plantation base
Hybrids

A number of the species covered by these profiles are being used, or have been used, to produce inter-specific hybrids. Hybrids are produced to try and combine positive characteristics from different species which would not otherwise arise from pure species mating. Pushing forestry into more challenging environments produces situations where there may not be a ‘natural’ forest or woodland analogue; i.e. looking for a pure species growing naturally on a similar site type may not be an option. In these cases it may be attractive to try and combine characteristics like wood qualities and frost tolerance for example, or fast growth rates and drought tolerance.

Hybrids can only be made within genera and often (as is the case in eucalypts) only within common groups within the genus. The species profiles refer to the value and/or use of the pure species as a hybrid parent.

General notes on silviculture and planting

Good genetic material is essential for success, but appropriate silviculture is essential for the genetic potential to be realised. Individual silvicultural requirements are included in a number of the species profiles but there are some general points and issues that are relevant for all species. In drier and more marginal sites, the application and timing of silvicultural treatments is even more critical e.g. it is possible (if undesirable) to delay thinning of plantings in higher rainfall zones where a similar delay in lower rainfall areas will result in intense competition for water and lost productivity. Thinning is a particularly important issue in the early stages of farm forestry development because of the generally low levels of genetic improvement. Higher variability in planting stock means that more trees must be planted in order to achieve sufficient quantities of suitable final crop trees.

Site preparation

Some cultivation is required to provide seedlings with optimal early growing conditions and access to soil water and nutrients. Because trees are deep rooted plants, the surface cultivation used for agricultural crops is rarely sufficient for good tree establishment. Combinations of surface cultivation, deep ripping 70-100 cm and mounding of topsoil have all been used to increase the early growth rate of seedlings and help them to out compete other plants (weeds) on site. The particular combination, depth of rip line and size, presence or absence of mound depends on soil conditions on the site. In general on dry sites the more, the deeper, the bigger, the better within cost and machinery constraints. Very sandy soils may not benefit unless they are overlying a clay layer within 90cm of the surface. These site preparation techniques should be combined with other weed control measures.

Weed control

Weed control is essential for effective tree growth especially in the early stages of plantation establishment and up to canopy closure. In widely spaced plantings on drier sites weed control may be required for a longer period. Weeds compete with seedlings for water, light and nutrients. Weed control should commence prior to planting as a component of site preparation and can be done via cultivation or application of chemicals (usually both). Many chemicals used for weed control have been developed to knock down native plants so particular care needs to be taken when using these chemicals around eucalypts and acacias. The effect of herbicides is also affected by soil type and climate and local prescriptions should be sought wherever possible. Mowing between rows of trees is often used to control weeds but complete removal is preferable if feasible.

Fertiliser

Most nurseries add normal and slow release forms of fertiliser (usually NPK and trace elements) to the potting mix before filling the pots. Examples of fertiliser use in Australian eucalypt nurseries are given by Doran (1990). This initial dose will assist the seedlings for a short time after planting but it may be necessary to apply additional fertiliser at planting. The particular mix can vary according to previous site use but application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of seedlings in Australia and elsewhere. Rates vary widely depending on the...
site and readers are directed to papers in Attiwill and Adams (1996) for examples. In drier areas, the usefulness of applied fertiliser will depend on available water.

In old highly leached soils with some accumulated organic matter, as in many parts of Australia, eucalypts have generally responded better to phosphorus additions than to any other single nutrient. In contrast, nitrogen has tended to provide the best response from a single nutrient addition in relatively recent soils that have low organic matter (Schönau and Herbert, 1989). Generally though, the response to both N and P together tends to exceed the response to either alone (attiwill and Adams, 1996). Techniques for identification of nutritional disorders and the symptoms of deficiencies in eucalypts are described by Dell et al. (1995). Also, a simple key for visual diagnosis of deficiencies in eucalypt seedlings is provided by Brundrett et al. (1996).

Spacing

Initial spacing will depend on species and improvement status, rainfall, access requirements and other land uses. In traditional commercial plantations, a fairly high planting density is used (up to 1200 stems per hectare) and then thinned successively as the trees start to compete. The initial thinning may be non-commercial but in most cases, forest owners would try to find a market for the thinned trees to try and recoup management costs. With genetically improved planting stock, lower planting densities can be used to avoid non-commercial thinning as more of the trees will be of final crop quality.

In low rainfall areas spacing will be critical as access to water is a critical limiting factor for growth and trees will compete vigorously for available moisture. In these areas it will be necessary to concentrate as much of the wood production potential of the trees onto the minimal number of stems (i.e. fewer but larger and more valuable logs) as the access to markets for thinnings will be less and the checks on growth due to competition more damaging to final returns.

An appropriate assessment program should be instigated to provide the data on which to make spacing and thinning decisions (see Reid and Stephen, 2001).

Protection

The increasing use of native species in plantations will result in greater damage due to natural pests and diseases. One of the primary reasons for the successful use of exotics is that they are often not susceptible to the natural pests and diseases present in the landscape. Often a decline in tree health is the culmination of various stresses. Imbalance for example, may result from severe insect attack combined with extreme environmental conditions such as prolonged drought or stress due to competition for water and nutrients. Weakened trees will prove more susceptible to pests and diseases so it is important to select healthy trees and aim to minimise impacts by reducing competition through thinning.

Related Publications:


Clarke NB, in review Wood Products from Farm Forestry – Hardwood Export Chips. A report for the Joint Venture Agroforestry Program. RIRDC Project No. CSF-56A, Rural Industries Research and Development Corporation, Canberra.


References


References


Species profiles

Many of these profiles have been adapted from earlier work by a number of authors in the CSIRO Forestry and Forest Products and the Australian Tree Seed Centre and two from elsewhere. We would like to thank the authors and acknowledge the significant contribution the following works have made to these profiles:


1. *Acacia mearnsii* De Wild.

Black wattle

Adapted from Doran, 2000.

**Key features**

- Small to medium-sized tree of variable form
- Fast growth rate
- Moderately frost tolerant
- Moderately drought tolerant
- Tolerant of a wide range of soils but achieves better growth and form on deep, moisture-holding soils
- Intolerant of salinity or waterlogging
- Has a generally weak coppicing ability
- Not windfirm
- The wood is hard and tough yet moderately easy to work and finishes very well
- The wood needs to be seasoned slowly to avoid checking and needs to be prebored as it can split when being nailed
- Provenances with better growth performance in early-age Australian trials include ‘Kyneton’, Victoria; ‘Bodalla’, New South Wales; ‘Braidwood’, New South Wales and ‘Tarpeena’, South Australia. However, comprehensive testing to identify provenances for farm forestry has not been conducted and farmers should consider carrying out their own testing.
- Niche may be in single-species clearwood woodlots, on suitable sites, to produce high-value furniture-grade timber in a much shorter time than is possible from other decorative species – this would require high initial stocking, pruning and progressive thinning.

**Species overview**

*Acacia mearnsii* is a fast-growing, light demanding, nitrogen-fixing large shrub or small tree that reaches 6-20 m in height. It is adapted to a wide range of sites and is generally described as a short lived species (15-20 years) but has been reported to live to 40 years on favourable sites (Searle, 2000). Deaths in plantations due to over-maturity are frequent after 10 years in South Africa (Doran and Turnbull, 1997). It will tolerate relatively infertile sites but requires a good supply of phosphorus for rapid growth. It has the ability to fix nitrogen, regenerate rapidly and is moderately frost tolerant (Brown and Ho, 1997; Searle, 2000). It does not tolerate sodic or saline-sodic soils (R. Boardman, South Australia, pers. comm., 2002).

In the past, native stands in Australia were the basis of a labour-intensive tannin extraction industry, but this demand is now met by overseas plantations (Jovanovic and Booth, 2002). As well as yielding bark extractives high in quality condensed tannin, this native hardwood is capable of producing a range of other wood products including paper pulp, cellulose for rayon, fuelwood, charcoal, composite boards, posts, sawn timber for furniture, parquet flooring and lining boards (Searle, 2000).

*A. mearnsii* is a useful species for erosion control, soil improvement, windbreaks, shade and shelter, and ornamental plantings.
Description and natural occurrence

Description

A large shrub or small tree, typically in the height range 5-15 m but at times reaching 20 m with a breast height diameter up to 45 cm but normally in the range of 10-35 cm. Open-grown specimens are freely-branched from near ground level and will often have a crooked main stem. In forest stands the stem is usually straighter and may be dominant for up to three-quarters of the tree height. The bark on younger stems and the upper parts of older trees is grey-brown and smooth, while that on older trees is brownish-black, hard and fissured. Both juvenile and adult foliage is bipinnate and is dark-green and fern-like. The flowers are pale creamy-yellow in globular heads and the seed pods more or less straight but often constricted between the seeds, dark brown to blackish when ripe. Mature seed is available for collection some 12-14 months after flowering and is not retained on the tree after two to three weeks making timing of seed collections critical (Doran and Turnbull, 1997; Searle, 1997).

Flowering takes place from October to December in Australia (Searle, 1997). The trees start flowering when about 2 years old, but large quantities of seed are seldom produced in plantations before the fifth or sixth year (Sherry, 1971). In Brazil seed production averaged 0.7 kg per tree in a 10-year-old plantation (Stein and Tonietto, 1997) however, open grown trees can produce large quantities of seed (e.g. several kilograms) in a good year. Mature seed is available for collection some 12-14 months after flowering and as it is not retained on the tree for more than 2-3 weeks the timing of seed collection is critical (Searle, 1997).

Acacia mearnsii is regarded as an outcrossing species with partial self-compatibility. Estimates of out-crossing rates in the species are variable and range from 48-100% (see review in Raymond, 1997). The flowers are mainly insect pollinated, with honey bees considered the most important pollinators due to their methodical foraging (Moncur et al., 1991; Grant et al., 1994). A detailed review of the flowering biology of A. mearnsii is provided by Raymond (1997).

Natural occurrence

This wattle occurs in the understorey of tall open forest or open forest dominated by eucalypts. It may occur on the fringes of closed-forest and rarely in woodland and coastal scrub. It can form dense, pure, even-aged thickets especially where it has recolonised cleared land. Best development is on easterly and southerly aspects of low hills in coastal lowlands and adjacent lower slopes of the tablelands and ranges (Doran and Turnbull, 1997).

Acacia mearnsii is a native of south-eastern Australia. It extends through southern New South Wales and southern Victoria to south-eastern South Australia and Tasmania (Figure 1.1). The northern limit is west of Sydney (33°43’S) and the latitudinal range is 33°S to 42°S. A. mearnsii occurs across an altitudinal range of about 1050 m, from coastal...
The natural occurrence of *A. mearnsii* falls mostly in the warm sub-humid zone, extending in places to the warm humid zone. At the highest altitudes it occurs in the cool sub-humid and humid zones. The species is rarely found in areas where the temperature exceeds 38°C. Coastal localities have no heavy frosts; inland there are 1-20 frosts per year and at some higher altitudes up to 80 frosts are recorded, with a record low of -12°C. The average annual rainfall is 440-1600 mm, and the lowest on record is around 360 mm. Seasonal incidence of rainfall varies from a well-defined winter maximum in the south, through more uniform, to a weak summer maximum in the northern-most parts of the occurrence (Doran and Turnbull, 1997).

This species has been recorded on basalt, dolerite, granite and sandstone but is common on soils derived from metamorphic shales and slates. The soils are mainly loams, sandy loams and deep forest podsols of moderate to low fertility. The best soils for *A. mearnsii* are moist, relatively deep, light-textured and well-drained, although it is often found on moderately heavy soils and occasionally on shallow soils. The soils are usually acidic, pH 5.5-6.5. It is not common on poorly-drained or very infertile sites (Doran and Turnbull, 1997).

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *A. mearnsii*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>700-2300 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-6 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>21-30°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>0-15°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>10-20°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *A. mearnsii* (Figure 1.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). The revisions were made to the climate parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Though in its natural distribution *A. mearnsii* only grows in areas south-east of Sydney, analysis of climatic conditions at successful plantations overseas...
clearly indicate that it is worth considering in areas which are somewhat wetter and warmer. Successful plantations are generally found in areas where the rainfall is over 700 mm and to achieve the fastest growth rates probably requires mean annual rainfalls (MARs) above 850 mm and mean annual temperatures (MATs) above 16°C (Schönau and Schulze, 1984). A. mearnsii’s natural distribution also includes locations with MARs as low as 440 mm and if slower growth is acceptable, the species is also worth considering for planting in colder and drier environments. Absolute minimum temperatures below -5°C can cause serious damage to A. mearnsii.

A. mearnsii is susceptible to insect attack and disease when stressed. To avoid this sites with shallow soils or soils of low moisture holding capacity, especially when combined with prolonged drought and/or low rainfall should be avoided.

Planting and provenance trials

Planting

Black wattle is widely cultivated in a number of countries throughout the world. Principal growing areas include Brazil with over 200 000 ha of plantation (Higa and Resende, 1994), South Africa with 160 000 ha (Boucher, 1980), down from 325 000 in the halcyon days of tannin production in the 1960s (Wiersum, 1991), plus 30 000 ha in East Africa (Zimbabwe, Kenya, Tanzania, Rwanda, Burundi), India with 20 000 ha and Indonesia with 15 000 ha (Wiersum, 1991). Black wattle is grown extensively in China for vegetable tannin production and when surveyed in 1987 the total area of plantations was 10 433 ha. In addition there are extensive, largely unrecorded plantings in agroforestry systems in many countries.

A. mearnsii is one of many tree species grown by nurseries in the Australian Capital Territory, New South Wales, Victoria and Tasmania for use in roadside, farm, amenity and ornamental plantings (Searle, 1997). Government and privately-owned plantations have been established in South Australia, Victoria and New South Wales. The largest government plantation, 400 ha, was established in Victoria in 1887 (Searle, 1997).

Provenance trials

Currently, long-term performance of black wattle provenances in Australian conditions is not known. Indications from recent plantings are that ‘Blackhill Reserve’ (Kyneton, Victoria) grows well in the Ballarat, Victoria, region. In Hamilton, south-west Victoria, at 5 years of age ‘Tuross River’ and ‘Bodalla’, New South Wales, grew well in terms of volume. At trials in the Australian Capital Territory provenances from ‘Bungendore’, New South Wales, and ‘Tarpeena’, South Australia, grew well at a site with 630 mm yr⁻¹ MAR and ‘Blackhill Reserve’ Kyneton, Victoria, grew well with 824 mm yr⁻¹ MAR (Searle, 2000).

High-altitude New South Wales provenances (‘Bungendore’, ‘Bombala-Dalgety’ and ‘Cooma’) and two low-elevation provenances, ‘Apsley’ (Tasmania) and ‘Minhamite’ (Victoria), were the most frost tolerant (Searle et al., 1994). These results are largely in accord with field data from...
South Africa where high-altitude New South Wales provenances were significantly more frost-tolerant than low-altitude New South Wales and Victorian provenances. Highly significant between-family variation for frost tolerance within provenances indicates potential for selection and breeding to increase the cold-hardiness of the species (Searle et al., 1991).

A comparison of tannin content of bark samples from 18 uneven-aged natural populations of black wattle in Australia showed Tasmanian and Victorian provenances (46.9% and 46.6%) had more tannin in their bark than the South Australian and New South Wales group (39.4% and 38.8%) (Guangcheng et al., 1991; Li et al., 1994).

**Breeding and genetic resources**

*Acacia mearnsii* shows significant variation in growth rate, form, branching density and size, adaptation to drought and low temperatures, and in wood and bark characteristics. It has been an important plantation species outside Australia for more than 100 years and selection and breeding programmes based on local landraces have been established in South Africa (Li, 1997) and Brazil (Higa and Resende, 1994). In South Africa two generations of breeding improved several traits of major economic importance: tannin content, incidence of gummosis, stem form and survival rate. A breeding strategy is described by Raymond (1987, 1997).

Searle (2000) suggests that in the absence of provenance recommendations based on long-term performance of black wattle in Australia, farmers could identify better provenances by planting their own provenance trials. Seed of a range of provenances for testing is available from CSIRO Forestry and Forest Products, Australian Tree Seed Centre in Canberra.

**Silviculture**

The utilisation of black wattle in Australia has been limited to harvesting from natural stands. Clear guidelines for silvicultural practice with black wattle have been developed in South Africa by the Institute for Commercial Forestry Research. However, the applicability of the South African guidelines to growing black wattle under Australian conditions and for different products, such as specialty timber, has not been evaluated (Searle, 2000).

**Propagation**

There are about 70,000 viable seeds kg\(^{-1}\) (Doran and Turnbull, 1997). Fully ripened seed has a hard seed coat and retains its viability well in storage. Seed storage is orthodox and storage of good quality seed in airtight containers in a dark, cool room should maintain viability for several years. To ensure rapid and complete germination, seed coat dormancy must be broken before sowing. Mechanical scarification can be very effective but the seed is more commonly treated by immersion in boiling water for one minute (Doran and Gunn, 1987). Treated seed may be surface dried and stored safely for at least one year.

Attempts to vegetatively propagate *A. mearnsii* have generally had limited success. However, recent work in South Africa has indicated that the technique of rejuvenating adult material through coppicing and meristem culture can now be applied to genetically superior trees and can be used for future clonal programmes (Beck and Dunlop, 1999). However, at the present time tissue culture remains very costly.

Measuring the height of *Acacia mearnsii* at 3 years of age in the Acacia species trial at Kowen, ACT.
Nursery establishment is generally by sowing pre-treated seeds directly into containers (Doran and Turnbull, 1997) or into beds to produce bare-rooted seedlings (Gao, 1997). Seedlings can reach plantable size (20 cm in height) in 4 months. Inoculation with appropriate rhizobium and mycorrhiza strains is rarely necessary but may be beneficial especially when seedlings are raised in sterilised media or planted on highly degraded soils. Searle (2000) notes that CSIRO Plant Industry, Canberra, has identified select rhizobia strains and a proven method of inoculation for commercial nurseries that can produce black wattle seedlings with better survival and growth in the nursery and field. They expect to have effective strains of rhizobia commercially available in 2002 (Brockwell et al., 1999).

Planting is carried out in June/July in South Australia and Western Australia while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts (where soils dry out earlier). Planting
in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred. Its coppicing ability is generally weak, although small stumps coppice readily.

**Establishment**

The seeds may be directly sown in the field in well-cultivated and weed-free ground. Seeding rate is 1.2-2.4 kg ha\(^{-1}\) and the seed is often sown in rows 1.8-2.7 m apart. Seedlings are then thinned at regular intervals until routine spacings are achieved. Direct seeding is a cheap method but it allows little control over tree spacing. Favourable seasons can result in high tree densities which may require labour-intensive thinning in the first year before trees become too large (Kevin, 2000).

The importance of site preparation by ploughing or ripping and weed control in promoting rapid establishment and growth has been demonstrated by Boden (1984). Black wattle is intolerant of weed competition when young and plantations must be kept weed-free until canopy closure (Luyt et al., 1987). Refer to Bird (2000) for more information and weed control prescriptions. Papers in Brown and Ho (1997) detail the various weeding operations applied in countries in East Africa, Brazil, China and South Africa [Doran and Turnbull, 1997].

Initial spacing and thinning regimes will vary with the purpose of planting. Searle (2000) suggests that closer initial spacing, say 1.5-2.0 m between trees within rows, will minimise branch development. However trees will need to be thinned out before competition for water and nutrients become limiting and the trees become stressed. When planting in drier areas it is advisable to use wider spacings between rows with 4.0 m currently being adopted.

Black wattle is a nitrogen fixing species but has shown very significant increases in wood volume and tannin yield after being fertilised with phosphorus (Schönau, 1983; Herbert, 1984; Waki, 1984). In the absence of any documented evidence on optimum fertiliser regimes for Australia, Jaakko Pöyry Consulting (1999) recommended that a combination of 60 kg phosphorus and 200 kg of potassium be applied per hectare at the time of planting (Searle, 2000). The best response to fertiliser was when ripping was used in conjunction with fertiliser application (Boden, 1984).

Boron is seriously deficient in Kenya and Tanzania, particularly in areas where trees suffer seasonal moisture stress (Boland, 1997). Sodium borate at 36.5% borax is applied at 70 kg ha\(^{-1}\) on such deficient soils. An *A. mearnsii* provenance trial in Fujian, China has also had fairly severe boron problems. However, the application of boron where it is not deficient can result in tree deaths due to toxicity.

**Management**

Thinning is commonly applied to maintain rapid growth, increase bark thickness (as this is directly correlated with stem diameter) and obtain revenue from thinnings to enhance the overall economics of growing black wattle. Refer to Bird (2000) for a detailed discussion of thinning in an Australian farm forestry context. Overseas the species is grown at high densities which even after thinning remain at around 1500-1700 stems ha\(^{-1}\). In South Africa trials reported by Craib (1935) indicated that to obtain optimum crop yields, thinning was required to maintain a freely developing crown on main crop trees without decline in leaf area from overcrowding or lack of soil moisture. This involved thinning early to 450-500 stems by the time a third of the rotation had passed, at age 3-4 years. This may be followed by a further light thinning to around 280-300 stems for the last third of the rotation, depending upon product size specifications to use of the timber. The timing of the thinning was found to be crucial as to try and regain current wood increment after loss of leaf area due to overcrowding was shown to be very difficult, if not impossible, at ages greater than 3-4 years, despite re-spacing.

Pruning early to reduce knot size conventionally entails cutting branches as close to the stem as possible without injuring the swollen zone at the base of the branch. Searle (2000) notes that this method has been employed successfully on a small scale in south-western Victoria. However, she says that Darren Doherty of Australia Felix Bendigo communicated to her another method, favoured by him to prevent gum exudation, which closely mirrors the approach of the South Africans. This involves pruning at about 3-4 cm from the stem; the branch stubs wither and die to leave a clean pruning wound. Pruning may also be applied to...
reduce the incidence of forked trees and allied wind damage (Gao, 1997; Ho and Fang, 1997).

Overseas, *A. mearnsii* is usually established in monoculture and managed for tannin production on a rotation length of 8-10 years (range of 5-12 years) after which time it is clear felled. Regeneration of cut-over areas is by replanting, spot or line sowing, or through natural means. Bark stripping, for tannin extraction, is best done when the sap is flowing and this occurs during the warm summer months. If the bark must be stored, the strips should be carefully dried in the shade in a well-aerated area to minimise mould development (Doran and Turnbull, 1997).

Growth

Production data from Australia is meagre. There is data available from a well-documented silvicultural trial on deep yellow podsolised sands (Caroline sand) at Mt Gambier, South Australia. It was planted in 1991 at two stocking rates and with and without fertiliser (there were no significant effect from the addition of fertiliser at either stocking). The trials were not thinned. The production data for the trials (see Table 1.1) is comparable with typical South African data, such as that reported by Stubbings and Schönau (1982) (R. Boardman, South Australia, pers. comm., 2002).

Black wattle reaches its maximum growth rate of up to 3.5 m yr\(^{-1}\) 2-3 years after planting in South Australia. In South Africa maximum height growth rates are up to 3 m yr\(^{-1}\) 3-5 years after planting (Wiersum, 1991). Bennell et al., (2004) quote a figure for stemwood production of 2.66 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) at an MAR of 500 mm. On appropriate sites and where the trees are fertilised, a mean annual increment (MAI) over 7-10 years of 15-25 m\(^3\) ha\(^{-1}\) of wood is feasible. Brown and Ho (1997) report similar yields in countries in Africa and in China.

Table 1.1: Production data from an *Acacia mearnsii* silviculture trial at Mt Gambier, South Australia (R. Boardman, South Australia, pers. comm., 2002)

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Stocking (stems ha(^{-1}))</th>
<th>mean DBH (cm)</th>
<th>Predominant Height [tallest 70 trees ha(^{-1})] (m)</th>
<th>Timber Volume (m(^3) ha(^{-1}))</th>
<th>Estimated bark yield (green t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1886</td>
<td>12.1</td>
<td>13.3</td>
<td>85</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>1821</td>
<td>14.7</td>
<td>20.0</td>
<td>140</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>6944</td>
<td>7.4</td>
<td>13.0</td>
<td>114</td>
<td>24</td>
</tr>
<tr>
<td>9</td>
<td>5556</td>
<td>8.6</td>
<td>18.0</td>
<td>172</td>
<td>36</td>
</tr>
</tbody>
</table>

**Protection**

Black wattle seedlings need to be protected from browsing by rabbits, hares and wallabies with tree guards or vermin-proof fencing (Searle, 2000).

Trees are more susceptible to insect and disease attack when they are stressed. Hence the more marginal the site for a species the higher the incidence and severity of such attacks is likely to be. Good site selection and the maintenance of the trees in good health are essential for successful and productive tree growth.

In Australia, the total number of insects associated with *A. mearnsii* is large and a number cause serious, sporadic damage that affects its survival or growth and form (Searle, 2000). The leaf-eating fireblight beetle, *Acacicola orphana* syn. *Pyrgoides orphana* (Coleoptera), is a serious pest (Elliott and de Little, 1984) and was one of the early disincentives for planting the species in Victoria, Australia (Searle, 1991). After a severe outbreak, the trees have a reddish-brown, scorched appearance due to their complete defoliation (Searle, 2000). Outbreaks of this beetle and its larvae occur during winter and spring. While chemical controls may be effective these insecticides will also affect the numbers of the beetle’s natural enemies and limit their influence in controlling any low-level insect outbreaks.
The most obvious diseases are gall-forming fungi, e.g. *Uromycladium tepperianum*. This fungus causes the development of rusty-red woody growths (galls) on branchlets and flower heads. Heavy infestations will finally kill the tree. There are no known controls other than removal of the galls to prevent the spread of the disease. Fertiliser applications may improve the vigour of the trees (Jones and Elliott, 1995; Searle, 2000).

An apparent physiological disorder known as ‘gummosis’, in which gum is exuded in the absence of any obvious injury, is a serious problem in commercial plantations outside of the natural climatic range of *A. mearnsii*. The disorder reduces bark quality and hinders stripping of bark. In South Africa this term has been applied to a complex of diseases associated with *A. mearnsii* (Roux et al., 1995). The most successful control of gummosis has been by selecting and breeding trees resistant to the disease (Wang, 1997). In Australia symptoms of gummosis as experienced in South African plantations do not appear to occur in native trees.

*A. mearnsii* plantations are susceptible to wind, hail, frost and snow damage. Black wattle is susceptible to wind damage because the root system develops mainly in the soil surface layer and tap roots are short. Light ground fires may kill trees up to 3 years old when their bark is quite thin. Trees that are older will usually survive this type of fire but may have their growth checked.

**Utilisation**

**Wood**

Sapwood is very pale brown and the heartwood light brown with reddish markings. It is fine textured and has distinct growth rings. The basic density is about 630 kg m\(^{-3}\) (756 kg m\(^{-3}\) Bennell et al., 2004) and the air-dry density 550-750 kg m\(^{-3}\) (Bootle, 1983). The moderately dense wood, which splits easily and burns well, makes excellent fuelwood and charcoal. Bootle (1983) states that black wattle’s green and seasoned timber has the same medium strength characteristics as blackwood (*Acacia melanoxylon*) (Searle, 2000).

The timber must be seasoned slowly to avoid checking. The wood is hard but is moderately easy to work and finishes very well. To avoid splitting, pre-boring is necessary before nailing. It is susceptible to attack by termites and borers (*Lyctus* sp.).

The wood is used for house poles, mine timbers, tool handles, industrial and domestic woodware, turnery, cabinet work, joinery, flooring, construction timber, matchwood, fuelwood, particleboard, fibreboard, hardboard, charcoal and pulp.

There is currently no market acceptance in Australia of black wattle for fuelwood, charcoal, composite boards, posts and specialty timber. Further marketing would be required to raise awareness of the comparative quality of these products and to distinguish black wattle from other acacias such as blackwood (*Acacia melanoxylon*) or others commonly called black wattle (Searle, 2000).

‘Experience with growing and processing black wattle for sawn timber is very limited in Australia but there is interest and enthusiasm about the species by the few who have grown, felled, milled, dried and worked with the species’ (Searle, 2000). Searle (2000) reports that anecdotal evidence suggests black wattle timber has good stability along with good machining, sanding, gluing and finishing properties. On favourable sites black wattle has the potential to produce specialty timber in less than 15 years (Searle, 2000).

The pulping properties of *A. mearnsii* render the woodchips suitable for a range of paper and paperboard products. Plantation-grown *A. mearnsii* is currently being used commercially in South Africa as a component of a wood furnish for kraft and soda-AQ pulp production and *A. mearnsii* woodchips are exported from that country to Japan for use in manufacture of kraft pulps (Logan, 1987). The woodchip export market is the only Australian market, with one or two small-scale exceptions, that recognises black wattle as a good source of quality wood (Searle, 2000). However, remoteness from sea ports (>150 km) and an ability to produce a marketable quantity are limitations for selling to the Japanese market. They have a minimum requirement of cf. 30 000 bone dry metric tonnes i.e. sufficient for a ship load. The large areas of plantations that would be required to meet minimum export demands, 60 000-100 000 green tonnes per year, and the fact that the wattle would be competing with blue gum, which has faster growth and better pulping
properties, make it unlikely that such an industry will develop in Australia (Kevin, 2000).

Black wattle’s moderately dense wood, which splits easily and burns well, makes excellent fuelwood and charcoal. In Australia the wood was once sought after to fire bakers’ ovens and some ceramic artists still prefer to fire their kilns with black wattle (Searle, 1996). The charcoal is extensively used for cooking in Kenya and southern Brazil and the wood is used in Indonesia for domestic fuel, village industries and curing tobacco leaves [Berenschot et al., 1988; Wiersum, 1991]. The cheaper establishment methods, such as direct seeding, that can be used for such a crop along with the species fast growth make firewood production an attractive option. Firewood can also be produced from timber plantation thinnings (Kevin, 2000). However, the poor coppicing ability of the species (coppicing being a popular method of managing fuelwood crops) after 3 years of age means that the crop would need to be clearfelled and resown or replanted (Searle, 2000).

As the sapwood of black wattle absorbs preservative well, treated posts are a potential product for on-farm use. It has also been suggested that they could be used in the vineyard industry. To be used in this industry, black wattle, as with other hardwoods, would have to compete with the widely used treated pine posts. Bird (1997) reports that black wattle posts have greater strength than treated pine posts of the same diameter (Kevin, 2000; Searle, 2000). Posts with bark intact have been used to support oyster racks in New South Wales (Searle, 1996).

Non-wood

A. mearnsii produces the world’s most important vegetable tannin, especially suited for use in the manufacture of heavy leather goods [Doran and Turnbull, 1997]. The bark of the species is very rich in condensed tannin (35-51%, dry weight) (Hillis, 1997; Searle, 2000). In addition to its use for leather tanning, the powdered bark extract is used to prepare tannin formaldehyde adhesives for exterior grade plywood, particleboard and laminated timber (Coppens et al., 1980; Yazaki and Collins, 1997). There is a small Australian market for black wattle tannin which is currently met by extracts imported mainly from South Africa. The powdered extract is used principally in adhesive resins used in the production of particleboard flooring (Searle, 2000). Industry development of tannin production is dependent on development of a tannin extract processing industry and innovative methods for bark stripping to compete with low labour costs overseas. A large black wattle plantation resource would be required to guarantee sufficient raw product (Kevin, 2000). Tannin prices dropped in 2000 while the cost of raw substitutes, melamine and phenol, rose. This could see an increased use of tannin but probably not to past levels, i.e. 8000 tonnes in 1984 (Searle, 2000). Refer to Searle (2000) for further discussion on this industry.

Tannin yields are influenced by several factors including genetic variability, age and environment. Tannin industries based on this species have been developed in Brazil, China, Kenya, India, South Africa, Tanzania and Zimbabwe (see papers in Brown and Ho, 1997). The main exporting countries are South Africa, Kenya and Tanzania and the main importers are the UK, Australia and the USA (Wiersum, 1991).
As black wattle is a nitrogen-fixing, pioneer species it is very suitable for environmental plantings. It establishes well from direct seeding and is noted for its rapid early growth. In southeastern Australia, it is commonly used in plantings on sites that receive rainfall down to about 600 mm per year, for shelter, shade, salinity and erosion control, landscape enhancement, soil amelioration and wildlife habitat (Searle, 2000). The species has been effective in controlling soil erosion on steep slopes and improving soil fertility (NAS, 1980; Waki, 1984).

The leaves (phyllodes) of *A. mearnsii* have a high protein content (15%), but palatability trials with sheep showed milled leaves to be unpalatable on their own and were only acceptable when mixed with other feedstocks (Goodriche, 1978). Goodriche (1978) considered that digestibility was probably affected by the high tannin content in the leaves and twigs (5.7%, dry weight). It is considered to be an inferior stock feed in Japan but has been fed to cattle in Hawaii during droughts (Doran and Turnbull, 1997).

Sawdust of black wattle has been found to an excellent medium for growing edible mushrooms in China (Ho, 1997).

*A. mearnsii* is a valuable source of pollen for bees during favourable seasons, as it flowers later than most other wattles (Clemson, 1985). It has a range of other wildlife values such as being a food source for insects and seed eating birds and the gum provides a good winter food source for possums and sugar gliders.

**Limitations**

*A. mearnsii* is an aggressive coloniser and has become a weed in some parts of southern Africa where fires occur (Boucher, 1980). It coppices weakly and is sensitive to severe drought, strong winds, and frosts of -5°C or lower. Poor stem form often limits utilisation of timber from plantations. In Australia the potential for insect damage must be recognised.

**Recommended Reading**


**References**


Searle SD, 1991. The rise and demise of the black wattle bark industry in Australia. Technical paper No. 1. CSIRO Division of Forestry, Australia.


Hoop pine, Moreton Bay pine, colonial pine

**Species overview**

*Araucaria cunninghamii* is a very tall tree, having a large, long straight bole with little taper and is free of branches for up to two thirds of the tree height. It is shade-tolerant when young, but grows best in high light conditions (CABI, 2000). It is windfirm, can tolerate salt winds and occasional mild frost, however it is susceptible to severe frosts when young (CABI, 2000). It prefers fertile soils, growing best on deep loams which originally carried rainforest. It suffers little damage from insects or fungi (DNR, 1996).

In Queensland over 50 000 ha of hoop pine has been planted for timber production. It is capable of producing knot-free timber of exceptional quality and is used in plywood, panelling, mouldings, particleboard, furniture, internal and external joinery, boxes and flooring (DNR, 1996). One of its major features is its uniformity of both appearance and

**Key features**

- Large symmetrical tree with little taper and of good form
- Moderate growth rate
- Can tolerate only mild occasional frost
- Grows best at sites with an average rainfall above 750 mm
- While it will grow on heavy soils it is not tolerant of waterlogging
- The tree is very fire sensitive
- Tree is susceptible to root and heart rots
- Wood is uniform in appearance and properties and is easy to saw and dress taking stains readily
- Sapwood susceptible to blue stain and termites but not Lyctus borers
- Wood has low strength and durability, should not be used in-ground and should be treated if used externally above ground
- Wood is used in heavy and light construction work (internal only), joinery, mouldings, flooring, furniture, veneers and plywood, and long fibre pulp
- Rotation length required for sawn timber is 40 to 55 years.

*Araucaria cunninghamii* stand in Queensland.
properties. The wide sapwood is very susceptible to blue stain and care needs to be taken in drying. It is easy to saw and dress and takes stains and polish readily.

Description and natural occurrence

Description

Hoop pine is a large, symmetrical tree up to 60 m tall, with a long, straight, cylindrical bole (to 40 m) 60-200 cm in diameter (CABI, 2000). It has little taper and is free of branches for up to two-thirds of the tree height. The crown is rather open with dark green foliage tending to be clumped at the end of branches. Some trees have long internodes between whorls of branches, that give it a spindly silhouette with tufts of foliage at the end (CABI, 2000). It is a relatively shade-tolerant tree and tends to establish immediately after pioneer species during secondary succession following disturbance (Keenan et al., 1997).

The bark is reddish brown to coppery on young trees and peels in horizontal strips. On older trees the bark is dark brown or black, hard and rough with horizontal cracks forming hoops or bands and rectangular scales (Boland et al., 1984).

This conifer has small linear leaves with stiff, sharp points, spirally arranged and grouped at the ends of branches. It has separate and different male and female flowers which appear from November to February. The fruit, or cones are terminal, almost globular, up to 10 cm in diameter and composed of flattened, wedge-shaped woody scales with lateral wings. A single seed is embedded in each scale. Cones ripen from December to February. Years of heavy, highly-viable seed crops are strongly periodic occurring at intervals of 2-6 years. Age of female sexual maturity is 10-12 years and of male sexual maturity is 20-25 years. It takes 2 years from pollination to mature seed (Nikles, 1996).

Natural occurrence

The natural range of hoop pine in Australia is from 12°S to 31°S and is limited to coastal regions (or within 160 km of the coast) of New South Wales and Queensland, from sea level to about altitude 1000 m (Figure 2.1). The major region is from the Clarence River, New South Wales, to Bundaberg, Queensland (Boland et al., 1984). It also occurs naturally in Papua New Guinea and Irian Jaya, Indonesia, at latitudes 0°N to 12°S and altitudes from sea level to about 2750 m.

The species grows on soils derived from basalt, diorite and limestone, through to schists with calcareous sediments and andesites, sandstones to recent coastal sand and river alluvia. Soils range from krasnozems, red-earths to dark grey self mulching soils on basaltic scoria with at least 50 cm of well aerated soil (Boland et al., 1984).
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *A. cunninghamii*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>750-2700 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Summer, uniform</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-2 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>24-34°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>2-19°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>15-26°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *A. cunninghamii* (Figure 2.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Although hoop pine is found naturally in sites with mean annual rainfall as low as 660 mm commercial plantations are typically found in locations receiving an average of more than 750 mm. Sites in Papua New Guinea suggest the species is suitable for uniform as well as summer rainfall environments. Dry season length at commercial plantations is usually less than two months (Jovanovic and Booth, 2002). Consideration of soil requirements, occurrence of frost (see section on ‘Silviculture’) and proximity to markets also need to be considered when deciding whether to plant hoop pine.
Plantings and provenance trials

Plantings

In Queensland, Australia, hoop pine plantations date back to 1917 and now cover some 50,000 ha. Large scale plantations have also been established in South Africa and Papua New Guinea. Limited planting, or experimental stands, occur in Malaysia (Chew, 1975; Greathouse, 1973; Shim, 1973), Thailand, the Philippines, India (Nair, 1971), Côte d’Ivoire, Africa (Malagnoux and Gautun, 1976), as well as Venezuela (Tillman, 1975), Argentina (Cozzo, 1963) and Costa Rica (Mesen, 1990) (CABI, 2000). The species grows well in India at altitudes up to 1000 m in the western Himalayas, and up to 1500 m in the eastern Himalayas.

Provenance trials

Large differences between provenances of hoop pine for growth rate, crown form and morphology were identified in a series of wide ranging trials which were established in Queensland in the late 1960s-early 1970s. Northern Australian provenances (especially ‘Coen’) and Papua New Guinea (PNG) provenances displayed very rapid early growth with dense broad crowns able to capture the site quickly and hence reduce the need for weeding (Nikles, 1978). However, PNG provenances were susceptible to frost in both south Queensland and upland, north Queensland trials, and to insect attack in south Queensland. An additional three trials and provenance resource stands (PRRs) were established in south and north Queensland between 1977-1980 (Nikles, 1996). Results of these, as well as generally confirming those of earlier trials, identified the following southeastern Queensland provenances as better performers and as important sources of germplasm for future breeding of the species in south Queensland, ‘Jimna’, ‘Goodnight Scrub’, ‘Yarraman’, ‘Kalpowar’ and ‘Polmaily’. Several PNG and north Queensland provenances were identified as important for deployments in central and north Queensland.

Breeding and genetic resources

Intensive selection and breeding for population improvement has been practised in Queensland for around the last 50 years. Plantation establishment with seed of selected superior trees from natural populations began in the 1920s. This was followed by formal tree improvement which began in the mid 1940s. However propagation with conventional grafting methods were unsuccessful but a new method (bark patch grafting) was developed in 1959 as a result of research into the biology of the species. In particular the species was found to have a very different bud system from that of the Pinus species (Nikles, 1961).

Improved seed of A. cunninghamiana is available from the Queensland Department of Primary Industries (DPI) Forestry Tree Seed Centre at Beerwah, Queensland (DPI website, 2002).

Silviculture

Propagation

The CSIRO Forestry and Forest Products Australian Tree Seed Centre have found that hoop pine seed germinates satisfactorily at between 20-30°C. Queensland Department of Primary Industry store their seed at below 8% moisture content, in sealed black plastic containers at -18°C. Incorrect storage conditions will result in deterioration of seed quality over a period of several months and reduced germination. DPI Forestry experience indicates that each 1000 viable seeds yields about 760 viable field plants (DPI website, 2002).

Seed is sown from mid to late August. After soaking in water for 4 hours to stimulate germination, the seed is sown in trays with a media of 50% vermiculite
and 50% sand and lightly covered with the same media. A fungicide can be applied in conjunction with watering. Trays are placed under shade and kept moist at ambient temperature. At the first watering after sowing, trays are drenched with a fungicide. Plants are dibbled into pots at 3-4 weeks and grown under 50% shade till March/April when they are shifted to full sun for hardening. Plants are conditioned by reducing watering frequency from twice a day when they are first moved into the sun to once a week watering by the end of August. The seedlings with heights of around 20 cm are ready for planting in October. Therefore, it takes 1.3 years from sowing mature seed to obtain plantable stock (Nikles, 1996; Lewty and Last, 1998). Further information on pots, potting media, sterilisation and fertiliser are available on the DPI Forestry Tree Seed Centre webpage (DPI website, 2002).

DPI Forestry nurseries specialise in the production and sale of plants for timber plantations. The plants are either genetically improved or from selected provenances to improve the timber yield. Details are available on the DPI Forestry Tree Seed Centre webpage (DPI website, 2002).

Attempts to propagate hoop pine vegetatively were confounded by its unusual orthotropic (shoots grow vertically) and plagiotropic (shoots grow horizontally) bud/shoot system and the occurrence of severe stock-scion incompatibility among field grafts. A grafting method to obtain orthotropic shoot development was devised by Nikles (1961). Rooted cuttings can be readily produced from young and old trees (Higgins, 1971) and seedlings of superior families. However, although hoop pine juvenile cuttings root well the low multiplication rate is likely to be a major impediment to the vegetative multiplication of the species. This is due to the branching system which precludes the construction of broadly topped hedges capable of producing large numbers of orthotropic shoots. Micropropagation of hoop pine has been achieved (Haines and de Fossard, 1977, Burrows et al., 1988, Nikles, 1996).

Establishment

Site selection is important for success. The average annual rainfall should exceed 750 mm yr\(^{-1}\) and the site should be relatively frost-free. Hoop pine grows best on well drained alluvial soils, and soils of volcanic origin. However, it can grow well on a wide variety of soil types as long as there is a reasonable depth of topsoil. Good drainage, a least in the top 45 cm, is essential. Site preparation should begin the winter before planting with clearing of unwanted vegetation. If drainage is poor or the ground has become compacted, mounding is required.
If forested or scrubby areas are to be planted, they should be cleared as for agricultural use and sown to a short grass (or cereal) such as couch at 3 kg ha\(^{-1}\) in order to assist in controlling woody weeds and to mitigate soil erosion risks, especially on steeper slopes. The planting sites should be spot treated with herbicides before and after planting using glyphosate. The spotted area should be kept clear of weeds for a radius of 1-1.5 m for up to 3 years (DNR, 1996). Grass competition should be controlled until the trees are beyond the reach of stock, when grazing may be introduced. Care must be exercised with application of herbicides as hoop pine seedlings are very susceptible to weedicides.

Planting should be carried out in summer when the soil is thoroughly moist. Planting density should be at a rate of 500 trees ha\(^{-1}\). A suitable arrangement for agroforestry might be 2.5 m apart within rows that are 8 m apart. Seedlings are frost sensitive but where heavy frost is possible, mounding can be carried out to elevate seedlings above ground level to reduce the risk of damage. Refilling of gaps when seedlings have died is not recommended as observations have shown that trees planted 3 months or more after the optimal time for planting have a much slower start and do not catch up to the initial plantings. Rather than refilling gaps, care to minimise losses at initial planting and not worrying about the few losses that do occur is the best course of action (DNR, 1996). When planted out, hoop pine becomes colonised with arbuscular mycorrhizae (AM). Survival immediately following planting out is likely to be improved if roots are already colonised with AM fungi (McGee et al., 1999).

Fertilising is usually unnecessary on former rainforest sites, but is advisable on other sites. No specific prescription can be given as the rate required will depend on the site. Rates of between 50-300 grams tree\(^{-1}\) of complete fertiliser at planting are common, followed by similar amounts after good rain in the spring or early summer. Another follow up application the following spring may also be beneficial (DNR, 1996).

Management

Thinning and pruning are necessary to ensure the production of the best possible wood product. Early thinning should take place before the trees are 5 years old. For woodlots, retain 300-350 stems ha\(^{-1}\), choosing the most vigorous of the best formed plants. For agroforestry, retain only 100-200 stems ha\(^{-1}\). Pruning should be done to a height of 3 m when the average height is 9.5 m. Continue pruning to a height of 5.4 m when more than 55% of the trees exceed 10 m. Always retain green crown for at least one-third of the tree’s height and prune only vigorous, well formed stems (DNR, 1996). Pruning should continue at intervals to achieve a clear log of at least 5 m. The most serious insect pest attacks on this species in Australia are associated with pruning injuries, which can be minimised if such operations are carried out at during dry seasons.

Growth

Hoop pine produces around 12 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) over a 45-50 year sawlog rotation (DNR, 1996).

Protection

In general hoop pine suffers little damage due to insect and fungal attack. The most serious insect pest attacks on this species in Australia are associated with pruning injuries, which can be minimised if such operations are carried out during dry seasons. The most significant diseases of plantation-grown hoop pine are root and heart rots caused by *Phellinus noxius* (CABI, 2000).
Fire protection will be required throughout the life of the plantation as the species is very fire sensitive. Each winter a fire break should be constructed around the perimeter of hoop pine plots. The break should be cultivated, slashed or flat bladed at least 3 m wide and maintained throughout the fire season. Slashing between rows of trees will give extra protection. (DNR, 1996).

Since hoop pine is sawn mostly for appearance grade products, sapstain is not acceptable and is prevented by good log management practices and kiln drying, but rarely through the use of chemicals. The Queensland Forestry Research Institute (QFRI) Timber Protection Program is actively researching the biodeterioration of wood caused by sapstain fungi and the chemistry of its control (Powell and Kreber, 1997).

**Utilisation**

**Wood**

Hoop pine has a white to pale yellow heartwood, with indistinct growth rings. The sapwood is white and is susceptible to attack by blue stain fungi but not by Lyctus borers. It is finely textured and has low strength, durability and shrinkage. The wood is uniform in both appearance and properties. It has a density of about 530 kg m⁻³ at 12% moisture content and is easy to work (Boland et al., 1984). It glues well but is difficult to bend. It varies in its acceptance of preservative impregnation. In tropical and subtropical regions, the timber is susceptible to attack by hoop pine borers (Calymmaderus species) unless treated (DPI website, 2002). Treated hoop pine cannot be used for in-ground purposes, but it can be used above ground if treated.

It is used for a wide range of purposes, including heavy and light construction timber, high quality finishing products such as mouldings, joinery, fine furniture and other appearance products, flooring, boxes and containers, veneers and plywood, and long-fibre pulp (Boland et al., 1984; CABI, 2000; DPI website, 2002).

**Limitations**

Low durability, sapwood susceptible to blue stain fungi, termites and hoop pine borers.

**Recommended Reading**


**References**


3. Corymbia maculata

Spotted gums


Adapted from Larmour, 2000.

Species overview

The spotted gums are very closely related and are tall trees up to 50 m on favourable sites. They are important commercial timber species, capable of producing excellent sawn timber and have a wide range of uses – heavy engineering construction and piles, poles and sleepers when treated, shipbuilding, flooring, handles for tools, furniture, panelling and internal decoration, charcoal and firewood (Cremer 1990). Trees are lignotuberous and coppice easily after harvesting. Spotted gums have a high tolerance to Phytophthora but plantations in high summer rainfall regions can be seriously damaged by ramularia shoot blight which is caused by the fungus Sporothrix piteroka. The Queensland Forest Research Institute is currently screening provenances for resistance to the fungus (David Lee, QFRI pers. comm., 2002).

Spotted gums are moderately drought tolerant. Seedlings and young trees are frost sensitive. Under lower rainfall conditions, where there is moisture deficit, the spotted gums are not quite as hardy as some of the other lower-rainfall species (Eucalyptus occidentalis, E. cladocalyx and the ironbarks). They are well suited to rainfall zones receiving above 550 mm yr\(^{-1}\), where severe frost doesn’t restrict establishment, in inland regions of southern Australia. Larmour et al. (2000) identified variation in frost tolerance within the spotted gums, indicating that it may be possible to improve their suitability for frost-prone areas through selection and breeding.

Description and natural occurrence

Species in the spotted gum group have smooth bark. Juvenile leaves are peltate and cordate with long petioles and adult leaves are concolorous.
Distribution of the spotted gums ranges from subtropical and tropical regions in eastern Queensland southward, becoming mainly coastal or subcoastal in New South Wales with a small outlying occurrence in eastern Victoria (Hill and Johnson, 1995).

The majority of the descriptors for *C. maculata* can also be used for *C. henryi* and *C. citriodora* subsp. variegata, with the exception of those relevant to morphology, distribution and climatic features.

**Description**

*Corymbia maculata*

This species generally has a long, straight bole and spreading crown, usually 35-50 m in height, with DBH reaching 1-2 m. It has a self-pruning habit, leaving a clear bole with heavy branching and forking generally restricted to the top third of the tree (Poynton 1979).

The bark is smooth throughout, pale grey, pink or cream, even in colour and shedding in small sheets or scales to expose a dimpled, glaucous-green surface, fading to pink, giving the bole a spotted appearance. It has a deep tap root and lateral root system.

The juvenile leaves are alternate, elliptical to ovate in shape, hairy with bristle glands. Adult leaves are alternate, lanceolate, concolorous and glossy (Hill and Johnson, 1995).

Trees flower annually, generally during winter, at least 14 months after appearance of buds. Prolific flowering occurs at intervals of several years, and heavy seed set on an irregular interval of around 7 years in natural stands. Fruits are mature approximately 6-8 months after flowering and seed is shed from 6 months after maturity, although a portion of seed-bearing capsules can be retained in the crown for 3 years (Pook et al., 1997). Seed is

*Corymbia henryi* natural stand in the Helidon Hills, Queensland, the northern most part of its limited distribution.
glossy red-brown, 2.3 mm long x 1.5-2.5 mm wide (Hill and Johnson, 1995). There will be regional and seasonal variability in seed availability.

Trees in Australian plantations have been observed to flower from 4.5 years of age (Roger Arnold, CSIRO Forestry and Forest Products, pers. comm., 2000).

Pollination is by insects and birds predominately, but gliders and flying foxes have been associated with mass flowering of spotted gums (McDonald et al., 2000).

The species can tolerate periodic droughts (Pook, 1986) but does not tolerate sites subject to prolonged waterlogging (Mazanec, 1999).

**Corymbia henryi**

Distinguished within the section *Politaria* by the larger and thicker leaves at all stages and the adult leaves with coarse venation, which is more acute than that found in the large leaves that occur in some southern examples of *C. maculata*. Also distinguished by the larger buds, flowers and fruits (Hill and Johnson, 1995).

**Corymbia citriodora** subsp. **variegata**

Previously described by Hill and Johnson (1995) as *C. variegata*. These authors saw *C. variegata* as a species similar to *C. citriodora* and more or less intermediate between that species and *C. maculata*. McDonald and Bean (2000) have since published a review of the taxonomy of this species and placed it into *C. citriodora* based on evidence that it is not morphologically or genetically different from this species. The main character distinguishing the two ‘species’ is therefore leaf oil composition and the two ‘species’ are really chemotypes of the same species, i.e. *C. citriodora* (citronellal type – lemon scented) and *C. citriodora* subsp. *variegata* (a-pinene type, not lemon scented).

**Natural Occurrence**

**Corymbia maculata**

*C. maculata* often forms almost pure stands in tall dry sclerophyll forests from the central New South Wales coastal range near Kempsey to the southern coastal ranges of New South Wales near Bega, with a disjunct population near Orbost in eastern Victoria (Figure 3.1). Latitudinal range extends from 30°30’S to 37°S. It is generally found on moist well-drained granitic soils at low altitudes (<400 m) along the coast and ranges, above 600 m near Moss Vale, south of Sydney, extending up the Hunter Valley to the Great Dividing Range, altitude 650 m near Dunedoo New South Wales, to 1000 m elevation north-west of Guyra New South Wales (Hill and Johnson, 1995).
Corymbia henryi

Locally abundant in dry sclerophyll forest on somewhat infertile soils, often but not always on more or less level country, from around Brisbane in Queensland southward to near Glenreagh, south of Grafton, New South Wales (Hill and Johnson, 1995) (Figure 3.2). The latitudinal range extends from around 27°S to 30°S.

Corymbia citriodora subsp. variegata

Widely ranging from the Carnarvon Range and the Dawes Range north of Monto in Queensland, contracting southward to sub-coastal regions as far south as the upper Nymboida River and north-west of Coffs Harbour in New South Wales. It occurs chiefly on soils of medium fertility, often on hilly country (Hill and Johnson, 1995) (Figure 3.3). The latitudinal range extends from around 24°S to 31°S.

Where will it grow?

Corymbia maculata

A climatic profile (Jovanovic and Booth, 2002) for Corymbia maculata, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>580-1,500 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Uniform/bimodal, summer</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-5 months</td>
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<tr>
<td>Mean maximum temperature hottest month:</td>
<td>20-32°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month:</td>
<td>0-7°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>10-19°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting C. maculata (Figure 3.4) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. The dry season length given above has been increased to five months because of data from trials in South Africa (Darrow, 1985) and evidence, which is emerging from trials in Australia, of the species’ drought tolerance (Roger Arnold, CSIRO Forestry and Forest Products, pers. comm., 2001). It should be noted that although the map of areas in Australia predicted to be climatically suitable to C. maculata includes areas in south-eastern Queensland and northern New South Wales, this species has been identified as highly susceptible to ramularia shoot Figure 3.4: Areas predicted to be climatically suitable for Corymbia maculata are shown in black (Jovanovic and Booth, 2002)
blight and has been discounted as a suitable plantation species by Hardwoods Queensland (QFRI website, 2002). This species is also being trialled in southern Australia with some success (see section on ‘Provenance Trials’).

**Corymbia henryi**

A climatic profile (Jovanovic and Booth, 2002) for *Corymbia henryi*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>830-1745 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature</td>
<td>26-31°C</td>
</tr>
<tr>
<td>hottest month</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>2-8°C</td>
</tr>
<tr>
<td>coldest month</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>15-20°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *Corymbia henryi* (Figure 3.5) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). As for the previous map (Figure 3.4) these revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. The major revisions include the raising of the dry season length to five months with the inclusion of trials in South Africa (Darrow, 1996). The upper limits of the mean minimum temperature of the coldest month and mean annual temperature was exceeded in a trial in South Africa, but as this was only one occurrence the previously accepted values have not been changed. The lower limit for mean annual temperature was also exceeded in South Africa (Darrow, 1996), but as this was also only one occurrence the limits were not changed. It should be noted that although the map of areas in Australia predicted to be climatically suitable to *C. henryi* includes areas in south-eastern Queensland and northern New South Wales, this species has been identified as highly susceptible to ramularia shoot blight and has been discounted as a suitable plantation species by Hardwoods Queensland (QFRI website, 2002). This species is also being trialled in southern Australia with some success (see section on ‘Provenance Trials’).

**Corymbia citriodora subsp. variegata**

A climatic profile (Jovanovic and Booth, 2002) for *Corymbia citriodora subsp. variegata*, from the natural distribution, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
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<td>Mean annual rainfall</td>
<td>600-1610 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Summer</td>
</tr>
<tr>
<td>Dry season length</td>
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<td>22-34°C</td>
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<tr>
<td>hottest month</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>0-10°C</td>
</tr>
<tr>
<td>coldest month</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>11-21°C</td>
</tr>
</tbody>
</table>

At present there is little provenance information to relate to the new taxonomic classification as provenances in older trials cannot be readily associated with the new subspecies assignment. Therefore the map of areas predicted to be climatically suitable for planting *C. citriodora subsp. variegata* (Figure 3.6) was generated...
based only on the climatic parameters for the natural distribution. Provenances of *C. citriodora* subsp. *variegata* have been identified by QFRI as the most tolerant of the three spotted gums to ramularia shoot blight (David Lee, QFRI, pers. comm., 2002). This species is also being trialled in southern Australia with some success (see section on ‘Provenance Trials’).

**Plantings and provenance trials**

**Plantings**

These species are important commercial timber trees, harvested from natural stands in New South Wales and Queensland (60% of the volume of native hardwood harvested in Queensland), and commercial plantations have been established in South Africa and Brazil. Spotted gums were established in Western Australia in 1928 and the early 1900s in South Australia (Turnbull and Pryor 1984). They have been established in increasing numbers over the last decade in inland areas of New South Wales, Victoria, South Australia and Western Australia where they have shown potential in farm-forestry and mine rehabilitation in the medium rainfall regions (550-800 mm annual rainfall) and under irrigation in lower-rainfall regions. Small scale plantings of spotted gums under irrigation have also been established in other parts of Australia, South Africa and Israel. Future commercial plantations of spotted gum are expected to be established in central and southern Queensland in areas receiving between 600-1200 mm yr\(^{-1}\) mean average rainfall (QFRI website, 2002).

**Provenance trials**

The spotted gums generally displayed poor survival and slower early growth compared to other more widely-grown eucalyptus species in species elimination trials established in Australia (Clarke et al., 1997; Tibbits and Sasse, 1999). However, more recent provenance-progeny trials using improved silviculture techniques and a broader genetic base have shown increased early growth rates and survival in regions of southern Australia (Tibbits and Sasse, 1999). Trials of spotted gums in the high summer rainfall regions of Australia (900+ mm) have concentrated on *C. citriodora* subsp. *variegata* and *C. henryi* due to the susceptibility of *C. maculata* to ramularia shoot blight in the 900 mm plus rainfall zone (Ivory, 1999). The spotted gum provenance with the highest resistance to ramularia identified to date is the ‘Woondum’, Queensland, provenance of *C. citriodora* subsp. *variegata* (David Lee, QFRI, pers. comm., 2002).

At trial sites around Hamilton in western Victoria, *C. maculata* has better growth and survival than the other two species. The ‘Batemans Bay’, New South Wales, and ‘Orbost’, Victoria, provenances were superior overall across the sites (Measki et al., 1998; Bird et al., unpublished, 2000).

Five provenance-progeny trials were established in 1995 on sites near Deniliquin (New South Wales), Holbrook (New South Wales) and Undera (Victoria). Results from measurements after three years [Tibbits and Sasse, 1999] demonstrate considerable within-provenance and family variation and also considerable variation between sites. Provenances performing well include *C. maculata* from ‘Wingello’, ‘Kioloa’ and ‘Bodalla’, New South Wales; *C. henryi* from ‘Grafton’ and ‘Ewingar’, New South Wales; and *C. citriodora* subsp. *variegata* from ‘Warwick’ and ‘Chinchilla’, Queensland.

One of the spotted gum provenance trials established in 1983 in the Wellington Catchment, Western Australia, has been reported by Mazanec (1999). Species differences were found for mean annual volume increment, *C. maculata* yielding slightly more than *C. citriodora* subsp. *variegata*. There

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**Figure 3.6: Areas predicted to be climatically suitable for *C. citriodora* subsp. *variegata* are shown in black (Jovanovic and Booth, 2002)**

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were no significant differences between provenances within species for volume. *C. citriodora* subsp. *variegata* from the ‘Richmond Range’, New South Wales, had the greatest volume followed by *C. maculata* from ‘Batemans Bay’ (second), ‘Nowra’ (third) and *C. henryii* from ‘Grafton’, New South Wales (fourth). Provenance rankings of the other traits measured were highly variable. Parrot damage was reported, which affected stem straightness. High mortality in parts of the trial from waterlogging indicates a preference for freely-drained soils in all three species.

Trials at Huntley and Jarrahdale in Western Australia, established in 1983, indicated that *C. citriodora* subsp. *variegata* and *C. henryii*, north of latitude 32°S, were performing better than *C. maculata* at those sites (Mazanec, 1993).

A glasshouse study of provenance variation in spotted gum seedlings in relation to frost tolerance was carried out by CSIRO which ranked the frost sensitivity of provenances according to exposure of leaf samples to three test temperatures from -8.0°C to -4.2°C. It showed that variation within and between species exists. The study found *C. citriodora* subsp. *variegata* to have significantly greater frost tolerance than *C. maculata*. Inland, high-altitude provenances of spotted gums had greater frost tolerance than those from coastal locations. The most frost-tolerant provenance was *C. citriodora* subsp. *variegata* from ‘Paddys Land’, at 1000 m altitude north-west of Guyra, New South Wales. The ‘Curryall’ provenance (north of Dunedoo, New South Wales, at altitude 650 m) of *C. maculata* ranked third overall and was significantly more frost tolerant than all other *C. maculata* provenances. The most frost-tolerant provenance tested would have required experimental frost temperatures of 1.5°C lower than the least tolerant provenance to produce the same degree of frost damage (Larmour et al., 2000). It must be emphasized, however, that such differences cannot be equated directly to provenance differences in the ability of whole seedlings to tolerate field frosts, or their ability to withstand the same frost minimum temperatures under field conditions (Raymond et al., 1992).

**Breeding and genetic resources**

Genetic resources of the spotted gum species are generally not considered to be at risk, with there being good representation of most of the species in national parks and state forests. Several small, isolated populations, such as are found along the Great Dividing Range near Dunedoo New South Wales, Mottle Range in eastern Victoria and near Moss Vale on the southern highlands New South Wales, could be considered vulnerable due to the small number of trees growing in restricted areas.

Provenance growth rankings of the spotted gums have been shown to change over time, and this could make the process of selection more difficult than in a species such as *E. grandis*, where superior seedlots selected at age four generally maintain their superiority (Darrow 1985). Tibbits and Sasse (1999) have outlined a breeding strategy to produce improved seed to develop spotted gum plantings in Victoria.
The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra can supply both single-tree and bulk-tree provenance collections of seed from natural stands of the spotted gums suitable for trials. Best bet provenances identified for particular areas and improved seed from seedling seed orchard’s planted near Deniliquin, southern New South Wales, in 1995 are also available.

Queensland Forest Research Institute’s Hardwoods Queensland have identified provenances of spotted gums that are more disease tolerant than others (e.g. Woondum/Gympie, Queensland) and several provenances well suited to drier regions. Seed is available through the DPI Forestry Tree Seed Centre, Beerwah, Queensland (DPI website, 2002).

Best-bet provenances for Western Australia include ‘Richmond Range’ and ‘Batemans Bay’, New South Wales, and are available from the CSIRO Forestry and Forest Products, Australian Tree Seed Centre (ALRTIG, 2002). Seed of the best provenance identified in three replicated species/provenance breeding trials established in 1983 in south-western Western Australia is available from the Forest Products Commission of Western Australia. The Commission also has a limited amount of improved seed from the above trial and expect seed from a clonal seed orchard to be available in the near future (Mazanec and Harwood, 2000; FPC website, 2002).

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

*C. maculata* has an average of 100 000 viable seeds kg$^{-1}$ of seed and chaff mix (Turnbull and Pryor, 1984). Seed storage is orthodox. The viability of seed stored dry (5-8% moisture content) in airtight containers at room temperature (approximately 24°C) will be extended under cool room temperature (3-5°C) (Gunn, 2001). No pre-sowing treatment is required. Rapid germination is achieved under moist, warm (25°C) conditions in the presence of light. Seedlings usually take 3-5 months to reach planting size of about 15-30 cm in height.

Propagation by vegetative cuttings is very difficult from seedlings and basal sprouts from coppiced trees (McComb and Wroth, 1986).

*C. maculata* is susceptible to damping-off and other fungal pathogens during the nursery phase. Approximately 3-5 months under a suitable nursery regime is generally adequate to provide quality seedlings for planting out. Seedlings should be hardened off before planting out, which should be done when the soil is moist and conditions are not excessively hot.

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for the spotted gums. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria) and farm forestry and landcare groups. Books such as Doran and Turnbull (1997), Florence (1996) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoodsqd/), or these documents can be obtained by contacting the organisations directly.

The spotted gums have a varying degree of frost sensitivity, therefore it is desirable to select sites which don’t include frost pockets and hollows. Ripping and mounding, especially on heavy clay soils, is generally recommended. Mounding and use of tree guards increase survival and growth of seedlings planted in frost-prone areas (Bird et al., 2000).

Weed control is critical, as spotted gum seedlings have a weak competitive ability, and weed competition suppresses growth. Generally, a mix of residual and knock-down (usually glyphosate) herbicides is applied before planting, and further control for up to 2-3 years is advantageous. Rates of application and effects of herbicides on spotted gum survival and control of weeds can be found in Hall and Burns (1991).
Seedlings can be planted by hand or by machinery. To allow machinery to be used a spacing of 3-5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha\(^{-1}\)) and 4 m x 2.5 m (1000 trees ha\(^{-1}\)). These spacings encourage rapid canopy closure, reducing weed problems, promoting good form and allowing ample selection for final stocking of 200-300 trees ha\(^{-1}\) (Bird, 2000; QFRI website, 2002).

In southern latitudes with winter and uniform rainfall patterns, planting is carried out during late winter/early spring. Later rather than earlier planting is best with frost-sensitive species like the spotted gums. Planting in northern latitudes usually occurs with the onset of summer rains between November-April, but February-April is preferred.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practiced in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell \textit{et al.} (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

Management

Regular thinning to a final stocking rate of 100-200 stems ha\(^{-1}\) is necessary if mean annual volume growth rates are to be maintained (Florence 1996). The spotted gum’s ability to shed branches well, in combination with the use of high initial stocking rates and the low incidence of knots, even in timber from unmanaged plantings, mean that little or no pruning will generally be required (Washusen \textit{et al.}, 1998; Bird, 2000).

Seven-year-old spotted gum plantation in western Victoria, thinned from 830 to 430 stems per hectare and pruned to 6 m.

Plantations of spotted gums in Australia have yet to reach a stage where commercial harvesting has been undertaken and management practices are still developing.

Growth

Growth data for plantation grown spotted gums is not available for Australia.

Naturally regenerated \textit{C. maculata} stands on the south coast of New South Wales, managed for saw log and mine timber production, indicate mean annual increment of 4.1-5.4 m\(^3\) ha\(^{-1}\) with stand density being reduced from 988 to 99 stems ha\(^{-1}\) between 10-60 years (Borough \textit{et al.}, 1984). Mean annual increments of up to 20 m\(^3\) ha\(^{-1}\) to age 4 years have been obtained in irrigated plantations in inland southern New South Wales (Tibbits and Sasse, 1999).
Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and by regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

Within the temperate uniform/winter regions of Australia spotted gum plantations are relatively free of diseases and pests, except for significant defoliation by Christmas beetles (Angopholgnatus sp.) in some trials in southern New South Wales (Tibbits and Sasse, 1999). Ramularia shoot blight, caused by the fungus Sporothrix pilereka, commonly affects spotted gums in higher-summer-rainfall subtropical regions of northern New South Wales and Queensland (Ivory, 1999), causing spotting, necrosis and distortion of expanding leaves and young stems and possibly leading to repeated die-back of the leader and upper laterals with resultant poor form and growth.

Short-term control of ramularia shoot blight in the nursery can be achieved through fungicide application, although control in established plantations is difficult to achieve (Ivory, 1999). The Queensland Forest Research Institute is screening provenances for resistance to this fungus with the ‘Woondum’ provenance of C. citriodora subsp. variegata proving most resistant to date. They are also looking at hybrids such as C. citriodora subsp. variegata x C. torrelliana that may provide disease resistance along with other desirable characteristics (David Lee, QFRI, pers. comm., 2002).

Damage caused by parrots and cockatoos on young plantations in Western Australia can seriously affect form and growth rates, with dominant leaders chewed off or ring-barked (Mazanec, 1999).

Utilisation

Wood

C. maculata yields excellent timber of high density and strength (Grant and Joe, 1994). The heartwood is pale to dark brown. The texture is moderately coarse and the variable grain is frequently wavy, giving an attractive fiddleback figure. Timber from natural and planted stands is used for heavy construction, tool handles, house fabrication, flooring, mine timbers, plywood manufacture, boat building, charcoal and firewood. The wood can absorb preservatives (due to a wide sapwood band) to produce treated transmission poles or small-diameter round logs. The sapwood is susceptible to Lyctus borer.

The air-dried wood density for spotted gum timber is high, ranging from 800 kg m⁻³ in younger plantation wood (Grant and Joe, 1994) to more than 1000 kg m⁻³ (Washusen et al., 1998).

In a study of timber from unmanaged planted trees, 25-42 years old, in northeastern Victoria and the south-west slopes of New South Wales, the spotted gums came out on top. The timber showed very little or no drying degrade and the recovery of high-quality appearance products was more than twice that of the benchmark species (60-80 year old mountain ash, Eucalyptus regnans). Knots were a minor problem, indicating that in a managed plantation very little pruning would be required (Washusen et al., 1998). Tibbits and Sasse (1999) found that young stands produced timber of similar characteristics to that of natural forests.

Spotted gum planted at a high-rainfall site in Gympie, Queensland, was assessed for its potential for kraft pulp and papermaking (Hicks and Clark, 2001). Of the 23 samples, representing 13 eucalypt species, aged 6-14 years, C. maculata had the highest values as export woodchips.
Hicks and Clark (2001) also noted that there is a strong association between low rainfall and poor pulpwood quality, suggesting that farmers growing trees in dryland regions, <600 mm annual rainfall, may produce poorer quality and therefore less marketable pulpwood.

Non-wood

The spotted gums yield both nectar and pollen in fair amounts when flowering heavily and are a favoured tree species for apiarists.

Limitations

Spotted gums display lower growth rates compared to the more widely planted eucalypts (E. grandis, E. nitens and E. globulus). Heavy branching, forking and a high incidence of kino rings can reduce timber quality (Poynton, 1979). C. maculata is very susceptible to ramularia shoot blight in higher summer rainfall regions in Australia (Stone et al., 1998; Ivory, 1999). Erratic seed production from natural stands restricts the availability of planting stock. The spotted gums are difficult to propagate by vegetative cuttings. Seedlings and young trees are frost sensitive.

Recommended reading


References


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


River red gum, red gum, Murray red gum

*Eucalyptus camaldulensis* Dehnh. subsp. *simulata* Brooker and Kleinig

*Eucalyptus camaldulensis* Dehnh. var. *camaldulensis*

*Eucalyptus camaldulensis* Dehnh. var. *obtusa* Blakely

Adapted from Doran, 2000.

**Species overview**

Globally, *Eucalyptus camaldulensis* is perhaps the most widely used tree for planting in arid and semi-arid lands, mainly in the Mediterranean region (Eldridge *et al.*, 1993), using seed from southern Australian provenances. Extensive plantations have also been established in tropical regions, mainly in South East Asia, Mexico and Brazil, using the climatically adapted northern Australian provenances (Midgley *et al.*, 1989).

It grows under a wide range of climatic conditions and soil types, is tolerant of extreme drought, waterlogging and soil salinity and coppices well. For these reasons *E. camaldulensis* is used for reclamation of degraded lands, especially salt-affected land subject to seasonal waterlogging, and particularly when the salinity is low to moderate (Marcar *et al.*, 1995; Sun and Dickinson, 1995). In terms of salt tolerance, Marcar *et al.* (1995) class *E. camaldulensis* as moderately tolerant with reduced growth at ECe of about 5 dS m⁻¹ or above and reduced survival at about 10-15 dS m⁻¹. It is also used in mine site rehabilitation in Australia (Langkamp, 1987).

*Eucalyptus camaldulensis* generally has poor form and may be subject to severe defoliation by insects (largely provenance and site dependent). This restricts its use for plantation establishment in the southern low-rainfall zone of Australia and in coastal areas of Queensland. It has been used as parent material for the production of hybrids, and the *E. grandis* x *E. camaldulensis* hybrids have better survival than *E. grandis* on drier sites and better growth rate, form and pulp properties than *E. camaldulensis*. These hybrids may be ideally suited to sites marginal for *E. globulus* on the edge of the 600+ mm annual rainfall range.

**Key features**

Medium-sized to tall tree of variable form

Tolerant of drought, high temperatures, periodic waterlogging and moderate soil salinity

Useful for reclaiming degraded land (saline and waterlogged land, mine spoils)

Deep penetration of roots assists survival and reduction of surface salinity by use of groundwater

Rapid growth when water is available and performs well under irrigation

Some provenances are tolerant of mild frost

Attractive, dense red heartwood

Wood used for construction timber, furniture, poles, posts, firewood, charcoal and pulp for paper

Termite resistant

Preservation is necessary for use in the ground

Subject to heavy defoliation from insects and pathogens both in southern Australia and coastal Queensland.
Eucalyptus camaldulensis var. obtusa

Description and natural occurrence

Description

As currently recognised E. camaldulensis comprises two varieties and one subspecies. The two varieties are a northern tropical form that is lignotuberous and has relatively obtuse opercula (rounded bud caps – var. obtusa), and a southern temperate form that is non-lignotuborous and has rostrate opercula (beaked bud caps – var. camaldulensis) (Pryor and Byrne, 1969). E. camaldulensis var. camaldulensis has a temperate distribution in the Murray-Darling River system extending from southern Queensland to Victoria. E. camaldulensis var. obtusa comprises all other populations occurring outside the Murray-Darling Basin. It has an extensive distribution primarily throughout tropical and subtropical Australia (ATSC website, 2002).

In the past, populations of E. camaldulensis var. obtusa and E. tereticornis have been difficult to distinguish in certain areas in northeast Queensland. The recognition of a new subspecies E. camaldulensis subsp. simulata by Brooker and Kleinig (1994) has, to some extent, resolved this problem. E. camaldulensis subsp. simulata occurs along a few river systems in northeastern Queensland. These include the Laura River, Palmer River, Walsh River and the North Kennedy River, however further field work is required to fully assess its distribution. This taxa shares many similarities with its close relatives E. camaldulensis var. obtusa Blakely and E. tereticornis but differs from both of these taxa by the following combination of characters: long horn-shaped opercula, yellow to yellow-brown seeds, broad-lanceolate juvenile leaves and a riparian habitat (ATSC website, 2002).

In Australia, E. camaldulensis commonly grows up to 20 m tall but rarely exceeds 50 m, while stem diameter at breast height can reach 1-2 m or more. In open woodlands it usually has a short, thick bole which supports a large, spreading crown. In plantations, it can have a clear bole of up to 20 m with an erect, lightly-branched crown. Form of the tree is variable but is typically poor in southern Australia. The bark is smooth white, grey, yellow-green, grey-green, or pinkish grey, shedding in strips or irregular flakes. Rough bark may sometimes occupy the first 1-2 m of the trunk on the southern E. camaldulensis var. camaldulensis.

Like other eucalypts river red gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowering time in natural stands depends on locality. Flowering peaks in summer in the south, in autumn in the north-west, and in winter-spring in the north-east of Australia (Banks, 1990). Pollination is mainly carried out by insects, but also by birds and small mammals.

Fruit development and maturation time can be as short as four months. For example, an August flowering in northern Queensland will provide mature fruit the following January. Production of the first
seed crop may occur within three years of planting (Boland et al., 1980). There will be regional and seasonal variability in seed availability.

Natural occurrence

Eucalyptus camaldulensis has the widest geographical range of any eucalypt and grows under a broad range of climatic conditions, from warm to hot and sub-humid to semi-arid, with natural populations in the Northern Territory, New South Wales, Queensland, South Australia, Victoria and Western Australia (Figure 4.1). It is commonly found on or near watercourses which often allows it to survive in arid and semi-arid regions. In low-rainfall areas E. camaldulensis relies on seasonal flooding and/or the presence of shallow groundwater. Rainfall variability is very high across its natural range.

This species occurs on a variety of soil types and is mainly a tree of depositional or alluvial sites with infrequent occurrence on the margins of salt lakes. It is common on heavy clays in southern Australia, but more generally occurs on sandy alluvial soils in the north. It has been recorded growing on calcareous soils in South Australia (e.g. near Port Lincoln) and Western Australia (e.g. DeGrey and Greenough Rivers, and Wiluna) (Jacobs, 1981; Eldridge et al., 1993). It sometimes extends to slopes at higher elevations, as in the Mt Lofty Ranges near Adelaide, Australia. Its altitudinal range is 20-700 m. The species exhibits large provenance variation in response to salinity and waterlogging (Marcar et al., 1995).
Where will it grow?

The species has been divided into northern and southern provenances for climatic analysis. No formal boundary exists between the northern and southern forms; rather studies suggest a gradual change over the range (Marcar et al., 1995).

The climatic ranges for the southern and northern provenances of this species have previously been described by Booth and Pryor (1991) and Marcar et al. (1995). Changes in the limits described here are a result of the use of improved climatic surfaces and additional collection records from both Environment Australias ‘ERIN’ and CSIRO Australian Tree Seed Centres ‘seed collection’ databases. For example, the mean annual temperature range for southern provenances is now 10°C to 25°C instead of 13°C to 22°C reported by Marcar et al. (1995). Similarly, the lower limit of the mean minimum temperature of the coldest month has been adjusted from 6°C to 1°C for the northern provenances.

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus camaldulensis* northern provenances, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Northern Provenances</th>
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<tbody>
<tr>
<td>Mean annual rainfall:</td>
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<tr>
<td>Rainfall regime:</td>
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<tr>
<td>Dry season length:</td>
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<td>Mean maximum temperature hottest month:</td>
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<td>Mean minimum temperature coldest month:</td>
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<td>Mean annual temperature:</td>
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* Particular care should be taken when planting the species in low-rainfall environments to ensure that local conditions are suitable and appropriate planting densities are used.

The map of areas predicted to be climatically suitable for planting northern provenances of *E. camaldulensis* (Figure 4.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Jovanovic and Booth (2002) note that *E. camaldulensis* is often found naturally along watercourses, so low rainfalls at these locations do not always indicate the species drought tolerance. Queensland Forest Research Institute (QFRI) have also found that northern provenances are generally not successful in coastal areas of Queensland because of problems with foliar pathogens and insects (Paul Ryan, QFRI, pers. comm., 2002).

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus camaldulensis* southern provenances, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
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<tr>
<th>Southern Provenances</th>
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<tr>
<td>Mean annual rainfall:</td>
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<td>Rainfall regime:</td>
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<tr>
<td>Dry season length:</td>
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<td>Mean maximum temperature hottest month:</td>
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<td>Mean minimum temperature coldest month:</td>
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<tr>
<td>Mean annual temperature:</td>
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</tbody>
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* Particular care should be taken when planting the species in low-rainfall environments to ensure that local conditions are suitable and appropriate planting densities are used.
The map of areas predicted to be climatically suitable for planting southern provenances of *E. camaldulensis* (Figure 4.3) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. However, as the southern provenances of *E. camaldulensis* generally display slow growth, poor stem form and susceptibility to attack by a range of insect pests the Australian Low Rainfall Tree Improvement Group actually consider it as having greater potential as a parent in interspecific hybrid combinations, with species such as *E. grandis* and *E. globulus*, than in plantings of the pure species (Harwood and Mazanec, 2000).

**Plantings and provenance trials**

**Plantings**

Globally, *E. camaldulensis* is perhaps the most widely used tree for planting in arid and semi-arid lands (Eldridge *et al*., 1993), with at least 1 million ha established by 1997. It has also been estimated (Jacobs, 1981) that over half a million hectares of plantations of southern Australian provenances had been established by the late 1970s, mainly in the Mediterranean region and particularly in Spain and Morocco.
Planting in the tropics, especially in South East Asia, Mexico, and Brazil, is increasing with the increased availability of the climatically-adapted northern Australian provenances (Midgley et al., 1989). There have also been extensive but largely unrecorded plantings of *E. camaldulensis* in many countries for shade and shelter.

**Provenance trials**

Provenance variation within *E. camaldulensis*, which is considerable over the natural range of the species, has been recorded for growth rate, wood properties, tolerance to salinity, alkalinity, drought, frost, and leaf oil content. Therefore it is very important to select the correct provenance for the purpose and location that the species is being grown. Better-performing tropical provenances like ‘Petford’ and ‘Katherine’, Queensland, are the most sought-after sources for breeding programmes in the seasonally dry tropics, while provenances from southern temperate Australia, like ‘Lake Albacutya’, Victoria, are suited to Mediterranean zones (Midgley et al., 1989; Eldridge et al., 1993; Kumaravelu et al., 1995; Pinyopusarerk et al., 1996a, 1996b).

Marcar et al. (1995) state that the best-performing northern provenances, particularly in the presence of salinity and seasonal waterlogging, include ‘De Grey River’ (although it has poor form) and ‘Wiluna’, Western Australia, ‘Katherine’ and ‘Mt Benstead’, Northern Territory and ‘Petford’, Queensland. In low rainfall areas, provenances such as ‘Tennant Creek’, Northern Territory, may be superior to popular provenances such as ‘Petford’, Queensland (Paul Ryan, QFRI, pers. comm., 2002). Best-performing southern provenances (in terms of survival and growth) for saline and seasonally waterlogged conditions include ‘Lake Albacutya’ and ‘Douglas River’, Victoria, and ‘Silverton’, New South Wales. As an all-round performer (in terms of survival, growth and form) under saline/waterlogged conditions in southern latitudes, ‘Lake Albacutya’ is the recommended provenance. However, the ‘Lake Albacutya’ provenance had relatively poor form in a trial in Western Australia despite it having the fastest growth rate, whereas the ‘Laura’, South Australia, provenance yielded a comparable volume in the trial and had a significantly better stem form (Mazanec, 1999; Harwood and Mazanec, 2000). On soils with a high pH, ‘Silverton’, New South Wales, and ‘Wiluna River’, South Australia, provenances have performed well in terms of survival and growth in southern temperate Australia (N. Marcar, pers. comm., 1997).

**Breeding and genetic resources**

Selected clones are being grown in Australia to ameliorate degraded sites such as mine spoils and those affected by waterlogging and salinity (e.g. Farrell et al. 1996). Hybrids are readily made between *E. camaldulensis* and *E. grandis, E. tereticornis, E. globulus* and other species of the subgenus Symphyomyrtus (Griffin et al., 1988). Hybrids such as *E. grandis* × *E. camaldulensis* could perform well on sites which are too dry for *E. grandis* (Darrow, 1995). Young trials established by the CSIRO Forestry and Forest Products Australian Tree Seed Centre indicate that the hybrid of *E. camaldulensis* × *E. grandis* has better form than *E. camaldulensis*. Clones of these hybrids are presently beginning to
become available from some nurseries in Australia e.g. Yuruga Nursery, Walkamin, north Queensland (ALRTIG website, 2002).

The origin of seed used in many of the older plantings of *E. camaldulensis* in Australia is unclear. To avoid unknown provenances being used in plantings, the CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra, Australia, provides both single-tree and bulk provenance collections of seed of *E. camaldulensis* for breeding programmes. It presently has an extensive range of seedlots from both tropical and temperate provenances in store.

**Silviculture**

Because of the widespread distribution of *E. camaldulensis* in Australia, the climatic variation over the range of its distribution is large. Silvicultural practices for the species may vary between the northern and southern provenances of the species because of the climatic variation.

One of the major silvicultural variations is in the timing of the planting season. Planting out is timed to coincide with rainfall and in southern latitudes is predominantly determined by the severity of frost and minimum temperatures experienced. Planting is carried out in June/July in South Australia and Western Australia while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred so that young seedlings will be exposed to a shorter period of high temperatures.

Sowing of seedlings is timed to produce healthy seedlings for the planting season. In the warmer climates, germination and growth of the seedlings is better, with seedlings reaching plantable size as quickly as 6-8 weeks, compared to as much as 4 months in southern regions where growth is much slower.

Spacing for planting and length of crop rotation depends mainly on the end products required, but are also influenced by growth rate of the trees.

Therefore a wider spacing and shorter crop rotation may be considered in warmer regions.

Weed control in the more tropical zones may be more important than in the temperate zones, due to low tolerance of the species to weed competition.

Because of the significant variation in silvicultural practices, some of which are referred to above, this section is not intended to be very specific, but to raise the awareness of the reader to make use of the references listed, so that the best silvicultural practices can be chosen.

**Propagation**

*Eucalyptus camaldulensis* is usually propagated from seed. There are about 700,000 viable seed kg⁻¹ of seed and chaff mixture. Seed storage is orthodox and the viability of seed stored dry (5-8% moisture content) in air-tight containers in the refrigerator (3-5°C) will be maintained for several years (Doran et al., 1987). No pre-sowing treatment is required.

The species is easily raised from seed in the nursery following the general methods for eucalypt propagation (Doran and Turnbull, 1997; Bird, 2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

This is one of a few eucalypt species suited to mass vegetative propagation through stem cuttings (Eldridge et al., 1993). Cuttings from juvenile shoots (i.e. below the 100th node) root readily in 30% of genotypes (Doran and Williams, 1994).
Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. camaldulensis*. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoodsqld/), or these documents can be obtained by contacting the organisations directly.

On compacted sites, or sites with a hardpan, deep ripping (to 1 m with a bulldozer) of the planting lines is recommended. Ripping in combination with mounding improves survival and growth on most sites, mounding being essential on wet or saline soils (Jacobs, 1981). Ex-agricultural land may require intensive site preparation by ploughing to a depth of 10 cm when the soil is moist, followed by disc harrowing three months later (Bird, 2000). Knock-down herbicides can be used before planting, especially on ex-agricultural sites, and complemented with an application of residual chemicals just prior to planting. Application can be either in spots of 1.5 m to 2 m radius around the planting hole, or in 1.5 m strips along the rip lines or over the planting mounds (Venning, 1988; Bird et al., 1996). mouldboard ploughing can give effective weed control by burying weed seed (Bird et al., 1996).

When pulpwood production is the principal objective, a spacing of 3 × 2 m (1667 stems ha⁻¹) is often used. Wider spacings of 4 × 2 m (1250 stems ha⁻¹) or 5 × 2 m (1000 stems ha⁻¹) are recommended when larger trees are required. Wider spacing between rows facilitates mechanical cultivation for weed control.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practiced in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can only respond to a fertiliser application if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

Management

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques. Thinning and pruning schedules will need to be developed for *E. camaldulensis* in Australian conditions.

Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). However, in Nepal pruning is found to be seldom necessary as *E. camaldulensis* sheds its branches readily.

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter growth of individual stems. The stand may be reduced to a final stocking of 100-300 stems ha⁻¹ when grown for sawlogs.

The species coppices well for five or more rotations. Felling during the dry season delays sprouting and increases the risk of the stump drying out. Felling by saw to give a cleanly cut short stump with minimum bark damage increases the chances of good coppicing. Coppice management requires the reduction of the number of coppice shoots on a stool (Evans, 1982) so the value of using a coppicing system needs to be considered in light of the cost of protecting the stumps at harvesting, thinning the coppice and the possible lost gains in productivity that might be achieved from the use of improved seed or provenances for the next rotation.
Growth

Growth data for plantation grown *E. camaldulensis* is not available for Australia and with the insect and fungal problems it experiences in Australia stand productivity is likely to be considerably lower than the better yields achieved overseas.

In overseas plantings in the drier tropics, yields of 5-10 m³ ha⁻¹ yr⁻¹ on 10-20 year rotations are common, whereas in moister regions up to 30 m³ ha⁻¹ yr⁻¹ may be achieved on 7-20 year rotations (Evans, 1982).

Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and by regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone *et al.* (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In Australia this species has been found to be moderately to highly susceptible to heavy insect defoliation (dependant on provenance and site) and fungal attack in low-rainfall areas in southern Australia and in coastal Queensland.

In the nursery, *E. camaldulensis* is susceptible to a diverse range of fungi, causing damping-off, collar rot and leaf diseases (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp. and *Cylindrocladium* spp.), but these problems may be circumvented by careful selection of provenances. Insects (e.g. termites and aphids) and rodents may be troublesome in the nursery, and both physical and chemical control measures may be needed.

In the field, leaves are often attacked by leaf chewing insects, particularly members of the Chrysomelidae and Curculionidae families (such as *Paropsis* spp., *Chrysophtharta* spp., *Goniipterus* spp. and *Oxyops* spp.) (Stone and Bacon, 1995). Other important leaf chewing insects are members of the Scarabaeidae family such as swarming scarab beetles and Christmas beetles (Coleoptera). Swarming scarab beetles can cause severe defoliation and/or dieback of the growing tips of young trees and are particularly important in young eucalypt plantations. A number of species have been recorded as pests in Queensland, including *Automolus* spp., *Liparetrus* spp. and *Epholcis bilobiceps*. The adults are active in summer and early autumn. Christmas beetles (mostly *Anoplognathus* spp.) can cause severe defoliation in young plantations prior to canopy closure (DPI website, 2002).

Leaf spot pathogens (e.g. *Mycosphaerella* spp., *Kymomyces* spp., *Mircosphaeria* spp., *Coniella* spp.) affect trees less than three years old and cause leaf spotting and defoliation (DPI website, 2002).

Utilisation

Wood

*Eucalyptus camaldulensis* wood burns well and makes a good fuel. The timber has a handsome red colour, a fine texture, and interlocking wavy grain. It is hard, durable, resistant to termites, and has many uses. The sapwood is susceptible to attack by *Lyctus* borers (Keating and Bolza, 1982). Correctly handled, the wood is useful for speciality furniture, construction timber, pulpwood, roundwood and fuelwood (Poynton, 1979). Preservation treatment is necessary for durability in the ground.

Wood density of plantation-grown *E. camaldulensis* varies with age, the provenance used, and planting site, but does not appear to be closely associated with rate of growth (Moura, 1986). Green densities of 500-700 kg m⁻³ for wood from young trees and 1130 kg m⁻³ for old trees are reported. Density is positively correlated with charcoal and pulp yield (Moura, 1986). In the tropics, fast growing provenances from northern Queensland (e.g. ‘Petford’) produce the highest density wood and the largest yields of charcoal and pulp (Eldridge *et al.*, 1993).
Non-wood

Some tropical provenances of *E. camaldulensis* (e.g. ‘Petford’) give 1,8-cineole-rich leaf oils and are potential sources of medicinal-grade oils (Doran and Brophy, 1990). *E. camaldulensis* is of major importance in Australia as a source of honey, producing heavy yields of nectar in good seasons (Clemson, 1985). It also provides the bees with an important source of good quality pollen.

Limitations

The major disadvantages of *E. camaldulensis* are its susceptibility to insect attack and pathogens in southern Australia and coastal Queensland, and its generally poor form in southern Australia. It also has little capacity to compete with weeds when young and this, compounded by a crown type that takes several years to shade-out weed growth, is a major limitation, especially in the tropics.

Recommended Reading


References


5. *Eucalyptus cladocalyx* F. Muell.

Sugar gum

Adapted from Doran, 2000.

Key features

Medium to tall tree of potentially good form, when better provenances used. Provenances for farm forestry purposes include ‘Kangaroo Island’, ‘Flinders Ranges’ and ‘Wirrabara’, South Australia

Moderate growth rate

Tolerates wide range of soils including infertile shallow and calcareous soils

Intolerant of waterlogging and does not do well on poorly drained clays, or very light sandy soils

Hardy to summer drought

Not well suited to the tropics

Performs well under irrigation

Low to moderate salt tolerance

Intolerant of very low temperatures and moderate frosts when young

Produces an excellent sawn timber and has been used extensively for railway sleepers, farm timbers and general construction timbers

Wilting sugar gum leaves are poisonous to stock

Niche is in 400-600 mm yr⁻¹ winter rainfall areas.

Species overview

*Eucalyptus cladocalyx* is a medium to tall tree of potentially good form, moderately fast growth rate, and good coppicing ability. It has been widely used in shelterbelts and for shade and amenity. This species is a prime candidate for farm woodlot planting in semi-arid areas with about 400-600 mm annual rainfall falling predominantly in winter. *E. cladocalyx* is an adaptable species which tolerates a wide variety of infertile soils including calcareous soils, but is intolerant of waterlogged and very light sandy soils. Mature trees can die in years of prolonged waterlogging. It is hardy to summer droughts but is not well suited to tropical conditions. It performs well under irrigation. *E. cladocalyx* is intolerant of very low temperatures and moderate frosts when young. The species has a low to moderate salt tolerance and reduced growth can be expected at an ECₑ of about 5 dS m⁻¹ and reduced survival at about 5-10 dS m⁻¹ (Marcar et al., 1995).

The wood of *E. cladocalyx* is often used in the round for telephone poles, fence posts and firewood. It is also used in heavy and general construction and in cabinet making. It is a useful species for honey and charcoal production.

Description and natural occurrence

Description

This medium to tall tree has a spreading crown. Height at maturity averages about 20 m but ranges from 10-35 m. The diameter at breast height averages about 75 cm with a range from 30 cm to 2 m. At maturity the leaves are clustered at the end of the branches, giving it an umbrella or storied look. It
is often heavily branched. On poor, shallow soils it is more stunted and branched and is occasionally multi-stemmed. The tendency towards multiple stems is reported to be more prevalent in provenances from the Eyre Peninsula, South Australia (Bulman et al., 2000).

Typically, stem form is fair to poor with about one third of trees on better sites classified as being of good form. Stems may be clear to two-thirds of the tree height on the more favourable sites, while on poorer sites stems are clear for only one-third to one-half the total height and often crooked. The bark is smooth, shedding in large irregular patches producing a colourful mottled yellow to orange, grey and blue-grey surface. Adult leaves are broad lanceolate, strongly discolorous with a dark green, glossy upper surface and a dull, paler lower surface (Brooker and Kleinig, 1990; Nicolle, 1997).

_Eucalyptus cladocalyx_ var. _nana_ Hort. is a smaller more spreading tree which grows to 15 m in height. It originates from the Eyre Peninsula and has been developed as a horticultural variety (Nicolle, 1997). It has a much bushier habit and hence is more suitable for shelter belts and garden plantings.

Like other eucalypts sugar gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowering occurs January to April (Boland et al., 1984), with mature seed available for collection about 12 months later. Seed crops may be retained on the tree for 3-4 years (Bonney, 1994). There will be regional and seasonal variability in seed availability.

**Natural occurrence**

_Eucalyptus cladocalyx_ is endemic to South Australia where it occurs in four separate areas (Figure 5.1). It achieves its best growth and form in the southern Flinders Ranges and towards the top of the Spencer Gulf. Other populations occur on Kangaroo Island and on the eastern side of the Eyre Peninsula around Cleve and further south in the Marble Range region.

In its natural range, _E. cladocalyx_ occurs mainly on skeletal or podsolic soils which are often rather shallow. In mainland Australia, this species occurs naturally on ridges, slopes and around the bases of mountains, while on Kangaroo Island it occurs along drainage lines, on flats and on gentle to moderate slopes.
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *E. cladocalyx*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for good survival and growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>350-1010 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Uniform, winter</td>
</tr>
<tr>
<td>Dry Season:</td>
<td>0-8 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month:</td>
<td>23-34 °C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month:</td>
<td>1-11°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>12-21°C</td>
</tr>
</tbody>
</table>

C Particular care should be taken when planting the species in low rainfall environments to ensure that local conditions are suitable and appropriate planting densities are used.

D Absolute minimum temperature may limit establishment (i.e. frosts). This may be closely related with mean minimum temperature.

Other factors such as *E. cladocalyx* intolerance of waterlogging and very light sandy soils also need to be reflected in site selection.

Plantings and provenance trials

Plantings

*Eucalyptus cladocalyx* is widely planted in Australia beyond its natural range and is especially common in farm plantings in western Victoria (Hamilton, 1999).

It has been successful in plantations overseas, usually where mean annual rainfall is within the range of 400-600 mm with a winter maximum. This includes parts of the highlands of central (e.g. Ethiopia) and southern Africa (e.g. Lesotho, Mozambique, South Africa, Zimbabwe), in various Mediterranean countries (e.g. Algeria, Italy, Morocco, Greece, Spain, Portugal) and Israel (Poynton, 1979; Jacobs, 1981; Turnbull and Pryor, 1984).

Provenance trials

The ‘Port Lincoln’ provenance of *E. cladocalyx* in South Australia has proven most drought tolerant in Western Australian plantings (Turnbull and Pryor, 1984). Variation between provenances in stem form, stature and time to first flowering has been noted in provenance trials in South Australia, with provenances from the Eyre Peninsula such as ‘Wanilla’ proving very poor for timber production due to poor form. Trees from the ‘Kangaroo Island’ provenance are the most vigorous but tend to heavier branching than those from the ‘Wirrabara’ provenance. For farm forestry purposes, ‘Wirrabara’, ‘Flinders Ranges’ and ‘Kangaroo Island’ provenances are recommended, based on preliminary trial information that has been collected by Australian Low Rainfall Tree Improvement Group (ALRTIG) partners (ALRTIG website, 2002).

Breeding and genetic resources

Despite the long-time use of the species as a farm and plantation tree in many parts of the world, it is only recently that systematic seed collections from individual trees from all known natural occurrences of the species have been undertaken by CSIRO Forestry and Forest Products. Seed is now available
for provenance trials and tree breeding work through the CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra.

Eucalyptus cladocalyx has been identified as a priority species for the low rainfall regions of southern Australia and a breeding strategy has been developed by the Australian Low Rainfall Tree Improvement Group partners (Harwood and Bulman, 2000). Seed of modest genetic improvement is available and a breeding program is underway (ALRTIG website, 2002).

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

Eucalyptus cladocalyx is usually propagated from seed. The seed is extracted by drying from the pale-brown mature fruit. There are approximately 120 000 viable seeds kg⁻¹ seed and chaff mix (Turnbull and Doran, 1987). Seed of this species is orthodox in its storage behaviour and will keep in good condition for several years if air-dried and placed in a refrigerator (3-5°C) in an airtight container.

Little success with rooting of stem cuttings of *E. cladocalyx* was achieved in preliminary trials at CSIRO Forestry and Forest products. Two provenances were tested and the following rooting percentages recorded respectively in two trials (i) ‘Wirrabara’, South Australia, 11.4% and 2% and (ii) ‘Flinders Chase’, South Australia, 2% and 2.1% rooting. The trials tested a number of species and provenances alongside known easy-rooting species. The easy-rooting species had high rooting percentages (*E. grandis* 85% and *E. camaldulensis* 76%) which showed that techniques used were suitable for them. While the results for *E. cladocalyx* are poor most of the cuttings that failed to root did produce callus. Further trials are planned with adjustments to the techniques in a hope to improve the rooting success of species such as *E. cladocalyx* (Brammall and Harwood, 2000).

This species is easily raised in containers in the nursery following the general methods for eucalypt propagation as described by Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Under suitable conditions plantable size is reached within six months from sowing.

**Establishment**

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. cladocalyx*. Detailed information on various establishment practices is available from several sources including: government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au), or these documents can be obtained by contacting the organisations directly.

This species has been established successfully in shelterbelts in Western Australia (Venning, 1988)
and Victoria (Bird, 2000) and along roadsides in South Australia by direct seeding (Venning, 1988). When using containerised planting stock, wider spacings are preferred. Poynton (1979) reported that this species is intolerant of excessive competition becoming whippy when grown in dense stands and developing a disproportionately small crown. In the moister areas of Victoria a common spacing for shelterbelts is 3 m x 3 m, while 4 m between rows and 2.5 m within rows extending out to 7 m x 7 m are spacings used in the drier areas of Victoria, South Australia and Western Australia (Venning, 1988).

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia and Western Australia planting commonly occurs in June-July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practiced in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can only respond to a fertiliser application if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

Management

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques in a farm forestry context. Thinning and pruning schedules will need to be developed for E. cladocalyx if it is to be grown for sawn timber in Australia. Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter of individual stems. When grown for sawlog the stand may be reduced to a final stocking of 300-100 stems ha⁻¹.

According to Poynton (1979), the species responds well to early and heavy thinnings in Africa.

_Eucalyptus cladocalyx_ will readily tolerate pollarding and this can produce a more compact and dense crown in open grown trees e.g. in shelterbelts (although this may make it more susceptible to termite or borer infestation).

_Eucalyptus cladocalyx_ is usually managed on a clear felling and coppice system for firewood production. This type of management system does not warrant or require pruning.

Growth

A range of mean annual increments are reported in Bird (2000) for different plantation areas in Victoria. These range from mean annual increments of around 2-3 m³ ha⁻¹ yr⁻¹ reported for 35-year-old trees in plantations in the Wimmera area with a mean annual rainfall of 400-600 mm to 14.7 m³ ha⁻¹ yr⁻¹ reported

Thinning trial of *Eucalyptus cladocalyx* 33 years old at Barrett Reserve near Horsham, Victoria.
In general, *E. cladocalyx* is a robust species which is rarely significantly affected by insects or pathogens. It is no more susceptible to insects and pests than most other eucalypts in Australia.

In Australia, gumtree scale (*Eriococcus confusus*) affects *E. cladocalyx* (Carne and Taylor, 1984). Young and pollarded trees are prone to infestation, especially those growing in unfavourable sites or those which have been weakened by defoliating, sap-sucking or wood-boring insects (Farrow, 1996). Dense colonies can cause branches to die back. Small saplings are the most susceptible to attack and can be killed by the direct effects of sapremoval and indirectly by the build up of sooty mould which covers leaves and inhibits photosynthesis. Infestations spread outwards from infested trees into surrounding trees leading to patches of dying and dead trees in plantations. Adult scale are attacked by a range of parasitic wasps and flies, by predatory larvae of moths (*Catoblepidae* and *Stathmopodidae*), by lacewing larvae (*Chrysopidae*), by hoverfly larvae (*Syrphidae*) and by the adults and larvae of several ladybirds. Ants interfere with natural enemy control as they defend the scale to ensure a supply of honeydew. Removal of ants generally causes outbreaks to quickly collapse. There is a tendency for scale numbers to build up in spring and early summer and for predators to catch up and reduce the scale numbers to very low levels by the end of the autumn (Farrow, 1996).

*Eucalyptus cladocalyx* is one of the preferred hosts of Christmas beetle, *Anoplognathus* sp. (Farrow, 1996). It is moderately susceptible to leaf blister sawfly (*Phylacteophaga froggatti*) (Farrow, 1996). Usually only juvenile foliage of young trees or young adult leaves near the ground are attacked. Large outbreaks can sometimes occur in young plantations due to the sawfly’s high capacity for increase which enables them to escape from the control exerted by their parasites.

**Utilisation**

**Wood**

The sapwood is whitish or very pale brown and the heartwood yellow-brown or dull grey to dark brown. The grain is often interlocked with fine uniform texture. The wood of *E. cladocalyx* is hard, durable and moderately strong and heavy. Timber
from natural stands has a basic density of about 750 kg m\(^{-3}\) and an air-dry density of about 1100 kg m\(^{-3}\). Thirty-five to forty-year-old trees in planted stands in northern Victoria had a basic density of 800 kg m\(^{-3}\) which is higher than that reported for mature specimens (Washusen et al., 1998). It should be dried carefully and slowly to avoid surface checking. It glues easily and stains well. The timber has good wearing and weathering properties that make it suitable for block or strip flooring. Pre-boring is advisable in nailing and the wood drills very well with a variety of drill bits (Pongracic, 1999). It is moderately resistant to termites, however, the sapwood is susceptible to attack by Lyctus and marine borers. The heartwood is resistant to chemical impregnation but the sapwood is not. Percentage of sapwood in 35-40-year-old, plantation grown, trees was found to be 12.5-13.3% (Washusen et al., 1998). It is used for poles, posts, railway sleepers, general construction and farm timber and makes good firewood (Anon, 1967; Keating and Bolza, 1982). Washusen and Waugh (2000) showed that wood from 40-year-old plantation grown *E. cladocalyx* met the requirements for high quality (appearance grade) sawn products and high rates of recovery of these grades were possible.

**Non-wood**

*Eucalyptus cladocalyx* var. *nana* and *E. cladocalyx* were ranked amongst the most promising species, in terms of growth and water use, to assist future reclamation of saline seeps by intercepting perched groundwater in the 400 mm rainfall region of south-western Australia (Biddiscombe et al., 1985; George, 1990; George, 1991; Greenwood et al., 1995).

In its natural habitat, *E. cladocalyx* provides sustenance and nest sites to a wide range of vertebrate and invertebrate species, including pygmy possums and sugar gliders and many varieties of birds from honeyeaters to lorikeets (Bonney, 1994).

**Limitations**

There are reports that wilted foliage may be poisonous to domestic animals such as cattle, sheep and goats (Poynton, 1979; Webber et al., 1985).

**Recommended Reading**


**References**


**Gympie messmate**

Adapted from Turnbull, 2000.

**Key features**

Medium to tall tree of very good form

Fast growth rate when correct provenance is planted on high potential forestry soils in suitable climatic zone (‘Gympie’ and ‘Cardwell’ are amongst the best seed sources for high potential sites)

Prefers acidic, deep, moderately fertile, freely drained soils

Intolerant of heavy clay soils

Not adapted to saline soils

Very sensitive to drought in the establishment phase but tolerates a 4-5 month dry season once established

Tolerates only light frost

Very sensitive to fungal pathogens in the nursery

Susceptible to windthrow especially when planted on shallow soils

Timber is strong, heavy and very durable and is used for fencing, bridge construction, transmission poles, mining timbers and sawn boards

Only marginally suitable for paper pulp

End splitting is a serious defect but is highly variable with age and provenance

In Australia it is best suited to the warmer parts of northern New South Wales and coastal Queensland on sites with relatively fertile soils and greater than 800 mm yr⁻¹ rainfall.

**Species overview**

*Eucalyptus cloeziana* has the potential to grow rapidly in subhumid conditions on a wide range of acidic or neutral soil types but is best suited to deep, moderately fertile, well-drained soils with a loamy or sandy texture. Brown and Hall (1968) recommend it for growing in woodlots for timber production in the warmer parts of northern New South Wales and in coastal Queensland where soils are relatively fertile. Early results of trials in Queensland suggest that suitable areas for establishment of *E. cloeziana* plantations include the area from the wet tropics south to Mackay, the Sunshine coast, the central and coastal Burnett and Moreton regions on suitable soils and where the mean annual rainfall exceeds 800 mm (QFRI website, 2002).

*E. cloeziana* has strong, heavy and very durable wood. In Australia it is used for fencing, bridge construction, transmission poles, mining timbers and sawn boards. The species is planted for high quality poles in the moister summer rainfall areas of southern Africa and it is grown for industrial charcoal production in Brazil. Laboratory tests have indicated that *E. cloeziana* has potential for fine paper production (Hicks and Clark, 2001).

Its sensitivity to fungal pathogens in the nursery has inhibited its use as a plantation species. *E. cloeziana*
is more sensitive than most other eucalypts to drought shortly after planting but once established it will tolerate a dry season of 4-5 months (Poynton, 1979). Some provenances are more drought-tolerant than others. For example, coastal, high-rainfall provenances have proven to be susceptible to drought on shallow, sandy soils while provenances of *E. cloeziana* from harsher inland sites have shown greater drought tolerance in these conditions. The species only tolerates very light frosts. Strong winds can cause windthrow problems, especially on shallow soils (Turnbull, 1979).

**Description and natural occurrence**

**Description**

In coastal areas *E. cloeziana* grows as a tall tree with an open, somewhat spreading canopy. On the best sites the species reaches its optimum development of 40-55 m tall with a diameter of 1-2 m, while on less favourable sites it may be 20-35 m tall and of variable form. In drier inland areas it has a short, straight bole and very open crown while on the harshest sites it may be reduced to a small, crooked tree less than 10 m (Boland *et al.*, 1984).

The stem form is generally very straight except on very infertile, dry sites where the stem is short and often crooked. Tall individuals on better sites have long, clear boles for up to 60% of total tree height. The bark is rough on most or whole of the trunk and larger branches, soft, flaky, tessellated, light brown or yellow-brown (Brooker and Kleinig, 1994). The smaller branches are smooth, greyish-white or yellowish. There is provenance variation in the degree to which the rough bark is retained with southern populations retaining their rough bark to a higher level than northern populations (Turnbull, 1979).

Distinctive features of the species are the discolorous, lanceolate or falcate adult leaves; the inflorescences which are axillary, compound and branched, with 7-flowered individual inflorescences; and the pedicellate, hemispherical fruit with 3-4 valves. Populations in drier areas have narrower adult and juvenile leaves (Turnbull, 1979). The seed is yellow-brown and somewhat lustrous (Brooker and Kleinig, 1994).

Like other eucalypts Gympie messmate does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). No detailed studies have been reported on the pollination and breeding system but observations suggest that *E. cloeziana* is insect pollinated (Turnbull, 1979). The flowering time is from November to February in Australia. Trees begin flowering from about their ninth year (Poynton, 1979). The time from bud to fruit maturation is about 16 months. The capsules may remain unopened on the tree for up to three years where heavy general flowerings occur at three year intervals (Turnbull and Pryor, 1984). There will be regional and seasonal variability in seed availability.

Some seedlings produce distinct lignotubers but others have a thick carrot-like swelling near the junction of root and shoot (Turnbull, 1983).
Natural occurrence

*Eucalyptus cloeziana* is endemic to eastern Queensland where it occurs between latitudes 15-27°S (Figure 6.1). It grows in a number of disjunct localities and is most common in sandstone ranges eastwards from the Great Dividing Range in a narrow strip east of Gympie (about 50 km inland from the coast in southeast Queensland), and on the Atherton Tableland in northern Queensland. There are some isolated occurrences in between (Turnbull, 1983; Boland et al., 1984). In altitude, it extends from near sea level on Hinchinbrook Island to a maximum of 950 m near Atherton (Turnbull, 1979).

It occurs in open forest and woodland, often dominant, on plateaus, tablelands and slopes (Chippendale, 1988).

It occurs in warm subhumid to humid climatic areas. Up to five light frosts occurring annually throughout the natural range except for low altitude areas in the north which are frost-free (Boland et al., 1984).

The best development of this species is on metasediments or loam of volcanic origin, usually of moderate depth, on lower slopes of valleys. It is common on shallow soils over coarse sandstone or on shallow to moderately deep coarse-textured soils derived from granite. It tolerates drier and less fertile sandy soils on ridges and plateaus but growth is poorer. The soils are usually well-drained (Turnbull and Pryor, 1984). It is not adapted to saline soils and it has reduced growth and survival at ECe 2-4 dS m⁻¹ (Sun and Dickinson, 1993; House et al., 1998).

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *E. cloeziana*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Values</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Rainfall regime:</td>
<td>Summer, winter</td>
</tr>
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<td>Dry season length:</td>
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<td>coldest month:</td>
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</tr>
<tr>
<td>Mean annual temperature</td>
<td>16-27°C</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The map of areas predicted to be climatically suitable for planting *E. cloeziana* (Figure 6.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Revisions to the range of climatic requirements included raising the lower limit for mean annual rainfall from 450-650 mm. However, for the successful establishment of plantations the Queensland Forest Research Institute suggest a lower limit for mean annual rainfall of 800 mm (QFRI website, 2002) on sites with suitable soils i.e. deep, moderately fertile, well-drained soils with a loamy or sandy texture. The dry season has also been shortened to 5 months using information from commercial plantings (Jovanovic and Booth, 2002).

**Provenance trials**

Comprehensive provenance trials have been established in several countries since 1977. Provenances from both northern and southern coastal or subcoastal areas of Queensland, e.g. ‘Cardwell’ and ‘Gympie’, have shown superior growth in Australian trials (Dickinson *et al.*, 1996) and in trials overseas in Brazil (Souza *et al.*, 1992), Congo (Bouvet and Delwaule, 1983; Delwaule and Monchaux, 1983; Vigneron, 1989), India (Manaturagimath *et al.*, 1991) and South Africa (Pierce, 1992). Considerable variation between families within provenances, and different levels of variation for different provenances were found in some of these trials. In most trials provenances with mediocre growth came from inland locations. In only a few instances have inland provenances grown well e.g. in a Brazilian provenance trial in Sao Paulo State where a provenance from the ‘Blackdown Tableland’ area in the southern inland zone was the fastest growing among eight *E. cloeziana* provenances tested (Timoni *et al.*, 1983).

**Breeding and genetic resources**

Most of the natural populations of *E. cloeziana* are secure or relatively secure in national parks or forest reserves but there is slight risk that some of the smaller isolated stands elsewhere could be lost through clearing of land for agricultural expansion.

The results of a Brazilian trial demonstrated that early selection can be used in breeding this species. Selection at the age of 29 months proved to be efficient, allowing a superior gain per unit of time, compared to other selection strategies (Marques *et al.*, 1996). Based on the variation in growth rate, stem straightness and some wood properties in initial provenance trials in Queensland, a future improvement strategy for the species was proposed by Dickinson *et al.* (1996). The strategy included more comprehensive provenance trials, provenance resource stands using the best trees from the best provenance regions, and seedling or clonal seed sources based on the very best trees selected in stands of satisfactory provenances. Seed orchards of *E. cloeziana* have since been established near Imbil and Mackay, Queensland, in December 2001 (QFRI website, 2002).

**Planting and provenance trials**

**Planting**

In Australia the species has been grown in plantations in Queensland and northern New South Wales. It has been grown successfully for poles in Kenya, Malawi, Swaziland, South Africa, Uganda, Zambia and Zimbabwe, principally in areas with an annual rainfall of 1000-1500 mm and a dry season of 4-5 months (FAO, 1974; Paynton, 1979). It also grows well in parts of Brazil, China, Congo, Madagascar and Nigeria.
Until the late 1970s most seed used in trials in other countries was collected from the Gympie area of southeastern Queensland. Since then a range-wide collection of provenances has been available from CSIRO Forestry and Forest Products, Australian Tree Seed Centre in Canberra.

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

*Eucalyptus cloeziana* is usually propagated from seed extracted by drying from mature capsules. Although sieving may reduce damage to germinating seeds by seed borne fungi (Donald and Lundquist, 1988), viable seeds are difficult to separate from chaff, which are similar in size, weight and colour (Boland et al., 1980). There are on average 260 000 viable seed kg⁻¹ of seed and chaff mix (Gunn, 2001) but there is considerable variation in seed size between different provenances. Seeds of drier inland provenances have larger seeds, usually 35 000-65 000 kg⁻¹ of seed and chaff whereas those from the tall open forests in moister coastal areas have 100 000-400 000 kg⁻¹ (Turnbull and Pryor, 1984). Seeds can be germinated without pre-treatment and the optimum germination temperature is about 27°C (Turnbull and Shepherd, 1984). However, the seed coat does contain inhibitors and germination may be improved by the use of procedures such as washing or even soaking the seed (Gunn, 2001). The seeds are orthodox and can be stored for several years in cool dry conditions provided their moisture content is kept below 8%. *Eucalyptus cloeziana* is difficult to propagate by cuttings. Preliminary trials reported by Catesby and Walker (1997) used cuttings collected from 95 clones from five seedlots. Mean rooting success at eight weeks was 21%. However, four clones within the best rooting family had a rooting success of 100%. Selection of clones for enhanced rooting may be possible because of the large within and between-family variation in rooting success observed in this trial. Clonal seed orchards using grafts of *E. cloeziana* onto root stocks have been successful (Boland et al., 1980).

General nursery practices are suitable for producing containerised seedlings of *E. cloeziana*. These are described in texts such as Doran and Turnbull (1997) and QFRI website (2002). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Young germinants of *E. cloeziana* are sensitive to damping off fungi but losses can be minimized by sowing in cool weather, watering sparingly, and using a fungicide. Best results are obtained by keeping *E. cloeziana* seedlings under a light shade until they are about 10 cm before moving them out into full sun. If moved too early, they tend to lose vigour, become discoloured and grow very slowly (Paul Ryan, QFRI, pers. comm., 2002). Approximately 3-4 months under a suitable nursery regime is generally adequate to provide quality seedlings for planting out. Seedlings should be hardened off (as above) before planting out which should be done when the soil is moist and conditions are not excessively hot. Planting out can be done from November to April, but between February to April is generally best (QFRI website, 2002).

**Establishment**

Soil ripping will be beneficial if there is a root limiting horizon and weed control is essential as it will improve survival and early growth rate. This is usually achieved by a combination of mechanical (e.g. cultivation) and chemical (herbicide) methods. Both residual and knock-down herbicides may be used. Information on appropriate herbicides and application methods is given by Fagg and Cremer (1990) and QFRI website (2002). The dense, compact crown of *E. cloeziana* assists in weed suppression after the establishment phase.

Planting at an initial spacing of 4 m x 2.5 m (1000 stems ha⁻¹) is recommended as a good stocking density for timber production. In drier areas where there will be more competition for water a 4 m x 3 m spacing may be preferable (QFRI website, 2002).

Planting should be carried out soon after the onset of summer rains. Established *E. cloeziana* will tolerate a 4-5 month dry season but in South Africa it is more sensitive to drought in the first month after planting than most other eucalypts and may need to be watered if weather conditions are unfavourable. Containerised stock has a higher survival rate than open-rooted stock (Poynton, 1979).
Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practiced in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997). General recommendations are also available on the QFRI website (2002).

Maintenance

The crown is relatively lightly branched when grown in a plantation and branch shedding occurs particularly well in this species (Poynton, 1979). Dickinson et al. (2000) propose a pruning regime to reduce the impacts of knots on timber quality for E. cloeziana and suggest that two pruning lifts are potentially all that is necessary, with a lift to 3.2 m at an average DBH of 8 cm and a lift to 6 m at an average DBH of 12 cm.

Dickinson et al. (2000) state that for high-growth species such as E. cloeziana a pre-commercial thinning to a minimum stocking of 400 trees ha$^{-1}$ at approximately 1.4-3.5 years, will maximise DBH growth of the remaining trees. It is suggested that commercial thinning to 150-200 trees ha$^{-1}$ will then be necessary at around age 8-15 years to ensure good growth rates are maintained. This stocking should then be sufficient to allow these trees to achieve a merchantable size in an acceptable rotation length.

E. cloeziana coppices readily (Poynton, 1979; Higa and Sturion, 1991) but opinions differ on whether the coppice regrowth has a stem form as good as that of trees of seedling origin (Barrett and Mullin, 1968). Coppice management requires the reduction of the number of coppice shoots on a stool (Evans, 1982) so the value of using a coppicing system needs to be considered in light of the cost of protecting the stumps at harvesting, thinning the coppice and the possible lost gains in productivity that might be achieved from the use of improved seed or provenances for the next rotation.

Growth rates

High growth rates are achieved when the correct provenance is planted on high potential forestry soils in a suitable climatic zone. In old E. cloeziana trials in south-east Queensland on moist sites, Leggate et al. (1998) cite work by Ryan (1993) which showed that merchantable volume MAI ranged from 7.8-19.7 m$^3$ ha$^{-1}$. The current MAI for young E. cloeziana grown in south-east Queensland on good sites, under new, intensive silvicultural regimes, and with some degree of genetic selection is 20 m$^3$ ha$^{-1}$ yr$^{-1}$ (Leggate et al., 1998).

Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In general, E. cloeziana rarely has its growth significantly affected by insects or pathogens.

In Australia, young stressed trees may be attacked by a longicorn beetle (Phoracantha spp.) and a range of leaf beetles (House et al., 1998). However, E. cloeziana appears to be the species of eucalypt most resistant to Christmas beetle (Coleoptera: Scarabaeidae, mostly Anoplognathus spp.) attack (QFRI website, 2002).
Seedlings and young plantations in Africa have been found susceptible to attack by termites unless control measures are taken (Calvert, 1971).

E. cloeziana is susceptible to drought, especially when young, and also requires freedom from competition by weeds in the establishment phase. It will not tolerate frosts below about -5°C, waterlogging or even moderate levels of salinity. Wind damage to shelterbelts in South Africa and Malawi has been reported (Poynton, 1979). Young seedlings may need protection from vertebrate pests such as rabbits.

Utilisation

Wood

The heartwood is yellowish-brown and the sapwood is distinctly paler in colour and up to 25 mm wide. The wood does not display any figure and is medium textured with a generally straight, uniform grain, although it is sometimes slightly interlocked (Keating and Bolza, 1982; QFRI website, 2002). Air-dry density of wood from mature trees averages about 1000 kg m⁻³ (Bootle, 1983). Young plantation-grown trees (five years) were found to have a basic density of 624 kg m⁻³, with a range of 489-732 kg m⁻³ (Dickinson et al., 1996). The timber is heavy, strong and very tough. The sapwood is not susceptible to lyctid borer attack and readily accepts preservative impregnation, however, the heartwood is extremely resistant to preservative treatment (Bootle, 1983). The timber is very resistant to termites (Keating and Bolza, 1982).

It can be satisfactorily dried using conventional air and kiln seasoning methods. In South Africa logs and sawn boards of E. cloeziana have shown a tendency to end-split but the extent to which this occurs varies greatly with age and provenance (Poynton, 1979). Its wearing and weathering properties are good. The timber is rated very hard (rated 1 on a 6 class scale) in relation to indentation and ease of working with hand tools. It machines, turns and dresses well and, as with most high density species, requires machining and surface preparation immediately before gluing. It saws well and planes to an attractive finish, taking a high polish.

The strength and durability of the timber and its ease of sawing makes it suitable for a wide range of uses. It is rather heavy for furniture making and light construction but is used in engineering as sawn and round timber in wharf and bridge construction, railway sleepers, poles, piles, cross-arms and mining timbers, mining timbers and railway sleepers. In construction it is used as unseasoned sawn timber in general house framing and as seasoned dressed timber in cladding, internal and external flooring, lining and joinery. It can also be used in fencing, landscaping and retaining walls, outdoor furniture and turnery (QFRI website, 2002).

Results of an Australian pulping study (Hicks and Clark, 2001) showed some promising results for E. cloeziana use for paper production. Among eucalypts, basic density has been correlated with paper properties and the range of densities for commercial pulpwood is 400-600 kg m⁻³. Twelve-year-old E. cloeziana in this study had a basic density of 644 kg m⁻³, but as paper companies are now accepting wood with higher densities for fine paper production, up to 650 kg m⁻³ in Australia and up to 700 kg m⁻³ in Japan, this species could be considered as acceptable for the production of fine papers. The researchers also found that E. cloeziana had a higher handsheet bulk than that of the pulp from current Tasmanian export woodchips and in an estimate of chemical pulping suitability based on the basic density, alkali requirements and pulp yields obtained from laboratory tests, E. cloeziana ranked around 20% higher than Tasmanian export woodchips and around fifth out of the 23 eucalypts being tested (Hicks and Clark, 2001).

Overseas E. cloeziana makes excellent charcoal and the branches make a very good fuelwood (Magalhaes and Carneiro, 1988; Trugilho et al., 1997; Poynton, 1979).

Non-wood

Although it has been recommended for forming the upper storey of tall shelterbelts in Australia (Brown and Hall, 1968), it has also been reported as being damaged by high winds when planted in shelterbelts in South Africa and Malawi (Poynton, 1979).

It yields a modest supply of both nectar and pollen for honey production (Blake and Roff, 1958). Its foliar essential oils have been analysed (Bignell et al., 1997; Boland et al., 1991; Daimo et al., 1999) but are not currently of interest for commercial production.
Limitations

It is not an aggressive colonizer and has no major disadvantages. Its sensitivity to fungal pathogens in the nursery has inhibited its use as a plantation species. Strong winds can cause windthrow problems, especially on shallow soils, and susceptibility to cyclonic winds has inhibited its planting in some tropical coastal areas. It is more sensitive than most eucalypts to drought shortly after planting.

Recommended Reading


References


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


7. *Eucalyptus dunnii* Maiden

*Dunns White Gum*


### Species overview

*Eucalyptus dunnii* is a large hardwood which can show rapid growth and often excellent stem form on fertile soils with suitable climate. In plantations, stem straightness can be superior to that of the highly regarded species *E. grandis* (Johnson and Arnold, 2000), with a finer branching habit. It has a demonstrated adaptability to a wide range of soil types of good depth and moderate to high fertility (Herbert, 1996). In trials and commercial plantations it has proved capable of superior growth and survival in some environments, in comparison to some more widely planted eucalypt species such as *E. grandis*, due to its superior frost and drought tolerance (Turnbull and Pryor, 1984; Darrow, 1996, Jovanovic *et al.*, 2000). *E. dunnii* is particularly well suited to warmer summer rainfall climates where winters are cold and frosts occur regularly. It produces timber suitable for a range of uses. In Brazil and Argentina it is considered suitable for pulp manufacture and a range of solid wood products such as light construction timbers and veneers. However, in comparison to many other eucalypts it has low seed production (Jacobs, 1981).

It has been planted in only a few countries on a commercial scale (Australia, Uruguay, Brazil, South Africa and China).

### Description and natural occurrence

#### Description

*Eucalyptus dunnii* is a medium-sized to tall forest tree with a wide spreading and heavily branched crown in more open situations. Mature heights of up to 50 m are attained with diameters at breast height up to 1.5 m. Form is generally excellent with a clear straight bole (in natural stands) up to

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**Key features**

- Medium to tall tree to 50 m of generally excellent form with clear straight bole up to 35 m
- In plantations form can be superior to the highly regarded *E. grandis* with a finer branching habit
- Can show rapid early growth on fertile soils with good depth
- Adapted to a wide range of soil types but requires good depth, moderate to high fertility and moist soils
- May require heavier fertilisation than *E. grandis* and some other plantation eucalypts growing on similar soils
- Survival is good in drought but growth is quite poor
- Can be grown in dry areas with the use of irrigation
- It tends to be a shy seeding species
- It produces a good kraft pulp for papermaking
- Timber is not sufficiently durable for external applications
- Timber has been used in building framework and joinery, particleboard manufacture, charcoal production and as fuelwood
- Niche is on sites in warmer summer rainfall regions with more than 900 mm rainfall, on sites with frequent winter frosts on deep, fertile soils on the coastal tablelands and ranges of northern New South Wales and southern Queensland, and irrigated sites in drier regions.
30.3-35 m (Boland et al., 1984). In gross morphological features, it resembles *E. saligna* and *E. grandis*, which are associated species. *E. dunnii* can be confused with *E. dalrympleana* subsp. *heptantha* (Boland et al., 1984).

Distinctive features of the tree are the brown, rough, more or less corky and persistent stocking of 1-4 m with smooth grey or whitish bark above and often long ribbons of bark that are shed from the upper trunk and main branches. It has cordate, crenulate strongly discolorous juvenile leaves, 7-flowered inflorescences, avoid buds with scar and hemispherical fruit with 3-5 strongly exserted valves (Boland et al., 1984; Brooker and Kleinig, 1994). The seed is grey-brown-black (Boland et al., 1980) and small with approximately 250 000 kg⁻¹ (Turnbull and Doran, 1987).

Like other eucalypts *E. dunnii* does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). *E. dunnii* is a generally a late flowering species, both in natural stands and when planted as an exotic (Boland, 1984; Graca, 1987). Typically it can take 10 years or more before it commences flowering and producing seed. Even after it has commenced seed production, seed yields are relatively low and irregular (Oliviera et al., 1988; Gardiner, 1990). However, when planted well south of its natural range in inland southeastern Australia, individuals have been observed to flower from as early as age four years (CSIRO Forestry and Forest Products unpublished data).

The reproductive cycle takes about two years to complete. Flowering in its natural habitat is from March to May (i.e., autumn). Capsules mature by early spring, with seed collection months being September-February (Boland et al., 1980).

**Natural occurrence**

*Eucalyptus dunnii* occurs mostly in two main small, disjunct, natural populations in the Moleton-Kangaroo...
River area of New South Wales, north-west of Coffs Harbour (30°S), and in the Border Ranges of New South Wales and Queensland (about 28°S) (Figure 7.1). Within these two populations, it occurs in disjunct communities varying in size from several up to more than 200 ha [Benson and Hager, 1993]. Several isolated small stands occur just south of the Border Ranges in the Richmond Range area of New South Wales.

In *E. dunnii*’s natural range the climate is warm and humid with frosts occurring about 20-60 times a year (Boland et al., 1984).

Natural stands of *E. dunnii* occur mainly in valley bottoms and on lower slopes of hills and escarpments. It also grows high on ridges in basaltic soils around the edges of rainforests (Benson and Hager, 1993). Stands occur on a range of aspects but rarely on north-western facing slopes. It prefers moist, higher fertility soils, particularly those of basaltic origin (Boland et al., 1984).

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *E. dunnii* Maiden, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climate Parameter</th>
<th>Value</th>
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<tr>
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<td>Uniform, summer</td>
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<tr>
<td>Dry season length</td>
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<td>Mean maximum temperature hottest month</td>
<td>24-31°C</td>
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<tr>
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<td>-1-17°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>12-22°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *E. dunnii* (Figure 7.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Information from trials in South Africa at Liff and Greenpoint (Nixon and Hagedorn, 1984) and at John Meikle Forest Reserve in Zimbabwe (Paynton, 1979) show that the species can cope with a dry season length of about five months rather than the two months indicated by its natural range. On more fertile sites with good soil depth it can show rapid early growth with excellent stem straightness and fine branching. Impressive growth rates, up to 4 m or more in height per year, have been achieved in coastal northern New South Wales (Johnson and Arnold, 2000) and under irrigation in southern inland New South Wales (Myers et al., 1994).

In drought-prone areas growth tends to be poorer even though survival is good (Darrow, 1996). It generally does not grow well on shallow soils (effective rooting depth <55 cm) with poorer water holding capacity (Herbert, 1994). However, supplementary irrigation can enable *E. dunnii* plantations to be extended into very dry areas, sometimes with outstanding growth results (Myers et al., 1994). In a species trial under effluent irrigation near Wagga Wagga in inland New South Wales (mean annual rainfall 570 mm), the top height of *E. dunnii* averaged 10.1 m at age 34 months (Myers et al., 1994). It was one of the best two out of 30 eucalypt species included in that trial, based on a rating that integrated growth and other traits including stem form.
Plantings and provenance trials

Plantings

Eucalyptus dunnii has been included in trials in many countries including South Africa, Zimbabwe, Kenya, Colombia, Brazil, Uruguay, Argentina, Chile, China and Sri Lanka and Australia (Johnson and Arnold, 2000). Though it has often shown promise in such trials, only in relatively few countries have larger areas (>1000 ha) of E. dunnii plantations been established. These countries include Australia, Uruguay, Brazil, South Africa and, more recently, China.

Its use as an exotic in many countries has been severely limited by low seed productivity – a consequence of its tendency to be a shy seeding species (Jacobs, 1981; Turnbull and Pryor, 1984; Oliveira et al., 1988).

Provenance trials

In 1990, CSIRO made seed collections from 188 individual trees of E. dunnii covering most of its natural range (Gardiner, 1990). This seed, combined with some limited earlier collections, has provided the base populations for most of the E. dunnii genetic tree improvement programs being pursued around the world today.

Results of trials of E. dunnii have shown variation between provenances for growth and form to be small in magnitude. In two trials in northern New South Wales which included 14 different provenances representing most of the species’ natural range, 3-year-old mean height of the poorest provenances was about 85% of that of the best, and differences in stem form among provenances were minor (Johnson and Arnold, 2000). This pattern of variation in growth and form between provenances of E. dunnii is generally demonstrated in provenance trials in Argentina (Marco and Lopez, 1995), Brazil (Pires and Parente, 1986; Oliveira et al., 1988; Kise, 1997); South Africa (Nixon and Hagedorn, 1984; Swain, 1994; Swain and Gardner, 1997) and China (Mannion and Zhang, 1989; Wang et al., 1999).

Breeding and genetic resources

Most of the natural stands of E. dunnii in New South Wales are now located within National Parks or reserved forests, so this rare species is not threatened or endangered.

Though provenance differences for growth and form in E. dunnii are generally small, large significant differences between families, within provenances, have been reported. The heritability of both growth traits and stem straightness has been found to be similar to that in other eucalypt species, indicating that reasonable genetic gains can be expected from selection and breeding for these traits. Base populations for ongoing genetic improvement should incorporate a relatively comprehensive sampling of the total natural range of E. dunnii to enable exploitation of the genetic variation that exists between families within provenances (Johnson and Arnold, 2000; Marco and Lopez, 1995).

The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra can supply both single-tree and bulk-tree provenance collections of seed from natural stands of E. dunnii suitable for trials and breeding programmes. It also has a small amount of improved seed of E. dunnii available.

Eucalyptus dunnii genetic improvement programs, of varying intensity, have been initiated in at least Australia (Johnson and Arnold, 2000), South Africa (SAPPI, 1997), Brazil (Oliveira et al., 1988), Uruguay (Chris Harwood, CSIRO Forestry and Forest Products, Canberra, pers. comm., 1997) and Argentina (Marco and Lopez, 1995). In Brazil, there are more than 100 ha of seed production areas for the species (Eldridge et al., 1993). However, seed production of these areas is relatively low. At around age 20 years, 15.8 ha of E. dunnii seed production area in Paraná State, Brazil, averaged around only 1.5 kg of seed per year (Chris Harwood, CSIRO Forestry and Forest Products, pers. comm., 1997).

Interspecific hybrids of eucalypts are becoming increasingly important to forest industries worldwide and E. grandis is one of the most commonly-used parent species in the combinations deployed. In southern Brazil, the hybrid of E. grandis x E. dunnii has provided some outstanding individuals (Chris Harwood, CSIRO Forestry and Forestry Products,
Canberra, pers. comm., 1997). Other combinations that have been successfully produced, at least to the seed stage, include E. dunnii x E. grandis, E. dunnii x E. urophylla, E. dunnii x E. macarthurii, E. nitens x E. dunnii, and E. macarthurii x E. dunnii (SAPPI, 1997).

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

*Eucalyptus dunnii* seeds are small, orthodox and will remain viable in storage for several years if kept dry (5-8% moisture content) in air-tight containers held at room temperature. The number of viable seeds is 250 000 ± 119 000 kg⁻¹ (i.e. mean ± standard deviation) (Turnbull and Doran, 1987). The viable seed are always contaminated with chaff of similar size, even when sieved. The recommended temperature for germination is 25-30°C (Boland et al., 1984) and the seed requires no pre-treatment.

General nursery practices are suitable for producing containerised seedlings of *E. dunnii*. These are described in texts such as Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. *E. dunnii* seedlings are generally raised in single containers or trays containing a number of individual cells. Rigid plastic cells or containers of 90 ml are capable of producing ideal nursery stock 150-200 mm high. Approximately 3-4 months under a suitable nursery regime is generally adequate to provide quality seedlings for planting out.

*Eucalyptus dunnii* will strike roots from stem cuttings but success rates reported to date have generally been low and success varies considerably between clones (Valle, 1978; Cooper and Graca, 1987). In a New South Wales study, cuttings taken from seedlings in spring provided better strike rates than cuttings taken in winter (H. Smith, State Forests of New South Wales, pers. comm., 2000). Grafting has been successful for breeding arboreta and seed orchards in South Africa (SAPPI, 1997). It is reported to coppice well (Cooper and Graca, 1987; Graca and Toth, 1990).

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. dunnii*. Detailed information on various establishment practices is available from several sources including: government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoodsqld/), or these documents can be obtained by contacting the organisations directly.

*Eucalyptus dunnii* responds well to deep ripping on compacted sites; complete soil cultivation rather than spot cultivation; chemical weed control and early fertiliser application (Nicholas et al., 1989). Seedlings can be planted by hand or by machinery. To allow machinery to be used a spacing of 3-5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha⁻¹) and 4 m x 2.5 m (1000 trees ha⁻¹). These spacings encourage rapid canopy closure, reducing weed problems, promoting good form and allowing ample selection for final stocking of 200-300 trees ha⁻¹ (Bird, 2000).

Herbert (1996) summarises South African silvicultural practices applied across different eucalypt species including *E. dunnii* – ‘Rotation lengths vary from 6-12 years for pulpwood and mining timber, depending on site quality, stocking density and timber demand. Common spacings are from 3.0 x 2.0 m (1667 trees ha⁻¹) to 3.0 x 3.0 m (1111 trees ha⁻¹). Sawn and veneer timbers are
grown on rotations of up to 25 years with regular thinning, resulting in a final stocking of about 250 trees ha\(^{-1}\) by mid rotation. Rotations for transmission poles are intermediate between those for pulp and sawn timber, retaining about 750 trees ha\(^{-1}\) at age 4 years followed by selective cuttings at marketable sizes (Schönau and Stubbings, 1987).

Wood from \textit{E. dunnii} grown at wider spacings (3 x 4 m) may be less desirable for chemical pulping as it was found to have a higher alkali consumption (which causes pulp degradation) during kraft pulping (Ferreora et al., 1997). In contrast, that from closer spacings (3 x 1, 3 x 1.5, or 3 x 2 m) had lower and acceptable levels of alkali consumption and were better suited to kraft pulping.

Planting out is timed to coincide with rainfall and in southern latitudes is predominantly determined by the severity of frost and minimum temperatures experienced. Planting is carried out in June/July in South Australia and Western Australia while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred so that young seedlings will be exposed to a shorter period of high temperatures.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practiced in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997). General recommendations are also available on the QFRI website (2002).

**Maintenance**

Plantations of \textit{E. dunnii} in Australia have yet to reach a stage where commercial harvesting has been undertaken and management practices are still developing.

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques in a farm forestry context. Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for high-value appearance-grade products (Bird, 2000).

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter of individual stems. When grown for sawlogs the stand may be reduced to a final stocking of 100-300 stems ha\(^{-1}\).

**Growth**

Growth data for plantation grown \textit{E. dunnii} is not available for Australia. On more fertile sites with good soil depth the species can show rapid early growth. In Australia, height growth of about 4 m per annum has been achieved in coastal northern New South Wales (Johnson and Arnold, 2000) and under irrigation in southern inland New South Wales (Myers et al., 1994). Overseas trials indicate height increments ranging up to 4.2 m yr\(^{-1}\), and diameter at breast height increments ranging up to 3.6 cm yr\(^{-1}\) (Marco and Lopez, 1995). Overseas volume growth ranges up more than 34 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) (Marco and Lopez, 1995; Higa et al., 1997).

Finger et al. (1995) provide a taper equation for \textit{E. dunnii} and Coetzee and Naicker (1999) provide both taper and volume equations for the species.

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and
diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and by regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

Exposure of *E. dunnii* seedlings in nurseries to excessive moisture and shade increase the incidence of fungal attack by damping off and collar rot (Turnbull and Pryor, 1984).

*E. dunnii* is a preferred host of Christmas beetles, which affect plantation increment in many parts of south-eastern Australia and northern New South Wales (Farrow, 1996; Simpson et al., 1997). Other insect pests which can cause significant defoliation of the species in Australia are autumn gum moths, leaf beetles, leaf blisters sawfly, psyllids and lerps (Farrow, 1996; Simpson et al., 1997). Infestation levels of all these insects on *E. dunnii* tend to vary greatly between both years and locations (Rob Floyd, CSIRO Division of Entomology, Canberra, pers. comm. 1998). To resolve this uncertainty about the effect of site on the level of infestation, it may be necessary to put in preliminary trials (Turnbull and Pryor, 1984). Stone (1993) noted that application on nitrogenous fertiliser did not appear to affect the level of psyllid infestation on *E. dunnii*.

Genetic variation in predation by some insects has been observed in *E. dunnii* (Stone et al., 1998) and may provide scope for minimising impacts through genetic improvement of its tolerance and/or resistance.

Whilst *E. dunnii* shows frost tolerance, it is susceptible to snow and wind damage. However, recovery from stem breakage early in the rotation can be sufficient to produce an acceptably straight bole by the end of the rotation (Swain and Gardner, 1997).

**Utilisation**

**Wood**

The heartwood of *E. dunnii* is pale brown and not clearly differentiated from the sapwood. The texture is medium, with a straight grain. The heartwood is not sufficiently durable for external use unless treated. The sapwood is susceptible to *Lyctus* borer attack (Boland et al., 1984). Air-dry density (of wood from natural stands in Australia) is about 800 kg m⁻³. Basic densities for two planted stands of *E. dunnii* were 513 kg m⁻³ (9-year-old, unknown provenance planted at Coffs Harbour, New South Wales) and 534 kg m⁻³ (12-year-old, ‘Kyogle’, New South Wales provenance planted at Gympie, Queensland) (Hicks and Clark, 2001). The timber has been used in the framework of buildings and joinery (Bootle, 1983) and has been found to be suitable for particleboard manufacture (Iwakiri et al., 1996) and fuelwood (Pereira et al., 1986; Wachira et al., 1994).

Care is needed in the early stages of drying the wood to avoid checks and splits; shrinkage from green to dry is about 5% radial and 10% tangential (Bootle, 1983). Sawing and drying trials of young trees (14 years old) from a plantation in Victoria, found *E dunnii* timber to be well suited to appearance-grade products; that sawing distortion was within acceptable limits; and that seasoning collapse encountered in some boards was not an insurmountable problem (Washusen, 1995).

In South African studies, kraft pulp from *E. dunnii* has shown excellent strength development during beating, high screened yields with low percentages of rejects, as well as acceptable values for burst strength, tear strength and breaking length in comparison to *E. grandis* pulp – a pulp known for its excellent papermaking fibres (Van Wyk and Gerischer, 1994). These results are in general concurrence with a number of other studies (see Ferreora et al., 1997; Backman and de Leon, 1998) and an Australian study of wood properties of trees from two planted stands of *E. dunnii* which also concluded that the species had good potential for chemical pulping (Hicks and Clark, 2001).
**Non-wood**

The concentration of 1,8-cineole in the oil extracted from the leaves of *E. dunnii* is generally considered too low for pharmaceutical purposes (John Doran, CSIRO, Forestry and Forest Products, Canberra, pers. comm. 2000).

**Limitations**

Its use as an exotic in many countries has been severely limited by low seed production (Xiang Dongyun, Guangxi Forest Research Institute, pers. comm., Jacobs, 1981; Turnbull and Pryor, 1984; Oliveira et al., 1988). It is prone to breakage from snowfalls and strong winds, though it has a propensity to recover good form from such events that occur early in its life (Swain and Gardner, 1997). Care in drying the wood is needed to avoid checks and splits (Bootle, 1983). It is a preferred host of Christmas beetles, as well as autumn gum moths, leaf beetles, leaf blister sawfly, psyllids and lerps which have the potential to impact on plantation growth (Stone et al., 1998). The species doesn’t do well on shallow soils and growth is severely limited by prolonged dry periods (Darrow, 1996; Herbert, 1994).

**Recommended reading**


**References**


Boland DJ, 1984. Australian trees grown in five overseas countries: comments on species grown and tested, seed handling, nursery and establishment techniques. Churchill Fellowship Report. CSIRO Division of Forest Research, Yarralumla, ACT.


Cooper MA, Graca MEC, 1987. Perspectives on the maximization of rooting of cuttings of *Eucalyptus dunnii*. Curitiba, Parana; Brazil: Circular Tecnica Centro Nacional de Pesquisa de Florestas. No. 12.

Darrow WK, 1996. Species trials of cold-tolerant eucalypts in the summer-rainfall zone of South Africa - Results at six years of age. Institute for Commercial Forestry Research (ICFR); Pietermaritzburg, South Africa. ICFR Bulletin Series No. 9/96.


8. *Eucalyptus fraxinoides* Deane and Maiden

**White ash**

Adapted from Doran, 2000.

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**Key features**

- Medium-sized tree to 40 m of variable form
- Fast growth
- Suited to dry, cool sites but is not tolerant of drought
- Does not perform well in warm, humid environments
- Very frost tolerant species
- Requires deep, well-drained soils
- Is intolerant of waterlogging
- Is relatively intolerant of drought
- Has potential for pulp production.

**Species overview**

*Eucalyptus fraxinoides* is a medium-sized to tall, fast-growing tree that is suited to dry, cool, well-drained sites but is not tolerant of drought. It is a frost-tolerant species which has been grown as a source of pulpwood for bleached fine writing and printing papers in South Africa and as a shelterbelt species in New Zealand. In Australia the timber from natural stands has been used for joinery, flooring and general construction and in New Zealand it has been sawn on a limited scale for internal joinery and furniture. The timber from plantation-grown trees seasons extremely well and is easy to work. It has not been utilised for planting to any extent in Australia, although it has been included in several trials and has been found suited to some sites in south-eastern Australia (Cotterill et al., 1985; Duncan et al., 2000). However, while growth rates are often very good on suitable sites, survival is often poor (Clarke et al., 1997; Duncan et al., 2000).

**Description and natural occurrence**

**Description**

A medium-sized to tall tree that attains 40 m in height with a DBH up to 1 m. At high altitudes in exposed situations it may be reduced to a smaller, somewhat bushy tree 10-20 m high. Trees of better form are often found in stands. The erect trunk of good form is usually one-half or more of the tree height. Bark is rough at the base for up to a few metres, compact, hard, fissured, dark grey. Upper bark sheds in long strips to leave a smooth yellowish white surface, frequently covered with insect ‘scribbles’. Juvenile leaves are sessile and opposite for a few pairs, soon becoming petiolate, alternating and pendulous, ovate to broadly falcate or broadly lanceolate, blue-green (dimensions to 20 cm long x 6.5 cm wide). Adult leaves are lanceolate to falcate, glossy green (dimension to 16 cm long x 2.5 cm wide). The inflorescences are axillary, 7-11-flowered, buds on short stalks, clavate, often warty, 0.7 x 0.3 cm, with operculums which are conical to slightly beaked. Flowers are white. The fruit are pedicellate, woody, glossy, urceolate or rarely truncate-globose, 1.1 x 1.1 cm, with descending disc and 4 or 5 enclosed valves. Seed is brown-black to black (Brooker and Kleinig, 1999).
Like other eucalypts white ash does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowering occurs during December-January in the natural distribution and December to early March, but mainly in February, in New Zealand. In New Zealand trees will usually begin to produce flowers at 7-9-years-of-age, sometimes on favourable sites at 3-6 years. Seed is collected from August through to March in natural stands. In New Zealand seed collections can be made at any time of the year. The optimum collection time is after November, when there should be two years’ seed crop on the trees. Mature trees carry a seed crop that has matured over two years after pollination (Miller et al., 2000; Gunn, 2001). There will be regional and seasonal variability in seed availability.

Natural occurrence

_Eucalyptus fraxinoides_ is confined to the higher eastern slopes of the southern highlands, south from Sassafras, and the upper slopes of the coastal escarpment of far south-eastern New South Wales, extending just across the border into the Howe Range in the north-eastern corner of Victoria (Brooker and Kleinig, 1999) (Figure 8.1). It has a latitudinal range of 35°-37°30’S and an altitudinal range of 150-1000 m.

The habitat is typically mountain and escarpment slopes which often experience mists and where regular winter snows occur, but the southernmost populations occur in coastal hills where the climate is milder. The climate is cool to warm humid with frosts (Boland et al., 1984). The frequency of frost varies with altitude from 10 to greater than 90 per year. At altitudes over 700 m light falls of snow occur and heavier falls at over 850 m, which will lie on the ground for several days (Jacobs, 1981).

It occurs on brown podsolic and transitional alpine humus soils. At the highest altitudes the trees grow in pure stands on shallow soil among granite rocks (Boland et al., 1984).

Figure 8.1: Natural distribution of _Eucalyptus fraxinoides_ (Jovanovic and Booth, 2002)
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus fraxinoides*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climatic Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>640-1660 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>16-30°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>-3-7°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>5-15°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *Eucalyptus fraxinoides* (Figure 8.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. In South Africa, *E. fraxinoides* is best suited to areas where the rainfall incidence is either uniform throughout the year or the maximum falls in summer. In Australia it is unaffected by frost in all but the coldest areas but is more sensitive to drought than the majority of eucalypts. It has withstood heavy snowfalls almost as well as *E. nitens*. However, under cold valley frost condition (cold air drainage), the canopies of trees 6-8 m high with adult foliage were frosted and killed from the growth tip to just above ground level (Gardner and Swain, 1996). Revisions to the climatic range include the altering of the rainfall regime to include a winter regime with the inclusion of trial information from Mt Gambier (Cotterill et al., 1985). The length of the dry season was altered from one to five months on the basis of trials at Draycott and Balgowan in South Africa (Gardner and Swain, 1996). The upper limit for the mean annual temperature was also revised from 14°C to 15°C by including trial information from Draycott (Gardner and Swain, 1996) and Lothair in South Africa (Darrow 1996).

*Eucalyptus fraxinoides* requires moist, deep and well-drained soils (Schönau and Purnell, 1987). In New Zealand the ash eucalypts have generally been planted in the cooler parts, but where the winter ground temperatures do not fall below -8°C. Warmer northerly aspects are preferred for planting, but frost hollows and areas with poor air circulation should be avoided as early-season or late-season frost can be very damaging (Miller et al., 2000).

Plantings and provenance trials

Plantings

This species has been planted on a small scale on both the North and South Islands and as horticulture shelterbelts around Auckland, New Zealand. Pure plantings of *E. fraxinoides* in New Zealand were estimated in 1997 at 212 ha, with a further 3 ha in mixed plantings, mostly 11-15 years of age. *E. fraxinoides* exhibited excellent growth at the Longwood Forest site in New Zealand and grew well on a number of other sites, although the good form of the trees at Longwood Forest was not repeated elsewhere (Miller et al., 2000).

It has also been trialled and planted in southern Africa and while results have been variable it has been described as a desirable species for
commercial production, because of vigorous growth on colder sites and the excellent pulping properties of the wood (University of Pretoria, 1997).

Provenance trials

*Eucalyptus fraxinoides* has been trialled in several countries including Africa, New Zealand and Australia with variable success. A number of provenances have been included in species and provenance trials but no comprehensive trialling of provenances has been done. Reported performance of this species has been variable and reasons for poor results not always conclusively established. Poynton (1979) reports that its poor growth in southern Africa was chiefly because it did not withstand drought well. However, it is still a commercially attractive species due to its good performance on colder sites and its excellent pulping qualities. In New Zealand its performance at one particular site, Longwood Forest in the south of the South Island, was particularly notable and this saw it being planted more widely. However, most subsequent *E. fraxinoides* plantings proved to be of variable or indifferent growth and/or form, and poor survival has been a feature (Miller et al., 2000). The species’ good frost tolerance, fast growth rate and attractive pulp and sawn timber properties mean that it has potential, but success of plantings will require careful site matching.

White ash showed excellent early growth (four years of age) in a trial near Mount Gambier, South Australia. The site was an ex-grazing pasture on a deep sandy soil. The mean height attained was 9 m, and mean diameter was 15.5 cm (Cotterill et al., 1985).

In species and provenance trials in the Australian Capital Territory *E. fraxinoides* was planted on three sites of varying rainfall (450-700 mm MAR) and soil type. It failed completely at two sites [Stromlo and Kowen] and had extremely low survival at the third [Uriarra]. The height and diameter growth of the surviving trees was moderate (Table 8.1). At the higher rainfall Tallaganda, New South Wales, site (1000 mm MAR and deep duplex soils) where it was grown as part of a small species trial (six species planted in three blocks each of 121 trees) the growth and survival of this species at 8 years was better than in the Australian Capital Territory trials, but survival was still low (Clarke et al., 1997).

*E. fraxinoides* was included in species and provenance trials on seven sites in Gippsland, Victoria, and results of the trials at 10-12 years were reported by Duncan et al. (2000) (Table 8.2). The three seedlots included were ‘Eden’ (seven sites), ‘Pikes Saddle’ (five sites) and ‘Tuross Falls’ (four sites), all from New South Wales. These trials included up to 36 eucalypt species and over 88 seedlots at the different sites. Rankings of *E. fraxinoides* were

### Table 8.1: Performance of *Eucalyptus fraxinoides* provenances at Uriarra, ACT and Tallaganda, New South Wales (Clarke et al., 1997)

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Age (yr)</th>
<th>Site Name</th>
<th>Rainfall (mm MAR)</th>
<th>Mean Survival (%)</th>
<th>Mean DBH (cm)</th>
<th>Mean Height (m)</th>
<th>Mean Height of Best Seedlot at Site (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pikes Saddle, New South Wales</td>
<td>12</td>
<td>Uriarra</td>
<td>700</td>
<td>6</td>
<td>13.6</td>
<td>12.7</td>
<td>16.9</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>12</td>
<td>Uriarra</td>
<td>700</td>
<td>2</td>
<td>11.4</td>
<td>9.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Tuross Falls, New South Wales</td>
<td>8</td>
<td>Tallaganda</td>
<td>1000</td>
<td>61 @ 4yrs</td>
<td>11.9</td>
<td>9.9</td>
<td>11.0</td>
</tr>
</tbody>
</table>


variable across sites and between provenances. The performance of all provenances was worst at the Flynn's Creek site and best at the Mt Worth East site, with both the 'Tuross Falls' and 'Pikes Saddle' provenances achieving stem volumes of around 300 m³ ha⁻¹. The Tostaree site had a history of fertiliser application increasing its productivity and *E. fraxinoides* performed best on gradational textured soils at higher rainfall sites. Survival in these trials was low with an average survival for the species of 48%.

Table 8.2: Best performing *Eucalyptus fraxinoides* provenance at each of seven trial sites in Gippsland, Victoria (Duncan et al., 2000)

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Age (yr)</th>
<th>Site Name</th>
<th>Rainfall (mm)</th>
<th>Soil Type</th>
<th>Approximate Stem Volume (m³ ha⁻¹)</th>
<th>Approx. Stem Volume of Best Seedlot at Site (m³ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuross Falls, New South Wales</td>
<td>11</td>
<td>Mt Worth East</td>
<td>1210</td>
<td>Clay loam</td>
<td>300</td>
<td>550</td>
</tr>
<tr>
<td>Tuross Falls, New South Wales</td>
<td>11</td>
<td>Delburn</td>
<td>1000</td>
<td>Clay loam</td>
<td>220</td>
<td>320</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>11</td>
<td>Flynn's Creek</td>
<td>760</td>
<td>Sandy loam</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>11</td>
<td>Stradbroke</td>
<td>600</td>
<td>Loamy sand</td>
<td>195</td>
<td>270</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>11</td>
<td>Stockdale</td>
<td>690</td>
<td>Loamy sand</td>
<td>80</td>
<td>170</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>10</td>
<td>Waygara</td>
<td>870</td>
<td>Sandy clay loam</td>
<td>130</td>
<td>180</td>
</tr>
<tr>
<td>Eden, New South Wales</td>
<td>10</td>
<td>Tostaree</td>
<td>820</td>
<td>Loamy sand</td>
<td>205</td>
<td>370</td>
</tr>
</tbody>
</table>

Table 8.3: Site details for two South African sites where *E. fraxinoides* was tested as part of a eucalypt species trial (Clarke et al., 1999)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Altitude (m)</th>
<th>Mean annual rainfall (mm)</th>
<th>Mean minimum temperature of coldest month (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shafton</td>
<td>1220</td>
<td>950</td>
<td>4.8</td>
</tr>
<tr>
<td>Helvetia</td>
<td>1700</td>
<td>775</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Clarke et al. (1999) reported growth and wood properties for nine eucalypt species tested in trials at two different sites, Shafton and Helvetia, in South Africa (Table 8.3). There were significant differences between sites for growth (diameter, height and volume), wood (lignin, pentosans and density) and pulp (yield, alkali consumption, rate of delignification and brightness) properties, but a greater proportion of the variation occurred between and within species for all properties except wood density. *E. fraxinoides*, *E. smithii* and *E. oreades*
were the most desirable species because of fast growth, high pulp yield, fibre yield and brightness but low kappa number and alkali consumption. The other species studied were E. grandis, E. dunnii, E. saligna, E. macarthurii, E. nitens and E. fastigata.

Breeding and genetic resources

A range of natural provenances of *E. fraxinoides* are available for establishing trial plantings from the CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra.

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

*Eucalyptus fraxinoides* is usually propagated from seed extracted by drying mature capsules. There are on average 138 000 seed per kilogram. Seeds can be germinated without pre-treatment and the optimum germination temperature is about 25°C (Gunn, 2001). The seeds are orthodox and can be stored for several years in cool dry conditions provided their moisture content is kept below 8%.

Information is not available on the use of vegetative reproduction with this species.

*Eucalyptus fraxinoides* does not coppice strongly (Poynton, 1979).

General nursery practices are suitable for producing containerised seedlings of *E. fraxinoides*. These are described in texts such as Doran and Turnbull (1997). In South Africa *E. fraxinoides* has been found to be particularly susceptible to damping off (Poynton, 1979). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

In New Zealand the species is also grown as bare-rooted seedlings. These seedlings must not be allowed to dry out and need to be packed in polythene-lined multi-walled bags or cardboard planting boxes, and stored and transported in crates. Most ash eucalypts can be planted as one-year-old bare-rooted stock, but container-grown stock permits the efficient use of seed of specific origin, growing stock that can be planted at a specific time, and more convenient holding-over of seedlings in a nursery (Miller et al., 2000).

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. fraxinoides*. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these documents can be obtained by contacting the organisations directly.

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used, a spacing of 3.5 m between rows is desirable (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha⁻¹) and 4 m x 2.5 m (1000 trees ha⁻¹). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha⁻¹ (Bird, 2000).

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia and Western Australia planting commonly occurs in June-July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites, but
there is often no response on ex-pasture sites, and soil degradation can result from very large applications of nitrogen fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting, e.g. water availability (low rainfall or heavy weed competition are two factors that can affect this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

Management

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) discuss the theory, objectives and techniques.

Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for high-value appearance-grade products (Bird, 2000). Branches should be removed before their diameters exceed 2.5 cm as large stubs increase the risk of fungal infection and stem decay (Nicholas, 1992).

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter growth of individual stems. The stand may be reduced to a final stocking of 300-100 stems ha⁻¹ when grown for sawlogs (Bird, 2000).

On suitable sites E. fraxinoides is a relatively fast-growing species which, overseas, is grown primarily for pulpwood. Pulpwood is usually grown on short rotations. In South Africa it is harvested at 10-20 years of age (Higgins, 1984). E. fraxinoides growth rates are generally lower than E. globulus growth rates so somewhat longer rotations (15-20 years) may be required when growing E. fraxinoides for pulp in south-eastern Australia. (Noble (2002) suggested a rotation of 10-15 years for E. globulus subsp. globulus in south-eastern Australia).

Growth

Growth data for plantation grown E. fraxinoides is not available for Australia. The range of MAIs for the best provenance of E. fraxinoides in species provenance trials in Gippsland, Victoria, was 3.7-28.5 m³ ha⁻¹ (Duncan et al., 2000).

Trees are capable of rapid growth; the highest mean annual height increment that was recorded in South Africa was 2.4 m over ten years (Poynton, 1979).

Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands and at as high a level as possible by the application of timely silvicultural treatment, not planting the species on sites that are marginal for it, and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996).

Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

Specific information on pests and diseases to which E. fraxinoides is susceptible in Australia is not available to date. However, some of those recorded for this species overseas give an indication as to possible problems in Australia.

Eucalyptus fraxinoides in New Zealand is attacked by a range of insects and fungi. The wood is also damaged by the larvae of various wood-borers such as those of the longhorn beetles, e.g. Navomorpha lineata. The eucalypt tortoise beetle, Paropsis charybdis, has caused defoliation in some stands of E. fraxinoides, but this has been reduced since the introduction of the parasite Enoggera nassaui (Miller et al., 2000). This beetle is endemic to Australia but is not usually a limiting pest in eucalypt plantations. The species is also susceptible to browsing by rabbits, hares, possums and deer in New Zealand (Miller et al., 2000). At a relatively warm, low-elevation site at Rotoehu, New Zealand, the success of E. fraxinoides was inferior to that of other species mainly due to the effects of insect and fungal attack. While its growth was vigorous at this site, it had poor form or low survival. Paropsis species were the primary cause for reduced crown health and Mycosphaerella leaf blotch had been equally severe. The species
also suffered moderate frost damage (Johnson and Wilcox, 1989). The root rot fungi, Phytophthora cinnamomi, has been reported as causing sporadic deaths on sites with fluctuating water tables in New Zealand (Miller et al., 2000).

In South Africa E. fraxinoides suffers high mortality due to root rot Phytophthora cinnamomi (Vuuren et al., 2000), and as species of Phytophthora are common in Australian soils it is possible that this has contributed to the low survival this species has experienced in many Australian trials. This intolerance to Phytophthora may also explain the preference of this species for well-drained soils and the fact that it often does best on higher slopes and ridges than in valleys where the presence of P. cinnamomi is more likely. The South African research to date indicates that tolerance to Phytophthora is under genetic control and therefore a breeding program can be developed to improve tolerance (Vuuren, 2002).

Utilisation

Wood

The heartwood of E. fraxinoides is straw-coloured to light brown, and the sapwood is not clearly distinguishable from the heartwood. The air-dry density is around 560-700 (670) kg m⁻³ (Bootle, 1983; Miller et al., 2000). The wood density of planted material is lower than of trees from natural stands. The timber has an attractive mahogany or ribbon-like grain when quarter-sawn, but is bland when flat-sawn. Kino or gum veins, thought to be caused by cambium damage or environmental stress on the tree, vary from nil to severe degrade within trees from the same stand. In Australia, timber that is light or moderately marked with kino is sold as a ‘natural feature’ grade. When used internally the sapwood is susceptible to borer (Lycus sp.) attack, but is not susceptible to the common house borer (Anobium spp.). In exterior use, the sapwood can be treated with CAA preservative but the heartwood cannot (Miller et al., 2000). Barr (1996) states that in his experience E. fraxinoides shows little tendency to end-check. It seasons well and is easily planed. Trials on young logs showed remarkable stability in seasoning, and the wood has been well accepted by several furniture-makers due to its attractive subdued grain and its stability for joinery work.

In Australia E. fraxinoides is used for joinery, flooring and general construction (Bootle, 1983). In New Zealand E. fraxinoides has been used on a small scale as mature trees have become available. It is used for internal joinery, drawer sides and cupboards. In Australia it is a top quality tree for shingles (Barr, 1996). In South Africa it has been used mainly for building construction, flooring, ceiling, interior fittings, furniture, tool handles, casks and cases, and for bentwood products like tennis racquets (Poynton, 1979).

In South Africa bleached fine writing and printing papers are made from E. fraxinoides (Higgins, 1984).

Limitations

Eucalyptus fraxinoides is not as adaptable as many eucalypts, being fairly site specific. It is particularly susceptible to drought (Poynton, 1979) and root rot fungi, Phytophthora cinnamomi (Miller et al., 2000; Vuuren et al., 2000).

Recommended Reading


References


Tasmanian blue gum

Craig Gardiner and Bronwyn Clarke – adapted from Gardiner, 2000.

Key features

Tall tree of excellent form

Capable of achieving fast growth rates

Absolute minimum rainfall for good growth is 600 mm yr\(^{-1}\) when grown on suitable sites

It is not very drought tolerant

Not generally suitable for summer-rainfall environments because of fungal disease problems

It prefers deep soils of sandy or loamy texture and good water holding capacity

It is not tolerant of waterlogging

Low to moderately salt tolerant

Seedlings are only moderately frost tolerant

It has an excellent coppicing ability

Is considered excellent for pulp production.

Species overview

*Eucalyptus globulus* is a fast growing species of good form on suitable sites in temperate regions. It requires deep, moisture holding soils but does not tolerate waterlogging. It is slightly to moderately salt-tolerant (Marcar et al., 1995). Drought deaths have occurred in some plantations, particularly in Western Australia (White et al., 1999). However, good growth rates have been achieved on sites with low rainfall, i.e. 600 mm yr\(^{-1}\), where evaporation rates are low and plantings are on moisture-holding soils (Harper et al., 1999).

*E. globulus* is widely planted as a short-rotation pulp species [10-12 years in Australia]. It is one of the major hardwood plantation species in southern Australia with 143 000 ha planted between 1995 and 1999, and more than 116 000 ha planted in 2000 (Wood et al., 2001; Borough, 2002). It has also experienced outstanding success as an exotic in many countries, with over 1 million ha of plantations established worldwide (Eldridge et al., 1993). The wood from mature native forests is strong and moderately durable and is used for light and heavy construction. The essential oil of *E. globulus* has dominated the market for cineole-rich oils since soon after the inception of the industry in 1852 (Doran and Saunders, 1993).

Description and natural occurrence

Description

*Eucalyptus globulus* was one of the earliest species of eucalypts to be both validly named and brought into cultivation; it was formally described by the French botanist Labillardière in 1799. Three other taxa, namely bicostata, pseudoglobulus and maidenii, are considered by some authors to be subspecies of *E. globulus* (Kirkpatrick, 1975; Chippendale, 1988; Jordan et al., 1993). This is based on the occurrence of geographically separated core populations of the four taxa, which are differentiated primarily on reproductive traits. Brooker and Kleinig (1999) considered the four taxa as separate species. In this species profile for *E. globulus* the remaining three taxa are not covered, and for the purposes of this report they are considered to be separate species.
The main distinguishing features of *E. globulus* are its solitary flowers, sessile (without stalk) or pedicellate (with stalks) up to 4 mm long and large warty fruits with pronounced ribs. In contrast, *E. maidenii* has up to seven fruits per umbel and the smallest capsules; *E. bicostata* and *E. pseudoglobulus* are three-fruited with *E. pseudoglobulus* having smaller capsules, fewer ribs on the capsule and longer pedicels than *E. bicostata*. A study by Jordan *et al.* (1993) has shown that some populations in western Tasmania, on King Island and the northern end of Flinders Island in Bass Strait, and in the Otway Ranges and parts of Gippsland in the mainland state of Victoria are intermediate between *E. bicostata* and *E. globulus*. The northern Flinders Island and Otway Ranges populations were previously considered to have greater affinity with *E. pseudoglobulus*.

*Eucalyptus globulus* varies from a multi-stemmed shrub on exposed sites to a very tall forest tree, 70-80 m tall, with a large open crown. The forest tree form has a tall straight trunk and its branches are retained for less than half the total tree height (Eldridge *et al.*, 1993). Bark on the lower trunk forms a rough, greyish or brownish, stocking while the upper bark is smooth and pale, often with a bluish or yellowish tinge; decorticating into long strips. The woodland form is a medium-sized tree to 20 m with a compact crown. The single trunk is much branched, the first usually fairly high up. On harsh, exposed sites, such as Flinders and King Islands, *E. globulus* grows as a multi-stemmed shrub (Boland *et al.*, 1984; Marcar *et al.*, 1995).

Seedling and juvenile leaves are opposite, sessile, amplexicaul, ovate, bluish green, glaucous, strongly discolorous (dimensions 6-15 cm long × 2.5-11 cm wide). The stems are square in section, flanged and glaucous. Adult leaves are petiolate, falcate, lanceolate or narrow-lanceolate, green, similar shade of green on upper and lower surfaces (dimensions 12-25 cm long × 1.7-3 cm wide) (Boland *et al.*, 1984).

The inflorescence is axillary, unbranched and usually single flowered (occasionally three). Buds are usually sessile, turbinate with four distinct ribs (sometimes more), extremely glaucous. The bud cap or operculum is flattened, very warty with a very distinct, central knob. The ribbed capsules are sessile, subglobular to hemispherical with four distinct ribs (sometimes more), glaucous; disc broad; valves four or five, more or less at rim level and partly covered by disc lobes. Seed is bluish-brown, flattened-elliptic in outline, shallowly reticulate (Brooker and Kleinig, 1999).

Like other eucalypts blue gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). The flowers are predominantly insect pollinated although birds and small mammals may also assist in pollination. Flowering can occur at any time of the year but generally occurs in September-December (Boland *et al.*, 1984; Brooker and Kleinig, 1999). Trees in irrigated and fertilised plantations can flower as early as 4 years of age while slower-growing trees may take up to 10 years to flower. In managed seed orchards, some individual trees can flower at a relatively young age but it may take some years before sufficient widespread flowering occurs in the orchard to ensure adequate cross pollination.

Mature capsules are present during autumn and winter and may persist for more than a year. Seed is usually collected in autumn and winter in natural
populations although it can generally be found at most times of the year. Seed capsules may remain on the tree for several years although it is unusual to find more than one crop of seed of the same tree. Some reports suggest that heavy seed crops occur every 3-5 years (Hillis and Brown, 1984). There will be regional and seasonal variability in seed availability.

Natural occurrence

Eucalyptus globulus has a discontinuous distribution mainly along the east coast of Tasmania with some populations occurring up to 70 km inland. It is also found on the islands in Bass Strait and in the extreme south of Victoria around Cape Otway, the Strezlecki Ranges and on Wilsons Promontory (Boland et al., 1984) (Figure 9.1). The latitudinal range is 38°26’S to 43°30’S (Eldridge et al., 1993).

It occurs in woodland, open forest or tall open forest vegetation types. Associated eucalypts include E. viminalis, E. ovata, E. obliqua, E. amygdalina, E. nitida, E. pulchella, E. delegatensis and E. regnans (Boland et al., 1984).

Eucalyptus globulus occurs in the warm to cool, humid to sub-humid zones of Australia. Frosts occur at most localities, even close to the coast, 5-40 or more each year. Absolute minimum temperatures do not fall below -8°C in the natural range.

This species is most common on soils derived from granite (Weiss, 1997) and granodiorite parent materials (Hillis and Brown, 1984). Extensive stands are also found on other plutonic rocks, sandstones, dolerite and on shallow humus soils over mudstone (Boland et al., 1984; Marcar et al., 1995), but not on strongly calcareous or alkaline soils. E. globulus also grows on coastal, gently undulating land, often on poor sands. Its best development occurs in moist valleys on fertile loamy or clay soils (Boland et al., 1984).

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for E. globulus, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for good survival and growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>600-1500 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform E/winter</td>
</tr>
<tr>
<td>Dry season</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>13-31°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>-1-12°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>4-18°C</td>
</tr>
</tbody>
</table>

E See comments below on potential disease problems in uniform rainfall areas of New South Wales.
The map of areas predicted to be climatically suitable for planting *E. globulus* (see Figure 9.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. The climate range suitable for plantations of the species had been determined previously by Booth and Pryor (1991) and Marcar et al. (1995). Improved data have altered the climatic limits from those originally published in Marcar et al. (1995). For example, the lower limit for the mean minimum temperature of the coldest month has been dropped from 2°C to -1°C and the lower limit for the mean maximum temperature of the hottest month has been lowered from 19°C to 13°C. Although there are a small number of high rainfall locations in the natural distribution, the species is generally grown in plantations in areas with annual rainfall less than 1500 mm. Good growth rates of *E. globulus* can be achieved on sites with annual rainfall down to 600 mm. Tasmanian blue gum is not generally suitable for summer-rainfall environments because of fungal disease problems. This may also be a problem in uniform-rainfall areas in New South Wales. It is also not recommended for the area north of Bunbury in Western Australia because of the high evaporative rate in this area (Jovanovic and Booth, 2002).

**Figure 9.2:** Areas predicted to be climatically suitable for *E. globulus* are shown in black. (Note that fungal diseases may be a problem in parts of New South Wales, see above) (Jovanovic and Booth, 2002)

Consideration of other factors such as soil requirements, occurrence of prolonged drought and *E. globulus’* susceptibility to insect pests also need to be considered when deciding whether to plant this species. The success of plantings of this species on sites at the lower end of the rainfall range will depend on other factors that affect moisture availability. Low evaporation rates and deep soils that retain moisture are two factors identified so far as contributing to plantation success at low-rainfall sites. *E. globulus* is also intolerant of waterlogged soils and prefers acid rather than alkaline soils (Weiss, 1997). Seedlings are not particularly tolerant of frosts and temperatures of below about -5°C will usually kill them. Mature trees may survive lower temperatures (Hillis and Brown, 1984). *E. globulus* has a low to moderate salt tolerance; reduced growth is expected at $EC_e$ 5 dS m$^{-1}$ with further reduction in growth and reduced survival at 5-10 dS m$^{-1}$ (Marcar et al., 1995). A combination of soil salinity and waterlogging could cause a reduction in growth at 2.5 dS m$^{-1}$ (Bennett and George, 1995).

### Plantings and provenance trials

#### Plantings

Early plantings of *E. globulus* occurred in Africa including Madagascar (Malagasy), Central and South America, Channel Islands, China, Ethiopia, India, Italy, Philippines, Portugal, Spain, Turkey and
the USA (Florida and California). Current overseas plantations of *E. globulus* are in areas of mild climate which are free of severe frosts. More than 800,000 ha are planted in Portugal and Spain with smaller but significant areas in Bolivia, Chile, China, Colombia, Ethiopia, Peru, USA (California) and several other countries (Eldridge et al., 1993).

*E. globulus* has become one of the main hardwood plantation species in southern Australia where it is being planted in the south-west of Western Australia, south-eastern South Australia including Kangaroo Island, southern Victoria and the north coast of Tasmania (Borough and Valentine, 2001).

**Provenance trials**

Twenty or more provenance trials were established from range-wide seed collections of *E. globulus* made by Orme in 1976 (documented in Orme, 1978). Provenance rankings from these early (1977 to 1985) trials should be viewed with caution as some provenances were represented by too few families (five) for a precise estimate of the potential performance of the populations they represent (Eldridge et al., 1993). A review of the growth performance of these provenances in trials across southern Australia, made by Kube et al. (1995), found that provenance variation was significant but no single provenance was outstanding. They found that the ‘King Island’, ‘Flinders Island south’ and ‘Uxbridge’, provenances from Tasmania were consistently good provenances across all regions. The ‘Otways’, Victoria, and ‘Seymour’, Tasmania, provenances performed well in Victoria and Western Australia but were only average on Tasmanian sites. The south-eastern Tasmania provenances of ‘Geeveston’, ‘Channel’, ‘Leprena’ and ‘Denison’ ranked highly in Tasmania but performance in Victoria and Western Australia was only average. Provenances from the west coast and midlands of Tasmania were consistently poor performers (Kube et al., 1995).

In 1988 the National Afforestation Program set up a number of eucalypt trials through ForestrySA. Many provenances of *E. globulus* and *E. nitens* were trialled across a range of sites. *E. globulus* performed the best across all sites, with the best-performing provenances being ‘Otways’ Victoria, ‘Pelverata’ Tasmania, ‘Jeeralang’ Victoria, and ‘King Island’ and ‘Flinders Island’ Tasmania (ForestrySA website, 2002).

During 1987 and 1988 the CSIRO Forestry and Forest Products Australian Tree Seed Centre organised seed collections from 612 trees from 82 provenances throughout the range of *E. globulus* (Gardiner and Crawford, 1987; 1988). These and other collections were used to establish large provenance-progeny trials in southern Australia (Eldridge et al., 1993). Many of these trials and those based on the Orme collections have formed the basis of current breeding programs by groups such as Conservation and Land Management (CALM) in Western Australia and the Cooperative Research Centre for Temperate Hardwood Forestry and the Southern Tree Breeding Association (see Breeding and genetic resources section below).

*E. globulus* was recommended as the most suitable species on six out of eight site types (rainfall x soil matrix) in eleven species and provenance trials in Gippsland, Victoria. Results of the trials at 10-12 years were reported by Duncan et al. (2000) who found that, of the 22 seedlots of *E. globulus* studied, those from South Gippsland, East Gippsland and the Otway Ranges were significantly more productive than seedlots from inland Victoria, south-eastern New South Wales and Tasmania, in this region. *E. nitens* performed best at the most productive site and *E. botryoides* at the driest site. On all other sites *E. globulus* was the most productive species with MAIs of the best seedlot ranging between 13.4 and 39.4 m$^3$ ha$^{-1}$.

**Breeding and genetic resources**

Selection and breeding work with *E. globulus* has been going on for around 15-20 years, but this work has really intensified over the last ten years. Initial selection and breeding was based on improving volume production but in recent years this has broadened to include other factors such as pulp yield and bulk density.

The Southern Tree Breeding Association runs the national tree improvement cooperative for *Eucalyptus globulus* in Australia. Recently, the Southern Tree Breeding Association and the CRC for Sustainable Production Forestry revised the *E. globulus* breeding strategy to focus on total tree
improvement, by integrating deployment with breeding. The majority of STBA members’ plantations are being grown primarily for pulpwood to be used in the manufacture of kraft pulp and paper products. However, members are increasingly interested in breeding for the production of alternative products such as solid wood, and this has therefore been included in the new strategy (McRae et al., 2001). Seedlings are available to the small to medium grower from a number of the Southern Tree Breeding Association members.

ForestrySA through their Green Triangle Treefarm Project, helps farmers establish plantations of E. globulus on suitable sites in the region. Assistance includes processing suitable planting material (ForestrySA website, 2002).

E. globulus seed, seedlings and cuttings developed through CALM Western Australia’s tree breeding and improvement program are being marketed as ‘Western Blue Gum’. Seedlings and cuttings are available from the Manjimup Plant Propagation Centre. Seed is available from the Forest Products Commission Western Australia Seed Centre and is priced from around $3 000 kg\(^{-1}\) for seed from native provenance stands up to $25 000 kg\(^{-1}\) for seed with the greatest level of improvement. They also have seed which is identified as suitable for growing sawn timber of E. globulus: this seed is currently being marketed at $25 000 kg\(^{-1}\).

Some interspecific breeding work has been carried out using E. globulus and to date the most successful has been the E. camaldulensis \(\times\) E. globulus hybrid being developed to increase drought and salinity tolerance of E. globulus (David Bush, CSIRO Forestry and Forest Products, pers. comm., 2002). Another hybrid that has had some success is the E. nitens \(\times\) E. globulus which is expected to improve the frost hardiness of E. globulus (Volker, 1995; Vergara and Griffin, 1997).

A range of natural provenances of E. globulus is also available from the CSIRO Forestry and Forest Products, Australian Tree Seed Centre in Canberra.

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading.

Eucalyptus globulus subsp. globulus one year old plantation established at a 2 m x 3 m spacing near Hamilton in Victoria.

Summary silvicultural information and practices specific to this species are outlined below.

Propagation

Studies undertaken at the CSIRO Forestry and Forest Products Australian Tree Seed Centre have established that E. globulus seed can be successfully stored for several years at room temperature as long as humidity remains low, so that the moisture content remains in between the range of 6-10%. Propagation is usually by seed which germinate readily in warm, moist conditions with no pretreatment. The ideal temperature for the germination of E. globulus is 25°C with the first germinants appearing after about 5 days (Boland et al., 1980). There are approximately 6500 viable seeds per kilogram (Gunn, 2001).

The most common method of producing seedlings is to machine sow pure seed directly into tubes or pots for later field planting. General nursery practices such as those described in texts by Doran and Turnbull (1997) and Bird (2000) are also suitable for producing containerised seedlings of E. globulus. Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Growth will be relatively slow in the nursery during the winter months unless supplementary heating is used. Seedlings should be protected from severe frosts (Weiss, 1997).

Eucalyptus globulus can also be propagated vegetatively although this has not proved to be particularly successful on a commercial scale. In fact,
many commercially important selections have proved very difficult to propagate from cuttings because of poor rooting ability. Recent advances have increased the success of vegetative propagation and since 1995 many companies have started planting extensive areas of *E. globulus* cuttings in Portugal. However, some vegetatively propagated clones have shown disappointing field growth, perhaps due to poor root structure (MacRae and Cotterill, 1997) and in some instances growth of clonal selections has actually been lower than seedlings from the same generation of the breeding program (Cotterill and Brindbergs, 1997).

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. globulus*. Refer to Bird (2000) for a detailed description of site preparation, weed control, fertiliser, thinning and pruning regimes suited to farm forestry in Australia. ForestrySA and Agriculture Western Australia has good information specific to growing blue gum in their regions on their websites, see: http://www.forestry.sa.gov.au/farm.htm and http://www.agric.wa.gov.au/environment/trees/index.htm.

Seedlings can be hand-planted or planted by machinery. Commonly used initial spacings used in plantation forestry in southern Australia are 4 m x 2.5 m (1000 trees ha⁻¹) and 4 m x 3.0 m (1200 trees ha⁻¹), with lower densities being used on poorer sites. Seedlings need to be fenced to provide protection from browsing by sheep, rabbits and other animals.

In the winter-rainfall regions of southern Australia planting times vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia and Western Australia seeds are sown before Christmas for planting in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging. In Victoria and New South Wales, seeds are sown in January-February, for spring planting in September or July-August in warmer districts where soils dry out earlier.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is practised in the establishment of eucalypts in Australia and elsewhere. This is particularly important on ex-forest sites but there is often no response on ex-pasture sites (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting, e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). In fact, where moisture availability is limiting it has been suggested that application of fertiliser can contribute to drought deaths in blue gum by increasing the water use of trees (Hafner, 2000). Hafner (2000) recommends that fertiliser should be applied only on infertile, well watered sites, where growth rates are suboptimal. For Western Australia this would mean sites with >800 mm MAR. Fertiliser application rates vary widely depending on the site and tree age, and readers should access further information from more detailed references such as Attiwill and Adams (1996), Nambiar and Brown (1997) and Dell et al. (2001). Deficiencies in numerous other nutrients and trace elements may cause a variety of disorders in this species and visual symptoms should be verified by chemical analysis of affected plant tissue (Dell et al., 2001).

Management

Thinning is not usually undertaken when the species is grown for pulp, but the final stocking may be reduced to as low as 100 stems ha⁻¹ when it is grown for sawlogs; possible thinning regimes are discussed in Bird (2000). A rotation age of 9-12 years is common in southern Australia for pulp plantations of *E. globulus* (ForestrySA website, 2002).

For sawlog production CALM Western Australia is recommending an initial spacing of 1000 trees ha⁻¹, reduced to 125-150 trees ha⁻¹ by age six years with a final rotation age of 20-25 years (Hingston, 2002). To produce clearwood, regular pruning is essential; refer to Bird (2000) for pruning techniques and Hingston (2000, 2002) for pruning regimes.

*Eucalyptus globulus* is a strongly coppicing species and pulp plantations overseas are often cut on a coppice rotation of 8-10 years, with 2-3 rotations before replanting (Jacobs, 1981). Underdown and Bush (2002) conclude that coppice appears to be a suitable management tool for blue gum plantations in southern Australia, especially on sites where the
first crop performed particularly well. However, they point out that the labour cost of thinning the coppice back to one stem, and the fire hazard this thinned material presents, are important considerations. Where the first crop performed poorly due to poor establishment and/or poor genetics, they state that replanting is likely to be a better option.

Growth

Eucalyptus globulus is considered a fast-growing species and height growth of 2-3 m yr\(^{-1}\) is commonly achieved on favourable sites. On favourable sites mean annual increments are between 20-35 m\(^3\) ha\(^{-1}\), but the yield achievable over large areas is generally 12-20 m\(^3\) ha\(^{-1}\). Mean annual increments for 10-12 year pulp plantings of E. globulus in Western Australia range from 5 to 35 m\(^3\) ha\(^{-1}\) (White et al., 1999) and in South Australia range from 5 to 32 m\(^3\) ha\(^{-1}\) (ForestrySA website, 2002). With the continuing use of improved genetic material, site selection and silvicultural practices, overall yields should improve. On low-rainfall sites down to 600 mm, growth rates of around 10-12 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) are likely [M Underdown, ForestrySA, pers. comm., 2002].

Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and by regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In Australia, juvenile foliage is very susceptible to attack by autumn gum moth (Mnesampela privata), Christmas beetle (Anoplognathus spp.), leaf blister sawfly (Phylacteophaga eucalypti), leaf beetle (Chrysomelid beetles - various genera), various scale insects including Eriococcus coriaceus and the blue gum psyllid (Ctenarytaina eucalypti) (Marcar et al., 1995). General practice in the management of insect infestations in blue gum plantations is to monitor insect levels and set thresholds beyond which spraying is considered if trees are small enough. This step is not taken lightly as spraying can also remove insect predators.

Eucalyptus globulus is also attacked by a number of diseases. Seedlings are highly susceptible to Botrytis cinerea (and other damping off type diseases) in the nursery, but this can usually be controlled with suitable spray regimes and phytosanitary practices. In some fast-growing plantations, juvenile foliage has been severely damaged by the leaf fungus Mycosphaerella spp. (Marcar et al., 1995). Significant provenance variation has been reported in the level of susceptibility, although all provenances were affected to some degree (Carnegie et al., 1994).

Young trees are easily damaged by fire but are rarely killed. Larger trees will survive severe fires and shoot from epicormic buds, but a succession of severe fires may be fatal (Kirkpatrick, 1975). However, the timber of any trees damaged by fire will be unsuitable for pulp or sawlogs. Seedlings and trees with juvenile foliage are often killed by moderate frosts, but adult trees may withstand occasional lower temperatures down to around -8°C. Mature trees can withstand high winds, but young fast-growing trees and coppice regrowth can be badly damaged or uprooted (Weiss, 1997).
Utilisation

Wood

The heartwood of *E. globulus* is light yellowish brown, open-textured, has distinct growth rings and is moderately durable. The sapwood is paler than the heartwood, but is often difficult to distinguish. Mature trees from natural stands have an air-dry density of about 900 kg m$^{-3}$ while young plantation-grown timber has an air-dry density of around 650 kg m$^{-3}$. The timber is hard and tough. It is used for light and heavy construction (Boland et al., 1984). It is a moderately good firewood with an oven-dry calorific value of 1 900 kilojoules kg$^{-1}$, burns freely and leaves little ash. It carbonises easily for good charcoal production and is still used for this purpose in many countries (Jacobs, 1981).

Most plantings of *E. globulus* in Australia to date have been for the production of paper pulp. Mature timber produces poor pulp, but as young plantation-grown wood is less dense it is suitable for paper and rayon pulps. The wood properties relevant to paper making, including basic density, fibre length, fibre coarseness, cellulose content and hemicellulose content, appear to be highly heritable in *E. globulus* (Cotterill and Brolin, 1997) and hence could be improved through breeding programs. Higher pulp yields have also been linked with higher-rainfall sites, and pulp yields increase with age (Abed et al., 1999).

Sawn timber needs care when sawing and drying to minimise checking of the tangential surface. Quarter sawing is desirable and can be used on larger diameter logs (for example greater than 40 cm mid-diameter) (Bootle, 1983; Washusen, 2001). However, a technique developed by CSIRO (Washusen et al., 2000) for small-diameter logs from young, fast-grown trees was used successfully to cut 17-year-old blue gum in a study carried out by CALM Western Australia. The method involved back-sawing the log from the outside, parallel to the bark. The milling and drying techniques used are described in Brennan and Hingston (2001) and Washusen et al., (2000). Considerable collapse can occur, but this can be recovered by steam reconditioning (Agriculture Western Australia, 2002). This study also found that the wood was relatively easy to process although this is not the experience when working with wood from native stands. Blue gum wood has a high incidence of spiral grain and can be difficult to nail, often requiring pre-drilling. It bends well and can be worked to a smooth, very resilient surface. Most finishes adhere well. Extreme care is required when preparing surfaces for gluing. It turns well and also holds edges well. Its hardness and density make it particularly suited for flooring in high traffic areas, especially where a pale colour is required (University of Tasmania, 2000). Other important wood products include fibreboard, particle board, parquetry flooring, cooperage, low-grade veneer and furniture (Jacobs, 1981).

When grown to a large size for sawn timber, growth stresses markedly reduce the output of high quality boards (Eldridge et al., 1993). Washusen et al. (2000) recovered only 5.7% to select and better grades of timber from a 15-year-old, unpruned, *E. globulus* plantation in the Murray Darling Basin (580-750 mm MAR). However, the staff of CALM Western Australia are optimistic about the use of *E. globulus* for sawn timber. They have found that using a wide-spacing-regime (stands are thinned to 100-150 trees ha$^{-1}$ by 5-6 years of age), pruning early (3-4 years), drying timber slowly and using the right milling technique (as outlined above) gives good results. In a study at Busselton (822 mm MAR), CALM Western Australia recovered 30% of 17-year-old Tasmanian blue gum into appearance grade products using the cutting pattern developed by CSIRO (Brennan and Hingston, 2001).

*Eucalyptus globulus* subsp. globulus woodchips used for making pulp and paper.
Non-wood

While *E. globulus* is primarily grown for wood products, it is also utilised for a variety of non-wood products. These are usually a by-product or additional use for trees grown for wood products. The leaves from felled trees may be distilled for their oil which is high in cineole (Doran and Saunders, 1993). Crude oil concentrations (w/w %, fresh leaf) extracted in bush stills fall in the range of 0.7%-1.3%. While these figures are not high compared to eucalypt species grown specifically for oil, *E. globulus* produces relatively large amounts of leaf biomass which helps increase oil production per unit land area and compensate for modest concentrations (Doran and Saunders, 1993). The oil is used for perfumery, flavouring pharmaceuticals and solvents (Weiss, 1997).

*Eucalyptus globulus* flowers produce pollen and nectar, and natural populations and plantations are used for the production of honey (Marcar et al., 1995).

*Eucalyptus globulus* has been planted for a variety of uses which include erosion control, amenity and roadside plantings, windbreaks and shelterbelts for pasture and livestock, and other watershed and environmental purposes (Jacobs, 1981). Extensive areas have been planted in Western Australia as part of salinity control measures (Marcar et al., 1995) and it has been used in the rehabilitation of mining sites in Western Australia and Tasmania (Langkamp, 1987).

It has also been used in plantations to reuse sewerage and chemical effluent, and has shown a degree of resistance to high levels of ozone which may be useful in regions with the potential for photochemical smog formation (Monk and Murray, 1995). A number of horticultural varieties showing dwarf characteristics (sometimes known as *E. globulus* var. *compacta*) (Chippendale, 1988) or fastigiate growth are utilised for ornamental plantings.

Limitations

Drought deaths in blue gum plantations have provoked questions as to the species suitability for lower-rainfall sites, 600-800 mm MAR. This problem has mainly occurred in Western Australia but may happen in other states if plantings move into lower-rainfall areas. A workshop to examine balancing productivity and drought risk in blue gum plantations was run in Western Australia in 1999 and is summarised in Hafner (2000). Several interacting factors have been identified as affecting available water as well as water usage. These include climate (rainfall and evaporation), soil factors (including fertility, salinity and depth) and stocking. Location in the landscape (slope position) and planting geometry (e.g. strips integrated with farming) will also influence water availability and become more important with decreasing rainfall and increasing evaporation. Also, the physiological strategies which enable the rapid growth of blue gums render them vulnerable to drought deaths during prolonged rain-free periods (White et al., 1999), i.e. *E. globulus* is slow to reduce its water use in response to water stress. One implication of this is that the addition of fertilisers, which increase growth and therefore water use, put trees at higher risk of mortality in times of limited water availability. Therefore options to manage water stress (to maximise growth with reasonable water use risk) include lowering stand densities (planting geometry, position in landscape, thinning), weed control and fertilisation. Hafner (2000) also notes that marginal sites which are dependent on stored soil water to supplement rainfall are susceptible to drought risk. First rotations on former pasture sites may use up the soil water store, resulting in second rotations requiring fallow (to recharge the soil profile) or management of water use (Hafner, 2000).

While *E. globulus* does not produce root suckers and does not naturally reproduce vegetatively, it still may have the potential to become a weed when seed escapes from plantations or amenity plantings. This has occurred in California, particularly around Los Angeles and San Francisco. The seed is not easily dispersed over large distances and the spread is likely to be relatively slow and hence should be easy to contain. Seed generally requires bare soil in order to germinate and the species is therefore not an aggressive coloniser.

There has been interest in developing *E. globulus* as a sawlog species on shortish (15-20 years) rotations. However, as outlined above in the ‘Utilisation’ section, there are a number of problems with sawing young, fastgrown wood of this species. The main problems seem to be the production of
tension wood and knots. The issue of knots can be addressed by pruning from an early age. Tension wood formation appears to be influenced by spacing and the wide spacing regimes being tried in Western Australia seem to be reducing its formation (Washusen, 2001; Hingston, 2001; Hingston, 2002). Where the conversion of a pulpwood regime to a sawlog regime is considered, smaller-diameter trees and poorer wood quality are inevitable (Hingston, 2002). Panelling, furniture and reconstituted products are possible products from these plantations.

Recommended Reading


References


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


10. *Eucalyptus grandis* W. Hill ex Maiden

*Flooded gum*


**Species overview**

_Eucalyptus grandis_ can grow rapidly under favourable conditions (to 2-3 m or more per year in height) and can tolerate short term flooding. It is reputedly one of the best native species available from Australia for establishment of fast growing timber plantations in subtropical and warm temperate climates overseas (Cromer et al., 1991). It is not suited to lowland areas in the humid tropics as it is susceptible to disease in these environments (Eldridge et al., 1993). It prefers moist, well drained, deep soils and will not tolerate poorly drained soils or long periods of waterlogging. _E. grandis_ requires >1000 mm rainfall for good growth, however, outstanding growth results have been achieved on drier sites with the application of supplementary irrigation (Myers et al., 1996; Arnold et al., 1996). E. _grandis_ is subject to frost damage, but appropriate hardening of seedlings increases the latitudinal and altitudinal range for plantations of this species (Eldridge et al., 1993). It can also tolerate low levels of soil salinity and acidity but will have a reduced growth response.

The timber is suitable for light construction, pulp for paper and rayon, poles and charcoal (Eldridge et al., 1993).

**Description and natural occurrence**

**Description**

_E. grandis_ belongs to _Eucalyptus_ subgenus _Symphyomyrtus_ (Pryor and Johnson, 1971) and is closely related to _E. saligna_ and _E. deanei_. There are no recorded natural hybrids of _E. grandis_ and _E. saligna_ from within their natural distributions.
The valves of *E. grandis* capsules are more incurved and broader than the thin, strongly erect or recurved valves of *E. saligna* capsules. The fruits of *E. grandis* are often glaucous, whereas those of *E. saligna* are not. *E. deanei* is separated from *E. grandis* and *E. saligna* by juvenile leaf characteristics (ovate to orbicular), while its fruits tend to be more pedicellate (Boland et al., 1984).

In its natural habitat, *E. grandis* is a medium-sized to very tall tree, 45-55 m (72 m) high with a short basal stocking of rough bark, then smooth, thin, fibrous or flaking, grey to grey-brown bark above. Branches are mostly smooth white or grey-white. Newly exposed bark may be bright pink. Form is generally excellent with a clear straight bole up to three quarters of the total height.

Juvenile leaves are stalked, opposite for several pairs then alternating, ovate, discolorous, green to dark green (dimensions 4-9.5 cm long x 2-4 cm wide).

Adult leaves are alternate, lanceolate to broad lanceolate, glossy dark green above, pale green below (dimensions 10-16 cm long x 2-3 cm wide).

The inflorescence is axillary, 7-11 flowered with flattened stalks 0.8-1.8 cm long. The buds are sessile or shortly stalked, pear shaped with a conical or slightly beaked operculum, 8 x 5 mm.

The flowers are white. Fruit are woody capsules, shortly stalked or sessile, conical to slightly pear shaped, often glaucous, to 8 x 5 mm. Often contracted towards the top; valves 4 or 5, exserted, broad and incurved. The seed is brown (Brooker and Kleinig, 1999).

Like other eucalypts flooded gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). The flowering period in its natural habitat is from April to August (i.e. late autumn through winter) (Brooker and Kleinig, 1994). Flowering occurs from as early as age 2-3 years (Burgess, 1983).

Pollination is effected primarily by insects. Seed capsules mature in around 5 months (Hodgson, 1976) and seed is commonly retained on the tree for periods of several months to several years after it matures (Boland et al., 1984). There will be regional and seasonal variability in seed availability.

**Natural occurrence**

*E. grandis* occurs naturally from Newcastle in New South Wales (32°52'S) along the coastal regions and subcoastal ranges until just east of Gympie (26°11'S) in south eastern Queensland. Further northwards (from approximately 18°S) it occurs in disjunct populations with the main ones being on the Eungella Tableland west of Mackay; near Ingham; on the Atherton Tableland; and, at the northern extreme of its range, on the Windsor Tableland west of Daintree (approximately 16°S); and at Carnarvon (approximately 25°S) about 450 km inland (Brooker and Kleinig, 1994; Eldridge et al., 1993) (Figure 10.1).

**Figure 10.1:** Natural distribution of *Eucalyptus grandis* (Jovanovic and Booth, 2002)
In northern New South Wales and southern Queensland, natural stands of *E. grandis* do not extend further than 100 km inland at an altitudinal range from sea level to around 600 m. In north Queensland its altitudinal range is from 400-1250 m. The species is often found growing as pure stands of tall open forest with an understorey of rainforest species. Where stands are not pure, associated eucalypt species can include *E. dunnii*, *E. microcorys*, *E. pellita*, *E. pilularis*, *E. resinifera*, *E. robusta*, *E. saligna* or *E. tereticornis*.

*E. saligna* and *E. grandis* overlap in northern New South Wales and southern Queensland with *E. saligna* generally found on drier sites up slope from *E. grandis* in the valleys.

Natural stands of *E. grandis* prefer the flats or lower slopes of fertile valleys, with moist, well drained, deep loamy soils of alluvial or volcanic origin (Boland et al., 1984).

**Where will it grow?**

A climatic profile (Jovanovic and Booth, 2002) for *E. grandis*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Mean annual rainfall:</th>
<th>725-3730 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall regime:</td>
<td>uniform, summer</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-6 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month:</td>
<td>22-34°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month:</td>
<td>0-16°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>12-25°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *E. grandis* (Figure 10.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Jovanovic and Booth (2002) state that although the species may be considered in areas with rainfalls as low as 725 mm, over 1000 mm is desirable for good growth. They also note that though their map in Figure 10.2 suggests a rather wider climatically suitable area, in practice in Queensland climatically suitable areas correspond very closely to the areas of natural distribution (Figure 10.1). However, supplementary irrigation can enable *E. grandis* to be planted on drier sites with outstanding growth results (Myers et al., 1996; Arnold et al., 1996). The revised climatic description and map are based on information from rainfed locations only.

Figure 10.2: Areas predicted to be climatically suitable for *Eucalyptus grandis* are shown in black (Jovanovic and Booth, 2002)
Consideration of other factors such as soil requirements and *E. grandis*’ susceptibility to insect pests (particularly on very high rainfall sites or when it becomes stressed due to drought) also need to be considered when deciding whether to plant this species. *E. grandis* grows best on deep, moisture holding soils of moderate to high fertility. It can not occupy upper slopes and ridge-top sites with poor skeletal soils unless rainfall is adequate (Streets, 1962). It is also intolerant of excessively moist or poorly drained soils or extended periods of soil waterlogging (Turnbull and Pryor, 1984). *E. grandis* is moderately tolerant of low soil salinity but with less vigorous growth. In coastal areas it is susceptible to scorching by salt laden air (Poynton, 1979). It is also moderately tolerant of soil acidities down to pH 5.5 though best growth is obtained with a soil pH closer to 7 (Marcar and Khanna, 1997).

**Plantings and provenance trials**

**Plantings**

Flooded gum is a species of major importance for plantations with over 1 million hectares in Brazil and about 300,000 ha in South Africa. There are also significant areas in several other countries e.g. Argentina, Australia and India (Eldridge et al., 1993).

**Provenance trials**

Results of trials around the world suggest that some of the most productive *E. grandis* provenances are from the northern part of New South Wales centred around Coffs Harbour (Burgess, 1988). However, significant differences in performance have often been noted between seedlots sourced from within one small geographic area (Matheson and Mullin, 1987; Eldridge et al., 1993; Arnold et al., 1996).

In humid environments at the higher end of its rainfall and temperature range, *E. grandis* becomes increasingly susceptible to disease. The Copperlodge provenance, the lowest altitude tropical provenance of *E. grandis* from west of Cairns, has been found to have the best disease resistance and therefore be the provenance most likely to succeed in environments at this end of the species planting range (Chris Harwood, CSIRO Forestry and Forest Products, pers. comm., 2002).

In a QFRI project to identify the best-bet species for operational plantings, over 70 species, provenances and hybrid combinations were evaluated on a range of sites, soil types and climates from northern New South Wales to Central Queensland. Early results indicate that *E. grandis*, and in particular seedlots from improved sources (e.g. Wedding Bells Seed Orchard, SFNew South Wales), is the species with the most immediate potential for producing high plantation yields suited to pulpwood production, on the greatest range of soil and site types in areas of Queensland south of Gin Gin (latitude 24.5°S). However, susceptibility to attack by the giant wood moth (*Endoxyla* spp.) and subsequent predation by the Yellow-tailed black cockatoo is a cause for concern in some areas (QFRI website, 2002; JVAP website, 2002).

**Breeding and genetic resources**

Because of the lack of geographic pattern of provenance variation in *E. grandis*, a useful strategy for improvement programmes has been to exploit variation within provenances (Burgess, 1988; Matheson and Mullin, 1987). Rapid gains in growth and adaptability have been achieved by planting a wide range of provenances and selecting the best individual trees for breeding programmes regardless of their provenance.

The hybrid of *E. grandis* × *E. urophylla* from Brazil has produced spectacular genetic gains, selected clones of which have proved more productive, with higher disease resistance, whilst producing higher density wood than pure *E. grandis* (Campinhos and Ikemori, 1989). Other combinations which have provided outstanding individuals in Brazil include *E. grandis* × *E. pellita*, *E. grandis* × *E. saligna* and *E. grandis* × *E. dunnii*. Early results of trials including hybrids of *E. grandis* × *E. camaldulensis* and *E. grandis* × *E. urophylla* have displayed good early growth (two years) at Miriam Vale, Central Queensland (QFRI website, Regional profile series ‘Region 4’, 2002). However, the former is moderately susceptible to attack by the giant wood moth and the latter demonstrated high variability in survival and susceptibility to insect attack and disease. The following hybrids are available from nurseries such as Yuruga, Walkamin, in northern Queensland, *E. grandis* × *E. camaldulensis*; *E. urophylla*.
x E. grandis, E. grandis x E. urophylla, E. grandis elite clones and the Yates ‘Saltgrow’ E. grandis x camaldulensis salt tolerant hybrids (PFNQ website, 2002).

The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra provides both single-tree and bulk provenance collections of seed of E. grandis for breeding programmes. It also has a small amount of improved seed of E. grandis available.

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

E. grandis is most commonly propagated from seed. The number of viable seeds is 670 000 kg⁻¹ (Gunn, 2001). The normal level of purity of the extracted and sieved seed of this species is only 10%. The seeds are orthodox and can be stored for several years in cool dry conditions provided their moisture content is kept below 8%. The recommended temperature for germination of E. grandis is 25°C (Boland et al., 1980).

E. grandis can also be reproduced vegetatively with relative ease, using grafting, rooted cuttings and micropropagation. Success with some techniques, including at least rooted cuttings, requires material in a relatively juvenile state of development. Most programs routinely apply a rooting hormone such as indole-3-butyric acid (IBA) to the base of each cutting prior to their insertion into the rooting medium to improve strike rates and rooting vigour.

Short rotation E. grandis crops are often managed under a system of coppice renewal (Turnbull and Pryor, 1984). The species coppices vigorously when young but after age 10-12 years, coppicing can become less reliable. The value of using a coppice system needs to be considered in light of the cost of protecting the stumps at harvesting and thinning the coppice, and the possible loss of productivity gains that might be achieved with the use of improved seed or provenances for a subsequent rotation.

In Australia, good results have been achieved with precision sowing of individual imbibed seeds into plug sized cells. The plug seedlings are later transplanted into the final propagation container. This system overcomes a need for thinning of seedlings in the container and also avoids problems of vacant cells. A cell size (container or individual pot) of 90 ml produces ideal nursery stock 150-200 mm high (G. Cahill, Narromine Transplants, Narromine, New South Wales, pers. comm., 1998). Cells which encourage development of vertical roots and which allow air pruning, encourage development of superior root systems (Nicholas et al., 1989).

E. grandis nursery plants can be frost sensitive when young and may need some protection, however they can withstand frost (absolute minimum temperature of -8°C) if appropriately hardened (Cremer et al., 1984).

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for E. grandis. Detailed information on various establishment practices is available from several sources including: government organisations (Sustainability and Environment, Victoria; Private Forests Tasmania), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull

Eucalyptus grandis 4-year-old shelterbelt at Coleambally, NSW.
(1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoodsqld/), or these documents can be obtained by contacting the organisations directly.

E. grandis responds well to deep ripping on compacted sites, complete soil cultivation rather than spot cultivation, chemical weed control and early fertiliser application [Nicholas et al., 1989]. Generally the response to N and P together tends to exceed the response to either alone [Cromer et al., 1998]. Most prescriptions for the use of fertilisers in plantations have been developed for ex-forest sites. When planting on ex-pasture sites with a history of fertiliser use their use may not be warranted (Bird, 2000). Refer to Attiwill and Adams (1996), Dell et al., (1995) and Nambiar and Brown (1997).

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used a spacing of 3.5 m between rows is required [Weiss, 1997]. A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha⁻¹) and 4 m x 2.5 m (1000 trees ha⁻¹). These spacings encourage rapid canopy closure, reduce weed problems, promote good form and allow ample selection for a final stocking of 200-300 trees ha⁻¹ (Bird, 2000; QFRI website, 2002).

Planting out is timed to coincide with rainfall and in southern latitudes is predominantly determined by the severity of frost and minimum temperatures experienced. Planting is carried out in June/July in South Australia while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred so that young seedlings will be exposed to a shorter period of high temperatures.

Management

Progressive thinning and pruning is required for clearwood production; texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques in a farm forestry context. Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter of individual stems. When grown for sawlogs the stand may be reduced to a final stocking of 300-100 stems ha⁻¹.

E. grandis stands managed on medium to long rotations (20 years plus) for production of solid timber are usually thinned from an early age, as early as 3 years or less, but those for short rotation
crops, such as pulpwood or small posts, are normally not thinned or pruned (Poynton, 1979).

**Growth**

Plantation grown *E. grandis* is notable for its good growth rates from an early age. Productivities reported from Australian plantations vary from less than 15 m$^3$ ha$^{-1}$ yr$^{-1}$ up to more than 34 m$^3$ ha$^{-1}$ yr$^{-1}$ (Carter, 1974; Cromer et al., 1991). Its mean annual increment (MAI) tends to peak between ages 10-17 years and the better the site the earlier it tends to peak (Binkley et al., 1997).

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and by regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996).

Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In the nursery, *E. grandis* is susceptible to various fungi causing damping off and collar rot including *Phytophthora* and *Pythium* spp. (Turnbull and Pryor, 1984). In *E. grandis* trials on a tropical lowland site near Ingham in Queensland, young trees were severely affected by the foliar fungus *Cylindrocladium quinquesepatum* (Cromer et al., 1991) causing outbreaks of leaf spot and shoot blights.

In Australia it is frequently attacked by a range of defoliating insects and significant damage can occur, especially in the early stages of plantation establishment before canopy closure and on grassland sites (Turnbull and Pryor, 1984). The predominant insect pests include leaf beetles, Christmas beetles, leaf blister sawfly, psyllids and lerp. Autumn gum moths have on occasions caused massive defoliation in some plantations even though *E. grandis* is only considered a secondary host for the species. Longicorn borers (*Phoacantha* spp.) and giant wood moth (*Endoxyla cinerea*) are major insect pests of *E. grandis*, at least in southern Queensland and northern New South Wales and are, arguably, the major limitation for growing the species commercially for anything other than chip wood.

*E. grandis* can not tolerate severe drought (Darrow, 1994).

**Utilisation**

**Wood**

Sapwood of *E. grandis* is a very pale pink, and is generally resistant to attack by *Lycus* borers (Boland et al., 1984). The heartwood varies from almost white to pink, or dark red-brown with a pink tinge (Keating and Bolza, 1982) and is moderately strong (Boland et al., 1984). The air dry density of the wood is 600-750 kg m$^{-3}$ (Warcar et al., 1995) and the timber has moderate strength and durability, straight grain but can have a coarse texture (Turnbull and Pryor, 1984).

Plantations of *E. grandis* are also grown in many countries for fuelwood, cellulose, sawn timber, posts, poles and veneers. Applications for *E. grandis*
sawn timber range from packing cases and house construction to flooring and furniture (Turnbull and Pryor, 1984). However growth stress and its effects can, in some cases, cause serious degrade of logs and sawn timber. Highly stressed trees can develop radial cracks and end splitting during and/or soon after felling.

Non-wood

On distillation, leaves of *E. grandis* can produce low yields of essential oils that contain a range of components including 1,8-cineole, alphapinene, beta-phellandrene, rho-cymene and beta-terpineol (Shieh, 1995). However, the species is not suitable for commercial production of oils due to its relatively low yield of this product.

Limitations

Perceptions that *E. grandis* is a high water using species have seen it discredited in some planting situations. Where lowering water tables or using effluent water are the objective this would be an advantage. However, research by Myers *et al.* (1996), who studied water balance in young irrigated plantations of *E. grandis* and *Pinus radiata* near Wagga Wagga, New South Wales, have shown that *E. grandis* is not necessarily a more profligate consumer of water than other rapidly growing forest tree species. They found water use by the two species to be similar for the same stage of canopy development.

Its high susceptibility to disease in lowland humid environments in the tropics will limit any expansion of plantings into these areas.

**Recommended reading**


**References**


Campinhos E, Ikemori YK, 1989. Selection and management of the basic population Eucalyptus grandis and *Eucalyptus urophylla* established at Aracruz for the

Boxes made from *Eucalyptus grandis* in Malawi.


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


JVAP website, 2002.


11. *Eucalyptus nitens* (Deane and Maiden) Maide

**Shining gum, silver top**

Adapted from Doran, 2000.

**Key features**

- Tall forest tree, generally of good form with moderately fast growth
- Grows on a wide range of moderately fertile soils, especially with clay subsoil
- Can be grown at higher altitudes and tolerates numerous and severe winter frosts and snow (absolute minimum temperature -12°C)
- For best growth performance requires greater than 1000 mm MAR
- Is intolerant of prolonged drought
- Seed slow to mature with production often small and irregular
- Moderately susceptible to disease and insect attack
- Cream coloured sapwood is susceptible to borer attack
- Timber is light coloured, has few kino veins, and is used for general construction work, flooring, joinery, panelling, furniture veneer, plywood, firewood, mining timber and pulp for paper
- Non-durable in the ground.

**Species overview**

A tall forest tree of moderately fast growth rate and good form, *Eucalyptus nitens* is an important plantation eucalypt for cool mountain areas where the annual rainfall is around 1000 mm or more. *E. nitens* is one of the frost hardiest of the commercial eucalypts and is relatively free of pests and diseases on appropriate sites. *E. nitens* is intolerant of sustained drought, low rainfall sites and is very susceptible to fungal and insect attack when stressed (White et al., 1994; Knight and Nicholas, 1996). Wood from fast-growing plantations is suitable for sawing with the application of suitable techniques. *E. nitens* is generally regarded as a highly satisfactory pulping species. Enthusiasm for planting *E. nitens* is tempered by shortage of seed, some concern about persistent branches, and susceptibility to defoliation by insects (Doran, 2000).
Description and natural occurrence

Description

_E. nitens_ is a tall to very tall forest tree 40-70 m, with a DBH 1-2 m or more on good quality sites. On poorer sites it may be smaller with height of 15 to 20 m and up to 0.5 m DBH. It has good form with a clean straight bole for one-half to two-thirds of tree height (Turnbull and Pryor, 1984). Mature trees may carry a short (2-5 m) basal stocking of rough dark grey-black bark. The bark on the upper trunk above the base is either smooth or decorticating in long strips, to leave a smooth yellow, grey and white surface, often with black horizontal insect scars. Young trees have conspicuously green bark.

The stems on seedlings and juvenile branches are square in cross-section and bluish green, bluish grey or covered with a white wax on the surface (glaucous). Juvenile leaves are sessile, amplexicaul, opposite for any pairs, ovate to 17x8 cm, discolorous, greyish blue to glaucous. Adult leaves are lanceolate to narrow lanceolate, glossy green. Buds have a conical cap (operculum) and there are seven flowers in the flower-heads on angular, flattened stalks. The fruit cupular or barrel shaped, glossy, without stalks, often faintly ribbed, with 3-4 valves to the rim or slightly projecting. Seed is brown to brown-black, flattened, with a pitted surface (Brooker and Kleinig, 1999).

Like other eucalypts shining gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowering occurs between January and March and mature seed is available by about October. Seed production in the natural stands of _E. nitens_ is often low and irregular (Moncur et al., 1994; Brooker and Kleinig, 1999). There will be regional and seasonal variability in seed availability.

Natural occurrence

The distribution of _E. nitens_ in Australia is in a number of small, disjunct populations from 38°S in central and eastern Victoria to 30°S in northern New South Wales (Eldridge et al., 1993) (Figure 11.1). Three distinct geographic races have been identified: northern and central New South Wales, southern New South Wales, and Central Highlands of Victoria. In southern New South Wales, _E. nitens_ is usually grouped for convenience into the three geographic areas of provenance referred to as Tallaganda, Badja Mountain and Brown Mountain.

The range of altitude for the species in Victoria is 670-1280 m up to almost 1600 m in northern New South Wales where the species is found near Ebor and Barrington Tops. It will tolerate severe frosts (50-150 annually) as low as -12°C and snow cover which may last for days or weeks each year (Boland et al., 1984).

Common habitats are slopes and mountain tops with best development of the species occurring on undulating tablelands. _E. nitens_ prefers deep, moist loams, but it will grow satisfactorily on a wide range of moderately fertile soils, especially if there is clay in the subsoil (Turnbull and Pryor, 1984). The sites are usually well drained and their pH values fall within the range of 4.5-6.0. The parent material frequently includes granite and granodiorite but also basalt, rhyodacite and various rocks of sedimentary origin (Turnbull and Pryor, 1984).
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus nitens*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climatic Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>700-2300 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature, hottest month</td>
<td>19-29°C</td>
</tr>
<tr>
<td>Mean minimum temperature, coldest month</td>
<td>-3-4°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>5-17°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *E. nitens* (see Figure 11.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Commercial plantations are usually grown in areas which receive a mean annual rainfall of at least 1000 mm but on suitable sites (with good

Figure 11.1: Natural distribution of *Eucalyptus nitens* (Jovanovic and Booth, 2002)

Natural stand of *Eucalyptus nitens* on Errinundra Plateau, Victoria.

Figure 11.2: Areas predicted to be climatically suitable for *Eucalyptus nitens* are shown in black (Jovanovic and Booth, 2002)
moisture holding soils) it can be grown successfully down to 700 mm.

Other important considerations when selecting *E. nitens* is its intolerance of sustained drought, low rainfall sites and its high susceptibility to fungal and insect attack when stressed.

**Plantings and provenance trials**

**Plantings**

In Australia, *E. nitens* has proved very vigorous in northern Tasmania, outside of its natural range, where it is grown mainly for pulpwood. It is also cultivated in many other countries including Argentina, Brazil, China, Chile, New Zealand, northern Portugal and Spain, South Africa and Zimbabwe (Jacobs, 1981; Miller *et al.*, 1992; Jayawickrama *et al.*, 1993). It has also shown promise in mountain areas near the Caspian Sea in Iran and has been planted in trials in the USA (California, Hawaii) (Turnbull and Pryor, 1984).

**Provenance trials**

In range-wide *E. nitens* provenance trials in Victoria (Pederick, 1976, 1977, 1979, 1985) at age 12 years and in similar but younger trials in New South Wales (Johnson, 1996), and in Tasmania (Turnbull *et al.*, 1993), the three central Victorian provenances of ‘Toorongo’, ‘Rubicon’, and ‘Macalister’ were the most vigorous, followed by New South Wales south and north. The ‘Toorongo’ provenance has been the most consistent in growth rate, and has produced slightly better branching and straighter stems than the ‘Rubicon’ and ‘Macalister’ provenances in Victorian trials (Pederick, 1985).

In African trials, summer rainfall provenances (from northern New South Wales e.g. ‘Ebor’) performed better than southern provenances (i.e. Victorian provenances) when planted in summer rainfall regions (Eldridge *et al.*, 1993).

Within provenances, higher altitude seed sources generally received significantly less frost damage than did those from lower altitudes, and there were significant differences between individual families within provenances. The most frost tolerant provenance was northern New South Wales, with ‘Toorongo’ being the least tolerant (Raymond *et al.*, 1992).

Twelve year old plantation of *Eucalyptus nitens* in Tasmania.

**Breeding and genetics resources**

The genetic resources of *E. nitens* throughout its entire natural range remain substantial due to the cessation of logging in the natural *E. nitens* forests of central Victorian and northern New South Wales with much of the resource now included in national parks or equivalent reserves.

There has been considerable interest in southern Australia in the hybrid *E. nitens* × *E. globulus* to utilise the greater cold tolerance of *E. nitens* on sites marginal for *E. globulus*. Tibbits and Hodge (1995) concluded that there could be a slight economic advantage in using the hybrid if pure *E. globulus* was unsuitable for the land to be planted. Parents of two Australian provenances of *E. nitens* from central Victoria and eastern New South Wales were crossed with *E. grandis* of coastal New South Wales origin to create first-generation hybrids that should be adapted to warmer, low altitude sites (Aimers-Halliday *et al.*, 1999).

The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra can supply both single-tree and bulk-tree provenance collections of seed from natural stands of *E. nitens* suitable for trials and breeding programmes. Improved seed, from both seed orchard and seed production areas, is available from the Tasmanian Seed Centre in Hobart.
Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

*E. nitens* is usually propagated by seed. The small, black seed is orthodox and will remain viable in storage for several years if kept dry and under refrigeration (CSIRO Forestry and Forest Products Australian Tree Seed Centre records, 1998 unpublished). There are, on average, 270 000 viable seed kg⁻¹ of seed and red-brown chaff mix (Turnbull and Doran, 1987). To break dormancy and promote rapid, even germination after sowing, seed should be exposed to moisture at just above freezing point (1-5°C) for three weeks (stratification). The seed can then be germinated at 20°C for about two weeks under warm, moist conditions in the presence of light.

*E. nitens* planting stock is usually raised in containers in the nursery. General nursery practices are suitable for producing containerised seedlings of *E. nitens*. These are described in texts such as Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. *E. nitens* seedlings are generally raised in containers composed of a number of individual cells. A cell size of 90 ml produces ideal nursery stock 150-200 mm high (G. Cahill, Narromine Transplants, New South Wales, pers. comm., 1998). Larger containers give better results with planting programmes which require greater flexibility or where sturdy seedlings with good root systems are needed for planting in difficult conditions.

Experience in New Zealand has shown that cleft-grafting is a suitable technique for clonal propagation of *E. nitens* in breeding arboreta and clonal seed orchards. The technique is described by Miller et al. (1992). *Eucalyptus nitens* will strike roots from stem cuttings (e.g. Maile and Nieuwenhuis, 1996), however the technique has not been applied operationally yet. There are still many research and development issues to be fully explored, one of the major issues being the variable and mainly low root strike of many genotypes. Micropropagation of *E. nitens* using tissue culture techniques has also been carried out successfully (e.g. Furze and Cresswell, 1985; Bandyopadhyay et al., 1999) but again the technique needs further research before it can be applied commercially.

Eucalyptus nitens will coppice but not as readily as some of its close relatives like *E. globulus*. Coppicing is not used commercially for plantation renewal in this species because of generally poor results achieved (Poynton, 1979; Miller et al., 1992). *E. nitens* seedlings can be coppiced if stock plants are starved of nutrients, 2-stage topping is applied and the period of coppicing extended from June to February (Aimers-Halliday et al., 1999).

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. nitens*. Detailed information on various establishment practices is available from several sources including: government organisations (Sustainability and Environment, Victoria; Private Forests Tasmania), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these documents can be obtained by contacting the organisations directly.

Soil should be ripped to at least 45 cm and down to 1 m if possible. Mounding may be necessary on sites with poor drainage.

Control of weed competition in the first few years after establishment is often critical to the survival and growth of eucalypts and *E. nitens* is no exception. Miller et al. (1992) recommends that glyphosate be applied before site preparation to kill root systems of some of the perennial weeds. After site preparation and at least one month before planting, apply a pre-emergent herbicide such as a triazine. A post planting application of herbicide is usually
necessary. The same chemicals may be used but care needs to be taken not to spray the eucalypt foliage when using glyphosate otherwise mortality will result. Similarly, contact between plant roots and simazine, as might take place on gravelly soils, should be avoided.

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia and Western Australia planting is carried out in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, (or July-August in warmer districts where soils dry out earlier).

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used a spacing of 3-5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha⁻¹) and 4 m x 2.5 m (1000 trees ha⁻¹). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha⁻¹ (Bird 2000).

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can only respond to a fertiliser application if other factors are not limiting eg. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site and readers should access further information from more detailed references such as Dell et al., (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

**Management**

Gerrand et al. (1997) provide a provisional management regime for thinning and pruning E. nitens plantations in Tasmania for sawlog production on a 30-40 year rotation. From an initial stocking of 1000 stems ha⁻¹, an early, light, non-commercial thinning is recommended at age 3 or 4 years, and a commercial thinning at age 10-12 years to final stocking of 250 stems ha⁻¹ to improve financial viability. Pruning is carried out to either 2.7 m or 6.4 m in three lifts commencing when the trees are 7 m tall at 3 years-of-age (after the non-commercial thinning) and final pruning by age 5-6 years.

**Growth**

Mean annual volume production in intensively-managed E. nitens pulp plantations falls typically in the range of 10-30 m³ ha⁻¹ yr⁻¹ (Webb et al., 1984; Turnbull et al., 1988; Miller et al., 1992; Gerrand et al., 1997). On a high rainfall site (1210 mm MAR) in East Gippsland Duncan et al. (2000) report a mean annual increment of 48.9 m³ ha⁻¹ yr⁻¹ for E. nitens at 12 years of age. Growth and yield models for E. nitens in Tasmania and New Zealand are provided by Candy (1997).
A financial analysis of *E. nitens* plantation sawlog production in Tasmania indicated that good financial returns were possible on moderately high to very high quality sites from intensive pruning and thinning schedules (Candy and Gerrand, 1997).

## Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

The juvenile foliage of *E. nitens* is susceptible to defoliation by the larvae of the autumn gum moth (*Mnesampela privata*) in plantations in southern Australia. The blue gum psyllid, *Ctenarytaina eucalypti*, may cause severe damage to the juvenile foliage of *E. nitens* causing deformed and stunted foliage and shoot tips (Farrow, 1996). In Tasmania, damage by coreid shoot-wilt bugs reduced growth, but not enough to inhibit planting for pulpwood (Elliott and de Little, 1984). Chemical treatment has been effective in controlling population numbers (Barton and Davies, 1993; de Little, 1989). Chrysomelid leaf beetles are also noted as a serious pests in Tasmanian *Eucalyptus* plantations (Anon, 1999). The ambrosia beetle, *Platypus subgranosus* degrades the wood of *E. nitens* (Neumann and Marks, 1976).

Crous et al. (1989) provide a listing of eucalypt leaf fungi, (largely *Mycosphaerella* and *Cryptosporiopsis*) which cause leaf spots and defoliation of *E. nitens* which may significantly affect growth performance. Breeding for disease resistance is seen as the only practical method for control in most cases. The disease *Endothia gyrosa* is common in south-eastern Australia and has caused numerous stem cankers and associated stem decay on otherwise healthy and vigorous trees in Tasmania (Yuan and Mohammed, 1997, 1998).

## Utilisation

### Wood

The wood is light coloured, and has few kino veins. McKimm et al. (1988) found that knots were the most common cause for downgrading its timber for structural purposes and the knots would tend to make it only marginally acceptable for appearance grade products. However, it is often marketed with the ash group as a general construction timber. The cream coloured sapwood is not easy to distinguish from the heartwood. Heartwood is straw-coloured or pale pink, straight-grained, tough but easy to work, not durable for external use. The wood of *E. nitens* is often of a slightly lower density than that of plantation grown *E. globulus*. Its air dry density is about 700-720 kg m⁻³ (Bootle, 1983; Boland et al., 1984). Drying needs much care because of its susceptibility to collapse, surface checking, end splitting and interlocked grain which is quite common. Bootle (1983), McKimm (1988), Wade (1991), Haslett and Young (1992) and Miller et al. (1992) provide more information.

The sapwood is susceptible to *Lyctus* borer attack. The holes of borers and associated black stains are often present, giving the attractive timber a very speckled appearance. However, the staining has to be severe before it has an effect on strength. *E. nitens* is non-durable (<5 years) in the ground. The sapwood may be treated with wood preservatives (McKimm et al., 1985).

*E. nitens* is generally regarded as a highly satisfactory pulping species (Orme et al., 1993; Williams, 1994; Wyk and Gerischer, 1994).

Uses include flooring, joinery, panelling, furniture veneer, plywood, firewood, mining timber and pulp for paper (Boland et al., 1984).
Non-wood

Although honey from *E. nitens* is amber coloured, and of medium flavour and density it is not a good honey producing species due to unreliable flowering (Goodman, 1973). Oil concentration in the leaves is too low to be of any commercial interest.

Limitations

Intolerant of drought, often has low seed production, wood experiences drying problems, non durable in ground.

Recommended reading


References


Swamp yate

Adapted from Harwood, 2000.

Key features

Small to medium-sized-tree of potentially reasonable form

Moderate growth rate

Tolerates a wide range of soils including clays, sands and calcareous soils

Most provenances are tolerant of highly saline conditions

Tolerates seasonal waterlogging

More tolerant of the combination of waterlogging and salinity than most other eucalypt species

Tolerates prolonged drought and heat

Suited to arid, semi-arid and sub-humid climates with a winter or uniform rainfall maximum

It is not suited to tropical and subtropical climates with a summer rainfall maximum and/or mean annual temperature of greater than around 22°C

Irrigation reduces tolerance to extreme heat and cold

Better provenances in Australian trials are ‘Ravensthorpe’ and ‘Grass Patch’ but further testing is required as Israeli trial results are contradictory

To date plantings have mostly been for firewood, shade, windbreaks and catchment afforestation rather than for industrial wood production

While Eucalyptus occidentalis is suitable for chemical pulping it has relatively poor pulp strength

Niche is probably the 350-750 mm yr⁻¹ rainfall zone on heavy, seasonally wet and/or saline soils that do not favour species that would potentially be more productive.

Species overview

*Eucalyptus occidentalis* displays excellent survival and moderate growth rates and has been extensively planted in many arid, semi-arid and sub-humid winter rainfall climates around the world where conditions are not suitable for the growth of other preferred species. Planting is mostly for firewood, shade, windbreaks and catchment afforestation.
Description and natural occurrence

Description

Eucalyptus occidentalis is a small to medium-sized tree, usually with a fairly dense, flat-topped canopy. There is considerable provenance variation in habit and stem form within the species. The trunk is usually short and forks at or below half the total height, resulting in a tree with several stout primary branches and a flat-topped crown (Boland et al., 1984). On the most favourable sites in its natural range E. occidentalis attains heights of 25-30 m and a DBH up to 80 cm. On poor or fire-prone sites, it may grow as a mallee no more than 5-10 m in height with several stems that arise from a basal lignotuber.

The bark is dark grey-brown to black, rough and hard, fibrous or flaky on the lower trunk, becoming loose and ribbony above. The bark of the upper trunk and branches is smooth white or pink (Chippendale, 1973; Brooker and Kleinig, 1990).

Natural occurrence

Eucalyptus occidentalis is endemic to the south-west of Western Australia where it occurs from Cape Arid (east of Esperance), towards the Boyup Brook area in the west, and north to Narrogin (Bird, 2000) and is mostly found within 150 km of the south coast (Figure 12.1). The latitudinal range extends from around 31°S to 35°S. Most natural stands are limited in extent, being restricted to wet, clayey depressions (Brooker and Kleinig, 1990), along streamsides and around the borders of freshwater and brackish lagoons, where the ground surface around the trees may be inundated for several months during winter and spring. It occurs in woodland plant formations, usually in pure stands, but sometimes associated with other eucalypts such as E. annulata, E. decipiens, E. falcata and E. loxophleba (Boland et al., 1984).
Eucalyptus occidentalis occurs naturally on a range of soil types, but most commonly on heavy-textured soils which are poorly drained, neutral to alkaline and may have a moderate to high level of salinity. There are some natural stands on better-drained gravelly, sandy loams (Boland et al., 1984).

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for E. occidentalis, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>350-910 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Uniform, winter</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-12 months</td>
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<td>Mean maximum temperature hottest month:</td>
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<td>Mean minimum temperature coldest month:</td>
<td>2-9°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>12.18°C</td>
</tr>
</tbody>
</table>

Particular care should be taken when planting the species in low rainfall environments to ensure that local conditions are suitable and appropriate planting densities are used.

The map of areas predicted to be climatically suitable for planting E. occidentalis (Figure 12.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. The species is tolerant of waterlogging and semi-saline soils and has reasonable growth and good survival in low rainfall environments, making it a good option in areas where these difficult conditions exist.

Figure 12.1: Natural distribution of E. occidentalis (Jovanovic and Booth, 2002)

Figure 12.2: Areas predicted to be climatically suitable for E. occidentalis are shown in black (Jovanovic and Booth, 2002)
Planting and provenance trials

Plantings

In Australia this species has performed well on saline irrigated and dryland sites in low rainfall areas of Western Australia, northern Victoria, New South Wales and South Australia and is widely planted, though not on a large scale, as a farm forestry species (Marcar et al., 1995; Harwood, 2001) and has been planted in the Barrett Reserve in the Wimmera, Victoria, from 1958-1978 (Bird, 2000).

The species has been successfully introduced into many countries with sub-humid and semi-arid winter rainfall climates. It is widely planted in southern Europe, North Africa and the Middle East and has also performed well in California, Mexico and Chile (Chippendale, 1973). Introduction to southern Africa commenced in the 19th century (Poynton, 1979), but the species has only performed well there in winter-rainfall and uniform-rainfall conditions. It has failed in tropical and sub-tropical environments with summer rainfall climates, for example in Chad (Jacobs, 1981) and Malawi and Zimbabwe (Poynton, 1979).

Provenance trials

Provenance trials have been conducted in several countries. The results from Israel are somewhat in contrast to those in Australia and Italy, in that the poorest provenance in Israel (64 km north of Esperance) is within 20 km of one of the best-performing provenances in the other trials, namely ‘Grass Patch’. More trials are required to determine the patterns of provenance variation in the species and the extent of provenance-by-environment interaction (Harwood, 2001).

Ten natural provenances were tested in small-scale provenance trials at five sites in South Australia, with mean annual rainfall in the range 360-500 mm. The trials were assessed at age 3-5 years. Analysis of the results (Bulman et al., 1999 unpublished) established that the ‘Grass Patch’ (33°14’S, 121°43’E) and ‘Ravensthorpe’ (33°35’S, 120°02’E) provenances were consistently good performers in terms of height and diameter growth, and also had the highest proportion of single-stemmed trees. Three provenances (‘Rocky Gully’, ‘Thomas River’ and ‘Esperance’) were consistently slower-growing than the other seven. There was little evidence of provenance-by-site interaction in these trials.

Unpublished 2-year and 4-year results of four provenance trials in Italy (two in Calabria and two in Sicily) indicate that ‘Grass Patch’, ‘Ravensthorpe’, ‘Broomehill’ and ‘Bremer Bay’ were the fastest growing provenances of those tested, while the ‘Peak Charles’ provenance (32°55’S, 121°01’E) performed very poorly (Harwood, 2001).

In Israel five provenances were tested in a provenance trial on loess soil at Snaim in the northern Negev Desert. The best provenance, from a location 5 km east of ‘Cape le Grande’ (33°56’S, 122°18’E), achieved a mean height of 7.7 m in 6 years, during which annual rainfall averaged 244 mm (Zohar and Moreshet, 1987). The slowest-growing provenance, from 64 km north of ‘Esperance’ (33°03’S, 121°45’E), had a height of only 4.07 m. The ‘Cape le Grande’ provenance had some trees with straight trunks and produced fewer fruits than the other provenances. On saline sandy sites in the Gulf of Elat, Israel, the highest growth rate and resistance to salinity was displayed by a provenance collected north of Esperance (Zohar, 1982).

Breeding and genetic resources

Significant differences between provenances for growth and stem form and the generally consistent performance of some of the superior provenances suggest that there are good prospects to improve the growth and stem form of *E. occidentalis* through provenance selection and subsequent breeding. The species has recently been selected as a priority dry-zone species for further breeding by forestry agencies in southern Australia, which have established several seed production areas and seedling seed orchards during the 1990s (Harwood, 2001).

In a breeding strategy for *E. occidentalis*, Harwood (2001) describes the target planting areas in general terms as suitable site types in the 350-750 mm winter/uniform rainfall zone in southern Australia. He notes that temperature, site topography, local hydrology and soil type interact with rainfall to determine available moisture, so the rainfall range is only a general guide. The species is typically
planted in lower parts of the landscape on heavy soils, and will tolerate salinities of up to 10 dS m\(^{-1}\) \(E_{ce}\) without reduction in growth. Salinities over 15 dS m\(^{-1}\) \(E_{ce}\) can reduce survival of the species (Marcar et al., 1995).

Elite individuals and provenances have been identified in trials belonging to ALRTIG partners Primary Industry and Resources South Australia (PIRSA) and Conservation and Land Management Western Australia (CALM). Seed of better provenances is available through the CSIRO Forestry and Forest Products, Australian Tree Seed Centre and the Forest Products Commission of Western Australia’s Seed Centre.

At present, somewhat improved quality seed is available from PIRSA seed production areas through the CSIRO Forestry and Forest Products Australian Tree Seed Centre. One seed production area is producing seed suited for saline conditions, while another is producing seed suited for dry, non-saline conditions (ALRTIG website, 2002). Improved seed from seedling seed orchards established by CSIRO and CALM, Western Australia, should commence commercial seed production in around 2005 (Harwood, 2001).

In Morocco, promising results have been obtained from hybrids of \(E. gomphocephala\) x \(E. occidentalis\) (Jacobs, 1981).

### Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

### Propagation

The seeds are orthodox and can be stored for several years in dry conditions at room temperature of about 20\(^{\circ}\)C, provided moisture content is kept below 8%. A temperature of 20\(^{\circ}\)C is suitable for germination. There are about 200 000 viable seeds per kg (Boland et al., 1980).

Some success with rooting of stem cuttings of the species has been achieved in preliminary trials at CSIRO Forestry and Forest Products, with two provenances of \(E. occidentalis\) achieving respectively in two trials (i) 35% and 18% and (ii) 28% and 51% rooting. The trials tested a number of species and provenances alongside known easy-rooting species. The easy-rooting species had high rooting percentages (\(E. grandis\) 85% and \(E. camaldulensis\) 76%) which showed that techniques used were suitable for them. While the results for \(E. occidentalis\) are variable they indicate that the species has potential for clonal propagation. Further trials with adjustments to the techniques are planned, with a view to improving the rooting success of species such as \(E. occidentalis\) (Brammall and Harwood, 2000).

General nursery practices are suitable for producing containerised seedlings of \(E. occidentalis\). These are described in texts such as Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

### Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for \(E. occidentalis\). Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these documents can be obtained by contacting the organisations directly.

On seasonally waterlogged and saline sites, mounding with a disc plough is recommended to provide a better-drained environment for early growth. Mounds about 30 cm high prepared in the year before planting, were used in Western Australia (Hall et al., 1972).

Spacing between trees varies from site to site, but is typically quite wide, to give each individual tree access to reasonable soil moisture in the dry climates where the species is typically planted. A spacing of 2.5 x 4 m is suggested for southern Australia (David Bush, Australian Low Rainfall Tree Improvement Group, pers. comm., 2002).
Spacings from 3 m x 3 m on the most productive sites, up to 4 m x 5 m in drier conditions have been used in Italy (Jacobs, 1981), and a spacing of 4 m x 4 m is commonly used in Israel (Zohar, 1991).

In South Australia and Western Australia seeds are sown before Christmas for planting in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. Growth will be relatively slow in the nursery during the winter months, unless supplementary heating is used. In Victoria and New South Wales, seeds are sown in January-February and raised over an 8-month period, for spring planting in September, or July-August in warmer districts where soils dry out earlier.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. water availability (low rainfall or heavy weed competition are two factors that can affect this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996), Nambiar and Brown (1997).

Maintenance

Overseas, many plantings are managed on a clear-felling rotation of about 12 years, for production of firewood or sometimes pulpwood (Jacobs, 1981). Plantings which are primarily for windbreaks, shelter-belts or timber could be managed on a longer rotation of up to 30 years.

After harvesting, the plantation may be regenerated by coppicing. This method of regeneration has proved very successful in many countries but is rarely employed in Australia (Jacobs, 1981). The value of using a coppicing system needs to be considered in light of the cost of protecting the stumps at harvesting and thinning the coppice. The other consideration is the possible loss of gains in productivity that might be achieved from the use of improved seed or provenances for the next rotation.

Coppice regeneration in Israel has been noted to be most vigorous after felling in the winter months, during the rainy season (Zohar et al., 1978). Coppice growth and vigour has also been shown to increase with basal diameter (Avolio and Ciancio, 1975). Coppice regrowth should be cut back to the best one or two stems per tree, once it reaches a height of about 3 m. If planting stock is of good genetic quality, yielding a high proportion of single-stemmed, straight trees, it would be possible to thin the stand and manage it for pole, or possibly sawlog, production.

Growth

A 35-year-old plantation of E. occidentalis at Barrett Reserve in Victoria had a basal area estimated to vary from 10.6-16.4 m² ha⁻¹. This was on a clay loam site with a mean annual rainfall of 420 mm. However, while trees at this site exhibited quite good form, most stands in southeastern Australia have very poor form for timber production with
trees forked well below half-height and the trunks bent and frequently leaning. Therefore, unless using improved seed, there is a need to select better provenances and carry out form pruning and rigorous thinning to have a chance of producing sawlogs (Bird, 2000). However, this form is good for wind breaks and doesn’t matter for salinity control.

In the severe climatic conditions of Morocco *E. occidentalis* produces a mean annual increment of about 3 m$^3$ ha$^{-1}$ (Jacobs, 1981). Yield tables are available for plantations in Calabria, Italy (Jacobs, 1981). For plantings with around 1000 stems per hectare, yield (to top diameter of 5 cm, excluding the stump) of the first rotation at 12 years of age was 1.5-6.0 m$^3$ ha$^{-1}$ yr$^{-1}$, depending on site quality. On sites of the best quality at age 12 years with a stocking of 970 stems ha$^{-1}$, height averaged 12.4 m and DBH 13.5 cm. In these stands, annual increment continued to increase with age up to the end of the rotation.

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In general, *E. occidentalis* rarely has its growth significantly affected by insects or pathogens. The species is reportedly susceptible to damage by lerps (*Cardiaspina* spp.), gumleaf skeletoniser (*Uraba lugens*), sawflies (*Pergidae*) and termites in its natural range in Western Australia. Minor damage from leaf-eating beetles has been reported in New South Wales (Marcar et al., 1995). Prolonged outbreaks of lerps on *E. occidentalis* in its natural range were attributed to a newly described species of lerp, *Cardia serranum* (Taylor, 1992).

In the natural range, hot fires occurring under dry conditions with heavy fuel loads will kill the stems of adult trees, although the trees will usually recover by coppice regrowth.

**Utilisation**

**Wood**

The heartwood is pale, hard, somewhat straight-grained and durable in damp soils (Boland et al., 1984). It has been used for building poles, piling, posts and heavy construction. Air-dry density of wood from mature natural stands is 850-900 kg m$^{-3}$. Wood properties of 3, ten-year-old plantation-grown *E. occidentalis* trees from southern Italy, with mean DBH of 14.7 cm and utilisable height of 10.6 m, were studied by Ferrari (1991). Ten other eucalypt species were also examined in this study, which reported many wood properties. Bark comprised 10.8% of the stem volume of *E. occidentalis*, and basic density of the wood averaged 672 kg m$^{-3}$. Mean fibre length was 0.79 mm. All eleven species studied displayed a marked tendency to collapse, although *E. occidentalis* was superior to all of the other species in this regard. The small dimensions of *E. occidentalis* made it unsuitable for sawn timber and veneer production. In Morocco, *E. occidentalis*, together with *E. cladocalyx* and *E. sideroxylon*, were judged to have wood of adequate strength for telephone pole production and poles could be preservative-treated by the Bethell process, which involves pressure impregnation with fungicide (El-Abid, 1984).

Six-year-old trees from plantations in South Australia had mean basic densities of 542 kg m$^{-3}$ under high levels of effluent irrigation and 566 kg m$^{-3}$ at lower levels (Clark et al., 1999). They had better pulping properties than *E. camaldulensis* from the same plantations. Kraft pulp yields of *E. occidentalis* were 50.8% and 49.4% respectively under high and low levels of effluent irrigation, the corresponding yields for *E. camaldulensis* being 46.5% and
44.8%. Mean fibre length of *E. occidentalis* was 0.51-0.52 mm. It was considered to show some promise for pulpwood production, its only serious fault being low pulp tearing resistance due to short fibre length (Clark and Rawlins, 1999). The above results are from irrigated stands; unirrigated stands in low rainfall areas (<600 mm yr⁻¹) are likely to be slower growing and produce poorer quality pulpwood (Hicks and Clark, 2001). *Eucalyptus occidentalis* wood has been used for pulp production in a pulp mill in Calabria, southern Italy (Harwood, 2001), but is mainly used for firewood in that country. Charcoal production and production of crates from *E. occidentalis* wood is also recorded in Italy (Jacobs, 1981).

**Non-wood**

Plantations in Italy play an important role in soil conservation in hilly areas of Calabria and Sicily, while roadside and shelterbelt plantings are valuable for amenity and protective purposes (Jacobs, 1981). Catchments in Calabria, southern Italy, which had been afforested with *E. occidentalis* were found to have lower water outputs and erosion rates than those covered with natural herbaceous vegetation. Water output and erosion were greater in recently-coppiced stands of *E. occidentalis* that in mature stands of the species (Avolio et al., 1980).

*Eucalyptus occidentalis* is now being planted in southern Australia in situations where rising semi-saline water tables are threatening agricultural land. Its ability to grow and transpire water at a reasonable rate under quite strongly saline conditions makes it particularly valuable for this application. On a saline discharge site in southern New South Wales, young *E. occidentalis* trees displayed greater salt tolerance and used twice as much water per tree as did *E. camaldulensis* trees 1 year older, primarily because of their much greater leaf area (Benyon et al., 1999). It is also one of the species recommended for planting near salt seeps in south-western Western Australia to improve water usage and reduce water and salt accumulation in surface soils (Pepper and Craig, 1986; Biddiscombe et al., 1989).

Groves of *E. occidentalis* irrigated by run-off water are planted in the arid region of Israel for amenity purposes. Low earth dams are used to trap run-off water to increase soil moisture reserves in the plantation areas (Zohar et al., 1988). It has been identified as a species with an attractive appearance suitable for ornamental planting in winter rainfall areas of southern Africa (Poynton, 1979). As an ornamental it has been used for park and avenue planting (Chippendale, 1973).

No results of intercropping involving *E. occidentalis* are reported in the literature, although arid-zone systems involving intercropping of *E. occidentalis* and fodder species are under evaluation in Israel (Zohar et al., 1988).

The flowers have some value for honey production. The bark is reported to have high levels of tannin (Jacobs, 1981).

**Limitations**

Its moderate growth rate and modest adult size, coupled with its poor stem form, with most trees forking well below half tree height, appear to have restricted its large-scale planting and use for sawn timber and pulpwood. However, the use of better provenances and improved seed will overcome these difficulties for this type of use.

**Recommended Reading**


References


**Red mahogany**

Adapted from Harwood, 2000.

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**Key features**

- Medium to tall tree of moderate to good form (when better provenances are used)
- Fast growth rate
- Tolerates a wide range of soils including relatively low fertility
- Intolerant of waterlogging for prolonged periods
- Adapted to humid and subhumid tropical climates
- Good growth requires rainfall greater than 1000 mm, at the lower end this will need to be combined with deep moisture holding soils and/or temperatures at the lower end of its mean annual temperature range i.e. around 19-22°C
- Intolerant of all but the lightest frost (Papua New Guinea provenances don’t experience frost and therefore may not tolerate any frost)
- Tolerant of a dry season up to 6 months
- Screening of Papua New Guinea provenances showed that its kraft pulping and papermaking properties are quite acceptable
- Timber from natural stands is easily sawn and seasoned and is suitable for poles, sleepers, flooring, panelling and general construction
- Papua New Guinea provenances have displayed the best stem form in limited trials to date, followed by Helenvale and Kuranda, Queensland
- Cape York, Queensland, provenances have poorest stem form (low forking and crooked stem)
- Niche in Australia is northern Queensland on frost free sites with suitable soils and where mean annual rainfall exceeds 1000 mm.

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**Species overview**

*Eucalyptus pellita* is a fast-growing species adapted to humid tropical environments with a dry season not exceeding 6 months. It can tolerate soils of relatively low fertility and a wide range of soil textures from sandy loam to clay loam, provided soil is not waterlogged for prolonged periods (more than a few days at a time). Given suitable soil and climate, mean height of 15 m at age 4 years can be achieved by the best provenances of *E. pellita* (Dickinson and Sun, 1995; Vigneron, 1992). Stem form is moderate to good, with a proportion (from around 25% to 75%, variable with provenance) of trees exhibiting forking below 10 m or having a crooked main stem.

*Eucalyptus pellita* currently plays a significant role in afforestation in only a few countries (Brazil, Cuba, Indonesia and the Philippines) but it has been identified by staff of the Queensland Forest Research Institute as particularly suitable for plantations establishment on coastal sites in northern Queensland. Its fast growth, adaptability to a range of environments, good resistance to pests and diseases and suitability for a variety of wood products are desirable features. In addition to its use as a pure species, it has great potential in interspecific hybrid combinations with, for example, *E. urophylla*. 
Description and natural occurrence

Description

Johnson and Hill (1990) described a new species (*E. scias*) with three subspecies, based on *E. pellita* populations in coastal New South Wales, Australia. *E. pellita* as now defined is restricted to northeast Queensland and New Guinea and this is what is described here. It is possible that populations from New Guinea and the northern part of Cape York Peninsula in Queensland will be recognized as taxonomically distinct with further revision of the group (Johnson and Hill, 1990).

*Eucalyptus pellita* is a medium-sized to tall tree up to 40 m in height and 1 m in diameter. At its best, in natural stands it has a straight trunk to about one-half of the tree height and a heavily branched crown. On poor sites it is often only 15-20 m tall. In tall shrub communities on deep silica sand, north east of Coen in northern Queensland, *E. pellita* grows as a multi-stemmed small tree no more than 7 m high, with a broad, spreading crown.

Distinctive features of the tree are its fibrous, fissured, brown bark to the small branches, discolorous leaves, broad peduncles and strongly exserted valves on large fruit with broad rims. The species is described by Boland et al. (1984), Chippendale (1988) and Brooker and Kleinig (1994).

Juvenile leaves are petiolate, ovate, green and discolorous. Stems of seedling and juvenile leaves are conspicuously quadrangular in section, with distinct flanges. Adult leaves are lanceolate to broadly lanceolate, discolorous, glossy green above (dimensions are 10-15 cm long, 2-4 cm wide). The leaves are distinctly mucronate with a distinct ‘drip-tip’ that is absent in *E. scias*. Both juvenile and adult leaves are held more or less horizontally, with the shiny adaxial surface uppermost.

Umbels are usually 7-flowered, occasionally 3-flowered, rarely 9-flowered; peduncle broadly flattened, 10-25 mm long; pedicels thick, angular and rarely absent. Buds with obconical hypanthia, usually with ribs continuing from the angular pedicels. The operculum shape is very variable, generally beaked and about 1-1.5 times the length of the hypanthium length. Fruits have 4 exserted valves and are sessile or shortly pedicellate, hemispherical to obconical, slightly ribbed, with a level, prominent disc. The operculum scar or rim is prominent, concave in shape and broader than the disk. Mature seed is brown and is collected from August to May.

Like other eucalypts red mahogany does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). In Australia, *E. pellita* flowers in December-February in its natural range in north Queensland and seeds are mature by the following October-November (Harwood, 1998). In Australia, in environments with a short dry season, planted trees commence flowering within 18-24 months. Given suitable climates and soils, most trees

Collecting *Eucalyptus pellita* seed at Mission Beach, Queensland.
in a planted stand which are thinned to a wide spacing (200 stems ha⁻¹), flower and set seed within 4-5 years (Harwood, 1998). The main pollinating agents include bees, other insects, and perhaps birds, which are attracted to the nectar of the flowers. There will be regional and seasonal variability in seed availability.

Over 50% of the seeds from some natural provenances are produced by self-fertilization or matings between very close relatives, and are thus inbred (House and Bell 1996). The outcrossing rates of the Bupul-Muting, PNG, and Lankelly Creek, Queensland, provenances were considerably lower than published values for other eucalypt species (Harwood, 1998).

Natural occurrence

_Eucalyptus pellita_ has two main natural occurrences. In the southern New Guinea lowlands (below 100 m altitude) it extends from around Morehead and Keru at 8°30’S in Western Province, Papua New Guinea, across the international border and as far north as Muting in Irian Jaya, Indonesia (latitude 7°40’S). The northern and western boundaries of its Irian Jaya distribution are not well known (Harwood, 2000). In Queensland it extends from Iron Range, Cape York Peninsula, at latitude 12°44’S to Ingham at latitude 18°36’S, generally within 50 km of the coast and at altitudes up to approximately 600 m (Figure 13.1).

_Eucalyptus pellita_ occurs mainly in open forest formations. Associated eucalypts (and now Corymbias) in Queensland include _E. tereticornis_, _Corymbia tessellaris_, _C. intermedia_ and _C. torelliana_. On Cape York Peninsula it is an uncommon component of transitional forests and woodlands mainly on the western side of ranges. In coastal north Queensland in the vicinity of Tully, _E. pellita_ is a component of the upper stratum of sclerophyll and mixed sclerophyll-rainforest types.

In New Guinea it is associated with species such as _Eucalyptus brassiana_, _Acacia aulacocarpa_ sens. lat., _A. mangium_, _Lophostemon suaveolens_ and other species of the monsoon vine forest alliance (Paijmans, 1976). It is found mainly around the edge of monsoon vine forest, with trees scattered in a strip 50-80 m wide (Gunn et al., 1992). It occurs occasionally in areas of impeded drainage dominated by _Melaleuca viridiflora_, _Banksia dentata_, _Asteromyrtus brassiana_ and _Acacia leptocarpa_. In Irian Jaya it occurs as the upper stratum of extensive tall open forests above rainforest; these forests are the largest natural populations of the species.

The distribution is in the warm humid climatic zone where frosts are generally absent although very occasional light frosts are experienced at the higher altitude Queensland occurrences. Most locations in north Queensland have a marked dry season with less than 40 mm of rain per month for about four consecutive months, but there is no effective dry
season in the extreme north of its distribution in Irian Jaya and Papua New Guinea (Royen van, 1963). In New Guinea, _E. pellita_ occurs on gently undulating lowlands, and is largely restricted to areas with good drainage. In Queensland, the species occurs mainly on gentle to moderate topography and is found only to a limited extent on steep, well-drained slopes. It prefers moist sites and the lower slopes of large ridges and grows alongside streams in the drier parts of its occurrence. Soils vary widely, from shallow, infertile sands on sandstone ridges to shallow sandy podsols and deep forest loams. In Papua New Guinea and Irian Jaya, it occurs on brown and red-brown sandy loams and clay loams. In Irian Jaya the soils are deep, well-drained acidic (pH 5) clay-loam podsols derived from laterites (Vercoe and McDonald, 1991).

**Where will it grow?**

A climatic profile (Jovanovic and Booth, 2002) for _Eucalyptus pellita_, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climatic Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>1080-3550mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, bimodal, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>1-6 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>28-34°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>10-22°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>19-27°C</td>
</tr>
</tbody>
</table>

*G* If soils are shallow or not of good moisture holding capacity then sites with a mean annual rainfall <1300 mm should not be considered.

*H* 0 – 6 months for Papua New Guinea provenances.

*I* 19–25°C without including Papua New Guinea provenances.

The map of areas predicted to be climatically suitable for planting _Eucalyptus pellita_ (Figure 13.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. The best growth of _E. pellita_ in plantations outside its natural range have been observed on well-drained clay-loam soils, but satisfactory growth has also been recorded on infertile sands and sandy loams provided adequate levels of nutrients are supplied through fertiliser application.

There are interactions between factors such as mean annual rainfall, temperature and soil. _E. pellita_ has exhibited good growth in Minas Gerais State, Brazil, where mean annual rainfall is only 1000-1200 mm but mean annual temperature is around 22°C (Iman-Encinas, 1997), increasing the effective moisture availability relative to that of hotter sites receiving similar rainfall. The water holding capacity of the soil also influences the effectiveness of rainfall. _E. pellita_ performed quite well in trials at Ratchaburi, Thailand, a tropical site with a mean annual precipitation of 1017 mm with a marked dry season (Pinyopusarerk, 1989). However, this site has deep soil with good moisture-holding capacity, whereas there have been several failures at other tropical sites with rainfall less than 1300 mm.
Plantings and provenance trials

Plantings

Many of the early introductions outside Australia were from locations originally known as *E. pellita*, but now assigned *E. scias* (Jacobs, 1981). Jacobs (1981) suggested that the Queensland provenances of *E. pellita* could provide the basis for important new eucalypt trials in tropical countries. Large quantities of seed from the Kuranda and Helenvale, Queensland provenances of *E. pellita* were introduced to Minas Gerais and Bahia States in Brazil in the 1970s and 1980s for establishment of wood-energy plantations. A collection from Kirrima Range, Queensland was the initial genetic base of the large *E. pellita* plantations developed in Cuba from the 1970s. Introductions of Queensland provenances to parts of India, southern Africa, the Congo and SE Asia also took place in the 1970s.

The New Guinea provenances were first collected in the mid 1980s and initial research trials established in northern Australia, several countries in SE Asia, southern China, Brazil and South Africa from the late 1980s onwards.

Provenance trials

Comprehensive trials of a wide range of Queensland provenances in replicated, randomised experiments have not yet been carried out. However, an overall review of trial results to date revealed some clear trends. Provenances from Cape York (provenances named as ‘Malwraith Range’, ‘Tozers Gap’, ‘Lankelly Creek’ and ‘NE Coen’, latitudes 12°40’S to 14°S) have performed poorly, relative to the ‘Helenvale’ and ‘Kuranda’, Queensland provenances from latitudes 15°45’S and 16°50’S respectively, everywhere that they have been tested together. The high level of inbreeding demonstrated in the ‘Lankelly Creek’ population by House and Bell (1996) may partly explain the poor performance of this provenance.

Field testing of New Guinea provenances started in the late 1980s. It soon became apparent that they were superior to Cape York and north eastern Queensland provenances in lowland tropical environments with short (0-4 month) dry seasons. They displayed better growth, survival and disease resistance under these conditions (Dickinson and Sun, 1995; Harwood et al., 1997). The New Guinea provenances were clearly superior to the Queensland provenances in growth and form at Melville Island but less clearly so at Cardwell, Queensland (Harwood et al., 1997). Where there is a longer dry season there appears to be little if any superiority of the New Guinea provenances over the best Queensland provenances, for example at Dongmen, latitude 22°23’N in southern China with a 6 month dry season (Pegg and Wang, 1994), or at a lowland tropical site near Vientiane in Laos (12°30’N) with a 5 month dry season (Pinyaposarerk et al., 1996). Results from provenance/progeny trials have shown that in addition to provenance differences, there are significant differences in growth performance among families within a provenance (Harwood et al., 1997).

Stem straightness at age 3.3 years has been assessed in a trial at Melville Island, Northern Territory (Harwood et al., 1997). New Guinea populations had significantly better form than those from Queensland. Of the Queensland provenances tested, Helenvale and Kuranda had better stem form than did the Lankelly Creek and Tozers Gap provenances from Cape York, these latter two being prone to low forking and crooked stems.

Breeding and genetic resources

The results of species and provenance trials which test *E. pellita* must be interpreted cautiously. In particular, some provenances and families, notably those from parts of New Guinea and Cape York, are likely to perform better in later generations of well-managed genetic improvement programs when the proportion of inbred, slow-growing individuals is reduced from the levels of up to 50% or more that occur in wild populations.

Seedling seed orchards based on New Guinea and Queensland provenances have been established in northern Australia (Harwood et al., 1994). Two of the orchards in northern Australia (Yapilika, Melville Island, Northern Territory, and Kairi, north Queensland) flowered heavily and produced substantial seed yields of around 10 kg ha⁻¹ within 4 years of planting, at a stocking of around 200 trees ha⁻¹.
The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra can supply both single-tree and bulk-tree provenance collections of seed from natural stands of *E. pellita* suitable for trials and breeding programmes. Small amounts of improved seed are currently available in Australia from CSIRO Forestry and Forest Products, Australian Tree Seed Centre and the Queensland Department of Primary Industry, Forestry Seed Centre.

Queensland Forest Research Institute has established second-generation seed orchards of *E. pellita* and clonal testing of selected trees of *E. pellita* for mass production is well established in demonstration plantings in coastal north and central Queensland (QFRI website, 2002).

Records of the following natural hybrids involving *E. pellita* and other species in the subgenus Symphyomyrtus were noted in a review by Griffin et al. (1988): *E. pellita* × *E. resinifera*, *E. grandis* × *E. pellita* and *E. brassiana* × *E. pellita*. Some of these hybrids in progeny trials in northern Australia and Java, display good form and vigour, equaling that of the best pure *E. pellita* individuals. Figueredo Luz et al. (1996) note the occurrence of hybrids of *E. pellita* with *E. tereticornis* and *E. grandis* in Brazil, which grew better than the parent species on sandy soils.

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

Propagation by seed is the easiest method. Seed storage is orthodox and the seed can be stored at moderate temperatures (around 20°C) for several years without losing viability, provided low moisture content (less than 6%) is maintained. Longevity is greatly reduced if seed is stored in hot and/or humid environments. One kilogram of seed yields around 300 000 germinants. No pre-treatment of the seed is required and it germinates satisfactorily at 25°C.

The species is easily raised from seed in the nursery following the general methods for propagation of eucalypts (Boland et al., 1980; Doran and Turnbull, 1997). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

Partial shading and protection from heavy rain are needed for 4-6 weeks after pricking out, after which seedlings are exposed to full sunlight. Watering is reduced 2-3 weeks before field planting to harden seedlings to field conditions. In tropical conditions seedlings should attain a stem height of 25 cm about 10 weeks after pricking out, at which time they are ready for field planting.

The species is very easy to propagate by rooting stem cuttings from seedlings and basal coppice shoots of coppiced trees, while cuttings from the crowns of saplings and mature trees are hard to root (Kondo and Pudjiona, 1996). Grafts can be made with shoots taken from crowns of mature trees onto seedling rootstock. The species should also be easy to micropropagate from excised axillary buds, as is routinely done with its close relative *E. urophylla*, although there are no published references to this technology being used for *E. pellita*.
Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. pellita*. Detailed information on various establishment practices is available from several sources including government organisations such as Queensland Department of Primary Industries, farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoods/qld/) or they can be obtained by contacting the organisations directly.

If scrubland or grassland is to be planted, ploughing and harrowing is recommended on gentle slopes. Mounding of planting rows, along the contours of slopes, is appropriate to improve drainage and minimise soil erosion.

Planting at an initial spacing of 4 m x 2.5 m (1000 stems ha⁻¹) is recommended as a good stocking density for timber production. In drier areas where there will be more competition for water a 4 m x 3 m spacing may be preferable (QFRI website, 2002). Spacings used in Brazil, Cuba and pilot plantations in Indonesia are typically 3 m x 3 m or 3 m x 2 m, and thinning is not carried out. In these plantations *E. pellita* was being grown on short rotations (8-12 years) for fuelwood, charcoal and more recently for chemical pulp production (Sturion et al., 1987; Turvey, 1995).

Planting in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred so that young seedlings will be exposed to a shorter period of high temperatures.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on expasture sites and soil degradation can result from very large applications of nitrogen fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. water availability (low rainfall or heavy weed competition are two factors that can affect this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al. (1995), Attiwill and Adams (1996), Nambiar and Brown (1997) and QFRI website (2002).

Management

As mentioned above weed control is an important ongoing priority in tree management, particularly in the first few years after planting.

When grown for pulpwood or fuelwood at close spacings (3 m x 3 m or closer), pruning of *E. pellita* is not required - lower side branches are shed leaving a clean bole of up to 10 m, although a proportion of trees fork below that height.

A pruning regime to reduce the impacts of knots on timber quality in sawlog plantations of *E. pellita* has not been developed but Dickinson et al. (2000) found that pruning trees at an approximate DBH of 8 cm was the best compromise to achieve all pruning goals. At this size, most branches are still alive, are <2 cm in diameter and trees can withstand the removal of the greater percentage of the green
crown (30-50%). To achieve removal of 40% of branches will require a pruning lift to 3.2 m. In cases where a 6 m pruned height is required, a further pruning lift could be conducted later at an approximate DBH of 12 cm and height of 12 m with approximately 30% of green branches removed at this time (Dickinson et al., 2000).

Early trial results indicate that for sawlog regimes in highgrowth species such as *E. pellita* a pre-commercial thinning to a minimum stocking of 400 trees ha\(^{-1}\) at approximately 1.5-3.5 years will maximise diameter (diameter at breast height - DBH) growth of the remaining trees. Dickinson et al. (2000) suggest that commercial thinning to 150-200 trees ha\(^{-1}\) will then be necessary at around age 8-15 years to ensure good growth rates are maintained. This stocking should then be sufficient to allow these trees to achieve a merchantable size in an acceptable rotation length.

Because the species coppices strongly, it is easy to establish a second rotation by thinning coppice shoots back to two per stump, at age 9-12 months after the first rotation is harvested. However, it should be noted that coppice management, which requires the reduction of the number of coppice shoots on a stool, is time-consuming and expensive (Evans, 1982). There is also the cost of protecting the stumps at harvesting, and the possible lost gains in yield that might be achieved from the use of improved seed or provenances for the next rotation.

### Growth

Growth rates in the order of 2.3 m yr\(^{-1}\) for height and 2.3 cm yr\(^{-1}\) for DBH can be expected on suitable sites (Harwood et al., 1997; Keenan and Bristow, 2001).

### Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

*Eucalyptus pellita* plantations have generally displayed good resistance to pests and diseases. In 1994, four fungal pathogens were identified on two-year-old provenance/progeny trials of *E. pellita* at Yalpilika, Melville Island, Northern Territory of Australia surveyed by Yuan (1996). Three of the species (*Aulographina eucalypti*, *Coleophoma eucalypti* and *Coniella australiensis*) were associated with leaf spot diseases while the fourth, *Botryosphaeria appendiculata* was a canker associated with stem dieback. However, subsequent observations (C.E. Harwood, unpublished observations, 1995 and 1996) indicated that these pathogens did not have a substantial impact on the yield of *E. pellita* in the seasonally dry environment of Yalpilika.

Symptoms of bacterial wilt disease were observed on one-year-old trees in a species-provenance trial testing *E. pellita* (1% of trees affected) and *E. urophylla* (9% of trees affected) near Innisfail in north east Queensland. The bacterium *Pseudomonas solanacearum* was isolated from infected trees (Dickinson and Sun, 1995). Bacterial wilt symptoms on young trees have been observed in two other trials of *E. pellita* near Cardwell in north east Queensland (C.E. Harwood, unpublished observations, 1993, 1996) but only a few trees were affected.

Plantations should be protected from fire. The species has thick bark and established saplings can therefore survive ground fires of low intensity. In the natural forests, mature trees can recover from crown fires of moderate intensity, although these may cause fire-scars in the main stem.

### Utilisation

#### Wood

The heartwood of *E. pellita* is an attractive red to dark red-brown colour (hence its trade name, red mahogany), while the sapwood is a pale creamy
brown in colour. It is generally medium textured with an even grain. At times the grain can be interlocked producing an attractive figure. The sapwood is susceptible to attack by Lyctus borer but readily accepts preservative impregnation (Boland et al., 1984; QFRI website, 2002). The air dry density of wood from mature trees from natural forests in Queensland is about 950 kg m\(^{-3}\) (Bootle, 1983; Boland et al., 1984). Generally, young (3-10 years old) plantation-grown *E. pellita* from Queensland and New Guinea has been found to have a basic density of 510-560 kg m\(^{-3}\) (Clark and Hicks, 1996; Magalhaes, 1988; Siarot, 1986; Tomazello Filho, 1987). Basic density of 10-year-old trees of the ‘Helenvale’ provenance was higher, 631 kg m\(^{-3}\), in one Brazilian study by Sturion et al. (1987). Because of its high wood density and relatively rapid growth, the species has found favour for fuelwood and charcoal production in Brazil and Cuba.

Recent testing of the wood of 5-year-old trees of the ‘Kirwai’, New Guinea, provenance of *E. pellita* grown in a lowland plantation in north Queensland (Clark and Hicks, 1996) showed that its kraft pulping and papermaking properties were quite acceptable, being very similar to those of plantation-grown *E. urophylla* of the same age and slightly inferior to those of plantation-grown *E. globulus*.

Timber of *E. pellita* from natural stands is rated as easily sawn and seasoned and suitable for poles, sleepers, flooring, panelling and general construction (Bootle, 1983). The wood can be dried satisfactorily using conventional air and kiln seasoning methods. Shrinkage of boards of 8.5 year old plantation grown *E. pellita* to 12% moisture content was 5.2% tangential and 1.9% radial. It has a durability rating Class 2 – highly resistant to decay when fully exposed to the weather, clear of the ground and well drained with free air circulation. Only moderately resistant to decay when used in the ground. It has a hardness rating of 1 – very hard in relation to indentation and ease of working with hand tools. Machines well and no difficulty has been experienced with the use of standard fittings and fastenings. As with most high density species, machining and surface preparation should be done immediately before gluing (QFRI, 2002).

Non-wood

Honey from the abundant flowers is the only commercial non-wood forest product provided by *E. pellita*. Yield of essential oil from the leaves is low, and quality is poor (Dellacassa et al., 1990; Doran et al., 1995).

**Recommended reading**


**References**


Clark NB, Hicks CC, 1996. The kraft and papermaking properties of 5-year old plantation-grown *Eucalyptus cloeziana*, *E. pellita* and *E. urophylla* from northern Queensland. Divisional Report No. DFFP 523. CSIRO Division of Forestry and Forest Products, Melbourne.


Turvey ND, 1995. Afforestation of Imperata grasslands in Indonesia: Results of industrial tree plantation research trials at Teluk Sirih on Pulau Laut, Kalimantan Selatan. ACIAR Technical Reports No. 33. Australian Centre for International Agricultural Research, Canberra.


14. *Eucalyptus pilularis* Smith

Blackbutt

Adapted from Clarke, 2000.

**Species overview**

*Eucalyptus pilularis* is one of the most important Australian hardwoods, and is the principal species sawn in coastal New South Wales and south-eastern Queensland. The hard, strong, durable timber is used for general building, flooring, poles, pulp and railway sleepers (Bootle, 1983; Boland *et al*., 1984). In Australia, large areas of *E. pilularis* in natural forests have been intensively managed for many years using natural regeneration or direct seeding. It is also one of the major species being established as part of the plantation initiatives in northern New South Wales and south-eastern Queensland, mainly on ex-agricultural land (Johnson and Nikles, 1997). Plantations have been established in northern Queensland as well where it is planted in areas such as Atherton and Herberton (PFNQ website, 2002). *E. pilularis* shows good growth and form on a variety of deep moist soils in subtropical and humid warm-temperate environments in the absence of severe frosts.

**Description and natural occurrence**

**Description**

*Eucalyptus pilularis* is a medium-sized to very tall forest tree with a straight bole and an open and spreading crown. Mature trees can reach heights of almost 70 m and can exceed 3 m diameter at breast height under favourable conditions (Boland *et al*., 1984). The range of mature height is 35-70 m (Turnbull and Pryor, 1984). The trunk is straight and typically clear of branches for one-half to two-thirds of the tree height (Boland *et al*., 1984).

**Key features**

- Medium to tall tree of good stem form
- Moderate growth-rate
- Sensitive to extreme dry conditions and seedlings are sensitive to drought at planting
- Intolerant of severe frosts and seedlings tolerate only very light frosts
- Performs best on deep, well drained soils and is intolerant of waterlogging
- Susceptible to the root fungus *Phytophthora* species
- Not tolerant of salinity
- Good general purpose timber (wood from natural stands) used mainly for building framework and poles but also for sleepers and paper pulp
- Growth stresses in regrowth logs and plantation-grown timber can cause excessive splitting and collapse (selection and breeding might reduce this problem)

*Eucalyptus pilularis* is a preferred species on the north coast of New South Wales and southern Queensland for hardwood plantations because of proven growth and survival in routine plantations over a wide range of ex-forested sites and ready marketability of the wood (Johnson and Nikles, 1997).
The common name, blackbutt, refers to the darkening of the lower rough bark by bushfires. The rough bark is persistent on at least the lower half of the trunk in all but young trees. It is finely fibrous, spongy, brown or grey over red-brown, becoming ragged towards the base in old trees. The bark on the upper part of the trunk and major limbs is shed in strips leaving a smooth white or yellowish-grey surface. Insect ‘scribbles’ are often conspicuous on the upper bark (Boland et al., 1984).

The seedlings and saplings are conspicuous in the field with many pairs of opposite, broad-lanceolate, strongly discolorous leaves. The branchlets are square in cross section and the flower stalks strongly flattened. Juvenile leaves are sessile, amplexicaul, opposite for many pairs, strongly discolorous, broad lanceolate to lanceolate (dimensions 13-17 cm long × 2.5-3.5 cm wide). Adult leaves are petiolate, alternate, lanceolate or falcate and oblique, concolorous, glossy to dark green (dimensions 9-16 cm long × 1.6-3 cm wide) (Boland et al., 1984; Brooker and Kleinig, 1994).

Like other eucalypts blackbutt does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowering in *E. pilularis* can occasionally commence as early as 3 years of age in plantations and it generally flowers and seeds well by age 8-10 in New South Wales, but may be earlier elsewhere (Turnbull and Pryor, 1984; Johnson and Nikles, 1997). The flowering period is from September to March in mainland New South Wales and Queensland (Boland et al., 1980; Brooker and Kleinig, 1994), and from April to October on Fraser Island, Queensland (Florence, 1969). New buds usually appear during late winter or spring, but flowering normally occurs two summers later (Clemson, 1985). No detailed studies of the breeding system of *E. pilularis* have been made, but it is likely to be similar to that of other commercial eucalypt species which have been studied, i.e. substantially out-crossed in large natural populations by means of insect pollinators (Johnson and Nikles, 1997). Fruit bats and blossom bats are probably also important long-distance pollinators of the species (Eby, 1995). Nectar-feeding birds such as honeyeaters and lorikeets are also likely pollinators of the species.

Seed collection months are from December to February in Australia (Boland et al., 1980). There can be a pronounced peak in seed shed in spring-early summer, but shed can occur in any month provided dry periods are experienced for at least two weeks in summer and somewhat longer in winter (Floyd, 1962). There will be regional and seasonal variability in seed availability.

*Eucalyptus pilularis* is a coppicing species, although it does not produce lignotubers and there is variation among trees in their coppicing ability. The seedlings
develop a carrot-like root which functions in much the same way as a lignotuber, and they can survive moderate fires (Turnbull and Pryor, 1984). It produces a large number of fine lateral roots in the surface horizons, but not strong tap roots (Florence, 1996). The presence of ectomycorrhizas on the seedling roots of *E. pilularis* enables this species to optimise phosphorus uptake on infertile soils. Ectomycorrhizas can infect the roots of *E. pilularis* within 30 days of sowing (Florence, 1996).

**Natural occurrence**

*Eucalyptus pilularis* occurs naturally along the entire New South Wales (New South Wales) coast from just north of Eden in far southeastern New South Wales (latitude 37°08’S) north to Fraser Island in Queensland (latitude 24°48’S) (Figure 14.1). However, it has a highly discontinuous distribution within its area of occurrence (Florence, 1996) with local fragmentation (Johnson and Nikles, 1997). It is most common and attains its best development in the coastal hills but it extends up to 150 km inland in Queensland. It has an altitudinal range from near sea level to about 400 m in coastal New South Wales and Queensland, and up to around 1000 m above sea level in the escarpment and sub-inland parts of northern New South Wales and southeastern Queensland (Burgess, 1975; Johnson and Nikles, 1997). It has a wide ecological range but prefers deep, mature soils which provide good water storage and facilitate root and water movement. The soils are frequently of low nutrient status and well-drained (Turnbull and Pryor, 1984).

In Australia the climate for most of the distribution is warm humid, subtropical in the north, and temperate in the south (Boland et al., 1984; Turnbull and Pryor, 1984). A few frosts (up to 15) occur each year at the higher altitudes away from the coast.

*Eucalyptus pilularis* is found on ridges, flats and in gullies on soil types ranging from recently stabilised dune sands to sandy loams or loams, yellow and red podzolics and krasnozems. It will also grow on clays and volcanic soils (Burgess, 1975; Boland et al., 1984). The species tends to be associated with rocks that have a high silica content, particularly those that have a high or moderate amount of quartz. On these sites mature soils form where weathering has been rapid. It does not grow well on poorly-aerated soils and will not tolerate temporary flooding. On poorly-aerated soils it is sensitive to soil pathogens such as Phytophthora (Florence, 1996).

**Where will it grow?**

A climatic profile (Jovanovic and Booth, 2002) for *E. pilularis*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>730-2460 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Bimodal, summer</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-4 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month:</td>
<td>22-31°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month:</td>
<td>3-12°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>10-22°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *Eucalyptus pilularis* (Figure 14.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). Only one revision to the climatic parameters from the natural distribution has been made and this was to raise the mean minimum temperature for...
the coldest month from 0°C to 3°C so that frost prone areas inland from the coast were not highlighted as climatically suitable (Jovanovic and Booth, 2002).

Other site considerations for planting are the species requirement for deep moisture holding soils with no waterlogging or salinity.

Plantings and provenance trials

Plantings

Several authors have observed that interest in *E. pilularis* as an exotic appears to be very limited (Turnbull and Pryor, 1984; Johnson and Nikles, 1997) compared to several other eucalypt species. This is despite its good performance in trials in Brazil, Argentina and southern Africa. Poynton (1979) observed that *E. pilularis* was one of the most desirable species silviculturally in southern Africa and had been used in Zimbabwe for plywood manufacture where it was regarded as the best of all the eucalypts for this purpose. However, it is no longer planted commercially in southern Africa, because the timber from young trees exhibits severe growth stresses.

This species is successful in Hawaii on sites with an annual rainfall of 1500-2000 mm (Jacobs, 1981). It is also grown in many parts of New Zealand, mainly in small-scale woodlots for farm use (Turnbull and Pryor, 1984).

Between 1994 and 2001, State Forests of New South Wales established nearly 5300 ha of new *E. pilularis* plantations, this is in addition to some 11 000 ha planted between the 1940s and the early 1990s. In New South Wales, *E. pilularis* plantations established in the last eight years are being managed for sawn timber on a 25-30 year rotation.

Provenance trials

A series of provenance trials of *E. pilularis* was established in New South Wales in 1964 (Burgess, 1975; Johnson and Stanton, 1993). A total of 15 seedlots (including two of *E. pyrocarpa* and one of a natural hybrid of *E. pilularis* x *E. planchoniana*) were planted over 11 sites between Yabbara (28°31’S) and Benandra (35°40’S). Johnson and Nikles (1997) describe the trials as providing limited provenance sampling, and some trials suffered heavy damage from fire or pathogens at less than 10 years of age which reduced their reliability. However the results of these trials do reflect trends observed in other trials. Statistically significant differences in height between provenances were found within sites and the ranking of provenances at the different sites was very similar, suggesting that there was only minor genotype by environment interaction.

Four provenances of *E. pilularis* from the northern part of the natural range displayed good survival and growth across at least half the sites on which they were tested. They were ‘Manning River’ (Coopernook, New South Wales), ‘Ellis’ (New South Wales), ‘Mapleton’ (Queensland) and ‘Whian Whian’ (New South Wales). It was concluded that material from a range of high-quality natural stands would grow well over a range of site types, and that seed should be collected only in high quality stands. The species can be divided into three geographic groups based on the large provenance differences displayed in the trials: south coastal (mostly mediocre to poor productivity); north coastal, poorer sandy sites (uniformly poor productivity); northern coastal-escarpment, higher quality sites in New South Wales and Queensland (generally superior productivity). The better northern provenances maintained their superiority of growth at most
of the southern and cooler central test sites, thus showing stability (Johnson and Nikles, 1997).

A provenance-progeny trial planted on a bauxite mine rehabilitation site at Huntly, Western Australia (south of Perth), in 1986, included three Queensland and six New South Wales provenances (Mazanec, 1994; Johnson and Nikles, 1997). Survival, height and diameter were assessed at two and a half years of age. Despite the fact that these were very early results they were remarkably similar to those described above for the trials in New South Wales. However, the best performing provenance, ‘Gallangowan’ (Queensland), was not included in the New South Wales trials. The ‘Gallangowan’ seedlot ranked highest in all traits, and overall the more northerly provenances performed best in the Western Australian trial.

New Zealand Forest Research has recently established a provenance-progeny trial of *E. pilularis* in the North Island, following renewed interest in the species for woodlot planting in New Zealand (Ruth McConnochie, NZ Forest Research, pers. comm., 2001).

Breeding and genetic resources

A breeding program for *E. pilularis* is proceeding in New South Wales and south-eastern Queensland. Large family trials using select tree seedlings from a wide range of north-eastern New South Wales and Queensland provenances were planted in northern New South Wales and south-eastern Queensland in 1997-98, as the basis for long-term improvement. These trials are currently yielding selections for clonal seed orchards (Ian Johnson, State Forest of New South Wales, pers. comm., 2002). Because of the limited interest in the species outside Australia, there has been little progress with tree improvement overseas, beyond provenance testing. The main reason is that the timber from young trees can exhibit severe growth stresses. However, Johnson and Nikles (1997) state in their breeding strategy for *E. pilularis* that the difficulties with wood quality should be amenable to reduction by selection and breeding.

*Eucalyptus pilularis* 25-year-old on north coast, NSW.
Improved seed from seedling seed orchards is likely to be available from New South Wales in four to six years time, 2006-2008 (Ian Johnson, State Forests of New South Wales, pers. comm., 2002). Improved seed from seedling seed orchards in Queensland will be available in 2003-2005 (Nikles et al., 2000; David Lee, Queensland FRI, pers. comm., 2002).

Natural E. pilularis hybrids have been observed with some other members of the subgenus Monocalyptus such as E. acmenoides, E. globoidea and E. planchoniana (Griffin et al., 1988), but hybrids with its closest relative, E. pyrocarpa, are not known (Burgess, 1975). If artificial hybridisation proves feasible, then potentially useful combinations of E. pilularis with species like E. pyrocarpa, E. acmenoides, E. phaeotricha, E. umbra, E. nigra and E. cloeziana might open up opportunities for extending the current planting range of E. pilularis to sites not suitable for the pure species (Johnson and Nikles, 1997).

Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

Eucalyptus pilularis is a prolific seeder and regenerates readily from seed in the field (Floyd, 1962). It is usually propagated from seed and there are on average 57 000 viable seed kg\(^{-1}\) of seed and chaff mix (Boland et al., 1980; Turnbull and Doran, 1987). Seed storage is orthodox, and mature seed can remain viable for 5-20 years if stored at a low moisture content (4-8%) in sealed containers at 3-5°C. When not stored in moisture-proof containers it is advisable to maintain a relative humidity in the storage room of between 20 and 40% (Boland et al., 1980).

No pre-sowing treatment is required. Germination takes place over 3 weeks under moist, warm conditions (20-25°C is optimal in the laboratory) in the presence of light (Turnbull and Doran, 1987). However, seed of E. pilularis has been known to germinate completely in almost total darkness at 26°C (Floyd, 1964).

Mature seed of E. pilularis is difficult to separate from its accompanying chaff and often large amounts of aborted seed remain even after a lengthy cleaning process. This makes it unsuitable for the single-seeding practices required for the economic production of cell-raised seedlings used in intensive plantation programs. A significant increase in germination percentage has been obtained using an imbibing and sugar separation treatment. The dried seed can then be vacuum sown (Cliffe, 1997). However, State Forests Nurseries (New South Wales) has found this method time-consuming, with only a 5% improvement over previous single-seeding methods. The current practice is to sow 6 particles of mixed seed and chaff per cell, resulting in about 35 000 seedlings per kilogram of seed and chaff, in seedlots with fairly low viability (Steve Sullivan, State Forests Nurseries New South Wales, pers. comm., 2002).

Eucalyptus pilularis had moderate rooting success in an experiment using leafy cuttings (Catesby and Walker, 1997). The cuttings were taken from seedling hedge plants that had been periodically decapitated to a height of 15-20 cm to promote the development of shoots for cuttings. Two-to-three-node cuttings were used, with the leaf area being reduced by approximately 50%. A commercial rooting hormone powder (0.8% IBA) was used and clones were set in a 3:2 vermiculite, perlite mixture. Mean rooting success for E. pilularis was 35% 15 weeks after setting. Considerable variation of rooting success between clones was found. The proportion of E. pilularis clones with >70% rooting success was 23%.

Studies of vegetative propagation of E. pilularis using shoots from basal coppice, young seedlings, and branch sections of older trees via micropropagation have been carried out by State Forests of New South Wales (Johnson and Nikles, 1997). Although both seedlings and coppice material can be successfully propagated by cuttings, with most clones producing some rooted plants, 60% or more of the cuttings within many clones do not develop a good root system. Detailed techniques to enable E. pilularis to be mass propagated commercially have yet to be finalised although sufficient plants of most clones for field testing can be produced (Ian Johnson, State Forests of New South Wales, pers. comm., 2002).
The regeneration of *E. pilularis* from coppice is not reliable and the ability of older trees to coppice successfully is poor (Turnbull and Pryor, 1984; Johnson and Nikles, 1997). However, a great majority of 3-4 year-old select trees felled for vegetative propagation experiments in New South Wales (in spring 1998 and 2001) produced abundant coppice within two to three months. Competing and shading vegetation was cleared back from the stumps (Ian Johnson, State Forests of New South Wales, pers. comm., 2002).

General nursery practices are suitable for producing containerised seedlings of *E. pilularis*; these are described in texts such as Doran and Turnbull (1997). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

At State Forests of New South Wales *E. pilularis* is germinated under 50% shade in Landmark Plug Trays which are seeded by a drum sower. Seed is covered with vermiculite for germination. When the plants have a good root system, around 4-8 weeks, they are transferred to 'Hiko' trays (2.5 cm circle x 10 cm in a tray of 40) or tubes (5 cm x 12.5 cm). These are kept in outside holding beds and given progressive exposure to full sunlight. Seedlings are grown-on in these beds for 2-4 months. The potting mix comprises composted pine bark fines, sand, coir fibre and composted sawdust (Steve Sullivan, State Forests of New South Wales Nurseries, pers. comm., 2002).

Seedlings are very sensitive to hot, dry winds before as well as after being planted out in the field, and fertilised seedlings are unable to withstand temperatures below -1°C (Poynton, 1979; Turnbull and Pryor, 1984).

In New South Wales, seed of *E. pilularis* is sown between April and November, for planting between November and March (Steve Sullivan, State Forests of New South Wales Nurseries, pers. comm., 2002).

**Establishment**

Direct seeding has been used previously but this has now largely been superseded by planting of containerised stock (Florence, 1996). Planting areas are ripped and mounded or cultivated depending on site conditions. Trees are planted at a spacing of 4.0 m x 2.5 m (1000 stems ha⁻¹) and a fertiliser treatment is applied shortly after planting to promote early growth. Weed control is carried out prior to planting and is continued for up to two years, as needed, after planting (Paul Brennan, State Forests of New South Wales, pers. comm., 2002).

Plantations of *E. pilularis* can be planted at a spacing as wide as 4 m x 4 m (625 ha⁻¹). There has been some argument in favour of wider spacing, this will increase the need for pruning which is relatively difficult with this species and also weed control (see section on plantation management below). Wider spacing may become an option if breeding can produce trees with improved form and finer branches (Florence, 1996).

**Management**

Pruning is not a routine practice at present in State Forests of New South Wales plantations, with natural branch shedding being encouraged by planting at a relatively high stocking (1000 trees ha⁻¹), thus encouraging the rise of the green crown and reducing branch diameter. The small lower branches are then cleanly shed (Phil Lacy, State Forests of New South Wales, pers. comm., 2002).

*Eucalyptus pilularis* has a capacity for rapid site occupancy from an early age and for individual trees to respond to large amounts of growing space. Diameter growth rates can be greatly increased when stands are thinned to a wide spacing during the rapid growth phase, and high levels of volume production can be maintained at relatively low stockings. Site quality is also an important factor, with trees on poorer sites being more sensitive to competition at a higher stocking. Where stands have been thinned heavily, site has less effect on the diameter of the trees. A stocking range of 200-300 stems ha⁻¹ is predicted to provide near maximum volume of sawlogs over a wide range of stand ages (Florence, 1996).

Though early and/or heavy thinning may be advantageous in terms of the response of the residual stand, too early or too heavy a thinning may be inadvisable under certain conditions. Wide early spacing may lead to heavy branching and poor form, particularly on sites where the trees are...
not growing rapidly in height and expression of dominance is not strong. Depending on the productive capacity of the site, State Forests of New South Wales commercially thins stands up to two times with an early non-commercial thinning at ages between 3 and 7 years. This thinning brings the initial stocking of 1000 stems ha\(^{-1}\) down to between 400-500 stems ha\(^{-1}\). This is followed by a commercial thinning carried out at around 10 years or later, when the stocking is reduced to about 200 stems ha\(^{-1}\) with a final rotation age of 25-30 years. Prescriptions are continually reviewed as more information is gained about \(E. \) pilularis in plantations (Phil Lacy and Paul Brennan, State Forests of New South Wales, pers. comm., 2002).

**Growth**

While an even-aged natural stand of \(E. \) pilularis will not grow as rapidly as the equivalent \(E. \) grandis or \(E. \) regnans stand on good quality sites, or achieve full-site occupancy as soon as \(E. \) grandis, it will build up to a strong peak in annual volume production at a relatively young age. Plots in natural stands at Mapleton, Queensland, achieved a mean annual increment (MAI) of 8-12 m\(^3\) ha\(^{-1}\) at 30-35 years of age. Well-managed plantations developed with improved seed and which receive timely silvicultural treatment are likely to be able to improve on this MAI. The current annual increment (CAI) for volume growth at these sites peaked at around 19-23 years of age and the mean annual increment (MAI) peaked at around 30-35 years (irrespective of stocking). Data from thinned plots in New South Wales suggest a peak CAI between 12 and 20 years and a peak MAI at around 30 years (Florence, 1996).

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

\(Eucalyptus \) pilularis has generally displayed good resistance to pests and diseases when planted on suitable sites. \(Phytophthora \) cinnamomi has caused losses in some plantations of \(E. \) pilularis in New South Wales, with deaths being concentrated in poorly drained flat areas or on lower slopes. Shoot dieback associated with infection by \(Botryosphaeria \) dothidea and defoliation associated with \(Mycosphaerella \) cryptica has occurred in a few plantations (Carnegie, 2000). Insect pests, including the leaf beetles \(Paropsis \) atomaria and outbreaks of \(Monolepta \) beetles \((\) Monolepta australis\()\), have occurred in a few young \(E. \) pilularis plantations in northern New South Wales. Damage from \(Monolepta \) beetles has been confined mainly to trees on ridge tops and hilltops and ranges from trace to severe, including death of young seedlings. Occasional severe damage by the chrysomelid leaf beetle \(Crytocephalus \) iridipennis in Queensland plantations has been recorded by Wylie and Peters (1993). Outbreaks of the scarab leaf beetle \(Epholcis \) bilopiceps has resulted in complete defoliation in experimental plantations in northern Queensland \((\)Wylie and Peters, 1993\()\). Evidence of longicorn infestation is common in plantations of \(E. \) pilularis over three years old \((\)Carnegie, 2000\()\). Small-diameter trees are seriously affected by the larvae of the giant wood moth \((\)Xyleutes cinereus\()\) (Wylie and Peters, 1993). Greaves and Florence \((\)1966\) reported 33% subterranean termite \((\)Coptotermes acinaciformis\()\) incidence in \(E. \) pilularis plantation trees. The termite species \(C. \) acinaciformis and \(C. \) frenchii are serious pests that cause piping in trees and harvested logs \((\)Greaves et al., 1967; Wylie and Peters, 1993\)\). The sapwood is resistant to attack by \(Lyctus \) borers \((\)Boland et al., 1984\)\).
Utilisation

Wood

*Eucalyptus pilularis* is an important Australian hardwood species and is the principal species sawn in coastal New South Wales and south-eastern Queensland (Boland et al., 1984). It is a major timber for building framework, flooring and poles, and is suitable for sleepers, and paper and pulp. Other uses include fencing, landscaping, boat building, internal quality furniture, outdoor furniture, turnery and parquetry.

The timber is relatively hard, strong, stiff and tough. The heartwood is durable [Class 2 on a 4 point scale] and is difficult to impregnate with preservatives. The heartwood is pale brown or yellowish brown, but timber from northern populations may sometimes have a pale pinkish tinge. The sapwood is distinctly paler, it is not susceptible to *Lyctid* borer attack, and readily accepts preservative impregnation but penetration of heartwood is negligible using current commercial processes (QFRI website, 2002). The texture is medium and even. The grain is usually straight and gum veins are common (Bootle, 1983). The presence of wavy interlocking grain can produce an attractive figure (PFNQ website, 2002).

The air-dry density of timber from natural stands is about 900 kg m\(^{-3}\) and the green density about 1100 kg m\(^{-3}\). Plantation grown trees at 11-17 years of age have an air-dry density of 745-820 kg m\(^{-3}\) (QFRI website, 2002) and can be satisfactorily dried using conventional air and kiln seasoning methods. Care is needed in drying to inhibit a tendency to surface check on the tangential face (Bill Joe, State Forests of New South Wales, pers. comm., 2002). There is a slight tendency to collapse in juvenile wood (near pith) (PFNQ website, 2002). The timber is not difficult to work, it machines well and accepts finishes well (QFRI website, 2002). Steam-bending properties are poor to moderate. Young regrowth material has potential for structural plywood as it is able to be glued easily, having a lower extractives content than mature trees (Bootle, 1983).

Regrowth logs exhibit much more spring and bow than mature stems and their central core is likely to suffer considerable collapse (Bootle, 1983). Young fastgrown trees are prone to end splitting which can cause problems in sawn timber and in its use for treated poles (Turnbull and Pryor, 1984).

The prospects for the genetic manipulation of wood quality in *E. pilularis* seem fair to good, in view of the variation found in various wood properties of plantation-grown *E. pilularis* in Australia and South Africa (Johnson and Nikles, 1997). A trial of *E. pilularis* in Brazil (Pasztor, 1983) was studied for mean wood basic density at 5 years of age and there appeared to be considerable variation among provenances.

Non-wood

In New Zealand *E. pilularis* is used in farm planting for posts and exterior uses (McKenzie, 1993). It provides reasonable shade and shelter (Poynton, 1979; Clemson, 1985) and has been used for shelterbelts in New Zealand.

*Eucalyptus pilularis* was included in species trials for rehabilitation of bauxite mine sites at Henty in Western Australia in 1986 (Mazanec, 1994; Johnson and Nikles, 1997).

This species is not an important tree for honey production, although it is of moderate value when seasonal conditions are favourable (Clemson, 1985). Its honey has a rather strong flavour, lacks density and is used for blending with better quality honeys. However, it is a good pollen producer.

Limitations

*Eucalyptus pilularis* is very site specific. It develops best on fertile sites that must be well-drained as it is very susceptible to *Phytophthora*. *E. pilularis* can have quite a high mortality in the nursery and is prone to unexplained mortality soon after planting. It is also very susceptible to drought at planting and seedlings will not tolerate other than light frosts. It is prone to windthrow and stem damage when young as the canopy is dense and the root system is shallow.

It is no longer planted commercially in southern Africa, because the timber from young trees exhibits severe growth stresses with the wood usually splitting excessively and seasoning badly. Checking and collapse are also common in the young wood, and it often contains kino ring (gum veins), all of which
factors can greatly reduce yields and quality of logs and sawn products. However, it is believed that difficulties with wood quality are likely to be amenable to reduction by selection and breeding (Johnson and Nikles, 1997).

Recommended Reading


References


15. *Eucalyptus saligna* Smith
Sydney blue gum
Adapted from Doran, 2000.

Key features

- Medium to tall tree, 30-50 m in height, of good form
- Moderate to fast growth (for maximum growth rate it requires >900 mm MAR; but good growth is possible down to around 700 mm MAR on deep, moisture-holding soils, with groundwater)
- Grows well under irrigation
- Grows best on clay loam to sandy loam soils
- Intolerant of heavy clay soils and poor drainage
- Moderate drought tolerance
- Moderate to high frost tolerance
- Low tolerance to soil salinity
- Timber strong and moderately durable
- Possible products include panelling, furniture, veneers, sleepers, building framing timber and internal flooring.

Species overview

*Eucalyptus saligna* is an excellent species for farm forestry plantings. It is a reasonably fast-growing hardwood, of good form, which thrives on a wide range of soil types. Although best growth is achieved on sites with a high rainfall [more than 900 mm yr\(^{-1}\)] well distributed throughout the year (Turnbull and Pryor, 1984), it can survive moderate droughts (e.g. Marks et al., 1973) and has been successfully established where mean annual rainfall gets down around 700 mm on deep moisture holding soils with groundwater. It is also a very suitable species for growing under irrigation but does not tolerate saline irrigation water (Myers, 1994; Des Stackpole, Sustainability and Environment Victoria, pers. comm., 2002). It is moderately frost tolerant and will withstand temperatures down to about -8°C (Martin, 1948).

The wood of *E. saligna* is relatively easy to dry and is useful for a wide range of products including general construction, joinery, decking, decorative flooring and panelling. It is acceptable for reconstituted wood products and pulpwood and has potential for furniture (Noble, 2000). In south-western Victoria (Jackson et al., 2000) and Western Australia (FPC website, 2002) it has been identified as a species with sawlog potential on moderately fertile soils in rainfall areas of 600-700 mm yr\(^{-1}\). It has also been noted as a good dryland plantation species in north-eastern Victoria on deep moist loams and alluvial soils, capable of producing high quality timber for veneers and flooring in a relatively short period (Washusen and Reid, 1996). It has failed in this area where grown on shallow soils or hillsides. In northern New South Wales, plantings have experienced problems with insects and slower growth than other eucalypt species. It has proven successful as a reforestation species in many countries, especially at latitudes between 25° and 35° or at higher altitudes in lower latitudes (Jacobs, 1981).
Description and natural occurrence

Description

A medium to tall tree, usually 30-55 m in height with a diameter at breast height up to 2 m. Exceptional trees may attain 65 m in height with a diameter at breast height of 2.5 m (Boland et al., 1984). The bark is rough and persistent as a basal stocking, moderately thick, short-fibred, often tessellated, brownish-grey, becoming thin and finally shedding in long thin flakes or strips. The rest of the trunk and branches are smooth grey-green, bluish-green or white (Brooker and Kleinig, 1999). The trunk is generally of good form, straight and clear of branches for one-half to two-thirds of the total tree height (Boland et al., 1984). It is a lignotuberous species of good coppicing ability.

The juvenile leaves are petiolate, opposite for several pairs then alternate, ovate (dimensions 12 cm long × 5 cm wide), discolorous, green to dark green. Adult leaves are alternate, petiolate, lanceolate to broad lanceolate, (dimensions to 16 cm long × 3 cm wide), discolorous, glossy green (Brooker and Kleinig, 1999). Inflorescences are 7-11 flowered with a flattened peduncle. Buds are sessile to shortly pedicellate, pyriform to 9 × 4 mm; the operculum is conical or slightly beaked; flowers are white. The fruit are woody capsules with a short pedicel or almost sessile, abconical to slightly pyriform, to 8 × 7 mm; valves 3 or 4, with thin pointed tips which are exserted and erect or outcurved (Brooker and Kleinig, 1999).

Like other eucalypts, E. saligna does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). In natural stands in Australia the flowering period is from January to April (summer and autumn) with ripe seed available November to March (Boland et al., 1980; Brooker and Kleinig, 1999). In its natural habitat, E. saligna usually bears heavy seed crops only every 2-3 years. The seed is brown, cuboid or flattish, irregular and somewhat toothed around the edge (Boland et al., 1980). There will be regional and seasonal variability in seed availability.

E. saligna and E. grandis are sometimes almost identical in appearance except for the valves of the fruit which are broadish, blunt and incurved for E. grandis and thin, pointed and strongly erect or outcurved for E. saligna. Also, E. saligna possesses lignotubers, which are absent on E. grandis.

Natural occurrence

In Australia E. saligna is a common species along the coast and nearby ranges from near Batemans Bay in southern New South Wales to around Maryborough in southeastern Queensland (Figure 15.1). Further north there are a few isolated, disjunct occurrences on coastal and inland high country including Kroombit Tops, the Blackdown Tablelands and Consuelo Tablelands (Brooker and Kleinig, 1994). These populations are outside the core populations (Burgess and Bell, 1983) and they share a number of features with the closely related E. grandis (Boland et al., 1984). The natural latitudinal range of E. saligna is 24-36°S, which overlaps with E. grandis in northern New South Wales and southern Queensland (Eldridge et al., 1993).

The climate is mostly warm humid. Frost frequency varies from nil in low altitude, coastal areas to more than 60 yr⁻¹ in localities on the eastern side of the northern tablelands in New South Wales (Boland et al., 1984).

Figure 15.1: Natural distribution of Eucalyptus saligna (Jovanovic and Booth, 2002)
Eucalyptus saligna grows in open or tall open forest with other notable eucalypt species and sometimes with E. grandis. It is found on drier sites, higher up the slope above the lower valley slopes dominated by E. grandis (Eldridge et al., 1993). In the south of its range E. saligna occurs in valleys and on sheltered slopes and in northern localities it extends to high slopes and ridges (Turnbull and Pryor, 1984). This species grows well on good quality alluvial sandy loams; other soils include podsols and volcanic loams. Soils are generally moist and well drained. E. saligna does not do well on waterlogged sites or heavy clay soils.

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for Eucalyptus saligna, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>700-2300 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, summer, winter</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-6 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>23-34°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>-1-17°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>10-22°C</td>
</tr>
</tbody>
</table>

Figure 15.2: Areas predicted to be climatically suitable for Eucalyptus saligna are shown in black (Jovanovic and Booth, 2002)

The map of areas predicted to be climatically suitable for planting E. saligna (Figure 15.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Minimum rainfall required is about 700 mm, and best growth occurs on sites with >900 mm mean annual rainfall.

Other considerations for choice of this species are that while it is suited to a variety of soil types, E. saligna prefers deep sands, clay-sandy loams and alluvial soils. It does not tolerate poor drainage and the survival rates of plantings on shallow soils or hillsides has been very low in north-eastern Victoria (Washusen and Reid, 1996; Bird, 2000).
Plantings and provenance trials

Plantings

Jacobs (1981) estimated that by the late 1970s at least half a million hectares of successful E. saligna plantations had been established outside of Australia, particularly in South America, southern Africa, India and Sri Lanka. It has also experienced some success in the warmer parts of both the north and south islands of New Zealand (McKenzie and Hay, 1996) and was previously one of the preferred eucalypt species in these locations, with >1000 ha being planted in plantations and farm woodlots by 1996. However, interest in E. saligna has declined since then due to persistent attack by a range of insect pests and slower growth than expected (Hay et al., 1999).

The staff of the Forest Products Commission in Western Australia have identified E. saligna as a species with sawlog potential on moderately fertile soils in 600-700 mm rainfall areas (FPC website, 2002). In eastern Gippsland, Victoria, E. saligna was identified as one of three better-performing species on medium rainfall (600-700 mm) sites of lower productivity (deep sands) along with E. botryoides and E. grandis (Duncan et al., 2000). In south-western Victoria it has also been identified as having sawlog potential (Bird, 2000). E. saligna is not currently included in the plantation programmes of either the Queensland (David Lee, Queensland Forest Research Institute, pers. comm., 2002) or New South Wales (Ian Johnson, State Forests of New South Wales, pers. comm., 2002) state forestry organisations.

Provenance trials

In general the results of provenance trials indicate that provenances from northern populations (i.e. Queensland) of E. saligna are not suited to southern Australia (Victoria and South Australia) except when irrigated. However, it is likely that provenances from northern populations will be better suited to summer rainfall sites in northern Australia (Skolmen, 1986; Burgess, 1988). No recommendation of particular provenances is possible at present as trial results have not shown any to be consistently better in growth or form.

In early results (3 and 4 years) of E. saligna and E. grandis provenance trials in Queensland (Peachester, north of Brisbane) and on the north coast of New South Wales (Coffs Harbour), E. saligna provenances matched the growth of E. grandis sources at the Queensland site but did not perform particularly well at the Coffs Harbour site. At the Queensland site the provenances ‘Cascade’ New South Wales, ‘Gibraltar Range’ New South Wales, ‘Kenilworth’ Queensland, ‘Wollemi’ New South Wales and ‘Gladfield’ Queensland, were amongst the leaders for diameter growth (Burgess, 1988). As a result of the poor performance of E. saligna (insect problems and slower growth than other species) in these trials and other plantings on ex-forest sites, this species is not being planted to any extent by State Forests of New South Wales. It has recently been included in trials on ex-pasture sites but these are too young to assess as yet (Ian Johnson, State Forests of New South Wales, pers. comm., 2002).

Four provenances of E. saligna were included in a eucalypt species and provenance trial at Mt Gambier, South Australia, in 1979. The trial site soils were deep, moderately fertile, sands and the average annual rainfall is 710 mm. The four provenances included three from New South Wales and the New Zealand land race ‘Bartlett’s Strain’ (Cotterill et al., 1985). The ‘Batemans Bay’, New South Wales, provenance was the best performer of the four provenances at all measurement ages and ranked around ninth for volume at 4 years. However, all provenances of E. saligna dropped in ranking by 8 years with species like E. nitens and E. globulus subsp. globulus outperforming them (David Sheriff and David Gritton, CSIRO Division of Forestry, pers. comm., 1993).

On high-rainfall sites (900-1200 mm MAR) in north-eastern Victoria, the provenance from ‘Batemans Bay’ (south of Sydney, coastal New South Wales) was consistently superior to ‘Beaumont’ (inland from Nowra, New South Wales) (Stackpole et al., 1995).

E. saligna was included in species and provenance trials on seven sites in Gippsland, Victoria, and results of the trials at 10-12 years were reported by Duncan et al. (2000). There were large differences among seven seedlots, one from Queensland, five from New South Wales and one New Zealand land race. The mean annual rainfall of the sites ranged from 600 to 1200 mm. Comparisons were difficult because only two seedlots were planted at all sites,
but New South Wales seedlots were generally better than the New Zealand land race which in turn was better than the outlying Queensland population from the ‘Blackdown Tableland’. The better performing provenances included ‘Wandandian’, ‘Batemans Bay’ and ‘Glenn Innes’, all from New South Wales. These trials identified *E. saligna* as one of three species most suited to a lower rainfall (600-700 mm) site on deep sands in the Gippsland region (Duncan et al., 2000).

A series of trials established at six sites in the Hamilton region of south-western Victoria found no significant difference between provenances of *E. saligna* for growth or form at 3-4 and 6 years of age. These were lower-rainfall sites (650-800 mm) and the provenances tested were all from New South Wales including ‘Armidale’, ‘Coffs Harbour’, ‘Bulahdelah’, ‘Mt Boss State Forest’, ‘Termell’ and ‘Clyde River-Yadboro’. There were differences in growth between sites, with this species doing best on the relatively fertile sites with sandy loam soils (heights of up to 11.2 m at 6 years). In these trials *E. saligna* exhibited better frost tolerance than *Corymbia maculata* (spotted gum). At 6 years some borer damage has been identified, particularly at one of the lower-rainfall (~650 mm) sites where trees were clearly stressed (Jackson et al., 2000; Tim Jackson, DSE Victoria, pers. comm., 2002).

**Breeding and genetics resources**

*Eucalyptus saligna* and *E. grandis* were not recognized as separate species until 1918 when *E. grandis* was separated (Jacobs, 1981). Exports of *E. saligna*/*E. grandis* seed from Australia up to that time carried the name of only one species, *E. saligna*.

There are some populations at the southern end of the range of *E. saligna* (Nowra to Batemans Bay, New South Wales) intermediate between this species and *E. botryoides*, with rough bark covering much of the trunk (Boland et al., 1984; Passioura and Ash, 1993; Brooker and Kleinig, 1999).

Individuals intermediate in morphology between *E. saligna* and *E. grandis* occur in some populations of the former (e.g. in central eastern Queensland). These may represent relict ancestral populations, long-term stabilized hybrid populations or more recently established hybridised populations (Burgess and Bell, 1983). According to Griffin et al. (1988), seven hybrid combinations have been recognized as occurring in nature including the intergrade with *E. botryoides*. However, no natural hybrids have been recorded between *E. saligna* and *E. grandis* or produced by hand pollination (Eldridge et al., 1993), although spontaneous hybrids have been reported from plantations in South Africa and Florida (Griffin et al., 1988). Spontaneous hybrids with *E. urophylla* have occurred in Brazil (Eldridge et al., 1993). One of the best known artificial hybrid combinations involving *E. saligna* is *Eucalyptus 12ABL* (*E. tereticornis* × *E. saligna*) which is propagated clonally and used in pulp- and fuel-wood plantations in the Congo (Hamel and Laclau, 1996).

Despite the clearing of many local areas for farmland, the conservation status of the remaining natural forests of *E. saligna* is reasonably good. In addition, the species is very widely planted and seed orchards of *E. saligna* have been established in Brazil and Zimbabwe (Eldridge et al., 1993).

The CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra can supply both single-tree and bulk-tree provenance collections of seed from natural stands of *E. saligna* suitable for trials and breeding programmes. Improved seed is currently not available within Australia, but progeny trials are being established in 2002; at the earliest seed from these would be available by 2007 (Chris Harwood, Forestry and Forest Products, pers. comm., 2002).

Staff from the Forest Products Commission of Western Australia have recently established seedling and clonal seed orchards of *E. saligna* and are preparing to establish further progeny trials. They currently have seed available from natural provenance collections of a better performing provenance identified in breeding trials in Western Australia. They also have seed collected from trees in the best families in their breeding trials (Liz Barbour, Forest Products Commission, pers. comm., 2002).

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.
Propagation

*Eucalyptus saligna* is easily raised from seed in the nursery. There are about 500,000 viable seed kg⁻¹ of seed and chaff mixture (Gunn, 2001). As seed is different in size to chaff, seed lots may be cleaned to a high level of purity by sieving. Seed storage is orthodox and the viability of seed stored dry (5-8% moisture content) in airtight containers in the refrigerator (3-5°C) will be maintained for several years. No pre-sowing treatment is required.

*Eucalyptus saligna* is suited to mass vegetative propagation through stem cuttings and can be propagated by air-layering and grafting (see review by Hartney, 1980). It can also be regenerated by coppicing the stump but the value of this needs to be considered in light of the cost of protecting the stumps at harvesting and thinning the coppice. The other consideration is the possible loss of gains in productivity that might be achieved from the use of improved seed or provenances for subsequent rotations.

Planting stock is usually raised in containers in the nursery. General nursery practices are suitable for producing containerised seedlings of the species. These are described in texts such as Florence (1996), Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

In the cool, moist conditions of New Zealand, *E. saligna* can be raised successfully in open nursery beds and established as open-rooted planting stock. This method has also been successfully employed in Benalla, Victoria in 1990-92 (Des Stackpole, Sustainability and Environment Victoria, pers. comm., 2002). Regular root pruning is a critical part of the process (Barr, 1971). Planting of open-root stock is best done under moist, cloudy, frost-free conditions.

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. saligna*. Detailed information on various establishment practices is available from several sources including government organisations (Sustainability and Environment, Victoria; Queensland Department of Primary Industries), farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these publications can be obtained by contacting the organisations directly.

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used a spacing of 3.5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha⁻¹) and 4 m x 2.5 m (1000 trees ha⁻¹). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha⁻¹ (Bird, 2000).

Many overseas plantings that are managed for lower-value products such as pulpwood, mining timber, charcoal or fuelwood aim to produce logs of small diameters and to maximise biomass. For this, closer spacings and short rotations are usually employed, e.g. spacings of 2.1 m x 2.1 m (2.4 m x 2.4 m in drier areas) with second and subsequent rotations regenerated by coppice thinned to two or three stems per stump (Jacobs, 1981; Hillis and Brown, 1984).

In South Australia and Western Australia planting is carried out in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, (or July-August in warmer districts where soils dry out earlier). Planting in northern latitudes, such as in Queensland, is carried out during the wet season between November-April, but February-April is preferred.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites, and soil
degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site, and readers should access further information from more detailed references such as Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

Management
Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques.

Eucalyptus saligna sheds branches well, especially in plantations at high rainfall sites, but tends to develop heavy branches when planted in wide spaced rows or open-grown, and at lower rainfall sites. Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). Branches should be removed before their diameters exceed 2.5 cm as large stubs increase the risk of fungal infection and stem decay (Nicholas, 1992; McKenzie and Hay, 1996).

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter growth of individual stems. The stand may be reduced to a final stocking of 100-300 stems ha⁻¹ when grown for sawlogs.

Regeneration of cut stumps should be controlled by grazing of new shoots by animals, poisoning or mechanical damage of coppice (Bird, 2000).

Growth
Growth data for plantation grown E. saligna is not available for Australia. In New Zealand E. saligna is reported to be capable of producing high volumes over a short rotation (McKenzie and Hay, 1996). Growth tapers off after about 10 years, and MAIs over the longer rotations (e.g. 50 years) required for sawlog production in countries such as New Zealand are usually in the range of 12-18 m³ ha⁻¹ yr⁻¹ (Turnbull and Pryor, 1984; McKenzie and Hay, 1996).

Growth rates of E. saligna in Western Australian plantings in 450-550 mm rainfall areas have been between 5.6 and 10.1 m³ ha⁻¹ (Table 15.1) (Bird, 2000).

Mean annual increments at 7-8 years of age for E. saligna in irrigated species and provenance trials at Shepparton, Victoria, were 10 and 18 m³ ha⁻¹ yr⁻¹ respectively (Des Stackpole, Sustainability and Environment Victoria, pers. comm., 2002).

Protection
In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the

<table>
<thead>
<tr>
<th>Site location</th>
<th>Age (yr)</th>
<th>Rainfall (mm)</th>
<th>Initial stocking (trees ha⁻¹)</th>
<th>Current stocking (trees ha⁻¹)</th>
<th>MAI (m³ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-east of Perth</td>
<td>12</td>
<td>550</td>
<td>333</td>
<td>125</td>
<td>5.6</td>
</tr>
<tr>
<td>North-east of Perth</td>
<td>8.5</td>
<td>450-500</td>
<td>–</td>
<td>106</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Table 15.1: Mean annual increment of E. saligna on two sites in Western Australia (Bob Hingston, CALM Western Australia, pers. comm., 2002)
control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use. 

Eucalyptus saligna is moderately susceptible to pests and diseases, particularly in coastal northern New South Wales and Queensland and when suffering drought induced stress.

Dieback disease has killed E. saligna in patches throughout natural stands in coastal New South Wales, the cause of which is unknown (Podger, 1973). Natural forests and plantations of E. saligna in New South Wales may be severely damaged by a wide range of insect pests amongst which are at least 16 species of psyllid (Hemiptera: Psyllidae) (Carne and Taylor, 1984; Stone, 1993, 1996; Farrow, 1996). Debilitated trees are then predisposed to attack by the eucalypt keyhole borer, Xyleborus truncatus, and to an associated brown-staining fungus, a combination often leading to death of trees (Moore, 1962).

The wood borer Phoracantha semipunctata (Cerambycidae), commonly called the longicorn beetle, is a serious pest of both natural and planted stands of E. saligna both in Australia and in other countries such as South Africa and USA (California) (Poynton, 1979; Carne and Taylor, 1984; Neumann and Marks, 1976; Hanks et al., 1995). A range of wood-boring Lepidoptera may occasionally cause severe log degrade of plantation E. saligna in Australia (e.g. xyloryctids such as Uzucha borealis and Cryptophasa melanostigma) (Carne and Taylor, 1984). Trees stressed by drought, particularly those planted on unfavourable sites, are very susceptible to attack (Carne and Taylor, 1984).

Heavy periodic Cardiaspina spp. psyllid infestation is characteristic of irrigated plantations of E. saligna around Shepparton and Deniliquin (Des Stackpole, Sustainability and Environment Victoria, pers. comm., 2002). Principal insect defoliators of juvenile E. saligna planted in Victoria include Phaulacridium vittatum (wingless grasshopper) and Phylacteophaga froggatti (leaf blister sawfly).

Armillaria luteobubalina has been associated with deaths of young trees of E. saligna in rehabilitation plantings in forests of E. marginata in south-western Australia (Shearer, 1995). Removal of stumps and roots of E. marginata, which are the sources of inoculum, is recommended. However, E. saligna is believed to be resistant to Phytophthora root rot.

Eucalyptus saligna is intolerant of salt-laden winds and saline irrigation water (McKenzie and Hay, 1996).

**Utilisation**

**Wood**

The heartwood is dark pink to reddish brown and the sapwood is paler and easy to distinguish. The sapwood is susceptible to attack by lyctus borers but can be preservative treated. The grain is usually straight but is occasionally interlocked causing ribbon figure on the quarter-cut face. It is moderately coarsely textured and gum veins are common (Keating and Bolza, 1982; Bootle, 1983; Boland et al., 1984; Hillis and Brown, 1984). The heartwood is moderately durable and the wood often contains gum veins (Turnbull and Pryor, 1984). The air-dry density of mature wood is about 850 kg m⁻³, but the density of rapidly grown wood from plantations is usually significantly less, i.e. nearer 500-600 kg m⁻³ (Bird, 2000).

Sawn wood is easily dried although timber from native stands can be slow, but suffers some collapse that appears as excessive shrinkage rather than collapse-checking as seen in ash eucalypts. Quarter-sawn boards (25 mm) are commonly air-dried to 25-30% moisture content before being dried to 12% in the kiln over five days and then reconditioned through steaming. E. saligna develops mature wood characteristics at an early age and logs can be back-sawn and dried when about 40 cm or more in diameter (Bird, 2000). The timber is relatively easy to work, fix, dress and finish and takes a good polish (Turnbull and Pryor, 1984). Darrow (1983) states that E. saligna is more suitable for sawn timber production than E. grandis as it is less prone to splitting and has a higher wood density.

In New South Wales in the past E. saligna timber from natural stands has been important for use in general construction, and particularly flooring. It is suitable for general building purposes, cladding, panelling, boatbuilding, for heavy furniture and for medium-density fibreboard and plywood (Bootle, 1983). In addition it may be used for
pulpwood, boxes and preservative-treated poles (Turnbull and Pryor, 1984; Wyk and Gerischer, 1994; Wachira et al., 1994). The heartwood is inclined to split which makes it unsuitable for girders. Young plantation-grown Sydney blue gum has great flexibility of end-use according to Waugh (1996), who rates it as ‘very good’ for round timbers, sawn engineering products, sawn appearance-products and engineering veneer products and ‘acceptable’ for fibre composites and paper. However, for most situations there are other species which grow faster and are more suitable for paper products.

The Forest Products Commission of Western Australia is planning sawing trials of plantation-grown wood later in 2002 (Liz Barbour, Forest Products Commission, pers. comm., 2002).

Non-wood

_Eucalyptus saligna_ is used in shelterbelts and makes a fine avenue tree (Poynton, 1979).

_Eucalyptus saligna_ 6-year-old break of slope planting 6 years with spotted gum at Holbrook NSW.

_Eucalyptus saligna_ produces a strongly flavoured, rather dark honey which frequently lacks density and does not store well (Clemson, 1985). Supply is also rather irregular.

_Eucalyptus saligna_ is not a candidate for production of essential oils because of low foliar oil concentrations (0.4%, fresh weight) (Boland et al., 1991).

**Limitations**

While it tends to be more frost and drought tolerant than its close relative _E. grandis_, it is slower growing and provides a denser wood that is less desirable for purposes such as pulp for paper production. There are still questions about its viability at lower rainfall sites as prolonged drought often leaves trees stressed and susceptible to disease and insect attack. End-splitting of logs shortly after felling may be a problem, especially in utilizing fast-grown plantation trees. Boards from the central part of the log are prone to split (Keating and Bolza, 1982; Bootle, 1983). In a New Zealand spacing trial, _E. saligna_ is intolerant of strong or salt-laden winds (McKenzie and Hay, 1996). McKenzie and Hay also record that in logs of _E. saligna_ high levels of growth stress are common; such stresses frequently cause brittleheart near the centre of the stem.

**Recommended Reading**


Rob C, in press. _Eucalyptus saligna_ (Sydney Blue Gum). Conservation and Land Management Farm Forestry, Katanning, Western Australia.


**References**


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


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16. *Eucalyptus sideroxylon* and *Eucalyptus tricarpa*

Red ironbarks

*Eucalyptus sideroxylon* A.Cunn. ex Woolls
*Eucalyptus tricarpa* (L.A.S.Johnson) L.A.S.Johnson and K.D.Hill

Adapted from Doran, 2000 and Stackpole, 2000.

Niche likely to be 400-600 mm rainfall areas in southern Australia, with *E. tricarpa* the better option in Western Australia, South Australia, Victoria and New South Wales below 34°S latitude and *E. sideroxylon* suited to areas in central western New South Wales north of 34°S latitude.

Species overview

Red ironbark is the common name for two eucalypt species, *E. tricarpa* and *E. sideroxylon*. *E. tricarpa* was formerly considered to be a sub-species of *E. sideroxylon*. *E. sideroxylon* is a relatively slow growing, coppicing species of indifferent form, but some provenances of *E. sideroxylon* do have good form. The form of *E. tricarpa* is typically better than that of *E. sideroxylon*, and it can attain a height of between 25-35 m but averages around 20 m. The red ironbarks have been planted widely for farm forestry purposes in drier parts of southern Australia, but not yet on a large scale. They have good growth on siltstone-derived soils of drier hills, though they are not suited to areas subject to seasonal waterlogging or salinity. They often perform very well on sites somewhat better in quality than their natural stands, and may be useful for planting in areas where eucalypts that are more demanding have failed. This could include sites where *E. globulus* has proven to be insufficiently hardy to survive on periodically droughty sites (Bush et al., 2001).

The timber, although difficult to work, is very heavy, hard and durable and is used in general construction, particularly where durability is important. It is also becoming increasingly popular as a fine furniture and joinery timber due to its deep-red colour and its ability to polish to a high finish (Boxshall and Jenkyn, 2000). However, care is required in drying and some difficulties may be encountered with gluing. The tree also has ornamental value; a red flowering form is used in horticulture. It also makes a good shelterbelt tree and is an excellent honey producer.

Key features

Small to medium-sized, occasionally tall forest tree of potentially good form (the form of *E. tricarpa* is typically better than that of *E. sideroxylon*, and provenance selection and silvicultural management should improve the form for both species)

Slow to moderate growth rate

Tolerant of drought and hot conditions

Tolerates low temperatures and moderate frosts when young

Adapted to wide range of soils and tolerates poor, shallow soils, but not tolerant of seasonal waterlogging

Exhibits low to moderate salt tolerance

Timber is used in general construction, flooring and decking, poles and posts, fine furniture and joinery

Plantation-grown timber is likely to be of a lighter colour than the deep red of timber from natural stands

Good shelterbelt species

Excellent honey producer

Valuable firewood and wildlife species; very important for endangered regent honeyeater
Description and natural occurrence

Description

*Eucalyptus sideroxylon* is a small to medium-sized woodland tree, commonly 10-25 m tall with exceptional specimens reaching 35 m, and with diameters (at breast height) up to 1.0 m. The form of the trunk is often rather poor, while the length does not usually exceed one-half of the tree height. *E. tricarpa*, a species of open forest, is of better form and attains 10-35 m in height, with an average around 20 m.

The ‘ironbark’ is persistent to the larger branches, hard, ridged and deeply furrowed, dark brown to black, with upper limbs covered in a smooth whitish bark. The ‘ironbark’ of *E. tricarpa* is dark grey to black.

Like other eucalypts the red ironbarks do not develop resting buds and grow whenever conditions are favourable (Jacobs, 1955). The juvenile leaves of *E. sideroxylon* are linear to narrow-lanceolate while those of *E. tricarpa* are narrow to broad-lanceolate. Adult leaves of *E. sideroxylon* are dull green glaucous or slate grey while those of *E. tricarpa* are dull green or rarely glaucous. Inflorescences are axillary and 7-flowered in *E. sideroxylon* and 3-flowered in *E. tricarpa*. Buds are on long slender pedicels with no scar. *E. sideroxylon* flowers are white, pink, red or pale yellow with a flowering period May-November; *E. tricarpa* flowers are white, rarely pink, with a flowering period June-February. Fruit are truncate-globose or in *E. sideroxylon* can also be barrel-shaped or cupular (Brooker and Kleinig, 1999).

Distinctive features are the ‘ironbark’ which is the blackest bark of all eucalypts, the pendent buds and fruits, the persistent outer opercula, staminodes and persistent staminal ring (Boland et al., 1984).

Seed is grey-brown, slightly flattened, and almost smooth (Boland et al., 1980; Brooker and Kleinig, 1999). *E. sideroxylon* seed is collected between July-May and *E. tricarpa* seed is collected between November-May (Gunn, 2001). As seed crops may be retained on the tree for 3-4 years, collections may be possible in other months (Stackpole, 2000). There will be regional and seasonal variability in seed availability.

Natural occurrence

With a latitudinal range of 25-36°S in Australia *E. sideroxylon* extends north from Wangaratta in Victoria through New South Wales and into southern Queensland (Figure 16.1). It occurs on the

![Eucalyptus sideroxylon buds and fruits, Jimberoo, NSW.](image1)

![Eucalyptus sideroxylon natural stand in Blow Clear West State Forest, near Parkes, NSW.](image2)
western slopes and plains of New South Wales and its easterly occurrences are located near Sydney and the Hunter valley (Boland et al., 1984). It is also widespread in south-eastern Queensland west of the Great Dividing Range; its extension into northern Victoria is small. *E. tricarpa* occurs in central Victoria on the low ridges and undulating country that extends inland of the Divide. It is also found in the near-coastal regions of southern Victoria, Gippsland, and south-eastern New South Wales (Boxshall and Jenkyn, 2000) (Figure 16.2). It has an approximate latitudinal range of 35°30’-38°15’S.

The climate over the natural range of *E. sideroxylon* is largely warm sub-humid but the species extends to the warm humid and warm semi-arid zones. The species experiences various rainfall regimes from winter, through uniform and summer and an extended dry season depending on provenance. *E. tricarpa* occurs in the warm sub-humid zone and experiences both winter and uniform rainfall regimes over its range. It can also experience an extended dry season in some parts of its range (Boland et al., 1984).

Both species are typically found on poor, shallow soils, including sands, gravels, ironstones and clays (Boland et al., 1984). *E. tricarpa* reaches its largest size and best form on fertile loams in East Gippsland (Stackpole, 2000).

**Where will it grow?**

### Eucalyptus sideroxylon

A climatic profile (Jovanovic and Booth, 2002) for *E. sideroxylon*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>350-1340 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Uniform, winter,</td>
</tr>
<tr>
<td></td>
<td>summer</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-12 months</td>
</tr>
<tr>
<td>Mean maximum temperature</td>
<td>24-34°C</td>
</tr>
<tr>
<td>hottest month:</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>0-13°C</td>
</tr>
<tr>
<td>coldest month:</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>12-23°C</td>
</tr>
</tbody>
</table>

J Particular care should be taken when planting the species in low-rainfall environments to ensure that local conditions are suitable and appropriate planting densities are used.

K Absolute minimum temperature may limit establishment (i.e. frosts). This may be closely related with mean minimum temperature.

The map of areas predicted to be climatically suitable for planting *E. sideroxylon* (Figure 16.3) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution,
on the basis of information from trials and plantings of this species both within and outside its natural range. Although this map indicates that *E. sideroxylon* is climatically suited to areas of Western Australia, South Australia and Victoria, trials in Western Australia and Victoria have identified *E. tricarpa* as being particularly well suited to hot and dry conditions in winter rainfall areas and it has been the better performer of the two species in trials in these states (ALRTIG website, 2002; Bird, 2000). However, *E. sideroxylon* does better in the uniform-summer rainfall areas of New South Wales.

**Eucalyptus tricarpa**

A climatic profile (Jovanovic and Booth, 2002) for *E. tricarpa*, based on data from the natural distribution, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th></th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall:</td>
<td>520-1095 mm</td>
</tr>
<tr>
<td>Rainfall regime:</td>
<td>Uniform, winter</td>
</tr>
<tr>
<td>Dry season length:</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month:</td>
<td>22-30°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month:</td>
<td>2-6°C</td>
</tr>
<tr>
<td>Mean annual temperature:</td>
<td>12-15°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *E. tricarpa* (Figure 16.4) was generated from the climatic details for the species natural distribution, as listed above (Jovanovic and Booth, 2002).

**Plantings and provenance trials**

**Plantings**

The acceptable growth in, and tolerance of, dry conditions, some frost and poor shallow soils has seen the red ironbarks widely planted in other parts of the world, e.g. parts of Africa, South America, Israel and India.

*Eucalyptus sideroxylon* has had reasonable to good success in Mediterranean countries, South Africa, Brazil, Zimbabwe and the Congo. It grows well on dry sites in Hawaii. *E. tricarpa* has been tried in many arid zones of the world as part of species introduction trials, notably in Israel and Chile, where it is considered a candidate for afforestation in 200-400 mm rainfall zones. It has also been successful in plantations, usually where mean annual rainfall is within the range of 400-600 mm with a winter maximum. This includes parts of South America (Jayawickrama et al., 1993), South Africa (Murless, 1994), Kenya (Berger and Lysholm, 1978), India (Gogate and Dhaundiyal, 1988), Morocco (Knockaert, 1984), Botswana (Lepetu, 1998) and Tunisia (Zednik, 1978).

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**Figure 16.3:** Predicted areas climatically suitable for *E. sideroxylon* are shown in black (Jovanovic and Booth, 2002)

**Figure 16.4:** Predicted areas climatically suitable for *E. tricarpa* are shown in grey (Jovanovic and Booth, 2002)
Provenance trials

Considerable variation was indicated between provenances of both species in plantings in Central Victoria (Bird, 2000). However, few comprehensive provenance trials, as a basis for properly assessing the potential of the species, have been reported on. Provenance trials of both species have been established in Western Australia (Wellington catchment), South Australia (Kersbrook), and Victoria (Shepparton, Kerang, Nathalia, Rutherglen and Hamilton). 

*E. tricarpa* appears the better performer at Wellington, Western Australia and Hamilton, Victoria. However, most trials to date include only a limited number of provenances and it is only in the last two years that more comprehensive trials have been established in Victoria and New South Wales. These include three *E. tricarpa* provenance-progeny trials which were established in New South Wales and Victoria in 2000 by the Australian Low Rainfall Tree Improvement Group (ALRTIG) (David Bush, Australian Low Rainfall Tree Improvement Group, pers. comm., 2002).

In the provenance trials conducted in Western Australia, four provenances of *E. tricarpa* and 5 provenances of *E. sideroxylon* were tested. The trial site was situated in the Wellington catchment east of Manjimup and had a mean annual rainfall of around 650 mm. These trials were assessed at 6 years of age. The ‘Bodalla’, New South Wales, ‘Orbost’ and ‘Bendigo’, Victoria, provenances of *E. tricarpa* were consistently good performers in terms of height and diameter growth, and also had the highest proportion of single-stemmed trees. One provenance of *E. tricarpa* (from ‘Anglesea’, Victoria) was consistently slower growing and had much poorer form. All of these *E. tricarpa* provenances grew faster than the five provenances of *E. sideroxylon*, with ‘Wangaratta’ (Killawarra forest, Victoria) the best of the latter species (Stackpole and Harwood, 2001).

In Greening Australia trials established on the north-west slopes of New South Wales, *E. sideroxylon* has been one of the best-performing species, although form is usually poor (but correctable) (David Carr, Greening Australia, pers. comm., 2002).

In a breeding strategy for *E. tricarpa*, Stackpole and Harwood (2001) describe the target planting areas as follows: in Victoria, (i) the 500-800 mm rainfall zone, on mudstone bedrock/sedimentary undulating terrain, in both inland and coastal districts; (ii) country where species such as *E. globulus* have been tested for groundwater control, such as break of slope country in northeast Victoria; and (iii) the inland slopes of the Campaspe, Loddon and Avoca river headwaters in central Victoria, where former ironbark country was cleared for light pasture (the last probably has the most potential). Note that in areas where *E. tricarpa* was formerly naturally occurring, deployment of exotic provenances might be considered inappropriate due to concerns about pollution of remnant natural genetic resources. Therefore, in these areas improvement might be restricted to selection of a broad base of superior material within local provenances. This approach will result in minimal disruption to local genetic structure, in the event of cross pollination to natural stands (Stackpole and Harwood, 2001).

In South Australia and Western Australia *E. tricarpa* is of great interest in areas with less than 650 mm annual rainfall. In Western Australia it requires good, relatively deep soil and does not perform at all well when planted in periodically waterlogged soils. For this reason this species might be planted on upper slopes in a complementary arrangement with river red gum (*E. camaldulensis*) or swamp yate (*E. occidentalis*) in the low-lying areas (Bush et al., 2001; Stackpole and Harwood, 2001).

In New South Wales, there is significant target plantation area. The species would be suited to replanting of recharge areas in low-rainfall water catchments (in the New South Wales part of the Murray Darling Basin for example). Target regions with suitable soils and conditions would include parts of the Riverina and the south west slopes (Stackpole and Harwood, 2001).

Breeding and genetic resources

Depending on site and silviculture, *E. tricarpa* seedling seed orchards may be expected to yield at least moderate seed crops from age 6-8 years (Stackpole and Harwood, 2001).

Seed of *E. tricarpa* collected from trees of superior form in natural and planted populations (Victorian plus tree collection) is available from CSIRO Forestry and Forest Products Australian Tree Seed Centre.
The first round of improved seed of this species is expected to be available in 2007 through the Australian Low Rainfall Tree Improvement Program and the CSIRO Forestry and Forest Products, Australian Tree Seed Centre (ALRTIG website, 2002).

A range of natural provenances of *E. sideroxylon* is also available from the CSIRO Forestry and Forest Products Australian Tree Seed Centre. Three seedling seed orchards of this species will be established in New South Wales in 2002 by ALRTIG (ALRTIG website, 2002).

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

*E. sideroxylon* seed has an average viability of 230 000 kg\(^{-1}\) and *E. tricarpa* seed has an average viability of 140 000 kg\(^{-1}\) (Gunn, 2001). Seed storage is orthodox. Seed of *E. sideroxylon* (2 seedlots) was stored at 18-22°C for 5 years without dropping below 60% viability in a storage trial at CSIRO. Only one seedlot of *E. tricarpa* was trialled and its viability dropped to 38% in this time (Gunn, 2001). Stackpole (2000) notes that *E. tricarpa* will keep in good condition for several years if stored refrigerated at 3-5°C in an airtight container. No pre-treatment is required for seed of either species and the recommended temperature for germination is 20°C, although no other temperatures have been tried for *E. tricarpa*.

The species is easily raised from seed in the nursery following the general methods for eucalypt propagation (Doran and Turnbull, 1997; Bird, 2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Under suitable conditions plantable size is reached within 6 months of sowing. *E. tricarpa* can be successfully grown as open root stock (Stackpole, 2000). Direct seeding of this species has not proven reliable (Boxshall and Jenkyn, 2000).

The rooting of stem cuttings of both species has been moderately successful in preliminary trials at CSIRO Forestry and Forest products, with *E. sideroxylon* achieving 28% and 4% respectively in two trials and *E. tricarpa* achieving 9% and 17% in the same two trials. The trials tested one provenance of each species alongside known easy-rooting species. The easy-rooting species had high rooting percentages (*E. grandis* 85% and *E. camaldulensis* 76%), which showed that techniques used were suitable for them. Further trials are planned with adjustments to the techniques in an attempt to improve the rooting success of species such as *E. sideroxylon* and *E. tricarpa* (Brammall and Harwood, 2000).

Stackpole (2000) notes that *E. tricarpa* will keep in good condition for several years if stored refrigerated at 3-5°C in an airtight container. No pre-treatment is required for seed of either species and the recommended temperature for germination is 20°C, although no other temperatures have been tried for *E. tricarpa*.

These species coppice vigorously and very persistently, and also tolerate lopping well (Poynton, 1979). Native stands of *E. tricarpa* are usually managed on a coppice system for wood production (Stackpole, 2000). However, the value of using a coppicing system needs to be considered in light of the cost of protecting the stumps at harvesting, thinning the coppice and the possible loss of gains in productivity that might be achieved from the use of improved seed or provenances for the next rotation.

**Establishment**

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for the red ironbarks. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these documents can be obtained by contacting the organisations directly.
Seedlings can be hand-planted or planted by machinery. To allow machinery to be used a spacing of 3-5 m between rows should be used (Weiss, 1997). No spacing prescriptions have been formalized for planted stands, but they should be readily derivable from existing systems (Stackpole, 2000). Knockaert (1984) tested three square planting spacings (1111, 625 and 400 stems ha$^{-1}$) of *E. sideroxylon* in Morocco and found the densest stocking preferable for volume production, but that 625 stems ha$^{-1}$ produced better piece size (individual log size). A range of spacings and planting designs are possible in farm forestry plantings in Australia. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha$^{-1}$) and 4 m x 2.5 m (1000 trees ha$^{-1}$). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha$^{-1}$ (Bird, 2000).

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia planting commonly occurs in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes usually occurs once the summer rains have begun between November-April.

Ritson *et al.* (1991) obtained growth responses from *E. tricarpa* to water-soluble nitrogen and phosphorus compounds applied within one month of planting, with continuing effect for three years. Application of potassium may also be beneficial in some cases (e.g. on duplex soils in Victoria) as well as addition of trace elements such as iron, copper and boron when required (Stackpole, 2000). However, it is not common to apply fertiliser on ex-pasture sites as it could result in problems with toxicity.

**Management**

Experience in South Africa showed that while fairly erect, *E. sideroxylon* generally has a slightly sinuous or sometimes even crooked bole which, nevertheless, under plantation conditions is usually clean to about half-height. Forks may be somewhat numerous, particularly in the region of the crown. Branching, on the other hand, is comparatively light, and the tree has a compact, often rather sparsely-foliaged crown when raised in stand form. As is to be expected, free-growing individuals have more robust limbs and fuller, denser heads of intermediate spread (Poynton, 1979).

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques in a farm forestry context. Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter of individual stems.

Bird (2000) comments that while red ironbarks are slow-growing, mature trees attain a good height...
and diameter and exhibit a considerable degree of natural branch shedding. Heavy form-pruning helps to some extent in correcting faults. Washusen et al. (2000) state that while unmanaged *E. sideroxylon* trees produced a moderate recovery of high-grade sawn boards, pruning would have markedly improved the recovery rate.

**Growth**

Growth data for plantation grown *E. sideroxylon* and *E. tricarpa* is not available for Australia. In species trial tests at Shepparton (Stackpole and Hamlet, 1999), volumes of 2 m³ ha⁻¹ were recorded at age two years, but these are very early results and unreliable for prediction of the likely performance over a rotation (Stackpole, 2000). In the trials in the Wellington catchment (Western Australia) measured at six years, *E. sideroxylon* averaged just under 1 m mean annual height increment and *E. tricarpa* just over 1 m mean annual height growth. Poynton (1979) noted that in South Africa *E. sideroxylon* seldom maintained a mean annual height growth of more than 1 m over the first decade. Based on estimates of volume growth in natural forests of central Victoria, it should be possible to obtain a mean annual increment of 2.5 m³ ha⁻¹. In planted stands where management, including thinning, fertiliser and weed management, as well as genetic selection, is carried out it should be possible to improve on these figures (Stackpole, 2000).

*E. sideroxylon* from Barraba, New South Wales, was included in two Greening Australia species trials in northern New South Wales. At the Tamworth site it had a mean height of 4.13 m (just under 1 m height growth per year) and mean diameter at breast height of 5.9 cm at 4.5 years of age. At the Wallangra site at five years of age it had a mean height of 5.7 m (just over 1 m height growth per year) and a mean diameter at breast height of 10.7 cm (David Carr, Greening Australia, pers. comm., 2002).

Results of a study by Washusen et al. (2000) suggest that a rotation of around 40 years would be desirable for *E. sideroxylon* as trees from a 26-year-old plantation had a lower recovery rate than the 40-year-old trees.

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In general, *E. sideroxylon* and *E. tricarpa* are robust species which are rarely significantly affected by insects or pathogens. Common pests of ironbark include the steel blue sawfly and lerpS, though trees may host a number of other sap-sucking and leaf-feeding insects. Sawflies (*Perga* species) have a voracious appetite and in heavy attacks stands can be defoliated. Lerp insect (psyllid) numbers can periodically increase, subjecting the host plant to a cycle of defoliation and recovery. These outbreaks may last for 2-3 years while environmental conditions are favourable. Severe infestations may cause some dieback and combined with other stresses may seriously weaken the host tree. Relying on natural predation is currently the only practical form of control (Boxshall and Jenkyn, 2000).

*E. sideroxylon* is a preferred host of Christmas beetles. Weather is the major controller of beetle numbers; outbreaks often occur when wet summers follow the break of a drought and can last several years. Insecticidal control of Christmas beetles in young plantations and farm tree plantings is sometimes warranted during outbreaks to prevent severe defoliation. No products are currently registered for control of Christmas beetles in south-eastern Australia but Farrow (1996) outlines treatments used successfully in experimental situations. In Christmas beetle prone
areas the planting of tolerant or resistant species and provenances of eucalypts is a better long-term strategy (Farrow, 1996).

Trees in higher rainfall and colder areas appear more prone to scale and associated sooty mould, psyllids and sawfly insects (Bird, 2000).

**Utilisation**

**Wood**

The sapwood is dull yellow and narrow. It is susceptible to *Lyctus* borer attack though amenable to impregnation with preservatives (Poynton, 1979; Boland et al., 1984). The heartwood is a dark earthen red with a fine, dense and often interlocked grain (Bird, 2000). It is very strong, very hard and very durable with an air dry density of around 1170 kg m\(^{-3}\) in natural stands (Boland et al., 1984). Plantation-grown timber will be lighter than that of older trees, and fiddleback may be a feature of certain trees. It has a high (Class 1) durability rating (Boxshall and Jenkyn, 2000).

Ironbark is relatively slow to air dry and care must be taken during the drying process to minimise surface checking. It can be air-dried with minimal degrade if handled carefully and initial air-drying is slow. Log ends should be sealed. Thick back-sawn boards are difficult to dry without degrade. It can also be successfully kiln dried, but due to its great density, severe final drying conditions may require humidity stress-relief and moisture-gradient equalization at the end of kiln-drying. The wood can be glued only with an epoxy resin (Pongracic, 1999). The lacquered surface resists mechanical damage well (Bird, 2000; Boxshall and Jenkyn, 2000).

The timber can be sawn for appearance-grade products using back-sawing strategies which have been shown to maximise the output of high quality products from small diameter eucalypts (Washusen et al., 2000). Forty-year-old *E. sideroxylon* from plantings in the southern Murray-Darling Basin had little degrade during drying and moderate green recoveries of select grade and better were produced (Washusen et al., 2000; Bird, 2000). Finished boards are often attractively figured and have a distinct lustre (Poynton, 1979). Ironbark can be sliced to produce veneers (Boxshall and Jenkyn, 2000).

Ironbark has been used for firewood, an application at which it excels and for which it is a preferred species in regions where it occurs. It is reported to have sold for $105 tonne\(^{-1}\) from a merchant’s yard in Armidale, New South Wales (Bhati, 2001). Its hardness, strength and durability resulted in other early uses such as piles, poles, posts, bridges, wharves, mine timbers and props, railway sleepers and general construction. Its resistance to wear makes it suitable for a range of applications which more recently include droppers for electric fences, outdoor furniture, decorative picket fencing, flooring and decking, stair treads, bench tops and turned products, such as spokes, bearings and craftwood. There is also an increasing use of this wood for fine furniture (Bird, 2000; Boxshall and Jenkyn, 2000). It is preferred as a farm fencing timber due to its in-ground durability (David Carr, Greening Australia, pers. comm., 2002).

**Non-wood**

The species is hardy and relatively easy to establish on mine fill sites and should therefore be appropriate for reclamation planting. However, for water table control in saline environments *E. tricarpa* and *E. sideroxylon* are inferior to *E. occidentalis* and they are completely unsuited if there is seasonal waterlogging or salinity >5 dS m\(^{-1}\). Clifton (1992) suggests that *E. tricarpa* would be very appropriate for break of slope plantations for recharge control. Species tried previously, mainly *E. globulus* proved to be too prone to drought death (Stackpole, 2000).

*E. sideroxylon* is widely used as an ornamental and for cut foliage in Australia and overseas. Cultivars have been selected from the red flowering form. Although *E. tricarpa* is not formally recognized in the nursery trade, it is highly likely that this species has been included in nursery trade collections (Stackpole, 2000). It is often selected for avenue plantings due to the striking appearance of the bark (David Carr, Greening Australia, pers. comm., 2002).

The species is important for honey production (Cremer, 1990). The endangered regent honeyeater depends on *E. sideroxylon* in New South Wales as a food source during its breeding season, where it migrates in response to flowering. The prolific nectar is also utilised by a number of other birds, such as honeyeaters and rainbow lorikeets (David Carr, Greening Australia, pers. comm., 2002).
Limitations

The species’ intolerance of waterlogging, poor tolerance of salinity and moderate growth will exclude it from some of the key tree planting sites, particularly discharge sites, in the 400-600 mm rainfall zone. Poor form, particularly of *E. sideroxylon*, may also limit its inclusion in plantings until selection and breeding provides access to improved germplasm. In the short term, the use of severe form pruning may assist with this problem (Bird, 2000).

Recommended Reading


References


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


17. *Eucalyptus smithii* R.T. Baker

**Gully gum**

Adapted from Doran, 2000.

### Key features

- Generally a medium to tall tree, 20-45 m in height, of reasonable to good form
- Moderate to fast growth
- Good frost tolerance
- Excellent coppicing ability
- Potential for pulp wood production
- A good source of commercial quantities of 1,8-cineole essential oil
- A possible niche is cold, moderate-rainfall (700-1000 mm MAR) sites in south-eastern Australia, perhaps for a combination of products such as pulpwood, essential oil and/or firewood.

### Description and natural occurrence

#### Description

*E. smithii* is a medium-sized to tall forest tree, usually attaining 20-45 m in height and 0.5-1.5 m in diameter at breast height with a long, well-shaped bole. On marginal sites it can be reduced to a small tree 10 m high with a short stout bole and heavy branching. A mallee form of the species is found in the upper Snowy River area near the border between New South Wales and Victoria. *E. smithii* has a covering of tightly-held, thick, longitudinally fissured, dark brown rough bark over part or most of the trunk. The mallee form has smooth bark throughout (Boland *et al.*, 1984; Brooker and Kleinig, 1999).

Juvenile leaves are sessile, amplexicaul, opposite for many pairs, lanceolate green (dimensions to 8 cm long x 1.3 cm wide). Adult leaves are stalked,
alternating, narrow-lanceolate, concolorous, dull, green (dimensions to 20 cm long x 1.5 cm wide). Inflorescences are axillary, unbranched, 7-flowered on stalks. Buds are pedicellate, clavate, diamond-shaped or ovoid with a scar present; operculum conical.

Like other eucalypts gully gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowers are white and flowering occurs December to January. Fruit are stalked, subglobular or hemispherical to campanulate with a steeply ascending, broad disc and 3 exserted valves. Seed is brown-black, flattened and shallowly reticulate (Brooker and Kleinig, 1999). Seed is collected between September and May in natural stands (Gunn, 2001). The species is reported to be shy to seed in Swaziland, Africa (Doran, 2002). There will be regional and seasonal variability in seed availability.

**Natural occurrence**

*Eucalyptus smithii* occurs on the eastern side of the Central and Southern Tablelands of New South Wales, south from Yerranderie to eastern Victoria, south of the Howe Range and the Angora Range; it also grows as a smooth-barked mallee in the upper Snowy River area (Brooker and Kleinig, 1999) (Figure 17.1). The latitudinal range is 34°S to 38°S. It occupies sites on lower slopes, near water courses and swamps and sometimes on scarps and ridges, on clay loam and sandy loams in tall open forest.

**Where will it grow?**

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus smithii*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climate Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>610-1930 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-6 months</td>
</tr>
<tr>
<td>Mean maximum temperature</td>
<td>20-27°C</td>
</tr>
<tr>
<td>hottest month</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>-3-7°C</td>
</tr>
<tr>
<td>coldest month</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>7-17°C</td>
</tr>
</tbody>
</table>

Figure 17.1: Natural distribution of *Eucalyptus smithii* (Jovanovic and Booth, 2002)

Figure 17.2: Areas predicted to be climatically suitable for *Eucalyptus smithii* are shown in black (Jovanovic and Booth, 2002)
The map of areas predicted to be climatically suitable for planting *E. sideroxylon* (Figure 17.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range.

Jacovelli (2002) gives the minimum mean annual rainfall for planting *E. smithii* in Africa as 850 mm, and rates the species as moderately hardy to drought, and very hardy in terms of frost tolerance. The species prefers good loamy soils or sandy loams with clay subsoil where the soil never dries completely. However, it is capable of growing on a wide range of soil textures as long as they are moderately fertile (Boland et al., 1984; Boland et al., 1991).

**Plantings and provenance trials**

**Plantings**

*Eucalyptus smithii* is widely planted in South Africa for timber purposes and in the eastern Transvaal it is harvested for its high-cineole essential leaf oil (Coppen and Hone, 1992). It has also been trialled and/or planted in other African countries such as Angola, Malawi, Rwanda, Swaziland, Tanzania, Zaire and Zimbabwe for oil production. However, the poor economic climate in the late 1980s and 1990s – poor oil prices and rising production costs – meant either that full scale oil production never materialised (e.g. in Tanzania) or that some production ceased (as in Swaziland). In South Africa, the area of eucalypt plantations dedicated primarily to oil has now reduced to about 1800 ha, most of the reduction occurring in *E. smithii* (Jacovelli, 2002).

### Table 17.1: Best performing *Eucalyptus smithii* provenance at each of three trial sites in the ACT (Clarke et al., 1997)

<table>
<thead>
<tr>
<th>Best Provenance</th>
<th>Age (yr)</th>
<th>Site Name</th>
<th>Rainfall (mm)</th>
<th>Soil Type</th>
<th>Mean DBH (cm)</th>
<th>Mean Height (m)</th>
<th>Mean Height of Best Seedlot at Site (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Dromedary, New South Wales</td>
<td>12</td>
<td>Uriarra</td>
<td>700</td>
<td>Sandy loam</td>
<td>17.8</td>
<td>16.9</td>
<td>16.9</td>
</tr>
<tr>
<td>Mittagong, New South Wales</td>
<td>12</td>
<td>Uriarra</td>
<td>700</td>
<td>Sandy loam</td>
<td>17.4</td>
<td>13.8</td>
<td>16.9</td>
</tr>
<tr>
<td>Mt Dromedary, New South Wales</td>
<td>12</td>
<td>Kowen</td>
<td>450-500</td>
<td>Sandy loam</td>
<td>13.2</td>
<td>8.3</td>
<td>12.7</td>
</tr>
<tr>
<td>Mittagong</td>
<td>12</td>
<td>Stromlo</td>
<td>600-650</td>
<td>Sandy clay loam</td>
<td>11.6</td>
<td>8.2</td>
<td>10.6</td>
</tr>
</tbody>
</table>
E. smithii is also planted in Asia (China), Africa, North America (Hawaii), South America, Australia (New South Wales and Victoria) and New Zealand.

Provenance trials

No comprehensive provenance trials of E. smithii have been reported and where provenances have been compared across sites in trials there has been no consistency in their performance.

Eucalyptus smithii was included in species and provenance trials in the Australian Capital Territory on three sites of varying rainfall. The three provenances included were ‘Bombay Rd’, ‘Mt Dromedary’ and ‘Mittagong’, New South Wales (Table 17.1). It performed best at the high-rainfall site at Uriarra with the ‘Mt Dromedary’ provenance being the highest ranking of all 120 species and provenances trialled at this site (based both on height and an index combining diameter at breast height and survival). At the lower-rainfall sites it did not perform as well against other species but all three provenances were ranked in the top third (Clarke et al., 1997).

E. smithii was included in species and provenance trials on seven sites in Gippsland, Victoria, and results of the trials at age 10-11 years were reported by Duncan et al. (2000) (Table 17.2). The three seedlots included were ‘Albion Park’ near Wollongong and ‘Bodalla’, New South Wales, at five sites, and ‘Mt Buck’ north of Orbost, Victoria, at seven sites. E. smithii ranked well at most sites, doing best compared to other species at the 690-1000 mm MAR sites on sandy clay loams. It performed poorly on the sandy Stradbroke site with low-rainfall and had its best growth at the high-rainfall site of Mt Worth East, but other species outperformed it at this site. There was no consistent pattern in the ranking of the E. smithii provenances across sites and at most sites the performance of all provenances was fairly similar, except at the Flynn’s Creek site where the ‘Mt Buck’, (Orbost, Victoria) provenance was inferior.

Where E. smithii has been grown on favourable sites in Central and Southern Africa this species has often produced higher biomass yields (wood and foliage) than other eucalypts. It appears to be a fairly

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Age (yr)</th>
<th>Site Name</th>
<th>Rainfall (mm)</th>
<th>Soil Type</th>
<th>Approx. Stem Volume (m³ ha⁻¹)</th>
<th>Approx. Stem Volume of Best Seedlot at Site (m³ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albion Park, New South Wales</td>
<td>11</td>
<td>Mt Worth East</td>
<td>1210</td>
<td>Clay loam</td>
<td>370</td>
<td>550</td>
</tr>
<tr>
<td>Mt Buck, Victoria</td>
<td>11</td>
<td>Delburn</td>
<td>1000</td>
<td>Clay loam</td>
<td>300</td>
<td>320</td>
</tr>
<tr>
<td>Albion Park, New South Wales</td>
<td>11</td>
<td>Flynn’s Creek</td>
<td>760</td>
<td>Sandy loam</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Albion Park, New South Wales</td>
<td>11</td>
<td>Stradbroke</td>
<td>600</td>
<td>Loamy sand</td>
<td>130</td>
<td>270</td>
</tr>
<tr>
<td>Bodalla, New South Wales</td>
<td>11</td>
<td>Stockdale</td>
<td>690</td>
<td>Loamy sand</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Albion Park, New South Wales</td>
<td>10</td>
<td>Waygara</td>
<td>870</td>
<td>Sandy clay loam</td>
<td>140</td>
<td>180</td>
</tr>
<tr>
<td>Mt Buck, Victoria</td>
<td>10</td>
<td>Tostaree</td>
<td>820</td>
<td>Loamy sand</td>
<td>310</td>
<td>370</td>
</tr>
</tbody>
</table>
consistent species throughout its natural range with regard to oil yield and cineole content, though there is some variation between and within provenances in terms of other factors like biomass production and frost tolerance. Provenance trials in Swaziland found the best overall performers came from ‘Tallaganda’ State Forest and ‘Narooma’. In South African trials ‘Larrys Mountain’ and ‘Mount Dromedary’ were the best-performing provenances in terms of growth performance and frost tolerance (Jacovelli, 2002).

In China, *E. smithii* has been identified through provenance trials as having great potential as a multi-purpose crop for fuelwood, pulpwod, fibreboard furnish and essential oil production due to its growth rate, biomass yields and wood production.

**Breeding and genetic resources**

The China Eucalypt Research Centre has developed a breeding program for improvement of this species for oil production (Chen, 2002).

A range of natural provenances of *E. smithii* is available, for establishing trial plantings, from the CSIRO Forestry and Forest Products, Australian Tree Seed Centre.

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

There are about 300,000 viable seed kg$^{-1}$ of seed and chaff mixture. No pre-sowing treatment is required and rapid and complete germination is achieved under moist, warm (20-25°C optimal in the laboratory) conditions in the presence of light (Gunn, 2001). Seed storage is orthodox and seed can be stored for several years in cool dry conditions provided their moisture content is kept below 8%.

In South Africa, *E. smithii* is rated as a difficult species to root from cuttings (Jacovelli, 2002). Shoot tip cuttings of *E. smithii* have been successfully propagated by the Oxford Forestry Institute. The Oxford Forestry Institute has also managed up to 67% success rooting shoot cuttings taken from seedlings grown from commercial seed, although there was marked variation in the rooting ability of clones. These results indicate that there is a possibility of using micropropagation for the rapid multiplication of selected oil-producing eucalypts (Jacovelli, 2002).

*Eucalyptus smithii* is a strongly coppicing species and this characteristic is exploited in its management for essential oil production.

General nursery practices are suitable for producing containerised seedlings of *E. smithii*. These are described in texts such as Florence (1996), Doran and Turnbull (1997) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

**Establishment**

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. smithii*. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website http://www.dse.vic.gov.au/), or these documents can be obtained by contacting the organisations directly.

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used a spacing of 3.5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantations. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m × 3 m (1111 trees ha$^{-1}$) and 4 m × 2.5 m (1000 trees ha$^{-1}$). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha$^{-1}$ (Bird 2000).

If growing specifically for oil production the objective of the plantation is to maximise leaf biomass rather
than woody material. Stocking densities higher than those usually employed for wood production have been tried with a view to achieving this. In Swaziland one grower planted at a spacing of 3.0 m x 1.5 m (2222 stems ha\(^{-1}\)) and Jacovelli (2002) suggests that even higher densities might be effective (even greater than 10 000 stems ha\(^{-1}\)). However, the sustainability of such high a stocking would need to be evaluated and tested on various sites (Jacovelli, 2002).

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia planting commonly occurs in June-July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes usually occurs once the summer rains have begun between November-April.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on expasture sites, and soil degradation can result from very large applications of nitrogen fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting, e.g. water availability (low rainfall or heavy weed competition are two factors that can affect this). Application rates vary widely depending on the site, and readers should access further information from more detailed references such as Dell et al. (1995), Attiwill and Adams (1996) and Nambiar and Brown (1997).

**Maintenance**

In South Africa the bole of *E. smithii* has tended to be slightly sinuous and apt to fork, and its branches to be ascending and frequently a little heavy. Also, dead stubs have tended to persist for some years (Poynton, 1979). The relatively poor wood quality of this species means that the cost of thinning and pruning may not be warranted as its likely range of products are firewood and rough farm timbers. When grown for pulpwood or firewood a coppice rotation of 10-15 years, as suggested by Noble (2002) for *E. globulus* subsp. *globulus* for southeastern Australia, may be appropriate for *E. smithii*. Further discussions of theory, objectives and techniques for pruning and thinning are given in Bird (2000) and Reid and Stephen (2001).

If managing for oil production a coppice system is often employed. Research in Swaziland found that the first rotation (seedling crop) should be longer (20-30 months, depending on the growth rates) than the subsequent coppice cycle. Presumably this gives the root system time to develop and become better able to support the subsequent coppicing. In Swaziland, the *E. smithii* coppice was cut on a cycle of 12-18 months, depending on growth rates. This cycle was based on the time taken to reach canopy closure. The number of times a crop can be coppiced depends on stocking levels, the coppicing ability of the species and the nutrient status of the site. In Southern Africa *E. smithii* plantations have been repeatedly harvested for oil for over 20 years with little apparent loss of stool vigour. As a general rule plantations with less than 75% stocking should be replanted. In Swaziland the stems were typically cut about 15 cm above the ground (Jacovelli, 2002).

Mechanical harvesting has not been considered appropriate or cost effective under African conditions to date. *E. smithii* is not as suited to mechanical harvesting as tough mallee species such as *E. polybractea* (Jacovelli, 2002).

**Growth**

There are no growth rates available for plantations of *E. smithii* in Australia. However, the range of mean annual increments for *E. smithii* at 10-11 years of age in species and provenance trials in Gippsland, Victoria, was 11.9-34.9 m\(^3\) ha\(^{-1}\) (Duncan et al., 2000).

**Protection**

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of
managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment, not planting the species on sites that are marginal for it, and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

There is little information on the susceptibility of this species to insects and pathogens in Australia due to limited planting to date.

In South Africa the species appears to be very susceptible to diseases, notably pathogenic fungi causing root rot and stem cankers (Jakovelli, 2002).

Utilisation

Wood

The heartwood of E. smithii is pale pink and easy to distinguish from the cream-coloured or bluish-grey sapwood. The wood is close-grained, interlocked, heavy, hard and moderately durable but not very strong. The sapwood is subject to Lyctus attack (Poynton, 1979; Boland et al., 1984; Cremer, 1990). Although E. smithii can produce reasonably straight stems, the wood splits badly and it can have spiral grain (Poynton, 1979; Jakovelli, 2002). The wood is difficult to work but is used to some extent for construction purposes (Poynton, 1979; Cremer, 1990).

Planted trees of 14-year-old E. smithii from two trial sites in the ACT were found to have basic densities of 552-568 kg m⁻³. Pulpwood evaluation tests carried out on these trees indicated it has considerable potential as a pulpwood species, ranking above E. nitens (a commercially important pulpwood species) at both ACT trial sites. Hicks and Clark (2001) note that E. smithii is already extensively planted in South Africa for this purpose and that further tree breeding work may be necessary to improve the form of trees from some provenances. Clarke et al. (1999) also report results of South African trials of nine species on two sites which were assessed for growth and pulp properties. They found E. smithii to be one of three most productive species in terms of growth and pulp properties. It had fast growth, high pulp yield and brightness but low alkali consumption and kappa number. The researchers also found that most variation in the commercially important properties (pulp yield, fibre mass per tree and alkali consumption) occurred between trees and suggested that the greatest gains from tree breeding were likely to be realized through selection of suitable individual trees from a range of provenances.

The timber has been utilised for fuelwood; round wood; pit props; sawn or hewn building timbers; exterior fittings; fences and pulp including short fibre pulp.

Non-wood

The leaves of E. smithii contain essential oil which has been extracted by commercial distillation in Australia in the past [Cremer, 1990] and was at one time the main commercial species grown overseas (Lassak, 1989). However, this distinction now belongs to E. globulus subsp. globulus. Boland et al. (1991) report that 1,8-cineole is the major component (75-84%) of the essential oil of E. smithii, with an oil yield based on fresh weight of 2.4-3.0%.

Other authors report oil yields of 1.0-2.2% and cineole contents of 70-80% [Poynton, 1979; Lassak, 1989]. The rectified oil is used in medicinal eucalyptus oil (Boland et al., 1991).

A range of oil yields have been reported, with the best such as the 600 kg of oil ha⁻¹ yr⁻¹ obtained in former Zaire, generally obtained from sites of high growth potential (e.g. deep, fertile soils and high rainfall). The average oil yield from 1979 to 1985 for plantations in Swaziland was 120 kg ha⁻¹ yr⁻¹. This was on sites with 845 mm MAR and an often prolonged dry season. This production can be compared with the yields obtained from natural stands of E. polybractea in Australia which are around 30-150 kg ha⁻¹ from an 18-month harvest cycle (Jakovelli, 2002).

A positive sign in the oil industry, as Jakovelli (2002) notes, is the resurgence in interest, mainly in developed countries, in natural products. Eucalyptus
oils have been increasingly used in a wide range of therapeutic products and applications, including aromatherapy. Aromatherapists sometimes prefer oil from *E. smithii* because of a perception that it is better tolerated by the skin (Beerling et al., 2002). However, as large quantities of eucalyptus oil are being produced by countries such as China, any decision to produce for this market should be carefully researched.

*Eucalyptus smithii* is a suitable tree for use in shelterbelts and windbreaks (Poynton 1979; Cremer, 1990).

**Limitations**

The relatively poor wood quality limits the range of products for which the timber can be utilised.

**Recommended reading**


**References**


18. *Eucalyptus tereticornis*

Forest red gum, blue gum

*Eucalyptus tereticornis* subsp. *tereticornis* Smith

*Eucalyptus tereticornis* subsp. *mediana* Brooker and Slee

Adapted from Doran, 2000.

**Species overview**

*E. tereticornis* is a versatile, fast growing and strongly coppicing tree species which is widely planted overseas. It has been especially successful in areas with summer rainfall followed by a moderate to severe dry season (seasonally-dry tropics), although fast-growing provenances adapted to a winter rainfall are also available from the southern part of its natural distribution.

Experience of growing the species in Australia does not mirror that from overseas. The species’ high susceptibility to insect and fungal attack in forestry trials and its poorer performance compared with other species make its use for high yield wood production untenable (Dickinson et al., 2001; David Lee, Queensland Forest Research Institute; Ian Johnson, State Forests of New South Wales and Des Stackpole, Sustainability and Environment,

**Key features**

- Fast growing tree of poor-moderate form
- Good drought tolerance
- Southern provenances can be frost tolerant
- Tolerant of seasonal waterlogging
- Strongly coppicing species
- Moderately salt tolerant
- Prefers fairly fertile well drained alluvial soils, sandy or gravely loams
- Some provenances are tolerant of very acid soils
- Suffers from wood borer and is very susceptible to some other insects and fungi
- Its susceptibility to insect attack has restricted is use for large scale wood production plantings
- A suitable firewood species
- An important habitat tree due to its hollow-forming habit and its suitability as a food for koalas
- A major source of pollen for honey production.

*E. tereticornis* subsp. *tereticornis* natural stand in Queensland.
pers. comm., 2002). However, the species is a valuable tree for land rehabilitation and habitat as it has a hollow-forming habit and grows in difficult environmental conditions (Seamus Batstone, Department of Primary Industry Queensland, pers. comm., 2002). The timber from this type of planting is likely to be good for firewood, turning, outdoor furniture, fencing, posts etc.

*E. tereticornis* is generally regarded as moderately frost tolerant, while certain provenances with greater frost tolerance have been identified from the southern, temperate part of the species distribution. It is a moderately salt-tolerant species (Sun and Dickinson, 1995 and 1997); reduced growth can be expected at EC$_e$ of about 5-10 dS m$^{-1}$ and reduced survival above about 10-15 dS m$^{-1}$ (Marcar et al., 1995). The Loch Sport, Victoria, provenance occurs on highly acid soils with a pH down to 3.5, and some tropical provenances occur on acid soils e.g. provenances from Papua New Guinea grow on soils of around pH 4. These populations may have an application in plantings on acid sulphate soils (Lex Thomson, CSIRO Forestry and Forest Products, pers. comm., 2002).

*E. tereticornis* is proving a valuable partner in various hybrid combinations with other fast-growing eucalypts, including *E. grandis* and *E. urophylla*. Wood from natural stands and overseas plantings is used for a wide range of purposes including light and heavy construction, flooring, fencing, firewood, outdoor furniture, charcoal, paper, poles, posts, mining timber, hardboard and particleboard, while the tree is used for shelterbelts, shade and in apiculture.

**Description and natural occurrence**

**Description**

A medium-sized to tall forest tree attaining 20-50 m in height and up to 2 m in diameter. The trunk is usually straight and clear for more than half of the total height, with the major branches steeply inclined. Bark is shed in irregular plates leaving a smooth or granular, mottled surface of white, grey, dark grey and bluish patches over the trunk. The trunk may carry a short stocking of rough, dark grey to black dead bark (Boland et al., 1984; Brooker and Kleinig, 1999).

There have been changes to the nomenclature of populations of *E. tereticornis* and *E. camaldulensis* in far northern Queensland. Red gum populations in far northern Queensland formerly known as *E. tereticornis* are now regarded as belonging to *E. camaldulensis*, including the Laura, Palmer, Walsh rivers (*E. camaldulensis* subsp. *simulata* Brooker and Kleinig) and Kennedy and Morehead Rivers (*E. camaldulensis* subsp. *obtusa* [Dehnh.] Blakely), (Doran and Burgess, 1993; Brooker and Kleinig, 1994). The Victorian population of *E. tereticornis* has also been revised and is now regarded as a subspecies i.e. *E. tereticornis* subsp. *mediana* Brooker and Slee (Brooker and Kleinig, 1999).

Juvenile leaves are on stalks, ovate, bluish green or green (subsp. *tereticornis*) or glaucous (subsp. *mediana*), to 13 × 8 cm. The adult leaves are stalked, alternate, narrow-lanceolate to lanceolate, concolorous, green (dimensions to 22 cm long × 3 cm wide) (Brooker and Kleinig, 1999).

The inflorescences are axillary and unbranched, 7-11 flowered, on stalks 2.5 cm long. The buds are stalked, alternate, narrow-lanceolate to lanceolate, concolorous, green (dimensions to 22 cm long × 3 cm wide) (Brooker and Kleinig, 1999). The seeds are usually black with pitted surface and toothed edges.
Seed of *E. tereticornis* subsp. *mediana* are variable with mixed black, single-coated and yellow, double-coated seeds (Brooker and Kleinig, 1999).

This species, like other eucalypts, does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). In Australia the flowering period is from April to October (subsp. *tereticornis*) or November to January (subsp. *mediana*) (Brooker and Kleinig, 1999) with mature seed available from January to March (Boland et al., 1980). There will be regional and seasonal variability in seed availability.

### Natural occurrence

*E. tereticornis* has the most extensive latitudinal range (9°-38°S) of any species in the genus eucalypts. It occurs along the coast and on the adjacent hills and plains of eastern Australia with *E. tereticornis* subsp. *tereticornis* occurring from around Batemans Bay, New South Wales in the south to about Cooktown in far northern Queensland (Figure 18.1). *E. tereticornis* subsp. *mediana* occurs in the Bairnsdale-Lakes Entrance area of eastern Victoria (Figure 18.1). Most populations occur within 100 km of the sea but the distribution extends further inland in Queensland; near Roma, Alpha, Charters Towers and Mt Surprise. *E. tereticornis* also occurs naturally in Papua New Guinea (Boland et al., 1984; Brooker and Kleinig, 1999).

The natural distribution of *E. tereticornis* ranges from monsoonal with a marked wet and dry season in Papua New Guinea and northern Australia to areas of summer rainfall in central and southern Queensland to uniform rainfall in temperate eastern Victoria (Eldridge et al., 1993). Coastal and lower elevations are frost free, but some inland sites may experience up to 30 frosts annually (Boland et al., 1984).

Alluvial flats subject to flooding are preferred by this species in low-rainfall regions. In higher-rainfall areas it grows on the lower slopes of hillsides and extends to mountain slopes and hillsides. Soils include rich alluvials, sandy or gravelly loams and seasonally waterlogged clays in forested wetlands (Boland et al., 1984; Stanley and Ross, 1986; Specht, 1990). A neutral or slightly acid pH is preferred (Marcar et al., 1995).

### Where will it grow?

Climate parameters for the natural distribution of both *E. tereticornis* subsp. *tereticornis* and *E. tereticornis* subsp. *tereticornis* are as follows (Tom Jovanovic, CSIRO Forestry and Forest Products, pers. comm., 2002):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>540-3180 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform/bimodal, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-8 months</td>
</tr>
<tr>
<td>Mean maximum temperature</td>
<td>21-35°C</td>
</tr>
<tr>
<td>hottest month</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>-1-17°C</td>
</tr>
<tr>
<td>coldest month</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>9-26°C</td>
</tr>
<tr>
<td>Absolute minimum temperature</td>
<td>-8°C</td>
</tr>
</tbody>
</table>

A climatic profile (Booth et al., 1988) for tropical *E. tereticornis*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key conditions for survival and good growth:
Mean annual rainfall: 580-2290 mm
Rainfall regime: Summer
Dry season length: not given
Mean maximum temperature hottest month: 28-36°C
Mean minimum temperature coldest month: 0-19°C
Mean annual temperature: 16-26°C

Figure 18.2: Areas predicted to be climatically suitable for *Eucalyptus tereticornis* are shown in black (Booth et al., 1988)

The map of areas predicted to be climatically suitable for planting tropical provenances of *E. tereticornis* (Figure 18.2) was generated from the revised climatic details for the species as listed above (Booth et al., 1988). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Overseas, *E. tereticornis* appears to grow best on well-drained, fairly light-textured soils in areas receiving an annual rainfall of >800 mm. It does, however, grow on a wide range of soils from light to heavy and is tolerant of seasonal waterlogging, moderate salinity (some provenances) and drought. A provenance of the species from Loch Sport, Victoria, has exhibited good tolerance to alkaline conditions and would be suitable to winter and uniform rainfall regions (Thomson, 1988). In Australia *E. tereticornis* has proven to be susceptible to insect and fungal attack on the coastal lowlands of Queensland and northern New South Wales. Insect attack has also been a problem in Victorian plantings.

### Plantings and provenance trials

#### Plantings

*E. tereticornis* was one of the earliest eucalypts exported as seed from Australia to various countries in the late nineteenth century, e.g. Pakistan, Ethiopia, Zimbabwe, Philippines, Uganda. Many of the early introductions into other countries were derived from very few original trees (Eldridge et al., 1993).

*E. tereticornis* has been especially successful when planted in areas with summer rainfall followed by a moderate to severe dry season (Eldridge et al., 1993). Davidson (1988) identified *E. tereticornis* as the third most important plantation species in the tropics with an estimated plantation area of 780 000 ha in 1980. It is also an important reforestation species in Sri Lanka, China, in South American countries such as Argentina, Bolivia, Brazil, Chile and Uruguay and in countries of central, southern and western Africa and the Pacific.

#### Provenance trials

Tree form and growth of *E. tereticornis* varies considerably according to provenance, as shown in the results of many provenance trials in many countries. The best provenances in overseas plantings for the wet-dry tropics are from near ‘Mount Garnet’, ‘Helenvale’, ‘Mareeba’ and ‘Ravenshoe’ in Queensland and from Papua New Guinea (Eldridge et al., 1993). In some instances growth rates can be impressive e.g. in Uganda, these provenances reached 14 m in height and 10 cm diameter after 4 years (J. Davidson data, cited in Eldridge et al., 1993).

Despite its promise *E. tereticornis* has not done well in trials in Australia to date. Its performance has been variable and has not reflected the performance of the species in overseas plantings.

The Queensland Forest Research Institute (QFRI) has tested *E. tereticornis* in over fifty species trials across northern New South Wales and southern Queensland in a large range of environments, and has two seed
orchards established. *E. tereticornis* was previously (in 1997) perceived to be a priority species suitable for ‘blue gum flats’, a land base that was plentiful, and was potentially available for plantation development. Across all these trials *E. tereticornis* has performed poorly relative to other species under test. It suffers from wood borer, is behind other species in growth and is susceptible to terps and *Mycosphaerella*. In north Queensland the species is doing better (Sun and Dickinson, 1997), but the spotted gums (*e.g.* Corymbia citriodora subsp. variegata), *E. pellita*, *E. cloeziana* and a range of Corymbia hybrids are doing better than *E. tereticornis* across all sites in replicated trials. As a result QFRI does not currently see a place for pure *E. tereticornis* in plantations, but some of the hybrids with *E. tereticornis* as a parent (see below) are showing potential (David Lee, Queensland Forest Research Institute, pers. comm., 2002).

The Department of Primary Industry Queensland is trialing *E. tereticornis* in several different areas. However, trials are only young and the provenance (Laura) that is doing well in a flood plain trial in the dry tropics of Central Queensland is now regarded as a subspecies of *E. camaldulensis*. Early data from a species trial on a tropical, coastal tablelands site (high rainfall, soil acidic with a pH 4-5 and very leached, high temperatures in summer and subject to quite severe frosts) shows a provenance from ‘Burdekin River’, Queensland, doing well with 92% survival and very competitive growth compared to the other 30 species. Further trials, being established this year, will include other provenances of *E. tereticornis* subsp. *tereticornis* (Seamus Batstone, Department of Primary Industry Queensland, pers. comm., 2002).

State Forests of New South Wales has done very little work with *E. tereticornis* to date. It has recently been included in species trials on poorer north coast sites but these have not been assessed yet (Ian Johnson, State Forests of New South Wales, pers. comm., 2002).

In Victoria its performance in several trials has been mediocre to very poor, insect attack being one of the major problems (Frank Hirst, Desmond Stackpole and Tom Baker, Sustainability and Environment Victoria, pers. comm., 2002). However, it would be a suitable farm forestry species for firewood production if routine silvicultural care were supplied (Des Stackpole, Forest Science Centre Victoria, pers. comm., 2002).

**Breeding and genetic resources**

*E. tereticornis* is of interest as a parent species in various hybrid combinations. It is being used in China with *E. urophylla* and the hybrid *E. urophylla* × *E. grandis* in an attempt to increase the resistance of these lines to termites, bacterial wilt and drought and to improve wood density and general adaptability (Xiang et al., 1996).

The hybrid *E. grandis* × *E. tereticornis* has demonstrated an ability to survive extended drought periods and to rapidly respond to improved soil moisture conditions when they occur in the Congo and Zambia (Turnbull and Pryor, 1984; Bouvet, 1997). Hybrids between *E. grandis* × *E. tereticornis* combine the good stem form and wood qualities of *E. grandis* and the drought resistance of *E. tereticornis* for planting in areas where there is a prolonged dry season and *E. grandis* cannot be grown (Venkatesh and Sharma, 1979).

Queensland Forestry Research Institute established trials on numerous sites to test suitability of eucalypt species, including interspecific hybrids from South Africa, for marginal subtropical environments in northeastern Australia. Early performance (two years of age) indicated that a hybrid of *E. grandis* × *E. tereticornis* was promising in a marginal inland environment of south-eastern Queensland (Lee et al., 2001). On the wetter coastal areas, however, the performance of these hybrids have been very poor, with much higher incidence of disease and insect attack (Dickinson et al., 2001).

State Forests of New South Wales also planted some *E. grandis* × *E. tereticornis* hybrids from South Africa in several trials near Casino, in 1998-99, and these were heavily attacked by insects. Most trees were reduced to runts or bushes and the few with any reasonable size and form at age 3-4 years are being attacked by borers. There are plans to include some hybrids of *E. grandis* × *E. tereticornis* from South Africa in trials in southern inland New South Wales, where insect pressures are probably lower. These will be planted in 2003-2004 (Ian Johnson, State Forests of New South Wales pers. comm., 2002).
Silviculture

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

Propagation

*E. tereticornis* is usually propagated from seed. There are an average of 600 000 viable seed kg\(^{-1}\) of seed and chaff mix (Gunn, 2001). No pre-sowing treatment is required and rapid and complete germination is achieved under moist, warm (25°, 30° or 35°C optimal in the laboratory) conditions in the presence of light. Seed storage is orthodox and seed viability will be maintained for more than 10 years if stored dry (5-8% moisture content) in airtight containers in the refrigerator (3-5°C) (Boland *et al.*, 1980).

*E. tereticornis* is relatively easy to propagate vegetatively. Grafting has also been successful, with good results using apical rind grafting in nursery beds (Martin, 1971; Fenton *et al.*, 1977). In this case scions should be taken from the basal part of young shoots about 3-5 mm in diameter and consist of a length of shoot with two leaves cut back to the petioles.

General nursery practices are suitable for producing containerised seedlings of *E. tereticornis*. These are described in texts such as Doran (1990) and Doran and Turnbull (1997). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Seedlings of *E. tereticornis* are planted out in the field when they reach a height of about 25 cm, which is usually around 3-5 months after sowing (Webb *et al.*, 1984). In tropical climates this should coincide with the onset of the wet season.

Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for *E. tereticornis*. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landscape groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. QFRI website http://www.dpi.qld.gov.au/hardwoods/qld/), or these documents can be obtained by contacting the organisations directly.

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used, a spacing of 3-5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m × 3 m (1111 trees ha\(^{-1}\)) and 4 m × 2.5 m (1000 trees ha\(^{-1}\)). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha\(^{-1}\) (Bird 2000).

Overseas, spacing and cropping systems are very variable - from community plantings around homes, villages and roads to closely-spaced commercial plantations - and depend on the end-products required. In India, when pulpwod and firewood are the principal objectives, a rotation of 5-6 years with a spacing of 1.5 m × 1.5 m is considered desirable (Tewari, 1992). Also in India, wider spacings of 4 m × 2 m or 6 m × 1.5 m are recommended when crops are to be grown between the tree rows during the first three years (Tewari, 1992).

On acid sulphate soil at Tan Tao, Vietnam, trees were planted on mounds to avoid waterlogging with a spacing of 1.5 m × 2 m (Nguyen Hoang Nghia, 1997).

Planting times in southern Australia vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia, planting commonly occurs in June-July whereas in many parts of Victoria and southern New South Wales planting would occur later, around September-October. Planting in northern latitudes usually occurs once the summer rains have begun between November-April, however February-April is preferred so that young seedlings will be exposed to a shorter period of high temperatures.
Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the successful establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites but there is often no response on ex-pasture sites and soil degradation can result from very large applications of nitrogen fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting, e.g. water availability (low rainfall or heavy weed competition are two factors that can affect this). Rates vary widely depending on the site and readers should access further information from more detailed references such as: Dell et al., (1995); Attiwill and Adams (1996) and Nambiar and Brown (1997).

Overseas E. tereticornis has been grown successfully under irrigation in places like India, Israel and Zimbabwe.

Management

Information on rotation age for Australia is not available but will vary with site quality and management objectives. Overseas, E. tereticornis is usually grown on a short rotation and clear-felled at an age that maximises production of logs of optimum size for a particular end use. This is usually small-diameter material suitable for pulpwood, mining timber, charcoal or fuelwood (Jacobs, 1981).

E. tereticornis regenerates by coppice and in India they expect to be able to regenerate from coppice at least three times (e.g. Gupta and Raturi, 1984). It is, however, a method of regeneration that is not likely to be employed much in Australia. Coppice management requires the reduction of the number of coppice shoots on a stool and this critical activity is time-consuming and expensive (Evans, 1982). The use of coppice will also mean missing out on the benefits of genetic improvement through tree breeding. The season in which the trees are felled affects the production of coppice regeneration. If trees are felled during the dry season, sprouting will be delayed and there is an increased risk of the stump drying out. Felling by saw to give a cleanly-cut short stump with minimum bark damage is best.

Growth

Growth data for plantation grown E. tereticornis is not available for Australia and with the insect and fungal problems it experiences in Australia stand productivity is likely to be considerably lower than the better yields achieved overseas.

Overseas, mean annual increments are very varied depending on site quality, climate factors such as rainfall, provenance used, stocking rate and plantation management. The mean annual increments (MAIs) for plantations, quoted in the literature, range from around 30 m³ ha⁻¹ in the Congo (for north Queensland provenances) down to 19.8-1.3 m³ ha⁻¹ for 8-year-old Indian plantations (Eldridge et al., 1993; Tewari, 1992). In a 12-year-old eucalypt species trial in north-eastern Mexico, 7.9 m³ ha⁻¹ yr⁻¹ of timber and 13.7 m³ ha⁻¹ yr⁻¹ firewood was produced (Foroughbakhch et al., 1997).

Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

In Australia, E. tereticornis has proven to be susceptible to Mycosphaerella species in trials in both Queensland and New South Wales. This fungus has also been a problem overseas, e.g. in South America. Overseas, tropical provenances of E. tereticornis show a higher degree of resistance than E. camaldulensis to leaf
spot and shoot blight caused by Cryptosporiopsis eucalypti. The capacity of this fungus to cause significant damage in red gum plantations in humid regions of Thailand and Vietnam has only recently been recognised (Sharma, 1994; Nguyen Hoang Nghia, 1997).

In Australia, E. tereticornis has a medium to high susceptibility to attack by a range of insect pests, particularly lerps (psyllids, Cardiaspina spp.) but also Christmas beetles (Anoplognathus spp. and Repsimus aeneus), leaf beetles (Paropsis spp. and Chrysophtharta spp.), sawflies (Perga, Pergagrapta and Pseudoperga spp.), gum tree scales (Eriococcus coriaceus and E. confusus), gumleaf skeletoniser (Uraba lugens), eucalypt weevils (Goniapterus spp. and Oxyops spp.), leaf-tying moth (Agrotera amatealis) and the defoliating, tessellated phasmatid (Cternomorphodes tessulatus) (Wylie and Peters, 1993). Bootle (1983) reported that the sapwood is sometimes susceptible to attack by Lyctus spp. Damage by wood borers has been observed both in Queensland and New South Wales trials of the species (David Lee, Queensland Forest Research Institute and Ian Johnson, State Forests of New South Wales, pers. comm., 2002).

Utilisation

Wood

The heartwood ranges from light to dark red, with a moderately coarse, uniform texture and interlocked grain. It is hard, strong and durable. The sapwood of E. tereticornis is distinctly paler than the heartwood and is grey or cream red in colour. The sapwood is sometimes susceptible to attack by borers (Lyctus spp.) but readily accepts preservative impregnation. Penetration of the heartwood with preservative is negligible using currently-available commercial processes (Queensland Department of Primary Industries, 1990). Density varies with tree age and environment. In areas of natural occurrence, green density is about 1200 kg m⁻³ and air-dry density about 1050 kg m⁻³ (Bootle, 1983). Overseas, the air-dry density of wood from fast-growing plantations is less and ranges from about 600-800 kg m⁻³ (Khan and Akhtar, 1973; Keating and Bolza, 1982).

In the southern USA the wood density of E. tereticornis was found to be substantially higher than for E. grandis or E. camaldulensis, making it particularly suitable for energy production (Franklin and Meskimen, 1975). The wood is susceptible to termite attack only rarely and is moderately resistant to marine organisms (Keating and Bolza, 1982). It has a durability rating of Class 1 and is highly resistant to decay in contact with the ground or in persistently damp or badly ventilated situations. Fast grown plantation trees, however, require preservation treatment for durability in the ground. E. tereticornis can be satisfactorily dried using conventional air and kiln seasoning methods. It is rated as very hard (rated 1 on a 6-class scale) in relation to indentation and ease of working with hand tools. The interlocked grain often makes it difficult to dress cleanly on the radial surface. It requires machining and surface preparation to be done immediately prior to gluing and readily accepts stain, polish and paint (Queensland Department of Primary Industries, 1990).

In Australia it is used in construction as a sawn timber for house framing, internal and external flooring, fencing and landscaping. It is also used for engineering purposes such as wharf and bridge construction, railway sleepers, piles and poles and for decorative work such as outdoor furniture, turnery and joinery (Queensland Department of Primary Industries, 1990).

Overseas, E. tereticornis is a major source of fuelwood, charcoal and timber for local use. It is also used for light and heavy construction, pulpwood and wood composite products and in India as raw material for the production of rayon grade pulp (Tewari, 1992; Boer, 1997).

Non-wood

Large quantities of crude E. tereticornis oil have been imported into Australia from China for medicinal use. These were rectified and later blended with locally-produced oils to achieve the required cineole content and levels of other compounds to enable them to meet overseas standards at a competitive price. In general the required 1,8-cineole content for medicinal oils is 70% (Lassak, 1989).
Boland et al. (1991) found that the volatile leaf oils of *E. tereticornis* collected from trees in northern Queensland and isolated by steam distillation contained the monoterpenoids 1,8-cineole [eucalyptol] (0.1-33%), limonene (4-19%), alpha-pinene (1-27%) and beta-pinene (0.1-18%) as principal components. The range in oil concentration was 0.9-1.4% (W/W%, fresh weight).

*E. tereticornis* is a major source of pollen in apiculture and produces a medium amber honey of distinctive flavour (Clemson, 1985). The wood and bark of the tree have a tannin content of 6-12% and 3-15%, respectively (Poynton, 1979), but are not used as a commercial source of tannin (Boer, 1997).

Some provenances (both tropical and temperate) have been found growing on highly acid soils with a pH down to 4-3.5, respectively, and may have a niche for reclamation of acid sulphate soils in coastal areas cleared for development (Lex Thomson, CSIRO Forestry and Forest Products, pers. comm., 2002).

This species has been used successfully to plant eroded gullies in Uruguay (Moron, 1961) and to reclaim low-lying areas in Argentina (Issa, 1959). It is widely used as a shelterbelt species and shade tree in countries such as India and Pakistan. *E. tereticornis* was used successfully for sand dune reclamation in Uruguay, when grown in association with *Dodonea viscosa* and other species (Caldevilla, 1962).

*E. tereticornis* is used as a pioneer species on tailings at the Bougainville copper mine, Papua New Guinea. This requires the regular application of N, P and boron (Hartley, 1977).

It is a large ornamental tree suitable for parks and a very important food tree for koalas (Wrigley and Fagg, 1996). Open eucalypt woodland comprising *E. tereticornis* is a suitable habitat for the common striped possum (*Dactylopsila trivirgata*) in far northern Queensland (Handasyde and Martin, 1996).

**Limitations**

Despite its widespread success overseas *E. tereticornis* has not done well in trials in Australia. Its use for wood production seems limited, with its main disadvantages being its susceptibility to heavy attack by lersps, *Mycosphaerella* fungi and wood borer.

**Recommended Reading**


**References**


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


19. *Eucalyptus viminalis* Labill. subsp. *viminalis*
Manna gum, ribbon gum, white gum
Adapted from Doran, 2000.

Key features

Medium-sized to tall tree of excellent form on suitable sites
Capable of achieving fast growth
Suited to cool, temperate environments
Very frost tolerant
Minimum annual rainfall for good growth 700 mm on deep moisture-holding soils
Prefers soils of moderate to high fertility
Tolerates a short to moderate dry season
Very susceptible to insect pests
Non-durable timber
Used for furniture, panelling, internal flooring, building framing, pulp
Popular food source for koalas, gliders and possums.

Species overview

*Eucalyptus viminalis* subsp. *viminalis* is suitable for planting in cool, temperate environments with an annual rainfall greater than 700 mm, a short to moderate dry season, and where frost tolerance is a required attribute. This is a fast-growing species suitable for use in plantations for sawn timber, pulp and paper production and fuelwood. It is also useful for windbreaks, shade and shelter, honey, wildlife (it is a favoured food for koalas and gliders), and for amenity plantings in parks and reserves. The other subspecies, although slower growing and of poorer form than subsp. *viminalis*, are also occasionally planted as a substitute where conditions for tree growth are too dry or soils too infertile for subsp. *viminalis*. This species is subject to predation by a wide range of insect pests. Trials have shown significant variation between provenances in growth rate, form and frost tolerance, indicating that provenance trials are essential when introducing this species to new areas. It tolerates fire and is suitable for coppicing.

Description and natural occurrence

Description

*Eucalyptus viminalis* subsp. *viminalis* is a medium-sized to very tall forest tree, usually in the range of 15-40 m tall, but occasionally reaching 90 m in Tasmania, with diameters at breast height up to 3 m. This is a smooth, white to grey-barked tree except for a short stocking of rough bark. Long ribbons of partly shed bark are often retained in the crown; this is the origin of one of the species’ common names, ribbon gum. In tall open forest the form of this species is excellent, with clean straight boles for two-thirds of total tree height and a narrow crown. Form, however, varies markedly in *E. viminalis* subsp. *viminalis* and in dry woodland situations it often is a short, crooked, umbrageous tree. Populations in the north-eastern parts of the New South Wales northern tablelands are now described as *E. nobilis*, the main distinguishing features being that they have 7 buds in an umbel rather than the 3 typical of *E. viminalis* subsp. *viminalis*, are smooth barked
virtually throughout and have larger juvenile leaves (Johnson and Hill, 1990). The other subspecies, subsp. cygnetensis and subsp. pryoriana, are small to medium-sized woodland trees of largely coastal distribution in southern Australia (Eldridge et al., 1993; Brooker and Kleinig, 1999).

Juvenile leaves are sessile, amplexicaul, opposite for many pairs, lanceolate to broad-lanceolate, green (dimensions to 9 cm long x 2 cm wide). Adult leaves are petiolate, alternating, lanceolate to narrow lanceolate, often undulate. Axillary inflorescences are unbranched, 3 flowered. Buds are with or without stalk; scar present; operculum pointed-hemispherical or conical.

Like other eucalypts manna gum does not develop resting buds and grows whenever conditions are favourable (Jacobs, 1955). Flowers are white with a flowering period from November-May. Fruit are without or with short stalks, cupular or hemispherical with 3 or 4 exserted valves (Brooker and Kleinig, 1999). Seed is black, brown or grey, irregular, often pointed at one end; flattish to ovoid (oval shaped); with shallow pitting on the dorsal surface; smooth-edged (Roland et al., 1980; Brooker and Kleinig, 1999; Brooker et al., 2002). Seed is collected throughout the whole year (Gunn, 2001). Note that there will be regional and seasonal variation in seed availability.

Natural distribution

_Eucalyptus viminalis_ subsp. _viminalis_ is widely distributed in south-eastern Australia between latitudes 31°30’S and 43°S (Figure 19.1). It is found from the southern part of the Northern Tablelands of New South Wales southwards. It is common in the mountains and foothills of eastern Tasmania, several Bass Strait islands and southern Victoria. It also occurs in an isolated population in the higher parts of the Mt Lofty Ranges in South Australia. Previously the species was described as extending to the New South Wales and Queensland border but the populations in the northeastern Northern Tablelands of New South Wales are now known as _E. nobilis_. The altitudinal range is from sea level to 1400 m, with the highest occurrences in New South Wales and the Australian Capital Territory. The other two subspecies have a coastal distribution: _E. viminalis_ subsp. _cygnetensis_ is limited to Victoria and South Australia, while _E. viminalis_ subsp. _pryoriana_ is found in Victoria only. They intergrade with

Figure 19.1: Natural distribution of _Eucalyptus viminalis_ (Jovanovic and Booth, 2002)
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *Eucalyptus viminalis*, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>700-2500 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Winter, uniform, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature</td>
<td>21-32°C</td>
</tr>
<tr>
<td>hottest month</td>
<td></td>
</tr>
<tr>
<td>Mean minimum temperature</td>
<td>-4-9°C</td>
</tr>
<tr>
<td>coldest month</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>4-17°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *E. viminalis* (Figure 19.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. This species has often exhibited a combination of frost resistance and growth vigour as shown at

Figure 19.2: Areas predicted to be climatically suitable for *Eucalyptus viminalis* are shown in black (Jovanovic and Booth, 2002)

Jessievale, South Africa (Darrow, 1984), or Kunming in the People’s Republic of China (Wang et al., 1989). The upper limit for mean annual rainfall was increased from 2127 mm to 2500 mm with the inclusion of information from trials in Colombia (Restrepo and Atehorta, 1989).

Other factors such as soil requirements, occurrence of prolonged drought and *E. viminalis*’ susceptibility to insect pests (particularly when it becomes stressed due to drought) also need to be considered when deciding whether to plant this species. *E. viminalis* grows best on deep, moisture-holding soils of moderate to high fertility.

Plantings and provenance trials

Plantings

*Eucalyptus viminalis* is an important plantation species in temperate regions of a number of continents as it combines reasonably rapid growth, good form and acceptable wood characteristics with some degree of frost resistance (Eldridge et al., 1993). It is planted in Europe, southern Russia, Asia, Africa, North America (California, Florida, Hawaii), South America, Australia (New South Wales, South Australia, Victoria) and New Zealand. Its main use in overseas plantations is as a short-rotation fibre crop for paper pulp and hardboard production (Hillis and Brown, 1984).
Provenance trials

In general provenance trials of the species have been inconclusive, particularly because they have inadequately sampled the geographical range of the species and the provenances tested (many provenances were represented by five or fewer families) (Eldridge et al., 1993).

Studies of central Victorian provenances of *E. viminalis*, using a series of trials, concluded that ecological races (edaphic ecotypes) of *E. viminalis* exist and that they have arisen from the natural selection of plants in particular habitats. Field and laboratory trials found that generally seedlings performed best in an environment similar to that of their natural occurrence, showing adaptations to the particular environmental conditions involved (Ladiges and Ashton, 1974, 1977; Eldridge et al., 1993).

Careful selection of seed sources for a specific planting site will improve the success of this species given the variety of natural habitats in which it occurs and the demonstrated genetic differences in growth rate, form, resistance to insect attack, frost and drought tolerance, and adaptation to different soils types.

*Eucalyptus viminalis* subsp. *viminalis* was trialled on seven sites in Gippsland (Table 19.1) and results at 10-12 years were reported by Duncan et al. (2000). Seedlots from Victoria (11), New South Wales (2 – one of which was actually *E. nobilis*) and Tasmania (1) were tested but only seven were included on any one site. Growth was best on the high-rainfall, improved pasture site at Mt Worth East and poorest at the low-rainfall sites (600-760 mm). On the sites

Table 19.1: Best performing *Eucalyptus viminalis* provenance at each of seven trial sites in Gippsland, Victoria (Duncan et al., 2000)

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Age (yr)</th>
<th>Site name</th>
<th>Rainfall (mm)</th>
<th>Soil type</th>
<th>Approximate stem volume (m³ ha⁻¹)</th>
<th>Approx. stem volume of best seedlot at site (m³ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendoc, Victoria</td>
<td>11</td>
<td>Mt Worth East</td>
<td>1210</td>
<td>Clay loam</td>
<td>420</td>
<td>550</td>
</tr>
<tr>
<td>Warburton, Victoria</td>
<td>11</td>
<td>Delburn</td>
<td>1000</td>
<td>Clay loam</td>
<td>230</td>
<td>320</td>
</tr>
<tr>
<td>Morwell, Victoria</td>
<td>11</td>
<td>Flynns Creek</td>
<td>760</td>
<td>Sandy loam</td>
<td>110</td>
<td>200</td>
</tr>
<tr>
<td>Yarram, Victoria</td>
<td>11</td>
<td>Stradbroke</td>
<td>600</td>
<td>Loamy sand</td>
<td>140</td>
<td>270</td>
</tr>
<tr>
<td>Fingal, Tasmania</td>
<td>11</td>
<td>Stockdale</td>
<td>690</td>
<td>Loamy sand</td>
<td>90</td>
<td>170</td>
</tr>
<tr>
<td>Wye River, Victoria</td>
<td>10</td>
<td>Waygara</td>
<td>870</td>
<td>Sandy clay loam</td>
<td>130</td>
<td>180</td>
</tr>
<tr>
<td>Martha Vale, Victoria</td>
<td>10</td>
<td>Tostaree</td>
<td>820</td>
<td>Loamy sand</td>
<td>310</td>
<td>370</td>
</tr>
</tbody>
</table>
with an intermediate rainfall (Waygara and Tostaree) growth was better on the improved pasture site than the ex-native forest site. Most of the provenances at the Tostaree improved pasture site outperformed those at a higher rainfall eucalypt plantation site at Delburn. Provenance growth was similar within sites at the two high-rainfall sites and at the Waygara site. At other sites one or two provenances had significantly better growth than other provenances at those sites, but were not consistent across sites. ‘Martha Vale’ and ‘Wye River’, Victoria, were the best at the Tostaree site.

_Eucalyptus viminalis_ has been identified as a sawlog species for 600-700 mm annual rainfall areas on deep fertile soils by staff at the Forest Products Commission of Western Australia. They have identified a better-performing provenance from three replicated family/provenance breeding trials across the south-west of Western Australia, and a special seed collection was commissioned from this native stand. Special collections from above-average provenance stands that have been thinned for sawlog production are also available from the Forest Products Commission Seed Centre (FPC website, 2002).

Staff at Forestry South Australia list _E. viminalis_ as a species with potential for sawlog production in the Green Triangle region of southeastern South Australia and western Victoria. However, this is purely speculative in a commercial sense. _E. viminalis_ proved to be one of the fastest-growing species at age 4 years in a growth trial of 36 eucalypt species near Mt Gambier (Cotterill et al., 1985). Results of a further trial with 49 tree plots of six species, including _E. viminalis_ subsp. _viminalis_, found mean annual increments of approximately 25 m³ ha⁻¹ at seven years for all species (Forestry South Australia, 2002). Other information on the performance of _E. viminalis_ in this region is scarce.

**Breeding and genetic resources**

The species is generally well conserved with many natural stands in national parks, but some particular ecotypes may not be adequately protected (Eldridge et al., 1993).

Increased tolerance of frost, drought, adverse soil conditions and insect attack, combined with good growth, is unlikely to be found in the one provenance (Eldridge et al., 1993).

A range of natural provenances of _E. viminalis_ subsp. _viminalis_ for establishing trial plantings is available from the CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra. Seed selected for Western Australia is available from the Forest Products Commission Western Australia’s Seed Centre (FPC website, 2002).

**Silviculture**

General eucalypt silviculture is suitable for this species. Further information is available through sources listed under recommended reading. Summary silvicultural information and practices specific to this species are outlined below.

**Propagation**

There are about 300 000 viable seed kg⁻¹ of seed and chaff mixture. Suitable sieve mesh size for cleaning seed is 1.4-1.7 mm. No pre-sowing treatment is required and rapid and complete germination is achieved under moist, warm (25°C optimal in the laboratory) conditions in the presence of light (Gunn, 2001). Seed storage is orthodox and seed can be stored for several years in cool dry conditions provided their moisture content is kept below 8%.

General nursery practices are suitable for producing containerised seedlings of _E. viminalis_. These are described in texts such as Doran and Turnbull (1997), Florence (1996) and Bird (2000). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market.

The species coppices well from the stump but the value of using a coppice system needs to be considered in light of the cost of protecting the stumps at harvesting, and thinning the coppice. The other consideration is the possible lost gains in productivity that might be achieved from the use of improved seed or provenances for the second rotation.
Establishment

Locally successful methods of plantation establishment for a range of major forest tree species are suitable for E. viminalis. Detailed information on various establishment practices is available from several sources including government organisations (Queensland Department of Primary Industries; Sustainability and Environment, Victoria), and farm forestry and landcare groups. Books such as Florence (1996), Doran and Turnbull (1997) and Bird (2000) are also valuable resources. Websites of many of the above organisations have ‘Fact Sheets’ available (e.g. DSE website: http://www.dse.vic.gov.au/), or these publications can be obtained by contacting the organisations directly.

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used, a spacing of 3-5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs are possible in farm forestry plantings. Readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Suitable initial spacings for woodlots are 3 m x 3 m (1 111 trees ha⁻¹) and 4 m x 2.5 m (1 000 trees ha⁻¹). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha⁻¹ (Bird 2000).

Planting times in southern Australia with winter/uniform rainfall vary from early winter to early spring, predominantly determined by the severity of frost and minimum temperatures experienced. In South Australia and Western Australia planting commonly occurs in June-July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier.

Application of a ‘starter dose’ of nitrogen and phosphorus fertiliser soon after planting to assist early growth is common practice in the establishment of eucalypts in Australia and elsewhere. This is particularly effective on ex-forest sites, but there is often no response on ex-pasture sites, and soil degradation can result from very large applications of nitrogen (N) fertiliser (Bird, 2000). Also, trees can respond to a fertiliser application only if other factors are not limiting e.g. moisture availability (low rainfall or heavy weed competition are two factors that can reduce this). Rates vary widely depending on the site; readers should access further information from more detailed references such as Attiwill and Adams (1996), Dell et al. (1995) and Nambiar and Brown (1997).

Maintenance

Progressive thinning and pruning is required for clearwood production, and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques in a farm forestry context.

Eucalyptus viminalis sheds branches well especially on good quality sites (deep moisture-holding soils and high rainfall), on poor soils and with low rainfall it is often branchy and of poor form (Poynton, 1979; Eldridge et al., 1993). Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for higher-value appearance-grade products (Bird, 2000). Branches should be removed before their diameters exceed 2.5 cm as large stubs increase the risk of fungal infection and stem decay (Nicholas, 1992).

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter growth of individual stems. The stand may be reduced to a final stocking of 100-300 stems ha⁻¹ when grown for sawlogs (Bird, 2000).

Growth

Growth data for plantation grown E. viminalis subsp. viminalis and E. viminalis subsp. mediana is not available for Australia. E. viminalis subsp. viminalis is capable of rapid growth on suitable sites. On seven sites in Gippsland, Victoria, mean annual increments of 9.7-39.4 m³ ha⁻¹ were achieved at 10-12 years of age (Duncan et al., 2000). This wide range in growth rates reinforces the need for careful site and species matching.
Protection

In Australia only a few of the numerous pathogens and insects found in eucalypt forests and plantations have acquired the status of serious and limiting forest pests. However, a certain amount of damage to natural forests and plantations by pests and diseases is inevitable, and is accepted as an inherent part of managing them. At present the main opportunities to reduce this damage are provided by management options such as maintaining the health and vigour of trees and stands at as high a level as possible by the application of timely silvicultural treatment; not planting the species on sites that are marginal for it and regular monitoring for insect damage or unhealthy trees (Abbott, 1993; Florence, 1996). Stone et al. (1998) note that in most situations the control of pests by pesticide application is not practical as it is prohibitive in terms of the costs involved, monitoring required and environmental issues of chemical use.

*E. viminalis* is moderately susceptible to attack by insects and pathogens, particularly on sites marginal for the species.

*Eucalyptus viminalis* subsp. *viminalis* is subject to predation by a wide range of insect pests. This species is the favoured host of the eucalypt weevil (*Goniopterus scutellatus*) which insect reaches its highest numbers on and causes most damage to this eucalypt. Chronic infestations are present in farmland areas where *E. viminalis* subsp. *viminalis* are predominant e.g. the Braidwood district of New South Wales. Larval infestations can cause substantial losses of growth in young trees (Farrow, 1996).

This eucalypt is also a preferred host for Christmas beetles (*Anoplognathus* species) and sawfly larvae (*Perga* species). Christmas beetles can cause dieback if trees are defoliated several times in a season. Sawfly larvae prefer young trees 2.5 m tall and can occur in large numbers over extensive areas of the New South Wales tablelands in some winters, but defoliation rarely causes tree death as the same trees are not generally attacked in successive years (Farrow, 1996).

*Eucalyptus viminalis* subsp. *viminalis* is moderately susceptible to leaf blister sawfly (*Phylacteophaga froggatti*). Outbreaks of this insect can occur in young plantations and can cause tree deaths if successive attacks occur within one growing season. *E. viminalis* subsp. *viminalis* is a secondary host during outbreaks of Autumn gum moth which insect prefers waxy, blue-green juvenile leaves like those of *E. globulus* (Farrow, 1996).

*E. viminalis* subsp. *viminalis* foliage is also eaten by possums and gliders. Severe defoliation by possums, leading to tree death is a major cause of dieback in natural stands of *E. viminalis* subsp. *viminalis* in the midlands area of Tasmania (Geard, 1994).

Utilisation

Wood

Although a common eucalypt, the wood is of limited commercial use for sawn timber because of seasoning problems. Despite this the wood has been used for internal joinery, furniture, wall panelling, flooring, handles, light construction, carpentry/joinery. The heartwood is pale pink or pale pinkish brown; not durable for exposed situations. Sapwood is up to 35 mm wide, but not visually distinct and is susceptible to lyctid borer attack. The texture is medium and even, grain variable and growth rings prominent. Air dry density is about 750 kg m⁻³ (Fenning Timbers, 2002). Hicks and Clark (2001) report a basic density of 506-517 kg m⁻³ for 14-year-old planted *E. viminalis*. It is difficult to dry without considerable degrade from internal honeycombing, surface checking and collapse. Reconditioning is usually desirable for dressed lines. Quarter sawing is recommended, followed by a slow initial rate of drying. Shrinkage is about 6% radial and 12% tangential, and after reconditioning it is about 3% radial and 6% tangential. *E. viminalis* subsp. *viminalis* is not suitable for use in the ground and not durable in exposed situations (Bootle, 1983; Fenning Timbers, 2002).

The wood is easy to work and glues satisfactorily, but may need pre-drilling when nailed near the ends of boards. Uses other than sawn timber include fibreboard and short-fibre pulp. *E. viminalis* is potentially of interest for plywood manufacture and as a fast-growing source of pulp (Bootle, 1983; Fenning Timbers, 2002).

Soft pink tones are a feature of manna gum, which has been compared to American cherry in colour, but with the distinctive grainy look of a eucalypt. It
is considered to have similar working properties to Victorian ash and is currently available in flooring, lining boards and furniture timber in Victoria (Timber Promotions Council of Victoria website, 2002).

Non-wood

The species is used for amenity and ornamental plantings, in shelterbelts and windbreaks and as a shade tree. It is also a useful honey species producing abundant pollen and a moderate supply of nectar from which a medium density, amber-coloured honey is produced (Poynton, 1979; Clemson, 1985).

Tree sap of *E. viminalis* subsp. *viminalis* is a major food for yellow-bellied gliders (*Petaurus australis*) and for three other species of gliders or possums; new leaves are food for the greater glider (*Schinobates volans*) (Kavanagh, 1987). Foliage is the preferred food of Australian koalas and is also used as a food source by brushtail possums. It is also utilised as a nest tree by a number of Australian species of birds.

Limitations

*E. viminalis* is susceptible to many insects and pests.

Recommended Reading


References


Gunn B, 2001. CSIRO Forestry and Forest Products, Australian Tree Seed Centre operations manual. CSIRO Forestry and Forest Products, Canberra. [Unpublished]


20. Grevillea robusta A.Cunn. ex R.Br.
Silky oak
Adapted from Harwood, 2000.

Valuable source of honey
Relatively free of pests and diseases but very sensitive to termites.

Species overview

Grevillea robusta has gained widespread popularity in warm temperate, subtropical and tropical highland regions of many countries, originally as a shade tree for tea and coffee and now as an agroforestry tree for small farms (Harwood, 1989). G. robusta is renowned for its climatic tolerance despite its restricted range of natural occurrence. It is easy to propagate and establish and is relatively free of pests and diseases. Its proteoid roots help it grow in low-fertility soils (Skene et al., 1996). It does not compete strongly with adjacent crops and it tolerates heavy pruning of its roots and branches. As a consequence of its colonising abilities, G. robusta may become a noxious weed in favourable conditions (Harwood, 1989; Doran and Turnbull, 1997).

It provides economically valuable products including timber, poles, firewood and leaf mulch. It is capable of producing good quality cabinet timber. With its fern-like pinnate leaves and prominent attractive orange flowers, it is also popular as an ornamental (Harwood, 2000).

Although Grevillea robusta grows rapidly in suitable environments, it is generally possible to find other species that will produce more wood on the same site, e.g. eucalypts or acacias. This and its typically short effective growing life in plantations, and poor coppicing ability, have meant it has not gained prominence as a species for commercial wood production in plantations (Harwood, 1989).

However, its demonstrated ability to grow well in line plantings overseas, along with its wide climatic tolerance and the possibility of producing a higher value product, recommend its consideration for inclusion in agroforestry systems in Australia.

Key features

Medium-sized tree of good form
Moderate to fast growth rate
Growth rate is best on reasonably fertile, deep soils in regions with a mean annual temperature range of 15-18°C, and a mean annual rainfall above 1000 mm and no prolonged seasonal drought
Growth is moderate in 600-800 mm annual rainfall zone, and in cooler climates with mean annual temperatures of 14°C or less
Does not tolerate heavy clay soils or waterlogging
Can survive frosts and temperatures down to -8°C but is more susceptible when young or during the growing season
Does not compete strongly with adjacent crops
The species has an attractive wood which is relatively easy to work and is suitable for many uses including poles, furniture, veneer, flooring and cabinet work
Trials indicate it can produce pulp of fair quality
The timber is not durable for outdoor applications unless treated
Has significant horticultural and ornamental applications
Description and natural occurrence

Description

An erect, single-stemmed tree typically reaching an adult size of 20-30 m in height and 80 cm in diameter. The crown is conical and symmetrical with major branches spaced at intervals of about 1 m and projecting upwards at an angle of 45°. Bark on the trunk is dark grey and furrowed into a lacelike pattern.

Young branchlets are angular and ridged, covered in rusty hairs, but glabrous on older growth. The fern-like foliage of this species is very distinctive. Leaves are 10-34 cm long and 9-15 cm wide, variably pinnate to bipinnate, with a glabrous green upper surface and silvery hairy under-surface. Petioles are 1.5-6.5 cm long. The species is semi-deciduous in its natural range, being almost leafless shortly before flowering (Boland et al., 1984).

The flowers are racemes, simple to 6-branched (Kalinganire et al., 2000) from near the base, and borne on older wood. The flowers are a bright orange and occur in numerous pairs along the flower spikes, on pedicels 1.5 cm long (Doran and Turnbull, 1997). Flowering and seeding commence from as early as six years of age in its natural range and occur in most years, but heaviest crops come from mature trees 20-40 years old (Harwood, 1989, 1992a). In its natural range, flowering peaks in late spring (October-November). The flowers are bisexual, and pollen is shed before the stigma becomes receptive. The main pollinating agents are nectivorous birds but may also include fruit bats (Kalinganire et al., 1996). Fruits are brownish-black, leathery follicles about 20 mm long containing two long, flat, broadly winged seeds. Seed is wind dispersed and therefore very light. In its natural range, seed matures on the tree and is shed over a short 1-2 week period so that timing of seed collection, usually in December-January, is critical. In tropical latitudes, flowering and seeding are spread out over a longer period; there may be 2 or more crops of seed produced each year. There are year-to-year fluctuations in seed production (Harwood, 1992a).

Proteoid roots (sections of the secondary roots which develop as dense cylindrical clusters of rootlets) develop in conditions of low phosphorus availability, and are thought to increase the plant’s ability to take up nutrients (Skene et al., 1996).

Natural distribution

The natural habitat of G. robusta is in northern New South Wales and southern Queensland, Australia, where it occurs from the east coast to as far west as the Bunya Mountains, Queensland, some 160 km inland (Figure 20.1). The north-south range of the species is some 470 km from the Guy Fawkes and Orara Rivers (tributaries of the Clarence River in New South Wales, latitude 30°10’S) to
just north of Gympie, Queensland (latitude 25°50’S). It is found across a wide range of altitudes from sea level to mountaintop occurrences at 1120 m in the Bunya Mountains (Harwood, 1992a). G. robusta is vulnerable to fire and hence is excluded from the fire-prone Eucalyptus forests and grasslands that occupy much of its natural range.

The distribution is in the warm humid to warm sub-humid climatic zones. Climate varies widely within the natural range because of the substantial altitudinal range and the rainfall gradients created by prevailing weather systems interacting with rugged topography.

The species is more common on rather fertile soils such as those derived from river alluvia or basalts but will grow on shallower, less fertile soils derived from sedimentary material. The pH range for good growth is around 4.5-7.5. Best growth is obtained on sandy loam, loam and clay loam textures. Heavy clay soils and prolonged waterlogging are not tolerated. In highly acid soils, symptoms of boron deficiency (Smith, 1960) and manganese toxicity (Child and Smith, 1960) have been observed.

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for G. robusta, incorporating data from both the natural distribution and from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Condition Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>700-2400 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter, summer</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-7 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>25-38°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>0-16°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>13-24°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting G. robusta [Figure 20.2] was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to the climatic parameters, initially derived from the natural distribution, on the basis of information from trials and plantings of this species both within and outside its natural range. Towards the hotter extremes of the tolerated temperature range, the dry season should be no longer than 4 months for good growth. Best growth is achieved at sites where the MAT is 15°C-18°C and the MAR is 1000-2000 mm (Harwood and Booth, 1992). The species can tolerate colder temperatures, particularly as the tree grows older, but will suffer damage if growing as seedlings.

Figure 20.1: Natural distribution of Grevillea robusta (Jovanovic and Booth, 2002)

Figure 20.2: Areas predicted to be climatically suitable for Grevillea robusta are shown in black (Jovanovic and Booth, 2002)
or young saplings in environments where the temperature drops below -5°C (Harwood and Booth, 1992). Commercial plantations outside Australia tend to have mean minimum temperatures of the coldest month above 6°C. However, experience in Australia is that in cultivation it grows remarkably well under dry inland conditions and tolerates quite severe frosts (Boden, 1990).

*G. robusta* is renowned for its climatic tolerance despite its restricted natural occurrence. It has performed well in equatorial tropical highland climates with a bimodal rainfall distribution and little seasonal temperature variation, and in Mediterranean climates with a dominant winter rainfall maximum, in contrast to the dominant summer maximum of its natural range. In Hawaii, India and the Caribbean, it has not done well in climates with annual rainfall much above 2000 mm, being subject to fungal and insect attack. It has generally not performed well in the equatorial lowlands. In many countries including Australia, it has grown satisfactorily in low-rainfall areas, down to 400-600 mm yr⁻¹ (Harwood, 1989).

Other factors such as soil requirements also need to be considered when deciding whether to plant this species. *Grevillea robusta* grows best on reasonably fertile, deep, open soils, it does not tolerate heavy clay soils or waterlogging.

**Plantings and provenance trials**

**Plantings**

Overseas, *G. robusta* has been widely cultivated for ornamental purposes, tea and coffee shade, and general farm planting, and in the last few decades increasingly as a producer of timber, poles and firewood on small farms and in larger plantations (Harwood, 1989). Countries where it has been introduced include Sri Lanka, India, Africa (e.g. South Africa, Algeria, Kenya, Rwanda, Tanzania), South America (e.g. Argentina, Brazil and Uruguay). It is considered by the USDA to have become naturalised in Hawaii and southern Florida and is classed as a noxious weed on ranchland in Hawaii (Skolmen, 1990). It is also found in California, Mexico and throughout the Caribbean.

*Grevillea robusta* planted next to a maize field in Kenya where it has been pruned and pollarded to reduce competition.

*Grevillea robusta* grows well in line plantings and as scattered trees over crops in warm temperate and subtropical climates. Recent studies on root architecture and water uptake indicate that *G. robusta* is relatively deep-rooted and thus may compete less with crop roots than do other trees (Howard et al., 1996). Its tolerance of repeated heavy pruning and pollarding allows farmers to regulate the amount of competition with adjacent crops. It can also be grown in monoculture in block plantings in woodlots or plantations, but this use is much less frequent (Harwood, 2000).

**Provenance trials**

Two provenance trials of *G. robusta* were established in the Atherton area of north Queensland as the species had shown promise in the area. The trials were measured at 40 months of age and significant differences between provenances were found in growth. ‘Duck Creek’ and ‘Tyalgum’ provenances from lowland New South Wales displayed the best growth (Sun et al., 1995).

In a trial of rainforest species at Mt Mee, south-eastern Queensland, *G. robusta* performed very well in almost all respects. The site has a long-term annual average rainfall of 1514 mm, but, during the trial it experienced some of the driest years on record in the region. *G. robusta* was among the top six of sixteen species trialed, with a mean height of 8.9 m and mean diameter at breast height of 16.7 cm at 6 years of age. Tree form was rated using a scale of 1 (poor) to 10.
The average rating of G. robusta was 8.6 (stem straightness and branchiness). Form problems in some individuals of G. robusta, which were due to wind damage, lowered the average form rating for this species. The prevalence of wind damage to this species in this trial was second only to Cedrela odorata (Lamb and Borschmann, 1998).

A provenance and family trial of G. robusta was established at Neerdie in south-eastern Queensland in 1995. Early trial results are reported by Harwood et al. (2002) who give an overall mean tree size at 4 years 4 months of 7.4 m in height and 8 cm DBH. The authors felt that this is typical of early growth rates for this species when planted on a suitable soil and climate in subtropical latitudes. The 'Duck Creek', New South Wales, provenance performed best of the well represented provenances (i.e. five or more families) and this reflected results from other trials including those at Atherton described above. However, the authors conclude that beside the poor performance of high-elevation provenances, no other significant geographic trend in provenance performance of G. robusta is apparent. The trials did identify significant differences in growth, forking and stem straightness between families within provenances, and this variation, along with that between provenances, indicates excellent potential for genetic improvement through selection.

Alley plantings of G. robusta were established on a farm in south-eastern New South Wales in 1992. The site receives an MAR of 640 mm. At 9 years of age the trees had attained a mean height of 8.3 m and mean diameter of 13.2 cm, and are in a healthy condition (Roger Arnold, CSIRO Forestry and Forest Products, pers. comm. 2001).

Breeding and genetic resources

Silky oak has no recognized subspecies or varieties and no hybrids with other species have been recorded (McGillivray, 1993). Advanced genetic improvement programs have not yet been implemented. Techniques for controlled pollination (Kalinganiire et al., 1996) and vegetative propagation are relatively straightforward and could be used in improvement strategies (Harwood and Owino, 1992).

Small amounts of seed from natural provenances of G. robusta are available from the CSIRO Forestry and Forest Products Australian Tree Seed Centre in Canberra. However, seed from identified superior provenances is expensive to collect and the quantities that can be collected are insufficient to meet current demand. Only a few kilograms of seed can be collected annually from some provenances, even if all seed bearing trees in the provenance are sampled (Harwood et al., 2002). The Neerdie,
Silviculture

Propagation

Propagation is usually from seed. Mean seed viability is 34,000 viable seeds kg\(^{-1}\) with a range from 18,000-51,000 viable seeds kg\(^{-1}\) (Gunn, 2001). Seed storage is orthodox. Seed stored at below 10% moisture content and refrigerated (3.5°C) retained its viability after 8 years (Gunn and Solomon, 1998).

No pre-treatment is required for germination, but the seed of this species has been found to occasionally harbour fungal spores which can inhibit/or slow germination. There are two methods of limiting losses due to fungal attack; the first involves using alternating temperatures (higher during day and lower at night) to speed up germination. In the laboratory temperatures of 30°C during the day and 20°C at night are used; in the nursery this would require sowing at an appropriate time of year in the right climate. The other method is to rinse the seed in bleach to kill fungal spores. Seed is soaked in a 1% bleach solution (sodium hypochloride) for about 3 minutes and then rinsed thoroughly before sowing (Debbie Solomon, CSIRO Forestry and Forest Products, Australia, pers. comm., 2001).

Seeds can be germinated on loamy soil under a shallow covering of sand and germination takes an average of 20 days (10-30 days).

General nursery practices are suitable for producing containerised seedlings of \(G. \) robusta. These are described in texts such as Doran and Turnbull (1997). Many nurseries will grow seedlings on request and some specialise in producing trees for the farm forestry market. Seedlings are grown on for around 4-6 months in the nursery until reaching a planting height of 20-40 cm.

Cuttings can be struck easily using shoots of seedlings or saplings (Swain, 1928), which can also be air-layered.

Establishment

Poor establishment technique and severe competition from grass and weeds will reduce growth rates. Site preparation for plantings in Australia could be similar to that used for two trial sites in Atherton, Queensland. Here, sites were slashed and planting rows cultivated and deep ripped. Trees were fertilised at planting and were kept weed-free by periodic applications of the herbicide glyphosate for the first 2 years (Sun et al., 1995). The site of the Neerdie trial in south-eastern Queensland was deep ripped and ploughed prior to planting. No fertiliser was applied at planting as fertility levels were considered adequate because the previous land use had been improved pasture for beef cattle production. Weed mat squares were placed around trees at planting and weed-free conditions maintained for 12 months. Subsequently the interrows were periodically slashed to control grasses, vines and woody weeds (Harwood et al., 2002).

Seedlings can be hand-planted or planted by machinery. To allow machinery to be used, a spacing of 3.5 m between rows should be used (Weiss, 1997). A range of spacings and planting designs is possible in farm forestry plantings; readers are referred to texts such as Bird (2000) and Reid and Stephen (2001) for discussion of options and their merits. Planting in rows and at wider spacings favours faster diameter growth and hence greater individual tree volume. Suitable initial spacings for woodlots are 3 m x 3 m (1111 trees ha\(^{-1}\)) and 4 m x 2.5 m (1000 trees ha\(^{-1}\)). These spacings promote good form and allow ample selection for final stocking of 200-300 trees ha\(^{-1}\) (Bird, 2000). Spacings used in the Queensland trials mentioned above were 4 m x 2 m (Sun et al., 1995; Harwood et al., 2002).

Many overseas plantings that are managed for lower-value products such as firewood and poles aim to produce logs of small diameter and to maximise biomass. For this, closer spacings and short rotations are usually employed, e.g. spacings of 1.5 m x 1.5 m (Kalinganire, 1996).

In southern latitudes with winter and uniform rainfall patterns, planting is carried out during late winter/early spring. Later rather than earlier planting is best.
with frost-sensitive species like G. robusta, but it is important that the soil still retains moisture from winter rains. Planting in northern latitudes usually occurs with the onset of summer rains between November and April, but February-April is preferred.

Fertiliser is seldom applied but an application of around 50 g per tree of an NPK fertiliser (12:12:12) shortly after planting would be appropriate for infertile soils. If there are symptoms of boron deficiency, an application at planting of 10 g per tree of elemental boron as borax or, preferably, the less soluble ulexite (a sodium-calcium borate mineral) is recommended (Doran and Turnbull, 1997).

Management

Progressive thinning and pruning is required for clearwood production and texts such as Bird (2000) and Reid and Stephen (2001) look at the theory, objectives and techniques. Thinning and pruning schedules need to be developed for G. robusta in Australian conditions.

Pruning in farm forestry woodlots is done to add value to the trees by aiming to increase the recovery of sawn timber from the trunk and to make it suitable for high-value appearance-grade products (Bird, 2000). G. robusta withstands pruning and pollarding well. However, pruning should not be done before trees reach 2 m as G. robusta has a light crown (FFAQI website, 2002).

Thinning removes defective trees and reduces competition between trees. The spacing of trees determines the ultimate height and diameter of individual stems. The stand may be reduced to a final stocking of 100-300 stems ha\(^{-1}\) when grown for sawlogs. A rotation length of 25-35 years is suggested for sawlog production on the southern Atherton tablelands (PFNQ website, 2002).

Proceedings of an international workshop (Harwood, 1992b) describe the use of G. robusta in agroforestry and forestry applications. The branches are pruned to regulate shading and competition with adjacent crops and are used for firewood, sticks for climbing beans and poles. The tree grows back well after heavy pollarding and pruning. The main trunk of the tree may be harvested as a sawlog from age 15-25 up to 40 years. G. robusta coppices well after being cut back to ground level at ages of up to two years, but coppicing ability declines sharply thereafter, so management on a coppicing rotation is not feasible.

Growth

Growth data for plantation grown G. robusta is not available for Australia. In Australian trials at Atherton in northeastern Queensland and Neerdie in south-eastern Queensland average growth rates at 3-4 years of age were just below 2 m yr\(^{-1}\) for height and 2 cm yr\(^{-1}\) for DBH (Sun et al., 1995; Harwood et al., 2002). Given good soils and suitable climate (MAT in the region of 15-18°C and MAR 1000-2000 mm, without prolonged seasonal drought), annual height increments of at least 2 m yr\(^{-1}\) and DBH increments of 2 cm yr\(^{-1}\) in the first 5 years have been achieved in many countries (Harwood, 2000). Doran and Turnbull (1997) report that in all but the most favourable conditions, growth slows greatly after 10-15 years.

In the 600-800 mm annual rainfall zone, and in cooler climates with MATs of 14°C or less, height increments of the order of 1 m yr\(^{-1}\) in the first few years would be a realistic expectation (Harwood, 1989).

Protection

Grevillea robusta is relatively free of pests and diseases in Australia, but it cannot withstand severe gales or persistent strong winds without damage to the branches. It has some resistance to frost. During the winter months in temperate latitudes, G. robusta can survive temperatures down to -8°C with little or no damage, but milder frosts of only -2°C or so ill cause damage during the growing season. Droughts of 6 months or longer will cause death or damage to established trees (Harwood, 2000).

Utilisation

Wood

The heartwood is pale pink on cutting, darkening to red-brown after drying, while the sapwood is cream coloured and up to 25-38 mm wide. Growth rings are not visible, although broad medullary rays give the wood a distinctive and attractive appearance.
on both the quarter-sawn and back-sawn faces. The air-dry density in natural populations is 540-720 kg m⁻³. The Australian standard trade name is southern silky oak. Seasoning properties are variable with shrinkage on seasoning rated low to moderate. The wood has a tendency to warp and check and should therefore be air-dried slowly, followed by a mild kiln schedule to avoid honeycombing. The wood is hard but it can be peeled and sliced satisfactorily. It is moderately durable to non-durable but can be treated with preservative. The wood is susceptible to marine borer, pinhole borer and termite attack. It is easy to work with both hand and machine tools.

In Australia G. robusta has been popular for cabinet work and indoor fittings, but supply is now limited. The sawn timber is of medium strength and is used for furniture, packing, flooring, panelling, plywood and the manufacture of small wooden items such as pencils (Bolza and Keating, 1972; Skolmen, 1974). The wood produces short-fibre pulp of acceptable quality (Ghosh, 1972) but has not been used for pulp production on a commercial scale. Mean fibre length is about 1.5 mm (PFNQ website, 2002).

The calorific value of the wood is about 4875 kcal kg⁻¹ and it is popularly used overseas for firewood and charcoal (PFNQ website, 2002).

**Non-wood**

*Grevillea robusta* is a useful tree for shade and is also a good species for intercropping as its deep-rooting system causes little interference with shallow-rooted crops and it can be successfully intercropped with banana, tomato and other agricultural crops (PFNQ website, 2002).

The dense, brilliant golden-yellow or orange flower heads, attractive silver, fern-like leaves and symmetrical crown encourage wide-spread and increasing use of the species as an ornamental. It is used in many tropical and subtropical countries for park and roadside plantings. In the United Kingdom and Europe it is commonly available as an indoor plant. In Australia, other *Grevillea* species and interspecific hybrids are commonly grafted onto rootstocks of *G. robusta* to produce ornamental planting stock. This practice takes advantage of the resistance of *G. robusta*’s root system to *Phytophthora cinnamomi* and its non-susceptibility to phosphorus toxicity, which is a problem for most other *Grevillea* species (Burke, 1983).

The leaves of *G. robusta* are used as a soil mulch and have been used by some farmers overseas as bedding in livestock stalls (Spiers and Stewart, 1992). The leaves contain a number of useful chemical compounds, in particular rutin, which has pharmacological applications (Cannon et al., 1973). However, the rutin concentration of 0.6 % of dry weight of leaves is too low to be of commercial value.

**Limitations**

Webb et al. (1967) considered that an auto-allelopathic compound associated with the living roots of *G. robusta* was responsible for the poor performance of plantations in Australia. The good growth of many successful plantations and woodlots in Africa suggests that in most plantations such an effect is minor, if present at all.

*Grevillea robusta* is an effective colonizing species and does have the potential to become a weed (e.g. in Hawaii, Nelson and Schubert, 1976).

The trees have brittle branches and can be damaged by high winds. The wood has some notable drawbacks, i.e. the sapwood is very susceptible to attack by borers and fungi, and even the heartwood is only moderately durable. The sawdust from *G. robusta* wood causes a skin allergy in some people (Skolmen, 1974).

**Recommended Reading**


References


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21. *Pinus pinaster* Aiton

Maritime pine

David Spencer.

**Key features**

- Medium to large tree with a clean cylindrical stem
- Genetically improved stock available
- Tolerates drier climates down to 400 mm MAR
- Thrives on freely-drained, neutral-acid, sandy soils
- Timber has good strength and density compared with many pines
- Propagation by seed, vegetative cuttings and natural regeneration
- Susceptible to intense fires; timber can be salvaged
- Defect-prone with incorrect silviculture in growth and seasoning of sawn green timber
- Effective at lowering water tables and assisting with salinity problems in recharge zones.

**Species overview**

*Pinus pinaster* (maritime pine) was one of the successful species to emerge from extensive species evaluation trials carried out in Australia about one hundred years ago. It has been used extensively, especially in South Australia and Western Australia, on sites which were considered too poor for *Pinus radiata*. In 1994 it was estimated there were about 29 000 ha of *P. pinaster* plantations (National Forest Inventory, 1997). In 1997, the Forest Products Commission of Western Australia (FPC) announced a plan to establish 150 000 ha over the next decade within the 400–600 mm MAR zone.

It is a medium-sized to tall tree that usually can grow to about 20–40 m in height on relatively good sites in Australia. It is better-suited to less fertile, well-drained soils like deep sands, deep gravels and sandy loams than most other conifers. It tolerates phosphate-deficient soils better than other *Pinus* species.

The timber of *P. pinaster* has higher strength and density than do other softwoods, including radiata pine. It is highly suited to veneer, sawn timber, reconstituted panel products and round timbers. Appearance-grade timber can be used for match-lining, furniture and joinery. Suitably treated with preservative, round timber can be used for fence posts and power poles. It can also be used for pulp and paper.

**Description and natural occurrence**

**Description**

*Pinus pinaster* is a medium-sized to tall tree, 20–40 m tall, and trees with an average DBH at maturity of 35–60 cm are common in thinned plantations; the bole is clear over most of its length. Crowns of plantation trees are globular, whilst those of old trees are wide and flat. Plantation trees have long, clean cylindrical stems, whilst open-grown individuals have a pronounced taper. It has a deep tap root, with secondary roots well-developed. Bark is thick, scaly or plated, deeply fissured and dark red-brown (CABI, 2000; Erle, 2001).

Shoots are stout, 7–15 mm thick, buff to yellow-brown, rough. Foliage buds are large, cylindric to
ovoid-acute, with red-brown scales having long free tips which can be a little sharp. Adult leaves are retained for 1.5-3 years, are 12-25 cm long in fascicles of two (with some fascicles of 3), with a persistent 2 cm sheath. They are green to yellow-green, sometimes tinged glaucous, spreading, very stout, about 2-2.2 mm thick, with serrulate margins (Erle, 2001).

Flowering occurs between late winter and mid-spring. Male flowers are usually abundant, clustered in rings beneath the expanding needles of the new season’s growth, with pollen-shed occurring in early spring. Female flowers occur on the tips of expanding shoots and are dull red in colour (CABI, 2000). Cones are nearly sessile, very oblique at base, symmetric, slightly curved ovoid-conic; glossy chestnut-brown in colour with a broad, raised transverse ridge rising to a central, small, up-curved prickle (CABI, 2000; Erle, 2001). Cones ripen in 18-20 months, between late summer and autumn. In cooler climates cones may persist closed on the tree for several years. Seed are shiny black-brown above and matt grey below with a wing which is easily removed (Erle, 2001).

Flowering in *P. pinaster* occurs from around 6 years of age and becomes regular from age 10-15 years. Full seed crops occur at intervals of 3-5 years (CABI, 2000).

Natural occurrence

The natural distribution of *P. pinaster* in the western end of the Mediterranean includes Spain and Portugal, the SW Atlantic coast of France (including Corsica), NW Italy on the coast and North Africa from Morocco to Tunisia (Figure 21.1). Its common name is derived from its preference for coastal or maritime environments. In general, it occurs naturally in warm temperate regions with an oceanic influence on climate, mainly in humid and sub-humid areas, where annual rainfall is greater than 600 mm. However, it is possible for trees to survive in areas with only 400 mm annual precipitation, providing that there is sufficient atmospheric moisture. In particular, the southern provenances (*P. pinaster* subsp. *pinaster*) grow well in semi-arid conditions (CABI, 2000). The species can tolerate long periods of drought but cannot tolerate shade. It is moderately frost tolerant.

In its natural range, *P. pinaster* may be found on both flat and mountainous sites. It seems to prefer siliceous soils with a coarse texture, especially sandy soils, but it can tolerate other soil types including some calcareous soils, especially when they have a coarse texture and are free-draining.
Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) has been developed for *P. pinaster* incorporating data from both the natural distribution and from sites where the species has been grown successfully in Australia. The latter include pre-1984 plantings and drier locations of the type being targeted in the FPC *P. pinaster* plan (discussed under ‘Species overview’). The description embraces areas of uniform rainfall, such as those in New South Wales where its suitability is currently under evaluation. The climatic profile provides the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Climatic Condition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>400-1200 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Winter, uniform</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-8 months</td>
</tr>
<tr>
<td>Mean maximum temperature hottest month</td>
<td>22-31°C</td>
</tr>
<tr>
<td>Mean minimum temperature coldest month</td>
<td>0-8°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>13-18°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *P. pinaster* (Figure 21.2) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). It does not include areas in Tasmania where the species is also currently under evaluation (David Bush, CSIRO Forestry and Forest Products, pers. comm., 2002).

Plantings and provenance trials

Plantings

*Pinus pinaster* is widely planted in Mediterranean Europe and Africa. It has also been introduced to the United Kingdom, New Zealand, South Africa and Australia (CABI, 2000).

*Pinus pinaster* was first established as a species suitable for plantations in South Australia by 1900, and from 1917 it was used on sites where *Pinus radiata* was unthrifty. It reached its greatest plantation area in the mid-twentieth century when 5% of state forests were planted with this species (Lewis, 1957). The plantation area was estimated at 6000 ha in 1976 (Butcher, 1976).

Figure 21.2: Areas predicted to be climatically suitable for *P. pinaster* in Australia (based on pre-1984 plantations and current trial developments) are shown in black (Jovanovic and Booth, 2000).
Plantations with *P. pinaster* began in Western Australia in 1923 and became extensive, with 21,400 ha planted by 1976 (Butcher, 1976). FPC Western Australia has been promoting the use of the more drought-tolerant *P. pinaster* for wood production and carbon sequestration in areas of lower rainfall and higher evaporation (400-600 mm MAR), where there are limitations to the expansion of other species. FPC aims to increase planting of this species to 150,000 ha in the next 10 years (FPC website, 2002). There are an estimated 600,000 ha of already cleared farmland with suitable soils (non-saline, adequate depth, non-waterlogged) in this rainfall zone in the south-west of Western Australia alone. The focus will be on tree breeding, genetic deployment and investigation of overseas genetic material, ability to better predict timber yields (so as to assess economic viability) utilising the best establishment and silviculture practices so that plantings are commercially attractive to farmers. Most plantings will be joint ventures with property owners (Shea *et al.*, 1998).

Smaller areas were planted in Victoria (1,400 ha in 1976) and New South Wales (100 ha in 1976) (Butcher, 1976).

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**Provenance trials**

Considerable provenance variation exists within the species. Four groups have already been identified (northern Spain and western France, Italy and its islands, northern Africa and southern Spain) with high levels of intra-group genetic diversity. Limited results so far indicate that *P. pinaster* provenances from the highest-rainfall areas have the best drought tolerance (Spencer, 2001).

In South Australian plantings, seed from the central coast region of Portugal showed greatest vigour, but seed of Corsican origin produced stems of the best quality. A provenance trial established in 1957 showed that seed collected locally from these early plantations was as vigorous as the best of the native seed sources. Responses to superphosphate were found on the most infertile sites, but at optimum dose radiata pine responded more vigorously. Subsequent developments in intensive silviculture saw *P. radiata* replace *P. pinaster* on most sites (Boardman, 1972,1974).

Plantations in Western Australia were originally established with seed from the ‘Landes’ provenance in France. Trials established in 1926 demonstrated that the ‘Leirian’ provenance from Portugal was greatly superior to others and consequently all plantings after 1942 came from this source (Butcher and Hopkins, 1999). By 1973 selective breeding had produced trees with 35% greater volume, 44% straighter and 35% improvement in branch size and angle (Butcher and Hopkins, 1992, 1993).

**Breeding and genetic resources**

Over the past four decades FPC’s breeding program has increased *P. pinaster* volume yield by 80% when compared with production from unselected seed sources. In addition, utilisable wood volume has been increased through better stem and branching characteristics. FPC Western Australia anticipates additional gains of some 40% for volume production by 2020 through the use of vegetative propagation to multiply elite families. Breeding since 1973 has produced drought-tolerant lines suitable for planting in the 400-650 mm rainfall zones north and south-east of Perth.
The Australian Low Rainfall Tree Improvement Group (ALRTIG) aims to introduce and test the genetically advanced material being produced by FPC to the eastern states. The hardiness of maritime pine makes it ideal for afforestation of sites where long droughty summers preclude the use of radiata pine. During 1999, ALRTIG's partners established a series of yield plots in the eastern states. A further series of trials involving lines of *P. pinaster* bred for specific traits (such as stem straightness, high growth, etc.) was established at ten sites in Victoria, New South Wales, Tasmania, South Australia and Western Australia during 2000 (ALRTIG website, 2002).

### Silviculture

#### Propagation

Propagation can be by means of seed or rooted cuttings. If seed is used, it is recommended that seed be collected from trees from certified breeding programmes in Australia. If seed is collected from existing plantations or the native range (overseas), the choice of mother trees aged at least 20-30 years old will ensure that seed is viable. Seed storage is orthodox and seed maintains viability for a long time (viability of >50% after 10 years) (CABI, 2000).

Open-rooted or container-grown planting stock can be produced; the latter is especially suitable for afforestation in hot and dry climates. Containerised seedlings require about 6 months in the nursery to reach planting size; open-rooted transplants a little longer (CABI, 2000). Open-rooted trees need very careful handling to overcome transplanting shock.

In Western Australia, FPC is concentrating on vegetative propagation, using cuttings from selected mother plants to quickly gain the benefits of tree breeding.

#### Establishment

Silvicultural practice developed for planting in the drier sandy soils of Western Australia varies from the standard practice in several ways, demonstrating the need to continuously evolve and appraise new techniques to suit particular sites. On many Western Australia site types, the top layer of sandy soil is ‘scalped’ to a depth of 10 cm in strips 1 m wide on the contour. This operation provides a suitable planting environment and controls weed growth. Ripping to a depth of 500 mm is done on certain sites to break root-impeding strata, though this step is not taken where there is no root barrier and ripping is likely to excessively dry the profile. Tractor-drawn machines that rip, scalp, plant and fertilise in one operation are being developed. The trees are planted in the centre of the scalped line. In areas considered likely to be ‘wet’, with high watertables in winter-spring, mounds are formed instead of the scalped lines. Original plantings had stocking rates of 700-1600 trees ha⁻¹, with rows typically 3.0 m apart. Current operations plant at 1800-2000 trees ha⁻¹ (O. Donovan, Area Co-ordinator, North Maritime Pine Division, FPC, pers. comm., 2000). This relatively high density ensures effective control of branch size and provides sufficient selection when thinning for the sawlog crop.

Trials of *P. pinaster* planted in central western New South Wales and the Upper South-East region of South Australia in 1999 had rows 3.0 m apart but 3.5 m between trees within a row (952 trees ha⁻¹), reflecting concern about early competition for moisture in a regime where there is no planned return from first thinnings, and the cost of falling to waste.

#### Management

Thinning the original stocking takes place after the crowns have closed. As *P. pinaster* is intolerant of shade, respacing should be wide. It is also necessary to open up the stands so that gaps between the trees will allow the soil to be recharged with adequate moisture from winter rains to sustain vigorous growth. The effects on wood yield of growing *P. pinaster* plantations on the sandy soils of Western Australia were examined in the mid 1970s (Butcher and Havel, 1976; Butcher 1977, 1997). The outcome was a change in management that minimised competition between trees for moisture and optimised growth and yield. The effects of this strategy will need to be recognised in spacing and management regimes adopted for farm forestry plantings in the eastern states where soil types are more variable and availability of soil moisture less certain.
Returns from the first silvicultural thinning operations should start in year 12 when stand density may be reduced by up to 60%. Growers in Western Australia have the advantage of a market demand for first-thinning products. This market will not always be present for most plantations established in the same rainfall zone in the eastern states. The next thinning is planned at age 20 years possibly effecting a further 50% reduction in stand density, leaving a minimum residual of 250 trees ha$^{-1}$. These figures will vary from property to property due to minor changes in soil and management practices.

Farmers are being invited to participate in share-cropping schemes. An area of about 20 ha is probably needed to make management and harvesting of the plantation economically viable. Trees are being grown on 30-40 year rotations with at least two thinnings.

In the wider-spaced plantings being utilised in New South Wales and South Australia the development and careful implementation of a pruning plan will be required in order to produce good quality timber and avoid knots.

**Growth**

The FPC, which is driving the joint venture scheme in Western Australia, anticipates that the lowest growth rates will be around 8 m$^3$ ha$^{-1}$ MAI and average around 12 m$^3$ ha$^{-1}$ MAI.

Mean annual growth rates of between 6-13 m$^3$ ha$^{-1}$ are estimated for the 400-600 mm rainfall zone in New South Wales and South Australia.

**Protection**

Maritime pine in Australia has very few pests and pathogens of significance.

Like most conifers $P$. pinaster is susceptible to intense fires. However, trees are capable of tolerating mild fires. The needle litter layer on the forest floor is slow to decay; this property is used by the FPC to conduct control burns in plantations to reduce the potential fuel load.

**Utilisation**

**Wood**

Sawn timber is the major product that is obtained from $P$. pinaster. Its annual rings are very visible, creating a distinctive pattern to the timber (CABI, 2000). It has pale yellow-brown sapwood with slightly darker heartwood, is straight grained, resinous and rather coarse in texture. It has an average air-dry density of 560 kg m$^{-3}$. Tree breeding has concentrated on straight stems and this has gone a considerable way to prevent defects associated with poor cutting and seasoning practices. However, $P$. pinaster is susceptible to numerous defects and strict kiln-drying schedules are more essential than with radiata pine. Logs usually have a high percentage of bark (20-40%) in the total volume removed.

The timber of $P$. pinaster has greater strength and density than other softwoods, including radiata pine. $P$. pinaster can be used for round wood, transmission poles, building poles, fences, posts (suitably treated with preservative); stakes; sawn building timbers for light construction; carpentry/joinery; flooring; wall panelling; exterior fittings; containers; pallets; crates; boxes; cases; furniture; veneers; boats; plywood; laminated wood; particleboard; fibreboard; pulp and fuelwood (CABI, 2000).

Maritime pine is used in the Australian construction industry interchangeably with radiata pine as it is graded under the same standard. In reality, smaller sections of maritime pine could be used for a given purpose because it has greater strength than radiata due to its higher density (Siemon, 1983). Recent studies indicate that maritime pine is suited for laminated veneer lumber manufacture by rotary peeling (Siemon, 1998). Production of reconstituted products such as medium density fibreboard and particle board from $P$. pinaster plantation thinnings is already at a high level. Demand for this species as a framing timber appears certain to increase in Western Australia. Traditionally, houses were built with double brick walls since bricks were cheaper than pine. Observations in new housing developments suggest that almost half the houses are now brick veneer with pine frames as in the eastern states.
**Limitations**

*Pinus pinaster* is one of a group of species that exhibits a fixed (or predetermined) growth pattern. Abnormal late-season shoot growth in this species has produced stem form problems in *P. pinaster* plantings in Western Australia. The two main types are lammas shoots (which result from elongations of the terminal bud) and proleptic shoots (which result from expansion of lateral buds at the base of the terminal bud). Where these two shoot types compete for dominance stem-forking and multi-leaders or ramicorns may result. Basket whorls can result from a third type of late-season growth known as sylleptic shoots. These abnormal late-season shoots are thought to be under genetic control and are most common in Atlantic provenances, in particular Portuguese provenances, which exhibit the best early growth rate in our climate. While the Corsican provenance is not prone to abnormal late-season growth, it exhibits slow early growth. Stem form problems due to these late-season shoots have become apparent on a wide range of ex-pasture sites in Western Australia that have abundant stored soil water and moderate to high levels of soil phosphorus. They usually occur after trees reach 2-3 years of age (Ian Dumbrell, Department of Conservation and Land Management, pers. comm. 2002). Pruning is the best option for management at present. Research into the problem is currently in progress in Western Australia.

**Recommended reading**


**References**


Siemon GR, 1983. Strength properties of Pinus pinaster Ait. in Western Australia. Forests Department of Western Australia Research Paper No 72. 5 pp.


22. *Pinus radiata* D. Don

Radiata pine

Rowland Burdon (New Zealand Forest Research Institute), Ian McLeod and Bronwyn Clarke – adapted from Burdon (2000b, 2002).

**Species overview**

Radiata pine is a very widely grown exotic conifer and is the most extensively used species in Australian commercial plantations, with a plantation area of almost 700,000 ha (Wood et al., 2001). It is a fast-growing species with generally good form (Burdon, 2000a, 2002). It is an adaptable species which can be grown on a diverse range of sites. For commercial production it is best grown on sites with deep (>80 cm), free draining soils of moderate to high fertility and annual rainfall >650 mm. The versatile timber is widely used for sawn timber, veneer, pulp, posts and export woodchips (ForestrySA website, 2002).

**Description and natural occurrence**

**Description**

*Pinus radiata* is an evergreen tree with a dense crown and dark green foliage. Height generally ranges from 30-45 m in mature exotic plantings with corresponding diameters of 50-75 cm. Diameter is affected greatly by site conditions and stand density, isolated trees attaining diameters up to 200 cm. In younger stands the crown is pointed while in old trees the crown is rounded or even flattened at the top. Needles are usually dark green, but may be yellowish or bluish green, in groups (fascicles) of three, typically 10-18 cm long (Burdon, 2000a, 2000b, 2002).

**Key features**

- Tall tree, fast growing, good form (MAI around 20 m³ ha⁻¹)
- Relatively undemanding in soil requirements
- Prefers winter rainfall, but tolerates uniformly distributed rainfall
- Intolerant of waterlogging, strong winds, shallow and saline soils
- Propagation by nursery seedlings, nursery cuttings or natural regeneration
- Easy to handle and transplants well
- Genetically improved stock is available
- Susceptible to fungal pathogens
- Cream coloured wood, saws easily and works well, accepts preservative treatment readily
- Versatile species in terms of products and has established market acceptance
- Unpruned logs typically knotty
- Trees and logs may be attacked by blue stain fungus if subjected to warm, moist conditions.

Trees and logs may be attacked by blue stain fungus if subjected to warm, moist conditions.

The form of trees in plantations is usually good on soils of lower fertility: straight, low taper, single stems and narrow crowns with small to moderate
branching. The form typically deteriorates on more fertile sites, with frequent forking, rapid taper and broad crowns with heavy branching (Burdon and Miller, 1992; Burdon 2000b, 2002). Branching pattern is naturally variable and somewhat irregular (Bannister, 1962). The bole tends to flare slightly near ground level and may have slight fluting, and is prone to developing some buttsweep and lean in response to prevailing winds. Bark on the lower portion of mature trees is dark brown, thick and fissured (Burdon, 2000a, 2000b, 2002).

As is the case with all members of the Pine genus, male flowers are in cylindrical yellow clusters which release large amounts of wind-borne pollen. Pollen is produced by around 5-6 years of age, depending on site and provenance. Production can begin very soon after the winter solstice but is later on colder sites. Female flowers develop into large woody cones with overlapping scales. Cones are usually large and persistent and take about two years from pollination to mature and ripen. They may be single but are usually in clusters, with a shape that is variable, but is mostly avoid-conical, and always asymmetric. Production of cones (and seed) is much greater in some maritime environments (e.g. near Mt Gambier) than at dryer and/or colder inland sites (Griffin, 1978; Ken Eldridge, pers. comm., 2001). Mature cones are pale or medium brown with large and thick scales which may remain unopened for a number of years. Cones often persist on branches long after opening (Burdon, 2000b, 2002).

Natural occurrence

*Pinus radiata* occurs naturally on the Californian mainland and islands off the coast of the California Peninsula (Mexico). Its natural latitudinal range is 28-29°N, while it grows well as an exotic within the latitudinal range 33-46°.

Where will it grow?

A climatic profile (Jovanovic and Booth, 2002) for *P. radiata*, incorporating data from sites where the species has been grown successfully as an exotic, gives the following key climatic conditions for survival and good growth:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>650-1800 mm</td>
</tr>
<tr>
<td>Rainfall regime</td>
<td>Uniform, winter</td>
</tr>
<tr>
<td>Dry season length</td>
<td>0-5 months</td>
</tr>
<tr>
<td>Mean maximum temperature of hottest month</td>
<td>18-30°C</td>
</tr>
<tr>
<td>Mean minimum temperature of coldest month</td>
<td>-2-12°C</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>10-17°C</td>
</tr>
</tbody>
</table>

The map of areas predicted to be climatically suitable for planting *P. radiata* (Figure 22.1) was generated from the revised climatic details for the species as listed above (Jovanovic and Booth, 2002). These revisions were made to a previous climatic summary for Australian plantations (Booth and Jovanovic, 1991) and include two Tasmanian sites and one Western Australian site not in the earlier summary.

Isolated trees can tolerate annual rainfall as low as 300 mm, but *P. radiata* generally needs 650 mm or more to be commercially viable (State Forests of New South Wales [website, 2002] recommend >700 mm MAR and Private Forests Tasmania [website, 2002] recommend >800 mm MAR for commercially viable plantations). There is speculation that the species could be grown commercially in rainfall areas as low as 500 mm as long as soils were not deep sands and if woodlots were thinned early and high pruned for clearwood production.

Figure 22.1. Areas predicted to be climatically suitable for *P. radiata* are shown in black (Jovanovic and Booth, 2002)
Higher rainfall produces better growth, but beyond 1800 mm disease and soil leaching become increasingly significant hazards. Winter rainfall is the most suitable pattern, but in Australia the species grows very well in many areas with uniformly distributed rainfall. Diameter growth can occur throughout the year, temperatures and moisture permitting (Burdon, 2000a, 2002).

Provenances vary in their degree of frost resistance (Hood and Libby, 1980; Burdon, 1992) but generally 5-50 heavy frosts per year are tolerated. The altitudinal limit for viable planting generally ranges from 1250 m at latitude 33° to 400-500 m at latitude 46° (Burdon, 2000a, 2000b, 2002).

On coastal sandy soils, the root system can be very deep. Root penetration is often severely restricted by soil depth or compacted layers, leading to instability of the tree, especially if saturated soil coincides with strong winds (Burdon, 2000a, 2002). Impervious white, black or grey clays such as those that occur in South Australia tend to impede drainage and root development and these waterlogged sites are not suitable (ForestrySA website, 2002). Whilst the species tolerates gravelly, rocky soils, sands and loams, and heavy clays, it prefers deep, well-drained soils and good rainfall. Waterlogging is not tolerated (Burdon, 2000b, 2002).

Plantings and provenance trials

**Plantings**

*Pinus radiata* was introduced into Australia in the 1850s and plantations became widespread in New Zealand, southern Australia,

northern Spain and Cape Province of South Africa by the 1930-1940s. The species has now become naturalised in New Zealand, South Africa, Australia and Chile. Areas of plantation also exist in Argentina, Ecuador, Uruguay, Colombia, Peru, Italy, France, British Isles, Kenya and several other African countries (Parker 1997; Burdon, 2000b, 2002). There are now some 4 million hectares of plantations of *P. radiata* worldwide (Burdon, 2000b, 2002). In Australia *P. radiata* is planted in New South Wales, Victoria, South Australia, Tasmania and Queensland with a total plantation estate of 740 000 ha (SFNSW website, 2002).

**Provenance trials**

Intensive provenance testing has been done, albeit belatedly in Australia (Johnson *et al.*, 1997; Burdon, 2000b, 2002). There are definite differences among the mainland provenances in soil and climatic tolerances and disease resistance, rather than growth potential. The two island provenances are distinctive in morphology, higher wood density and slower growth. There is interest in hybridising domesticated stock with the ‘Guadalupe’ provenance for its straight stems and higher wood density (Burdon, 2000b, 2002). The ‘Año Nuevo’ and ‘Monterey’ provenances, which have given rise to past domesticated stocks, are broadly adapted but the ‘Monterey’ provenance has high tolerance of poor soils, while it is evidently less tolerant of frost and snow. The ‘Cambria’ provenance, while susceptible to needle-cast diseases, is of interest for Western Australia because of its greater tolerance to *Phytophthora cinnamomi*, soil salinity, phosphate deficient soils, waterlogging, marginal or drier sites and its good productivity and tree form (FPC website, 2002). Early trial results in low rainfall areas of South Australia show ‘Guadalupe’ performing well at all sites and ‘Cambria’ performing well on some sites (ForestrySA website, 2002).

**Breeding and Genetic Resources**

Because of the extensive experience and accumulated knowledge about this species, research now concentrates on refined management, including fertiliser requirements; protection from pests and disease; and breeding programmes.
Pinus radiata often shows a high level of genetic variation in relation to branching, stem form, frost resistance, disease resistance, wood properties and other characteristics (Burdon, 1992; Matheson et al., 1997; Shelbourne, 1997). Breeding programmes conducted in Australia for around 50 years have resulted in extensive genetic improvement (Burdon, 2000a). Initially the focus was on growth, form and disease resistance with good results (Burdon and Miller, 1992; Carson et al., 1999; Burdon, 2000a). Improvements in tree form were obtained from selection of better phenotypes, but improvement in stem volume depended more on progeny testing (Burdon, 2000b, 2002).

Changing silvicultural practices such as site amelioration and shorter rotations, designed to lower growing costs, have adversely affected wood quality. This has altered the thrust of genetic improvement to focus more on wood properties (Matheson et al., 1997; Shelbourne, 1997; Sorensson et al., 1997; Jayawickrama and Carson, 2000). Improvement in this respect has been achieved mainly by selecting trees with short internodes, to keep the knots smaller and to maintain better tree form (Burdon, 2000b, 2002).

Improved seed, seedlings and cuttings are available in most states of Australia through commercial nurseries and some state forestry nurseries and seed centres. The Southern Tree Breeding Association (STBA) breeds elite genetic material of *Pinus radiata* and through its members and seedEnergy Pty Ltd provides the industry with seed and cuttings of this material. The Private Forestry Tasmania website (http://www.privateforests.tas.gov.au/) provides a list of local pine suppliers with comprehensive information about seed source, prices, ordering information etc. The Western Australia Forest Products Commission (FPC) seed centre has improved seed available including selections with *Phytophthora* resistance. Seed prices range from $250-$950 kg⁻¹ of pure seed, depending on the level of improvement. Seedlings, cuttings and open rooted stock are also available from the FPC Nursery and some commercial nurseries (FPC website, 2002; Agriculture WA website, 2002).

New Zealand also produces improved seed which is utilised by many growers in Australia. State Forests of New South Wales and ACT Forests are both members of the New Zealand Radiata Pine Breeding Company Ltd. Seed suppliers in New Zealand are: Proseed NZ Ltd (http://www.proseed.co.nz), Trees and Technology Ltd (http://www.biotech.org.nz), Carter Holt Harvey Forest Genetics (http://www.forestgenetics.chn.com), and PF Olsen & Co Ltd (http://pfolsen.nzforestry.co.nz). The seed is subject to certification of genetic merit for individual traits under the GFPLUS scheme (Radiata Pine Breeding Co. Ltd. 2002).

In addition to supplying seedlings, some nurseries will be selling cuttings. Such cuttings may represent scarce, top-quality seedlots, that are multiplied as cuttings, but contain tree-to-tree genetic variation that arises from genetic recombination that occurs in the course of seed production. A further refinement, which is likely to be on stream in the marketplace, is represented in mass propagation of particular clones, which not only promise additional gain but also the absence of unwanted genetic variation. Cuttings, however, still tend to show maturation, or ‘physiological ageing’ if the same individual is propagated in this way over any length of time; this tends to improve tree form but eventually reduce vigour and ease of propagation. Avoiding unwanted maturation over time remains a challenge.

**Silviculture**

Owing to the wide use of this species in plantations, appropriate silviculture is well developed and regional information on silviculture, timing of operations and even costings are also available (see recommended reading below).
Propagation

Seed extraction is usually carried out in a kiln using temperatures around 55°C. Seed can be stored almost indefinitely in an atmosphere of nitrogen even at ambient temperatures. Stratification is usually not necessary and viability is usually very good. The only exception to this is pure or hybrid material of the Guadalupe Island population which does need stratification (Burdon, 2000b, 2002).

Vegetative propagation by shoot cuttings is used on a significant scale. In favourable conditions, cuttings can be grown in open nurseries. Seed can be machine sown at 5-6 cm spacing within rows in nursery beds. Fertilisers, including N and P, are usually used and a number of selective herbicides can be used to control weeds. Mycorrhizal fungi are normally incorporated into nursery soil and are discussed by Chu-Chou (1979) and Burdon (2000a).

Bare-rooted planting stock as well as container stock can be used, and can be produced in 6-8 months in warm sites, but up to 18 months may be needed in cold locations. Cuttings can be set in the nursery from late autumn to early spring. Root pruning contains the size of seedlings and prepares them for planting. Topping of seedlings may be necessary if they are held in the nursery too long (Burdon, 2000b, 2002).

Establishment

Site preparation may simply entail removal of any surface vegetation and using herbicides to control competing grasses and broad-leaved weeds (Burdon, 2000b). Ripping is required where there is an impervious hardpan or clay layer within 50-100 cm of the surface. Mounding is required on wetter sites where large mounds help to keep seedlings out of the water and they also provide a stimulus to growth. On drier sites machine planting without prior cultivation helps to reduce water loss from the soil, although where there is dense bracken, ripping along planting lines may be necessary (ForestrySA website, 2002). The burning of existing vegetation may reduce soil fertility on some sites. Windrowing the vegetation is more widely used, but care is needed to leave topsoil in situ (Burdon, 2000b, 2002).

The key to good establishment is good weed control and with P. radiata this will be required for up to five years post planting. Poor weed control is the main reason seedlings fail to survive or grow because weeds and grasses choke and smother out seedlings. Poor weed control also reduces growth as weeds compete with trees for water and nutrients.

Planting is preferred over natural regeneration and direct seeding, in order to control both stocking and genetic quality. Well-established plantations exhibit

*Pinus radiata* pruned
over 90% survival and good first year growth. In South Australia and Western Australia planting is carried out in June/July while the soil is still wet from winter rains. Planting may occur later if site access is not available due to waterlogging, which is often a problem. In Tasmania, Victoria and New South Wales planting is done in September, or July-August in warmer districts where soils dry out earlier. Planting in northern latitudes, such as in Queensland, is carried out during the wet season between November-April, but February-April is preferred.

Fertilisers, most commonly phosphates and superphosphates, are often applied to seedlings at planting and top-dressings can be applied over established stands if required. Expasture sites may have adequate levels of nitrogen and phosphorous from past applications of superphosphate, but may have deficiencies of minor elements (Burdon, 2000b, 2002).

Initial stocking has been reduced over the years from around 2000 trees ha\(^{-1}\) to 1000 trees ha\(^{-1}\) or less. This is a result of better establishment techniques, improved genetic quality of the stock, and often the inability to market early thinnings (small wood) (Burdon, 2000b, 2002). Initial stocking rates of plantations in the Green Triangle area of South Australia and in Western Australia are generally around 1600 trees ha\(^{-1}\) (ForestrySA website, 2002; Agriculture WA website, 2002).

**Management**

Thinning regimes have also changed over the years (Lewis and Ferguson 1993; Burdon 2000a) and many modern thinning regimes are based on a combination of early, heavy thinning. A non-commercial first thinning may be used if small wood cannot be marketed. Aggressive pruning is also carried out to about 6 m height, to produce good yields of clear timber from the butt logs. Short rotations, down to 25 years or less, with final stockings of 200-250 stems ha\(^{-1}\) are used to maximise the rate of economic return. Delayed thinning can, depending on the site, cause stagnation of growth, onset of disease and vulnerability to wind damage (Burdon, 2000b, 2002). However, the most appropriate thinning and pruning regime for a particular site needs to take into consideration markets, growing conditions, costs etc. Currently in the Green triangle area of South Australia and Western Australia pruning is only done to external trees and plantations are thinned at 5-7 year intervals starting at age 10-15 years (depending on growth rate) and are clearfelled at age 30-40. This is because there is currently no premium clearwood market in these regions. However, an early thinning and pruning regime may still be economically rewarding without this premium market, as rotation length would be reduced to 20-25 years (ForestrySA website, 2002; Agriculture WA website, 2002). The ForestrySA website (2002) has a fact sheet on pruning radiata pine for clearwood which aims to help growers decide whether pruning is worthwhile for their particular forest.

Very low-intensity ground fires, to reduce the fire hazard, can be tolerated by mature stands. Crown fires are fatal, and may result in dense natural regeneration following the release of large quantities of seed from unopened cones. Similar regeneration can follow clearfelling (Burdon, 2000b, 2002).

**Growth**

Height growth of up to 2 m yr\(^{-1}\) may be achieved after 2-5 years of age (Burdon, 2000b, 2002). Mean annual increments of fully-stocked stands in Australia are between 10-30 m\(^{3}\) ha\(^{-1}\) depending on rainfall and the average in Australia is probably 15-20 m\(^{3}\) ha\(^{-1}\) (Bird, 2000; Burdon, 2000b, 2002; ForestrySA website, 2002). The average mean annual increment in the Green Triangle region is 20-23 m\(^{3}\) ha\(^{-1}\) (ForestrySA website, 2002). The average growth rate of radiata pine in Victoria is currently 18 m\(^{3}\) ha\(^{-1}\), with more than 30 m\(^{3}\) ha\(^{-1}\) achievable on good sites (Hoef, 2002).

**Protection**

Several insects and pathogens have become serious threats to *P. radiata* plantations in Australia but to date improvements in site selection and management along with breeding for resistance have been successful in reducing the risks.

Pathogens have included the pine needle blight fungus (*Dacrycarpus septosporus*) that does not usually kill infected trees but may cause partial defoliation and much reduced growth. Site selection
and spraying have been successful in Australia (Parker, 1997) and a Dothistroma-resistant ‘breed’ is on stream in New Zealand (Jayawickrama and Carson, 2000). The root pathogen Phytophthora cinnamomi is locally important where there is seasonal waterlogging, especially in Western Australia (Burdon, 2000b). FPC have available seed bred for P. cinnamomi resistance (FPC website, 2002).

*Sphaeropsis sapinea* (syn. *Diplodia pinea*) causes ‘autumn brown top’ in Australia’s summer-rainfall areas. It results in shoot/leader dieback, crown wilt and whorl canker, and can attack both wounds and uninjured shoots. It also affects drought-stressed trees and is a major cause of the blue-stain of timber. The needle-cast fungus, *Naemaculatus minor* (syn. *Cyclaneusma minus*), is notable for its widespread occurrence more so than for its impact.

Commercially important insect pests in Australia have included the woodwasp *Sirex noctilio* which attacks suppressed and weak trees. Proper forest management, especially thinning on time, and biological control, has reduced its potential for damage. The bark beetle *Ips grandicollis* is a significant pest in Australia and infests young trees. Browsing by rabbits, hares, wallabies, possums or livestock cause damage to the growing tops of young trees and plantations should be fenced to restrict their access.

Wind damage can occur with strong winds on wet sites, especially if the root system is shallow (e.g. over a claypan). Very young plantations may be topped, sometimes leading to excessive buttsweep but recovery is often rapid (Cremer, 1990). Stem breakage may occur where rooting is deeper and also following thinning operations.

Although a very low intensity fire may be used on a mature stand for hazard reduction, fire damage occurs easily and crown fires are fatal. ForestrySA (website, 2002) prescribe that a minimum 10 m fire-break/access track should be left around each plantation, with internal access breaks at least every 400 m (for logging and fire access). These breaks should be grazed or slashed annually to help control fires.

Ground frosts may be responsible for mortality during establishment. Their effect can be minimised by good site preparation such as mounding in frost-prone areas to elevate the seedlings above the level of surrounding ground.

**Utilisation**

**Wood**

*Pinus radiata* sapwood is cream coloured, while the heartwood is pink, but prolonged exposure to light causes darkening and browning. Heartwood content is typically low in trees under 20–25 years old. The wood saws and seasons well, is easily worked, can be machined and polished, and is very easy to nail and to glue. Untreated wood mostly has very low natural durability but it can be readily treated with preservative and is easily painted. Air dry density of the wood is about 500 kg m\(^{-1}\) at 12% moisture content. However, it can vary significantly according to site, and is generally markedly lower in young trees.

The wood of *P. radiata* has a wide range of uses including construction (mainly light but some heavy), finishing uses, joinery, furniture, veneers and various reconstituted wood products. It is also used for both mechanical and chemical pulping, and with preservative treatment is used as posts and poles which are widely used in fencing and vineyards (Bird, 2000). Most of the final crop is sawn into timber, with the residues and thinnings used largely for pulping (Burdon, 2000b, 2002).

Disadvantages of the wood include high grain spirality tending to cause distortion and internal checking on drying (Bamber and Burley, 1983; Harris, 1989;
These problems seem to be far worse on high-fertility sites. Resin pockets in the wood can degrade otherwise high-value finishing timber. Knots are prevalent in timber from unpruned logs of *P. radiata* and they generally become too large for good-quality light structural timber if rapid stem diameter growth is encouraged on fertile sites. The presence of larger knots together with low stiffness does limit the usefulness of the wood. It is not suitable for steam bending, and requires skill to stain satisfactorily. Lamination can be used to produce large structural members.

Blue stain fungus can be minimised by clearing logs from the field without delay, or by prompt fungicide treatment, especially during the warmer months. This fungus does not affect the structural properties of the wood but can seriously downgrade the product for appearance purposes.

**Non-wood**

Bark is recycled and burned as an energy source at large wood-processing plants. It is also used in horticulture, for mulches and for potting mixes. While it has quite a good tannin content it has not been used significantly for tannin extraction [Burdon, 2000b, 2002].

**Limitations**

The successful use of *P. radiata* is limited by its climatic tolerances and interrelated problems with fungal pathogens and insect pests. Temptations exist to grow it in high-risk situations. The high growth rate of the species very often makes it impossible to grow satisfactorily in mixture with other species.

Plantations may cause major reductions in catchment water yield through a combination of interception and transpiration losses, although flood peaks tend to be greatly reduced. This may also be an advantage where there is a need to reduce water tables.

**Recommended reading**


**References**


Glossary

Adaxial – adjacent to, or turned towards, the axil, as the upper surface of a leaf in relation to the stem.

Alkali consumption – alkali is a chemical used in paper making, high consumption makes the process more expensive.

Alternate – when parts are adjacent but have other structures in between e.g. when leaves along the stem are on one side and then the other, alternating up the stem and never opposite each other.

Amplexicaul – stem clasping, when the leaf base clasps the stem.

Axil – the angle between the leaf and the stem.

Axillary – referring to a plant part occurring in the axil e.g. the inflorescence.

Back-sawing – a sawing method where the growth rings are approximately parallel to the face of the board when the board is viewed in cross section. This method has been found useful in reducing the effects of growth stresses when sawing small-diameter, fast grown, young wood of eucalypts.

Beaked – when the operculum is markedly or slightly contracted to form a beak.

Bipinnate – a compound leaf where there are two levels of division i.e. the primary leaflets (pinnae) are also pinnate i.e. are made up of secondary leaflets (pinnules).

Campanulate – in fruit, bell shaped. However, the bell is seen upside down.

Capsule – woody fruit, containing the seeds.

Checking – a separation of the wood fibers within or on a piece of wood resulting from tension stresses set up during drying, usually the early stages of drying.

Clavate – club shaped.

Clearwood – part of the sawlog outside of the knotty core that is free of knots or branch defects.

Collapse – refers to the flattening or buckling of wood cells during drying, resulting in excessive and/or uneven shrinkage and a corrugated surface. Collapse may also be referred to as washboarding or crimping.

Concolorous – when the surface of the leaves is the same colour on both sides.

Coppice – shoots that grow from a cut stump or near the base of the trunk. These are usually juvenile at first but further development of the shoot will result in intermediate and then adult-type leaves.

Cuboid – cube shaped.

Cupular – cup shaped.

Disc – of eucalypt fruit, diagnostic feature at the lip or rim of a eucalypt capsule. If it is level or ascending it forms a thick rim to the fruit, if it is descending the rim will be thin and sharp.

Discolorous – when the two surfaces of a leaf differ in colour.

Ectomycorrhiza – soil inhabiting, evidently symbiotic, fungi that modifies plant roots by enveloping them and penetrating between the cells, allowing a nutrient exchange. The presence of these fungi are often essential for healthy plant development.

Exserted – raised above the surface.

Falcate – curved like the blade of a sickle. Leaves with a curved midrib are falcate.

Fascicles – in pines, a bundle of needles (leaves).

Fusiform – spindle shaped, broadest in the middle and tapered at each end.

Glaucous – bluish green, bluish grey or covered with a white wax on the surface.

Hybrid – the progeny of a cross-fertilisation by parents with different genetic systems. From the Latin hybrida meaning a mixed breed.

Hypanthium – (hypanthia pl.) floral cup or tube. In eucalypts it is the structure at the top of the pedicel partly or wholly enclosing the ovary.
Inflorescence – the arrangement of flowers on a floral shoot.

Intramarginal Vein – the first prominent vein of a leaf in from the edge and running more or less parallel with it.

Kappa number – a measure of the amount of lignin remaining in pulp after cooking i.e. the bleachability of a pulp. A low kappa number is good and means there was a small amount of lignin remaining.

Kino – a dark, reddish exudate (gum) formed at an injury site in eucalypts.

Kraft pulp – a popular chemical pulping process involving the cooking of wood chips in a solution of sodium hydroxide and sodium sulfide. It produces pulp with high strength and can be used for a wide variety of wood species.

Lanceolate – lance-shaped, pointed at the tip and broader toward the base.

Lignotuber – a woody tuber.

Mechanical pulp – pulp consisting of fibres separated entirely by mechanical means.

Medullary Rays – radiating projection of pith (e.g. as in Grevillea robusta).

Mucronate – terminating in a short point.

Obconical – reversely conical, shaped like an inverted cone.

Oblique – of the leaf, when the two sides of the leaf base meet at different points on the midrib or petiole.

Operculum – in eucalypts, the cap of the flower bud.

Opposite – when a pair of leaves is attached to the same point on the stem.

Orthodox – of seed storage behaviour, generally defined by the seed’s tolerance to drying and low temperatures. Orthodox seed will store well for long periods when dried to a low moisture content (below 10%) and kept at low or sub zero temperatures, without damaging viability. Orthodox seed includes eucalypts, acacias and casuarinas.

Outcrossing – a breeding system in which parents are less closely related to each other than if mating occurred at random (may also refer to a species that has specific barriers to selfing e.g. Grevillea robusta, or a species that exhibits such inbreeding depression that inbred individuals never reach maturity).

Ovate – of leaves, when they are oval shaped with the broad end at the base.

Pollarding – cutting back the crown of a tree, often done to reduce shading by the crown and so that new shoots develop which produce a rounded, denser crown.

Pedicel – the individual stalk of each flower arising from the top of the peduncles; usually round in cross-section but in some species they are square or two-angled. Buds with no pedicel are sessile.

Pedicellate – having a pedicel (as opposed to sessile).

Peduncle – the enlarged stalk holding a cluster of flowers. It may be round, square or flattened in section.

Petiole – of a leaf, a stalk attaching the leaf blade to the stem.

Petiolate – of a leaf, having a petiole (as opposed to sessile).

Protandry – in plants, where a flower first opens in the male phase (anthers dehisce) and later becomes female (stigmas receptive). This condition is a way of ensuring out-crossing rather than selfing by separating the male and female gametes temporally.

Provenance – the original geographic source of seed, pollen or propagules; a way of describing the origin of a seedlot or population of plants. It describes a subset of the genetic diversity within a whole species.

Pyriform – pear shaped.

Quarter sawing – a sawing method where the growth rings are at right angles to the face of the board when the board is viewed in cross section. Eucalyptus are often quartersawn to produce a more stable timber.

Ramicorn – a vigorous branched which is steeply angled (usually less than 30° to trunk). Such branches can threaten the integrity of the main stem and should be removed early by pruning.

Reticulation – network of veins in leaves.
Rhizobia – soil inhabiting nitrogen fixing bacteria that forms symbiotic associations with the roots of plants e.g. in the Acacias.

Rostrate – beaked.

Salinity classes – non saline = $E_{C_e} < 2 \text{ dS m}^{-1}$; slightly saline = $E_{C_e} 2-4 \text{ dS m}^{-1}$; moderately saline = $E_{C_e} 4-8 \text{ dS m}^{-1}$; severely saline = $E_{C_e} 4-8 \text{ dS m}^{-1}$; extremely saline = $E_{C_e} > 16 \text{ dS m}^{-1}$.

Seedlot – a specific collection of a provenance of a species made at a particular point in time.

Sessile – without a stalk.

Soda-AQ pulp – a chemical process of pulping that uses sodium hydroxide as the active chemical.

Stocking – the persistent bark on the lower trunk of an otherwise smooth-barked tree.

Stool – tree stump, usually used for stumps cut to produce coppice.

Subgenus – a natural group between genus and section used in the classification of plants.

Subspecies – a form of a species having a distinctive identify and occupying a particular habitat or region.

Terminal – of the inflorescence, at the end of a branchlet.

Tessellated – of bark, occurring in small thick flakes or small squares.

Truncate – shortened in shape like its cut off at the end as in truncate globose where the shape is spherical but like a piece has been cut at the top.

Turbinate – top shaped.

Undulate – of a leaf surface, wavy.

Urceolate – urn shaped.

Valves – the 3-5 triangular sections at the top of the capsule which are raised in mature capsules to release the seeds. Valves may be sunken and difficult to see inside the capsule or exserted and very conspicuous.

1,8-cineole – otherwise known as ‘eucalyptol’, the active ingredient in the essential oil of eucalypts.