AUSTRALIAN TREES AND SHRUBS:

SPECIES FOR LAND REHABILITATION AND FARM PLANTING IN THE TROPICS

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Editors ~ John C. Doran and John W. Turnbull

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. Its primary mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australian and developing country researchers in fields where Australia has special competence.

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ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
ATSC	Australian Tree Seed Centre
AusAID	Australian Agency for International Development (formerly AIDAB)
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CGIAR	Consultative Group on International Agriculture Research
CIAT	Centro Internacional de Agricultura Tropical
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTFT	Centre Technique Forestier Tropical
DANIDA	Danish International Development Authority
dbh	Diameter breast height
FAO	Food and Agriculture Organization of the United Nations
F/FRED	Forestry/Fuelwood Development project
GIS	Geographical Information Systems
ICRAF	International Centre for Research in Agroforestry
IRBET	Institut de Recherche en Biologie et Ecologie Tropicale
IRDC	International Research and Development Corporation
IRRI	International Rice Research Institute
IUFRO	International Union of Forestry Research Organisations
LARP	Laos/Australia Reforestation Project
MAI	Mean annual increment
MPT	Multipurpose Tree
NAS	National Academy of Sciences
OFI	Oxford Forestry Institute

PREFACE

This book is an extensive revision and enlargement of "Multipurpose Australian Trees and Shrubs: Lesser-known Species for Fuelwood and Agroforestry" which was published by the Australian Centre for International Agricultural Research (ACIAR) in 1986. This book was a popular reference text in Australia and other countries with similar environments and has been reprinted. In view of rapid advances in knowledge of many of the species and changes in taxonomy, it was decided to revise and enlarge the book. The revision has been undertaken by scientists at CSIRO Forestry and Forest Products. John Doran assumed the major role of preparing the monographs of the new species and editing the book and the number of authors increased. The additional expertise has been provided by Trevor Booth and Lex Thomson.

There has been a critical reappraisal of the content of the book with new species added and previous monographs receiving extensive revision and up-dating. Species of greatest potential receive two to four pages of text while minor or little-known species are relegated to quarter-page treatments. The original book focused only on lesser-known species but now some of the better-known and more widely planted species such as *Eucalyptus camaldulensis* and *Grevillea robusta* are included. There are now descriptions of 166 species. New coloured photographs have been used to illustrate the habit of the trees and shrubs described. Most tree and stand photographs were taken in natural forests and woodlands. The five introductory chapters which support the species descriptions have been retained and revised to a greater or lesser extent.

Since the first edition of this book was published in 1986 the area of tropical forests and woodland has continued to shrink in Africa, Latin America and Asia. Remaining forests are often degraded and hence less productive and there has been extensive degradation of soils due mainly to inappropriate agricultural practices. On the positive side, prospects for greater development of growing wood and other tree products in small-scale plantations are becoming more feasible and attractive as population pressure on natural resources increases and agriculture becomes more intensive. Smallholders, especially in Asia, are increasingly taking the option of growing trees on their land either as woodlots, line plantings or with crops in a variety of agroforestry systems.

The search for suitable trees to include in these plantings is focusing on improving the productivity of those species already in use and in finding new species to meet particular environmental and social situations. Smallholders are pragmatic and will generally grow the trees most suited to their needs whether they be indigenous or exotic. Often they plant a mixture of species to provide a variety of products and services and reduce the risk of loss. While the developing countries are increasingly exploring their own woody genetic resources there is still a demand for exotic trees to fulfil particular roles or provide specific products. In Australia, the rising awareness of the rural community of the role of trees in preventing or ameliorating land degradation has stimulated interest in the use of Australian trees and shrubs.

Australia has rich genetic resources of woody plants many of which are adapted to the harsh climatic conditions and the nutrient deficient soils of this vast continent. Evaluation of Australian trees and shrubs to meet local and international needs was stimulated when ACIAR initiated a program of research to utilise more fully the potential of the Australian woody flora to meet the wood needs of resource-poor people in developing countries.

In 1983 ACIAR convened a meeting of foresters, botanists and others conversant with the woody flora of Australia. About 170 species of trees and shrubs were nominated as having potential for planting in a range of environments for fuelwood, poles, shelter, fodder and other community uses. Some of the selections were short-lived, crooked multi-stemmed shrubs but which might nevertheless meet the needs for small-scale planting. Emphasis was given to lesser-known species with a tropical and subtropical distribution, especially those adapted to infertile soils. The species selected were those which were considered:

- plants capable of providing products and services in addition to fuelwood;
- adaptable plants that are easily established and maintained; and
- plants capable of growing in extreme environments including arid and humid tropical zones, infertile soils, heavy clays, saline, highly alkaline or waterlogged sites or exposed coastal situations.

Other characteristics considered desirable were: an ability to fix atmospheric nitrogen, a capacity for rapid growth, ability to coppice, and good burning properties.

The first edition of this book included descriptions of the botanical, ecological, silvicultural and utilisation characteristics of 100 selected species. One of the problems of describing lesser-known species was that published information about their requirements and performance was sparse. Much of the information was derived from observations of the authors, field notes, herbarium specimens and personal communications from botanists, foresters and others observing plants in the field. Since then a large number of field trials have been established in Australia and other countries to evaluate their performance. The results of some of this research have been published and some of the lesser-known species have realised their potential and are now widely planted. In the humid tropics, species such as *Acacia aulacocarpa* and *A. crassicarpa* are being planted, on saline sites *A. ampliceps* and *A. maconochieana* have proved outstandingly tolerant, and in the semi-arid areas of West Africa and India *A. holosericea* and related species are being used as a source of human food. Other species did not perform as was predicted and although we now know much more about their ecological requirements, they are little used. This research has added substantially to what was often sparse knowledge of the species.

We particularly draw attention to potentially undesirable characteristics of some species. Fast-growing, aggressive trees and shrubs are often appropriate for cultivation in areas experiencing severe fuelwood shortage or where erosion is a serious problem but it must be recognised that under some environmental conditions these species have the potential to be invasive and to spread to areas where they are not wanted. Such species should be introduced with care and their performance carefully monitored.

It is anticipated that this book will provide a useful reference text for all those concerned with selecting and growing trees and shrubs in rural areas of developing countries and in the more tropical parts of Australia.

John C. Doran
John W. Turnbull
1997

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Chapter 1

THE AUSTRALIAN ENVIRONMENT

A.G. Brown, J.W. Turnbull and T.H. Booth

The purpose of this chapter is to provide an introduction to the main features of the Australian environment within which the trees and shrubs described have evolved. Other accounts of the Australian environment that provide more detail or have a different emphasis are given by Leeper (1970), Moore (1970), Alexander and Williams (1973), Jeans (1977), Beadle (1981), ABS (1988) and Groves (1994). Emphasis here is on those factors of the environment for which data are likely to be available in field situations in other countries where Australian trees and shrubs might be used, so facilitating the initial selection of species through the use of homoclimes. Because the natural distribution of trees and shrubs of interest may be limited by factors such as fire or competition, both of which can be manipulated under cultivation, and because information about the physical environment can give no indication of the adaptability and plasticity of potentially useful species, observations of natural occurrence are of limited worth for predicting performance under cultivation. Homoclimal information gained by testing a species as an exotic, however, has much more predictive value.

Moisture availability and temperature are very important influences on the survival and growth of plants, and thus the following account concentrates on these factors. Despite the value of integrating measures of moisture availability such as those of Thornthwaite and Mather (1957) and Penman (1963) only basic meteorological information is presented because of the ease with which such measures can be comprehended and because the indices do have limitations (Burley and Wood 1976).

GEOGRAPHY AND LANDFORMS

Australia, including the island of Tasmania, lies between latitudes 10°41'S (Cape York, Queensland) and 43°39'S (South Cape, Tasmania) and between longitudes 113°09'E and 153°39'E. It extends some 3700 km from north to south and about 4000 km from east to west. The land area, 768 million ha, represents about 5% of the world's land surface. It is almost as large as the United States of America (excluding Alaska) and about 50% larger than Europe (excluding the former USSR). It is considerably smaller than Africa or South America (Table 1.1), but if one compares only the areas south of 10° latitude (Torres Strait), Australia is in an intermediate position. More than one third of the land area of Australia is north of the Tropic of Capricorn (23°26'S), a factor which contributes to the comparatively frequent very high temperatures of inland areas.

The geologically very old Australian land mass is characterised by vast plains and plateaux. About 87% of the land lies at altitudes below 500 m and only 0.5% is above 1000 m. There are three major landform features, viz. the western plateau, the interior lowlands and the eastern uplands. The western half of the continent consists of a great ancient plateau of altitude mainly 300–600 m, although the low but often rugged mountains of the

Table 1.1. A comparison of the geographic features of Australia, Africa and South America.

	Australia	*Africa*	*South America*
Area ($10^6 \times km^2$)	7.7	29.8	17.8
Mean altitude (m)	330	660	650
Highest point (m)	2228	5895	6959
Land surface below 200 m (%)	39	10	38
Land surface above 1000 m (%)	0.5	23	13

MacDonnell, Musgrave and Hamersley ranges reach 1000–1500 m. The interior lowlands include the arid central basin of relatively young sedimentary rocks and gentle low topography. The eastern uplands are bounded by a well-watered coastal plain extending along the whole of the eastern seaboard; this is paralleled by the Great Dividing Range, 150–400 km wide, and consisting mostly of tablelands, ranges and low mountains. There are only limited mountain areas above 1000 m including the highest point on the continent, Mt Kosciusko (2228 m). A detailed physiographic map of Australia that subdivides the continent into major and minor regions in a hierarchy of increasing uniformity of relief types has been prepared by Jennings and Mabbutt (1977). Their nomenclature is followed in this book and a simplified version of the map appears as Figure 1.1.

The rivers of Australia have small flows by world standards; most streams in the interior flow intermittently while some flow rarely. About half of the western plateau has no coordinated drainage and over much of central and western Australia the river systems die out on the desert plains. The many salt lakes of arid Australia reflect the disintegration of surface drainage. A corollary of the failure of the river systems is the extent of aeolian sand surfaces — about one million km^2 of sand plain and about the same of sand-ridge desert. Remnants of ancient drainage systems may be present in the arid zone and the water-gathering nature of these and accumulated sand or gravel in old channels provide important ecological niches for trees, which may attain dimensions surprising in view of the low average precipitation. Elsewhere the microtopography of the plains may so greatly redistribute rainfall that tenfold variation in pasture production may be observed. Although well-established, deep-rooted plants may be less influenced by these effects, it is quite certain that even for these plants moisture redistribution can have a significant effect, as has been reported for mulga *(Acacia aneura)* groves in central Australia (Perry 1970; Winkworth 1983). In such circumstances, climatic data alone will not give a reliable indication of the moisture requirements of naturally occurring species.

Figure 1.1. Major landform provinces of Australia (adapted from Jennings and Mabbutt 1977).

CLIMATE

The climate of Australia is predominantly continental with the weather conditions consistent with a relatively small land mass of modest altitude surrounded by extensive areas of water and situated in the low to mid-latitudes. Weather patterns are strongly influenced by the great anticyclones that travel from west to east in these latitudes. Over much of the continent the climate is characterised by low rainfall, high air temperatures and high levels of solar radiation. The wetter and cooler climates occur over relatively small areas, mainly in Tasmania and the southeast of the mainland within 100 km of the sea. The *Year Book of Australia* provides data on representative localities in Australia as well as periodically covering selected aspects of climate in special articles. Larger-scale maps are available in Parkinson (1986). Meteorological records of stations of forestry interest are given by Hall et al. (1981), while Australia (1988) is a comprehensive source.

Temperature

The summer is warm to hot (Figure 1.2). The isotherms of summer maxima generally run parallel to the coast, the highest temperatures occurring in the arid northwest; in the southeast the broad pattern is modified by high elevations and strong sea breezes. (In comparing these isotherms with those from other countries, note that some maps depict not actual temperature, but what the temperature would be if the surface were reduced to sea level.) The north–south gradient is not as great as the latitudinal range might lead one to expect, probably because of the common occurrence of cloud in the north in the summer months.

Mid-winter is warm in northern Australia and cold in the south (Figure 1.3). The highlands of southeastern Australia are too cold for plant growth in the winter months, and snow may occasionally reach down to 600 m. The frequency and severity of frost depend

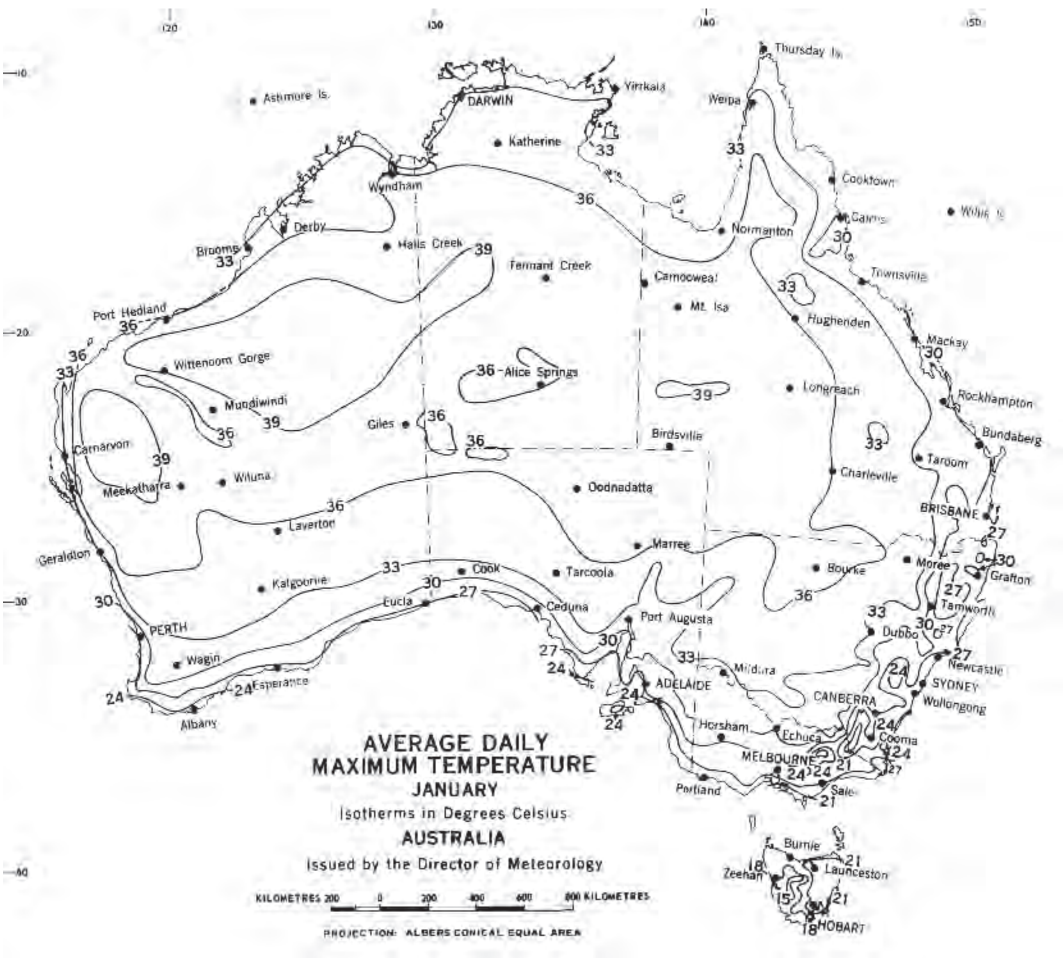

Figure 1.2. Average daily maximum temperature in January (summer) (ABS 1994).

on latitude, altitude and nearness to the sea. The actual incidence of frost is highly variable from year to year; occasional early frosts in autumn or late frosts in spring may be of considerable ecological importance. Figure 1.4, based on Fitzpatrick and Nix (1970), shows areas delimited by dates that represent one standard deviation prior to the mean date of the first occurrence of a screen temperature below 0°C in autumn, and one standard deviation after the mean date of last occurrence in spring. The extreme minimum temperatures recorded in each State are shown in Table 1.2. The actual minimum temperatures experienced by young plants near the soil may be much lower than the screen temperatures, and will be greatly influenced by the degree of exposure to the sky, the soil characteristics of adjacent surfaces and microtopography (Turnbull and Eldridge 1983; Cremer and Leuning 1985). For these reasons small young seedlings in plantation situations may be exposed to significantly greater cold than when regenerating naturally in the presence of other plants, and thus records of screen minima from Australia may not be a good guide to frost hardiness of plants grown in cultivation.

Rainfall

Australia is the world's most extensively dry continent (excluding polar regions) with erratic rainfall and frequent droughts. The annual 10 and 50 percentile rainfall maps are shown in Figures 1.5 and 1.6. On average, in 1 year in 10 the total rainfall has been less than the 10 percentile value; in half the years rainfall has been lower, and in half the years rainfall has been higher, than the 50 percentile value. The 50 percentile value is generally close to the arithmetic mean. About half the country has a median (50 percentile) rainfall of less than 300 mm and almost one-third has less than 200 mm. The driest States are South Australia (88% of area has less than 300 mm), Western Australia (73%)

Figure 1.3. Average daily maximum temperature in July (winter) (ABS 1994).

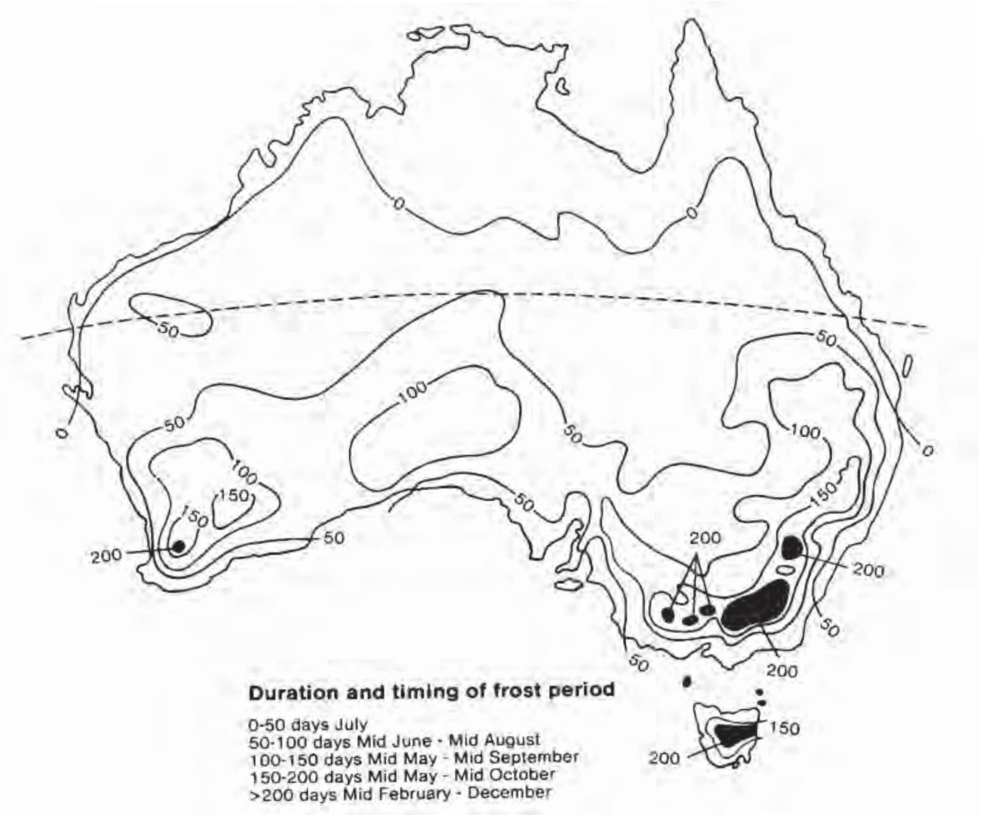

Figure 1.4. Duration and timing of frost periods (adapted from Fitzpatrick and Nix 1970).

and the Northern Territory (51%). Wetter areas are confined to coastal strips and to mountainous areas of the southeast and south of Australia.

The rainfall pattern is strongly seasonal in character with a winter rainfall regime in the south and a summer regime in the north (Figure 1.7). Uniform rainfall occurs in much of New South Wales, parts of eastern Victoria and southern Tasmania. The monsoonal rains of the extreme north fall between November and March; they are rather unreliable. In southwestern and southern Australia fairly reliable, mainly winter rains are associated with the fronts of atmospheric depressions moving across the continent. Tropical cyclones occur and move erratically in the summer or early autumn period in northern Australia, but they may bring rain to areas far to the south. Orographic rains are most important to a small part of the northeastern coastline of Queensland.

Table 1.2. The lowest temperatures recorded in the Australian States (based on Foley 1945 and Hall et al. 1981).

State	*Location*	*Latitude*	*Longitude*	*Elevation (m)*	*Temperature (°C)*
New South Wales	Charlotte Pass	36°20'S	148°20'E	1759	–22
Victoria	Mount Hotham	36°59'S	147°09'E	1861	–18
Tasmania	Oatlands	42°18'S	147°22'E	432	–13
Queensland	Stanthorpe	28°39'S	151°36'E	792	–11
South Australia	Kyancutt	33°08'S	135°34'E	58	–8
Western Australia	Booylgoo	27°45'S	119°55'E	610	–7
Northern Territory	Alice Springs	23°36'S	133°36'E	5	–7

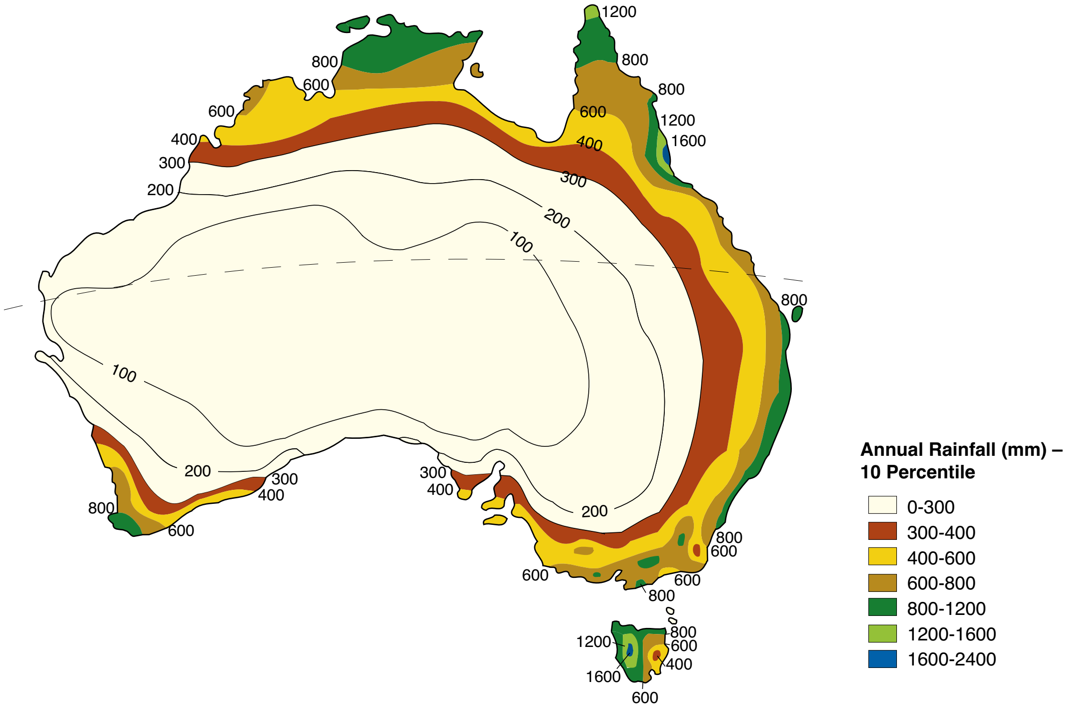

Figure 1.5. Annual 10 percentile rainfall (ABS 1983).

More than 80% of the continent has at least three months each year that are without effective precipitation. Erratic rainfall and drought, disastrous for the agricultural and pastoral industries, are recurring themes over most of Australia. Coasts facing west and southwest in the temperate zones receive exceptionally constant rainfall; the variability increases inland and northwards as storm rains replace winter showers as the main source of precipitation. The variability is greatest on the west coast near the Tropic, but in fact a very large area extending three-quarters of the way across the continent is essentially similar, and even the central coast of Queensland has a value of 28%. Only in the northernmost portions of the continent is rainfall as reliable as the agricultural south. Aridity or drought is a most conspicuous feature of the environment of mainland Australia.

Two further points may assist the reader in comparing the Australian position with that of other countries. First, one can say that one-tenth of all years will have the rainfall shown in Figure 1.5 or less, rather than falling closer to the median value shown in Figure 1.6. Second, the variability in Australia is mostly greater than the world mean of places of the same average rainfall (Leeper 1970).

Annual rainfall is a first approximation of the supply of water for plants but the effectiveness of rainfall is modified by seasonal distribution, intensity, evaporation, surface runoff, and seepage or subsurface flow, all of which have a direct bearing on the availability of soil moisture, which in turn depends on the water-holding capacity of the particular soil type. High-intensity rains fall at a rate that exceeds the infiltration capacity of the soil surface, and a large fraction of the rain may run off. Even gently sloping soil surfaces with a poor structure may absorb little moisture from rainfall of moderate intensity, and soils of poor structure are common in Australia.

The rate of evaporation of rain also influences its effectiveness; the annual evaporation from an open tank exceeds annual rainfall everywhere on the mainland except in the eastern highlands, and exceeds 2000 mm over 75% of the total area.

The two factors of high rainfall intensity and high evaporation combine to diminish effectiveness of

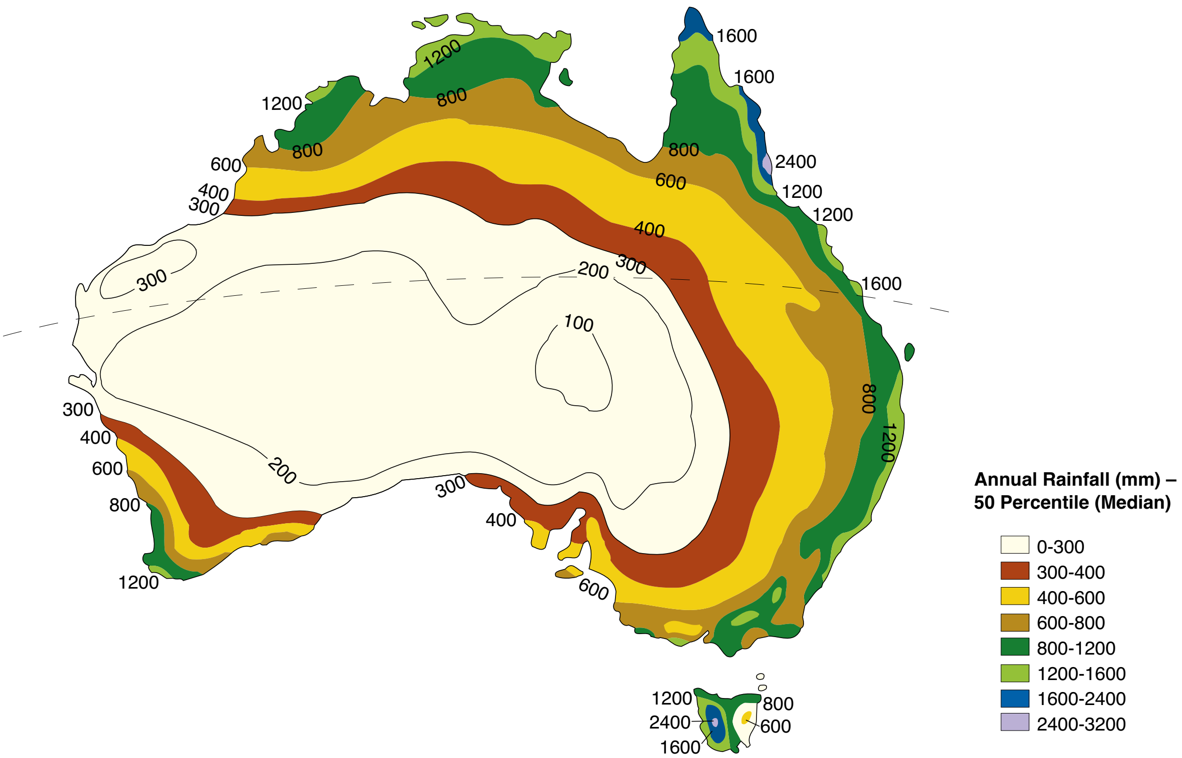

Figure 1.6. Annual 50 percentile (median) rainfall (ABS 1983).

rainfall in northern parts of the continent. At the same time, significant runoff may mean that in water-gaining areas much more moisture is available to plants than figures for average precipitation alone would suggest. The variable occurrence of reserves of soil moisture is undoubtedly a major factor in the development of indigenous vegetation; species from such localities may not thrive when planted in areas of corresponding climate but with different surface drainage characteristics. Rare groups of years of above average rainfall may have particular significance for the regeneration of trees and shrubs in normally arid or semi-arid areas. Thus records of mean or median rainfall may give a poor indication of the requirements for successful establishment in exotic situations.

HOMOCLIMES

Australia's tropical region covers two separate zones with distinct climates. First, the monsoonal tropics characterised by well-defined wet and dry seasons are comparable to climates in eastern Indonesia, northern Thailand, parts of Myanmar, and southern and eastern India. Much of central and western Africa (south of the Sahel), northeastern Brazil and Venezuela have a similar climate (Figure 1.8). The second zone, the humid tropics, occupies a relatively small area along the northern coast of Queensland between latitudes 16°S and 19°S. It is comparable to much of Southeast Asia, the Congo Basin in central Africa and the Amazon Basin of South America.

Subtropical sub-humid and subtropical humid climates are confined principally to southeastern Queensland and northeastern New South Wales between latitudes 20°S and 32°S. Similar climatic conditions occur in southern China, parts of northern India, eastern areas of South Africa, Zimbabwe, southern Brazil, Paraguay and northern Argentina.

The basis of separating the arid and semi-arid regions from the rest of Australia lies not only in the low rainfall they receive but in that it is erratic, so the growing season for many agricultural plants can be as short as one month and rarely exceeds five months. In arid and semi-arid regions, the median is a more appropriate measure of rainfall than the mean because

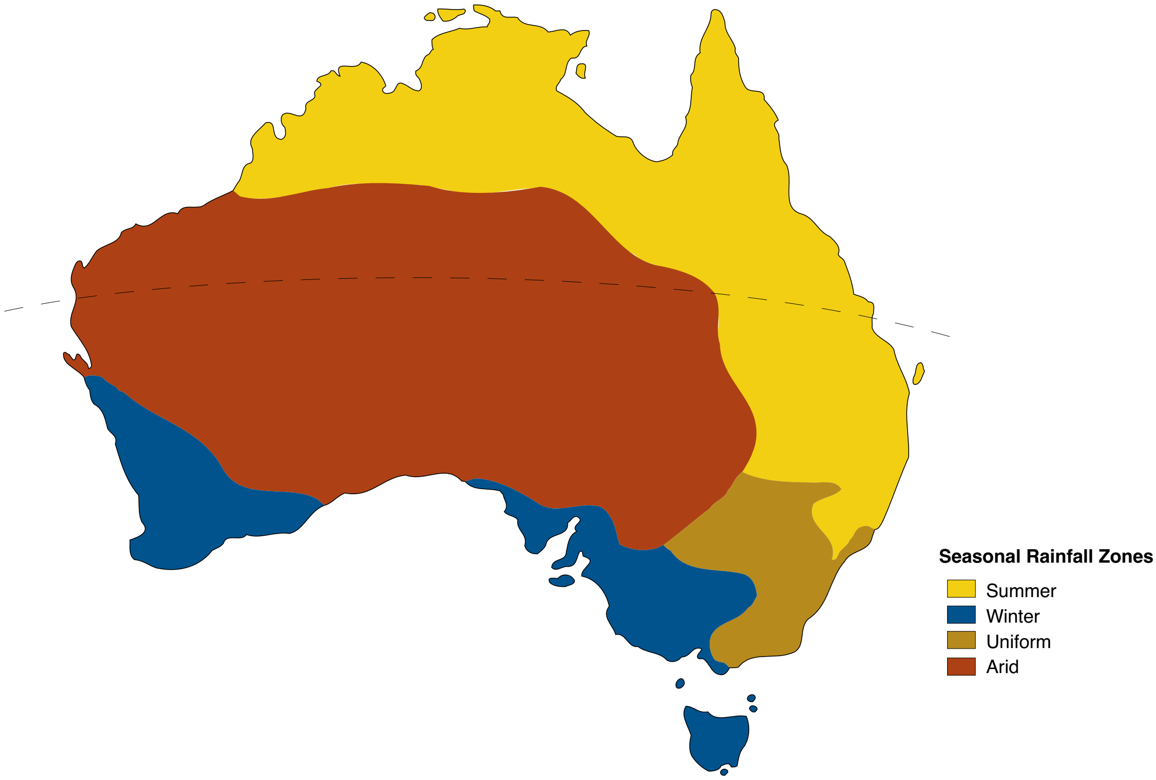

Figure 1.7. Seasonal rainfall zones (modified from Anon. 1983).

the combination of many small falls and few large falls exaggerates the influence of the few large falls, the mean in these circumstances being much higher than the median.

The northern arid and semi-arid zones extend across most of northern Australia between latitudes 16°S and 24°S. This climatic region corresponds with that of many developing countries, especially in the Sahel and Horn of Africa, southern Arabia, north-western India, Argentina and northeastern Brazil. The more temperate arid and semi-arid zones occur south of latitude 24°S and have low, erratic rainfall occurring mainly in winter. Similar climates are found in northern Africa, southwest Africa, the Middle East, Pakistan, southern Argentina, and northern Mexico.

The temperate humid and sub-humid climates of Australia occur in the extreme southwest, the south-east, and Tasmania. Comparable climates occur in southern Europe and countries fringing the Mediterranean Sea, in Chile, New Zealand, South Africa and parts of the United States of America. Species from these temperate zones often grow well in high altitude tropical areas. The success of *Eucalyptus globulus* in Ethiopia, the Nilgiri Hills of India and the Andes of Peru provides an example.

The climatic matchings produced using the zones shown in Figure 1.8 are very broad. For example, the temperate region includes both Kitimak in British Columbia (mean annual temperature 7°C, mean annual precipitation 2939 mm) and Tunis (mean annual temperature 18.5°C, mean annual precipitation 443 mm). Before computers were widely available, classifications were often used to show where particular species might grow. For example, maps were developed to show areas of Brazil and South Africa which were suitable for particular eucalypt species (Golfari et al. 1978; Poynton 1979). This work was highly successful, but it suffers from major disadvantages. Trying to describe a particular tree's climatic requirements in terms of an existing classification is like buying a ready-made suit; it may or may not be a good fit. The computing technology now available can provide a 'made-to-measure' description for each species or provenance, and in seconds generate a

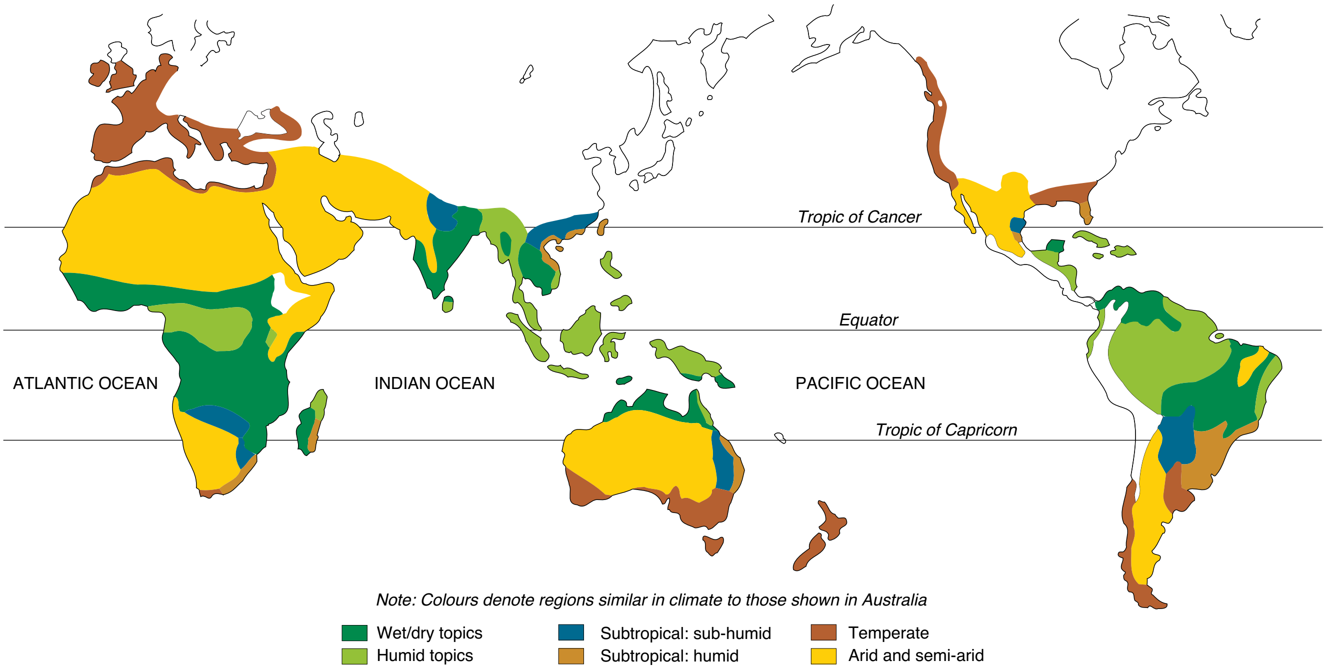

Figure 1.8. Climatic regions of the world (from Department of Trade and Resources 1982).

detailed map showing exactly where environments suitable for that tree exist (Booth 1996).

The key to this capability has been the development of methods of climatic interpolation. The map shown in Figure 1.9 was produced by a program which uses data interpolated for nearly 100 000 locations across China. Information for these locations was calculated from an analysis of data from over 2000 meteorological stations. Figure 1.9 shows areas of China which are climatically suitable for *Acacia mearnsii* according to the following description:

Mean annual temperature (°C)	14–22
Mean minimum temperature of coldest month (°C)	0–17
Absolute minimum temperature (°C)	> -5
Mean maximum temperature of hottest month (°C)	21–35
Mean annual precipitation (mm)	700–2300

This description has been developed from information on the species' natural distribution as well as its successful introduction into other areas (Booth and Yan 1991). Climatic mapping programs such as that used to produce Figure 1.9 have been developed for several countries including Australia, Zimbabwe, Indonesia and Vietnam, as well as regions such as Africa and Central/South America and the whole world. Many of these programs are described in a recent ACIAR proceedings entitled *Matching Trees and Sites* (Booth 1996). Descriptions of the climatic requirements of many well-known species have already been developed and tentative descriptions of requirements of lesser-known species in this book will be possible as information from successful trials becomes available. As more data are gathered from trials it will be possible also to describe the effects of soil conditions on growth. The ACIAR proceedings describes the use of the Plantgro model and simulation mapping programs, which use soils as well as climatic information to provide indications of the likely growth potential of particular trees on particular sites.

Figure 1.9. Green shaded areas are climatically suitable for *Acacia mearnsii* according to requirements described by Booth and Yan (1991).

SOILS

The soils of Australia have undoubtedly had a major influence on the evolution of the flora; the tolerance shown by many species to unfavourable conditions when grown in other countries is a reflection of their persistence under adverse conditions in their native habitat. Most of the major Australian soil groups have equivalents in other parts of the world, yet the soil cover of the continent presents a number of features that together give it some distinctive character (Hubble 1970):

- generally low nutrient status with widespread and severe deficiencies of phosphorus and nitrogen, and some deficiencies of trace elements, multiple deficiencies being common although accommodated by the indigenous flora;
- poor physical condition of surface soils, which over large areas have poor infiltration characteristics, set hard on drying and tend to surface sealing;
- large areas of soils with strongly-weathered or differentiated profiles; and
- the prominence and variety of soil micro–relief patterns of mounds and hollows (gilgai) with associated soil profile differences, which affect the distribution and growth of indigenous species.

A soil map of Australia of the size of this book would be either excessively complex or excessively generalised. Therefore for the present purpose reliance will be placed on the following rather general comment. Soil geography at the continental level is reasonably well covered at a scale of 1:2 000 000 by the *Atlas of Australian Soils* (Northcote et al. 1960–68; Northcote et al. 1975) and at a scale of 1:5 000 000 by Anon. (1980). Neither the U.S. Soil Taxonomy (Soil Survey Staff 1975) nor the FAO-UNESCO (FAO 1990) systems have been or will be used for soil survey in Australia, although features of Australian soils may be described by these systems for international audiences. A new classification system for Australian soils is described by Isbell (1996). Systems of soil classification in general have an agricultural bias, and are of less value for forests.

The soil classification used in descriptions of species ecology in this book is that of Stace et al. (1968), which recognises 43 groups of soils based on the degree of profile development and degree of leaching (Table 1.3). This system provides a better link to international systems than does that used by Northcote et al. (1960–68).

The native vegetation has not had an important influence on soil formation. The generally dry soil surface conditions, limited meso-fauna, woody nature of much of the litter, and efficiency of plants in withdrawing nutrients before abscission of plant components have tended to slow the incorporation of litter in the surface soil. For the most part reserves of organic matter in surface soils are only l–2%; perhaps more than 75% of the land has values less than 1% (Division of Soils, CSIRO 1983, p. 554). Since nitrogen levels (as well as other properties related to soil fertility) are correlated with those for organic matter, it is easy to understand the importance of nitrogen-fixing plants, including *Acacia* and *Casuarina*, in many Australian ecosystems.

Australia is geologically old with relatively minor geological events since the Tertiary (beginning 60 million years ago). There has been no recent mountain building or extensive vulcanism, and glaciation in the Pleistocene period affected only 0.5% of the continent, mainly in Tasmania. Consequently little new parent material has been exposed and there are many ancient land surfaces.

The most extensive example of the ill effects of old age is lateritic soil. This commonly occurs as a peneplain with ironstone or laterite on the surface or subsurface overlying kaolin up to a metre or more in thickness; the ironstone may be present as gravel or boulders. Sand may overlie the ironstone, constituting

Table 1.3. Australian Great Soil Groups in order of degree of profile development and degree of leaching, as defined and described by Stace et al. (1968) (based on Beadle 1981).

I. No profile differentiation. Nos 2–6 classed as Regosols, which are deeper soils formed from transported rock particles which may or may not have been weathered chemically.	1. LITHOSOLS. Stony and gravelly soils; texture varies from sand to clay loam; rock fragments usually present.	Elevated rocky or stony areas. Arid to humid. Many communities.
	2. SOLONCHAKS. Highly saline; sands to clays, the clays often granular and cracking on drying; surface sometimes salt-encrusted.	Near the sea, or in arid zone. Halophytic communities.
	3. ALLUVIAL SOILS. Formed on alluvium. Texture, stoniness, depth, colour and carbonate-content vary.	All parts of the continent, usually associated with rivers, fan-formations. Vegetation various.
	4. CALCAREOUS SANDS. Siliceous sands enriched with calcium carbonate.	Mainly littoral zone.
	5. SILICEOUS SANDS. Quartz sand without or with a coating of hydrated ferric hydroxide, hence white, yellow, yellow-brown to red. Acid throughout.	Coast, or inland as dunes.
	6. EARTHY SANDS. Sandy profiles, yellow or red. Some contain ironstone gravel. Acid.	Semi-arid areas with xeromorphic communities, or arid areas with hummock grassland.
II. Minimal profile development. Soils exhibit little or no evidence of leaching, either because they occur in drier climates, or the high clay content retards water movement through the profile.	7. GREY, BROWN AND RED CALCAREOUS SOILS. Shallow (to about 40 cm), weakly structured loams to light clays with fine carbonates throughout (pH about 9). Grey-brown or red. Organic matter very low.	Arid zone. Support halophytic shrubland.
	8. DESERT LOAMS. Moderate texture contrast. A horizon to 10 cm deep, neutral to alkaline, light brown to red-brown. B horizon with added clay, alkaline.	Arid zone; alluvial plains and associated stony uplands (gibber downs). Support halophytic shrublands.
	9. RED AND BROWN HARDPAN SOILS. Shallow to moderately deep. A horizon non-saline, acid to neutral. B horizon indurated with silica cementation and clay, massive, sometimes with gravel.	Arid zone; restricted to central WA and northeastern SA. Support *Acacia* shrublands.
	10. GREY, BROWN AND RED CLAYS. Deep clays, usually paler with depth. Surface soils granular, acid or alkaline, cracking, often with gilgais. Subsoil blocky, acid or alkaline.	Along watercourses and floodplains. Support grasslands in driest areas, woodlands of *Casuarina*, *Acacia* and *Eucalyptus* elsewhere.
III. Dark soils. Clayey soils with a relatively high organic content. Occur between 500 and 1000 mm isohyets.	11. BLACK EARTHS. Heavy clays with fairly uniform texture profile, dark grey to very dark brown to black. A horizon, neutral to alkaline. Lower horizons with secondary calcium carbonate. Crack deeply on drying.	Tas. to north Qld. High fertility. Support grassland or *Eucalyptus* woodland with a grassy understorey.
	12. RENDZINAS. Shallow alkaline soils developed on limestones or marls.	Small areas in eastern States. High fertility. Vegetation as No. 11.

Table 1.3. *continued*

III. Dark soils. *continued*	13. CHERNOZEMS. Resemble No. 11, but differ in having only less clay in topsoil which is mildly acid.	Small areas in the eastern States, supporting *Eucalyptus* woodlands with a grass understorey.
	14. PRAIRIE SOILS. A horizon light clay or loam, dark grey-brown, brown or black, acid. B horizon more clayey; acid to mildly alkaline.	Coastal to sub-coastal areas from southern Qld to Tas. and SA. Support *Eucalyptus* forest or woodland.
	15. WIESENBODEN (Meadow Soils). Related to Nos 11 and 13, but they have gley formed under conditions of waterlogging, pH 6.0–8.0.	Same areas as No. 11. Support *Eucalyptus* spp. tolerant of waterlogging, e.g. *E. ovata*, *E. tereticornis*, or *Melaleuca* spp.
IV. Mildly leached soils. Texture-contrast soils, mostly with brown or grey-brown A horizons and darker brown B horizons.	16. SOLONETZ. Sandy or loamy A horizon abruptly differentiated from clayey B horizon. A horizon neutral to slightly alkaline. B horizon very compact resulting in poor drainage, pH high (to 9.0).	Semi-arid regions in southeast and southwest. Support *Eucalyptus* woodlands.
	17. SOLODIZED SOLONETZ AND SOLODIC SOILS. Resemble No. 16 but are more leached. A and B horizons abruptly differentiated. A horizon sandy, acid; B horizon columnar to blocky, very alkaline below.	Widespread in all States in areas with mean annual rainfall of 400–1000 mm. Support *Eucalyptus* and *Acacia* woodlands.
	18. SOLOTHS (Solods). Resemble No. 17 but are acid throughout the profile.	Occupy small areas. Vegetation as No. 17.
	19. SOLONISED BROWN SOILS. Contain abundant calcium carbonate. Profile sandy throughout. A horizon neutral or slightly alkaline, brown to red-brown. B horizon with much carbonate, alkaline.	Semi–arid and arid south in west and east. Support mallee, or woodlands (chiefly *Casuarina cristata*).
	20. RED–BROWN EARTHS. A horizon loamy. B horizon with added clay, calcium carbonate present. Usually with high base status.	Mainly south of the Tropic of Capricorn between 400 and 630 mm isohyets where they support *Eucalyptus* woodlands.
	21. NON-CALCIC BROWN SOILS. Similar to No. 20 but with no calcium carbonate in the B horizon. Profile slightly acid to slightly alkaline.	Semi–arid southeast and southwest. Support *Eucalyptus* woodlands.
	22. CHOCOLATE SOILS. Acid, friable clay loams; some leaching but high in bases. High fertility.	Mainly southeast, Qld to Vic. Support *Eucalyptus* woodlands and forests.
	23. BROWN EARTHS (Brown Forest Soils). Yellowish, reddish or dark brown throughout. Light loams to clays. Surface acid to neutral; pH and bases increase with depth.	Humid climates from SA to northern NSW. High fertility and support *Eucalyptus* forest or rainforests.
V. Soils with predominantly sesquioxidic clay minerals. Other than having uniform colour profile, the 7 Soil Groups have little in common.	24. CALCAREOUS RED EARTHS. Soil uniformly sandy, clay increasing slightly with depth; profile alkaline.	Arid zone. Support *Acacia* scrubs, *Casuarina cristata* woodlands, or *halophytic* shrublands.

continued over

Table 1.3. *continued*

V. Soils with predominantly sesquioxidic clay minerals. *continued*	25. RED EARTHS. Red throughout except for surface organic matter; contain some clay; structure weak crumby to blocky. Acid.	Widely distributed in northern arid zone to wetter tropics. Support *Acacia* woodlands (drier) to *Eucalyptus* forests (wetter).
	26. YELLOW EARTHS. Similar to No. 25 but yellow to yellow-brown. Acid.	Sub–humid to humid areas, NSW to Cape York; southwest and northwest WA. Low fertility and usually support xeromorphic communities.
	27. TERRA ROSSA SOILS. Shallow red or red-brown soils developed on highly calcareous materials. Neutral to slightly alkaline.	Uncommon; close to coast in southeast and Tas. Support *Eucalyptus* communities including some types of mallee.
	28. EUCHROZEMS. Red, clayey, strongly structured; derived from basalt. A horizon dark with organic matter, mildly leached, slightly acid. Clay increases with depth.	Small patches in the east and tropics between 630–750 mm. Support *Eucalyptus* woodlands.
	29. XANTHOZEMS. Yellow, clayey, friable, strongly structured, with moderate horizon differentiation, acid, high fertility.	Sub-humid regions in the east in summer rainfall zone. Support drier types of rain-forest or grassy *Eucalyptus* forests.
	30. KRAZNOZEMS (Red Loams). Deep, red or red-brown; high organic matter in surface. Acid (pH 4.5–5.5); base saturation about 50%.	Mainly east from north Qld to Tas. with mean annual rainfall 850–3700 mm. Support rainforests or tall *Eucalyptus* forests.
VI. Mildly to strongly acid and highly differentiated: Podzols and Podzolic Soils.	31. GREY–BROWN PODZOLIC SOILS. A horizon grey to grey-brown, medium textured; A2 distinct but not bleached. B horizon yellow to yellow brown, with blocky structure and high clay. Acid except neutral in lower B.	East and southeast from southern Qld to SA Mean annual rainfall 500–1000 mm. Support *Eucalyptus* forests and woodlands.
Characterised by strong eluviation of clay and sesquioxides from the A horizon and their deposition in the B horizon. The soils occur in wet climates.	32. RED PODZOLIC SOILS. A1 grey-brown; A2 light grey to yellowish; both sandy loam to clay loam. B horizon red brown to red, sandy clay to heavy clay. Profile acid; base saturation high to low.	Humid east and north. Support *Eucalyptus* forests and woodlands, rarely rainforests.
	33. YELLOW PODZOLIC SOILS. A horizon greyish or brownish sand to clay loam. B horizon yellow-brown, friable, clayey. Profile acid.	Mainly humid east. Support *Eucalyptus* forests and woodlands; *Nothofagus* forest in Tas.
	34. BROWN PODZOLIC SOILS. Profiles brownish to yellowish throughout. B horizon with some eluviated clay.	More humid areas of Tas., highlands of Vic., southwestern WA. Support tall *Eucalyptus* forests and woodlands or heaths.
	35. LATERITIC PODZOLIC SOILS. A horizon sandy; B horizon mottled yellow-brown to red clay. Ironstone present. Acid throughout.	Many parts of the continent with mean annual rainfall exceeding 500 mm. Support *Eucalyptus* forest or woodland.
	36. GLEYED PODZOLIC SOILS. Profile of the podzolic type with mottling from A2 downward which are the result of waterlogging. Acid throughout.	Areas subject to waterlogging, mainly humid southeast. Support species adapted to some waterlogging, e.g. *Eucalyptus ovata* and *Melaleuca* spp.

continued over

Table 1.3. *continued*

VI. Mildly to strongly acid and highly differentiated: Podzols and Podzolic Soils. *continued*	37. PODZOLS. Strongly differentiated sandy profiles. A1 dark, with organic matter; A2 white. B yellow to red to black with eluviated clay, sesquioxide and organic matter.	High rainfall areas, chiefly near coast. Low fertility soils, supporting xeromorphic woodlands, scrubs or heaths.
	38. HUMUS PODZOLS. Resemble No. 37, but have a dark coloured (sometimes black) B horizon formed as an accumulation at the level of watertable.	High rainfall areas, chiefly near the coast in areas subject to waterlogging. *Banksia* or *Melaleuca* dominant.
	39. PEATY PODZOLS. Profile surmounted by a thick layer of brown or black peat up to 25 cm deep. Very acid (pH 4–5).	Mainly southwest Tas. in perhumid cool–cold climates.
VII. Dominated by organic matter. Profile with much organic matter in the topsoil obscuring the effects of other components. Formed under wet conditions, some with waterlogging.	40. ALPINE HUMUS SOILS. Horizons merge. A horizon ca 25 cm deep, grey, brown to black, friable. Lower layers brown to yellow brown, merging to grey. High fertility.	Highlands of southeast. Support subalpine woodlands, heath, or grasslands.
	41. HUMIC GLEYS. Similar to No. 36 but with much organic matter intimately incorporated in the dark A horizon. Acid to neutral, some subsaline.	East coast behind littoral zone or valley plains along rivers. Support *Eucalyptus* swamp forests, or *Melaleuca* or *Casuarina* spp.
	42. NEUTRAL TO ALKALINE PEATS. Organic matter accumulated under influence of alkaline ground–water.	Coastal areas, southeast SA, northwest Tas.
	43. ACID PEATS. Dark–coloured to black; organic matter. Profiles up to ca 1 m deep, waterlogged permanently or regularly.	High mountains and plateaux, NSW, Vic. and Tas.
VIII. Fossil laterite residuals.	44. IRONSTONE GRAVEL SOILS. Gravelly soils sometimes with a sandy matrix; massive ferruginous laterite commonly present and sometimes part of the mottled zone below. See No. 35.	Extensive areas in southwest WA. and small areas in northwest WA. and NT., arid zone and the east. Vegetation various, but always xeromorphic.

sand plain. The laterite is a relic of warmer and wetter climates in earlier geological times, when weathering extended in some cases to a depth of 60 m. The durable ironstone capping may break away where the underlying clay is eroded, leading to the formation of a newer, lower land surface with more normal soils. Sands derived from weathered laterites are of low fertility and have been spread over wide areas, adding to the already poor sandy soils derived from older sandstone and granite formations.

Among the best soils are the undulating ‘downs’ of central western Queensland where, in the central basin, moderately fertile self-mulching clays have formed from underlying fresh sediments.

Between these two extremes a variety of soils has formed on various mixtures of the deeper weathered horizons of ancient profiles, accumulations or detritus on lower plains and fresh parent rock. The nature of the old materials, rather than current climate, has been the dominant influence on the soils now present. Even the more prominent hills generally have a mantle of soil, albeit often shallow. The balance in many cases appears to have been rather delicate, and consequently the disturbances that have accompanied European settlement over the last 200 years have tended to accelerate erosion. These changes are however of little significance in the present context.

Over large areas Australian soils are more acid than pH 6. Such soils are common in wetter climates, but contrary to what might be expected are not unusual in more arid areas. The extent of acid soils is such that only a relatively small number of indigenous species are adapted to alkaline conditions, and where soils in prospective planting areas have a high pH the range of candidate species from Australia is consequently rather limited.

High concentrations of salt (sodium chloride) are common in soils close to the coast; under drying conditions incrustations may form on the soil surface. It is not unusual to find species of *Casuarina* growing in such soils. High concentrations of salt (sodium chloride and sulfate) may also be found in inland soils, especially in and near shallow valleys of old river systems: the origin of this material is not always clear; although in some instances parent materials contain abundant salt. Certainly the limited opportunity for leaching, arising from low rainfall and high evaporation, contributes greatly to the salinity problem; the small runoff, unmatched in any other continent, is illustrated by the following figures (Australian Water Resources Council 1976):

Area (km^2)	7 690 000
Average rainfall (mm)	420
Evapotranspiration (% rainfall)	87
Runoff (% rainfall)	13

Saline soils, dominated by chlorides, occur over great areas of southern and central Australia (more than 5% of total area, Northcote and Skene 1972). Even greater expanses (25–30% of total area) of sodic soils occur over many parts of the continent.

The soils of other continents show some similarities but many differences with those of Australia. Parts of Africa come closest to the Australian scene, but the latter has a much greater occurrence of strongly differentiated soils with sodic clay B horizons. Such soils are also lacking in South America, while Australia has few deep, highly leached, strongly acid sesquioxide soils common in that continent, and on which some Australian trees have grown very well. Further contrasts between Australia and other continents are given by Sanchez and Isbell (1979).

FIRE

Much of the Australian flora is adapted to particular fire regimes (combinations of fire intensity, frequency, and season) (Gill et al. 1981). In addition to their direct effects on plants, fires have a less obvious and less well understood effect on nutrient status and cycling of the vegetation. The adaptive traits of trees and shrubs growing in fire-prone environments are discussed in Chapter 2.

In arid and semi-arid areas, extensive fires are rare because of the usually discontinuous nature of the fuels (Luke and McArthur 1978). In dry forests and woodlands, especially in northern Australia, annual fires are common. There is evidence that since Europeans arrived 200 years ago these fires have become more extensive, burning later in the dry season and with higher intensity than was the case when only Aboriginal people were present. At least some of the woody plants are adversely affected by present fire regimes, and relict communities of more fire-sensitive species are in retreat. In the tall moist forests of the southeast of the continent, fires are rare but when they do occur — perhaps at intervals of many decades — they are of high intensity due to the large accumulation of fuel and the extreme weather conditions (high temperatures, low fuel moisture content, low humidities and strong winds) associated with them (Pyne 1991). Between these two extremes are found a range of vegetation types in which fires of moderate intensity occur every few years.

PEOPLE

Studies of fossil pollen in eastern Australia show that eucalypts and other myrtaceous plants have become much more frequent, and casuarinas and other fire-sensitive flora less frequent, in the last 130 000 years. In the same period the amount of fine charcoal in the sediments markedly increased, and it has been suggested that this change in fire occurrence reflects the influence of Aboriginal people (Singh 1982). The hunting fires of the Aboriginal people would have favoured those species adapted or capable of adapting to fire.

When Europeans arrived 200 years ago, the influence of Aboriginal people lessened and was replaced by a variety of agricultural and industrial influences (Saunders et al. 1990). A large fraction of the rainforest was cleared, commonly for dairying; extensive areas of woodland in the southern half of the continent were cleared for cereals and improved pastures. Fire regimes were changed to new and variable patterns of burning to which in at least some cases the woody vegetation is not well-adapted. Watering-points were established in arid and semi-arid range-lands, so permitting population increases in native grazing animals (kangaroos) as well as providing for introduced hard-hoofed animals. The latter now include sheep, cattle, horses, buffalo, goats, pigs, donkeys, deer and camels. Hares and rabbits were established, the latter attaining plague numbers before the advent of myxomatosis in the 1950s reduced their population. A wide range of plants was introduced, some of which have become weeds, and now these frequently compete strongly with indigenous flora. Sometimes the new fire regimes have made regeneration a more precarious process than previously, when climatic factors presented the main difficulties (Adamson and Fox 1982).

It is both fortuitous and fortunate that the genetic resources of the trees of interest in the present context have probably not been greatly reduced by the changes described. Many of them have natural ranges in the north or more arid parts of the continent where the rates of change have been least, and their longevity has lessened the immediate effect of any problems with regeneration. Although arrangements in Australia for *in situ* conservation of indigenous flora are steadily improving, there is no assurance that existing provisions will be adequate for all species and provenances of value to other countries, and thus the conservation status of such species warrants examination on a case-by-case basis.

INSECTS

A large insect fauna has co-evolved with the Australian native flora. The insects associated with eucalypts have received most attention from forest entomologists because of the dominance of that genus; 'from germination, and throughout its life, every organ of a eucalypt provides food and shelter for numerous and diverse forms of insect life' (Carne and Taylor 1978). Remarkably few insect species have become recognised as pests; predators, parasites, diseases, competition and other agencies generally prevent more than very temporary expression of their capacity to increase to damaging levels.

If these same species are transferred to other countries where Australian trees may be growing, the likelihood of their causing damage is increased because the full range of factors controlling population levels in Australia is likely to be lacking. There have already been examples of insects, inconspicuous in Australia, causing significant losses among exotic eucalypts. Because of these examples, and the attention accorded to quarantine measures by the Australian agricultural and pastoral industries, foresters involved in the testing and use of Australian flora in other countries make every effort to prevent insects accompanying exported seed or other plant material. It is realistic to expect that from time to time trouble will be experienced in exotic plantings through the establishment of insects indigenous to Australia. In such cases biological control by natural parasites or predators would be desirable, and if successful would reduce the troublesome insects to an inconsequential level.

In their review of the interaction of eucalypts and insects in Australia, Carne and Taylor (1978) drew attention to the importance of stress in rendering trees susceptible to insect attack. Although some factors such as unseasonal weather are beyond the control of the grower, others such as off-site planting or severe competition due to weeds or dense stands can and should be avoided.

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Chapter 2
AUSTRALIAN VEGETATION

J.W. Turnbull

The woody plants of Australia have been noted for their uniqueness from the time of their discovery and study by European botanists. How different they are is a matter of interpretation, but a degree of uniqueness derives from the fact that some 75% of the species are endemic to Australia and the woody vegetation over most of the continent is dominated by two large genera, *Eucalyptus* and *Acacia*. At a higher taxonomic level, almost all angiosperm families in Australia occur widely in other parts of the world. In this sense, the Australian flora is a typical segment of the world flora and the special character of Australian plants has to be explained in terms of the geography and environment in which they have evolved (Barlow 1981).

Prolonged isolation of Australia following the break-up of the southern super-continent of Gondwana has contributed greatly to the distinctiveness of the vegetation. Australia has been isolated from other continents and even from its near neighbour, New Zealand, for at least 60 million years. During this long period great changes occurred in the climate and soil, which were important in the evolution of the modern flora.

EVOLUTION OF THE MODERN FLORA

The most significant events shaping the evolution of Australian flora took place during the Tertiary period (3–65 million years ago) and the Quaternary period (present to 3 million years ago). During the early Tertiary it is probable that Australia was uniformly humid with a warm seasonally-wet climate, a set of conditions that favoured the development of lateritic soils on the already highly-weathered land surface over much of the continent. These laterites still persist in tropical areas and on mesa formations in the arid zone. Laterisation reduced an already low soil fertility level by progressively fixing phosphorus in insoluble iron and aluminium complexes. Infertile sands derived from weathered laterites were dispersed across the continent and added to similar poor sandy soils derived from sandstone and granite.

Land movements and volcanic activity in the late Tertiary provided some soils of higher fertility in eastern Australia but overall soil fertility appears to have declined in the period leading up to the present. Beadle (1966, 1981) suggests that such soil changes were responsible for the primary evolutionary directions within the Australian flora; many elements of the modern flora have adaptations that enable them to survive and grow on nutritionally very poor soils.

Evidence from fossils indicates that mesophytic communities dominated by temperate rainforest covered much of Australia, including the interior, in the early Tertiary. Major climatic changes occurred in the remainder of the Tertiary, possibly due to the northwards drift of the continent into drier latitudes. It has been postulated that about 10 million years ago the north of Australia became arid or semi-arid and that these conditions moved progressively southwards. The moist temperate climate contracted southwards, except in the eastern ranges, and the northern leading edge of the continent entered the moist humid tropics. The scenario, with significant fluctuations during the Quaternary including several glacial periods, suggests that there has been a major increase in the extent of arid areas in Australia in the last 15 million years.

The increased aridity and greater climatic variability would have fragmented the temperate rainforests established in the relatively stable, humid climate of the early Tertiary. These formations became generally restricted to moister enclaves in eastern and southern Australia, although remnants adapted to drier conditions are now represented in so-called 'softwood scrubs' by species such as *Brachychiton populneus*, *Flindersia maculosa* and *Geijera parviflora*.

Expansions and contractions of communities in response to climatic fluctuations have left disjunct, relict species and populations amongst the present vegetation associations. Many of the species in the modern flora have experienced a variety of environmental conditions and clearly have needed a wide ecological amplitude to survive. The gene pools must have undergone considerable sorting and selection during these vicissitudes leading to the evolution of new species and a high overall genetic variability in the more-widespread species.

Many Australian species have specialised adaptive traits for survival and reproduction that suggest that fire has been a major influence in their evolution (Gill 1981a). It seems likely, however, that long-term evolution of the flora has been influenced more by changes in climate and soils and that the major effect of fire has been relatively recent. Singh et al. (1981) suggest that the use of fire by Aboriginal people in the past 40 000 years, probably resulting in more frequent and less intense fires than in pre-Aboriginal times, has been at least partially responsible for the dominance of *Eucalyptus* and other fire-adapted genera over large areas of Australia. This situation appears to be very different from the more distant past when fire-sensitive plants seem to have been more widespread.

VEGETATION TYPES

Each plant species has a range of environmental conditions in which it is able to grow. Some species with wide ecological tolerances tend to be widely distributed while those with a narrow range tend to be restricted to specific habitats. Species with similar requirements occur in associations or communities, which together constitute the overall vegetation.

Different types of vegetation can usefully be characterised by criteria such as life form, height and leaf size. There have been various attempts to devise a classification to accommodate satisfactorily the distinctive vegetation of Australia. The system most widely recognised at present was drawn up by Specht (1970) and defines structural forms of vegetation in terms of life form and projective foliage cover of the tallest stratum (Table 2.1). The use of foliage cover rather than canopy cover in classifying Australian vegetation takes special account of the open nature of *Eucalyptus* crowns. Trees and shrubs are involved in 20 structural forms defined by five life forms and four classes of projective foliage cover.

In the classification, a tree is defined as a woody plant more than 5 m tall, usually with a single stem. A shrub is a woody plant less than 8 m tall, frequently with many stems arising at or near the base. Projective foliage cover is the percentage of area covered by foliage, measured by a vertical point quadrat technique. The categories include six types of forest ranging from tall closed-forest to low open-forest. They encompass the older and still commonly used terms of 'rainforest,' 'wet sclerophyll forest,' and 'dry sclerophyll forest'.

The broad vegetation types have been mapped by Carnahan (1977) to show their probable distribution immediately prior to European settlement 200 years ago (Figure 2.1).

The following brief accounts of major Australian vegetation types include only those structural forms of vegetation in which woody perennials over 2 m in height are prominent. Heaths, low shrublands, hummock grasslands and herblands are therefore not covered.

Closed-forests

Such forests are commonly known in Australia as 'rainforests'. They are tree-dominated communities, almost

Table 2.1. Structural forms of vegetation in Australia (based on Specht 1970).

	Projective foliage cover of tallest stratum			
Life form and height of tallest stratum	*Dense (70–100%)*	*Mid-dense (30–70%)*	*Sparse (10–30%)*	*Very sparse (< 10%)*
Trees > 30 m	Tall closed-forest	Tall open-forest	Tall woodland	Tall open-woodland
Trees 10–30 m	Closed-forest	Open-forest	Woodland	Open-woodland
Trees 5–10 m	Low closed-forest	Low open-forest	Low woodland	Low open-woodland
Shrubs 2–8 m	Closed-scrub	Open-scrub	Tall shrubland	Tall open-shrubland
Shrubs 0–2 m	Closed-heath	Open-heath	Low shrubland	Low open-shrubland

always with a 'closed' canopy, and usually characterised by broadleaved evergreen species lacking adaptations to dry conditions. A closed canopy means the crowns of the trees touch or overlap so that little sunlight penetrates to the forest floor. Tree and shrub components occur in at least two layers. Closed-forests at one time covered much of the landmass of Australia and provided the primitive stocks that gave rise to the bulk of the modern Australian flora.

The closed-forest communities occur primarily in eastern Australia from tropical northern Queensland to cool temperate Tasmania at altitudes from near sea level to 1200 m or more. Small outliers occur along the tropical coasts of the Northern Territory and Western Australia. Fragments of closed-forest derived from ancient communities are also found in gorges and other specialised environments within the arid and semi-arid zones of tropical and subtropical Australia. The total area of closed-forest at the time Europeans began clearing for agriculture was less than 1% of the land area and is estimated at 6–8 million ha, of which about 2 million ha remain (Webb and Tracey 1981). According to Baur (1989), there is 1.2 million ha of rainforest in Queensland and 0.7 million ha in Tasmania. The biodiversity of rainforest formations is much more than might be expected from its limited area, for they include perhaps half of the total terrestrial biota of Australia (Bell 1981).

Closed-forest formations usually occur in areas with a mean annual rainfall in the range 1200–2500 mm but the drier types may extend to regions with 600–800 mm. Four main types have been recognised: tropical, subtropical, warm temperate and cool temperate. These closely approximate to the mesophyll vine forest, notophyll vine forest, microphyll fern forest and nanophyll moss forest of Webb (1959). The main differences between the tropical and temperate closed-forests are the greater structural complexity and the larger number of tree species present in a given area of the former type. A closed-forest (rainforest) is strictly defined to exclude species that do not regenerate within a well-developed or only slightly disturbed canopy (Webb and Tracey 1981). This definition excludes all species of *Casuarina*, *Eucalyptus* and *Melaleuca* and all but a few species of *Acacia*, *Lophostemon* and *Tristania*. Acacias such as *A. aulacocarpa*, *A. bakeri*, *A. cincinnata*, *A. fasciculifera*, *A. hylonoma*, *A. mangium*

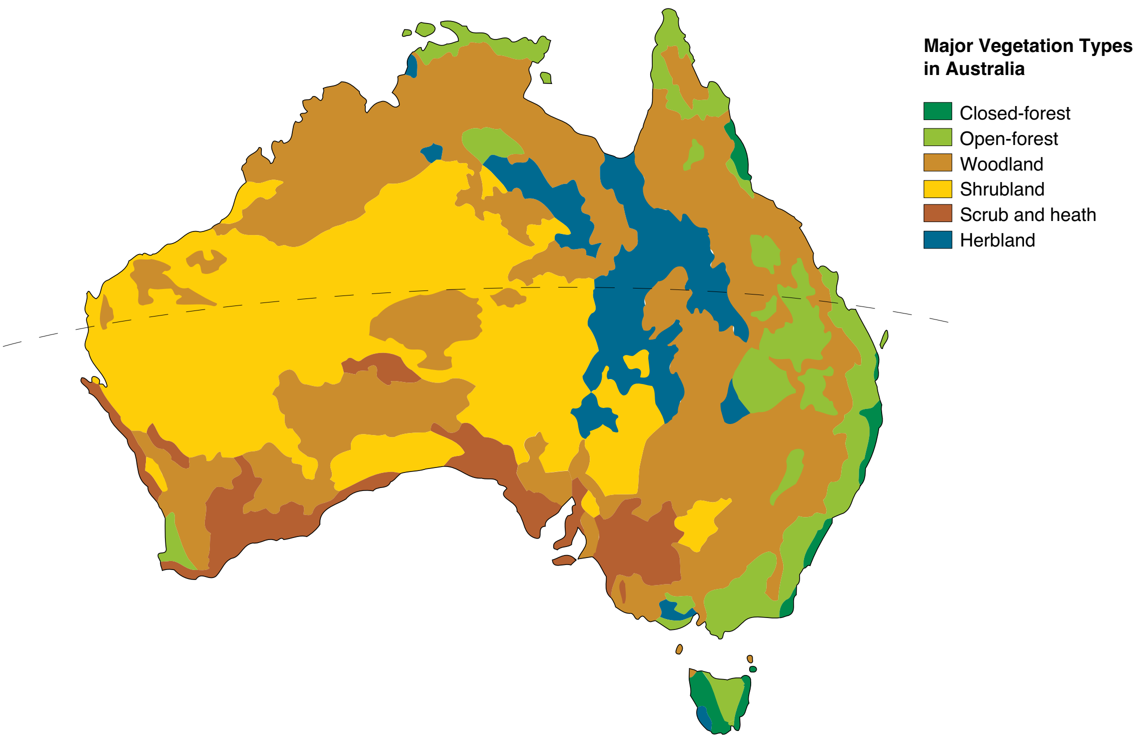

Figure 2.1. Major vegetation types in Australia (from Carnahan 1977).

and *A. melanoxylon* may be regarded as components of closed-forest but are more often found in marginal communities or in more extensive disturbances within the closed-forest, usually where the soils are of low fertility.

The complex pattern of closed-forest and eucalypt open-forest within climatically suitable regions of eastern Australia is primarily related to soil nutrient status (Webb 1969) or to the influence of topography on soil properties. Closed-forests occur on the more fertile soils and have only a limited occurrence on soils derived from acidic rocks such as rhyolites, sandstones and some shales. Soil physical properties are of lesser importance, although closed-forests in higher rainfall areas typically grow on well-drained soils. The ecological balance between the eucalypts and acacias on one side and rainforest species on the other is much more precarious on soils of lower fertility than on highly fertile soils. Frequent fires may maintain a eucalypt or acacia community on a soil of somewhat low nutrient status, which in the absence of fire would support closed-forest. Similarly where soils are temporarily or permanently waterlogged, closed-forest may give way to open-forest dominated by *Melaleuca* species.

Many trees of the closed-forest formations are relatively slow-growing, intolerant of poor soils and sensitive to fire. They commonly provide fine timbers but are of little value for the rapid production of posts, poles and fuelwood now so much in demand in developing countries. It is on the margins of closed-forest where fires are frequent or the soils are of lower fertility that fast-growing, adaptable species with a high potential for planting are to be found. Well-known, successful species such as *Acacia mangium*, *Eucalyptus grandis* and *Melaleuca leucadendra* typically occur in such situations.

Several specialised forms of closed-forest exist in particular habitats and these communities have the potential to provide useful trees and shrubs for planting. They include forests designated semi-evergreen vine forest, softwood scrub, gallery rainforest and mangroves.

Semi-evergreen vine forest, sometimes called ‘monsoon forest’, occurs in northern Australia where the mean annual rainfall of 1300–1500 mm is concentrated in a short summer wet season and there is little effective rainfall in the remainder of the year. In drier areas these forests may extend along watercourses or occupy sites receiving runoff water from higher ground. They occur on a wide range of soils including lateritic red earths, lateritic podzols and even dune sands. They include such species as *Acacia auriculiformis*, *A. aulacocarpa* and *Alphitonia excelsa*. Where water availability is limiting during the dry season, the canopy is lower and dominated by deciduous species such as *Bombax ceiba* and *Terminalia sericocarpa*. In many inland and coastal vine forests of the Northern Territory up to 90% of species may be seasonally deciduous. While many of these species tolerate seasonal drought, it appears that they possess neither the physiological capabilities nor the regenerative capacities which enable eucalypts to compete so effectively in a fire-prone environment (Brock 1988).

Another interesting group of communities occurs sporadically in semi-arid and sub-humid zones of northern Australia. It includes species of genera that otherwise occur in wetter closed-forest. These species are shrubs or trees that form distinctive communities referred to as ‘softwood scrubs’ in some localities or occupy the understorey in eucalypt forest or are found as scattered individuals in *Acacia* shrubland. These dry closed-forest taxa include species of potential value for fuelwood and agroforestry such as *Acacia shirleyi*, *Brachychiton* spp., *Lysiphyllum cunninghamii*, *Terminalia oblongata* subsp. *volucris* and *Ventilago viminalis*.

Gallery rainforests are closed-forests that fringe watercourses. They may occur within the general closed-forest complex and include species such as *Grevillea robusta*, *Melia azedarach* var. *australasica* and *Toona ciliata*. Elsewhere they extend as ribbons into drier country where they may be dominated by *Syzygium floribundum*, *Grevillea robusta*, *Casuarina cunninghamiana* or *Nauclea orientalis* sometimes in association with *Eucalyptus camaldulensis* or *E. tereticornis*.

Mangrove communities are found on many parts of the Australian coast and in structural terms vary from tall to low closed-forests to open shrublands. They can therefore be regarded as rainforest. Adam (1992) treats mangroves as just one of many rainforest formations even though some occurrences are on climatically dry coasts or have a shrubland structure.

In general, mangrove communities occur in the intertidal zone on the coast or in river estuaries and range in height from over 30 m to less than 5 m.

Globally, about 80 species in several genera are regarded as mangroves and the Australian flora includes about 40 species in 15 families. The canopies of mangroves have few species and in many stands there is only a single species. Mangrove species have characteristics which are regarded as adaptations to growing in saline and waterlogged environments. Some produce root adaptations, pneumatophores, which facilitate gaseous exchange, especially of oxygen. *Avicennia marina* produces thin pencil-like pneumatophores from long cable roots while in *Bruguiera* species they are thick and knee-like.

More detailed accounts of Australian closed-forest can be found in Beadle (1981), Webb and Tracey (1981), Figgis (1985), Werren and Kershaw (1987), Brock (1988) and Adam (1992).

Open-forest

In Australia open-forests are usually dominated by *Eucalyptus* trees, although in drier areas species of *Acacia* and *Callitris* may assume dominance. The projected foliage cover is 30–70%, so that the penetration of the main canopy by light may be substantial, and the trees usually develop a forest form with flat crowns and trunks greater in height than the depth of the crowns.

Extensive areas of open-forest cover a broad geographical range from the tropics to temperate regions with great variation in canopy height and structural complexity. Open-forest extends across the northern part of the Northern Territory and to the coastal and highland regions of northern Queensland, southwards through coastal New South Wales, eastern Victoria and Tasmania. The formation is also common in the southwestern corner of Western Australia.

The open-forest formation has been divided into three subformations, viz. 'tall open', 'open' and 'low open' (Table 2.1). In ecological and forestry literature tall open-forest has commonly been referred to as 'wet sclerophyll forest' and open- and low open-forest as 'dry sclerophyll forest'. Tall open-forest covers 126 000 km^2, principally in New South Wales (55%) but with substantial areas in Victoria (21%) and Tasmania (17%). Open-forest extends over 217 000 km^2 and is prominent in Western Australia (22%) although the main areas are in New South Wales (42%) and Victoria (26%) (Specht et al. 1974).

A striking feature of the open-forests of Australia is dominance by species of the genus *Eucalyptus*. Typically two or three eucalypt species grow together as co-dominants in the same stand. Only in a few forest types, mainly in drier or cooler areas, is a single species dominant. For example, some of the more significant tall open-forests are dominated by *E. camaldulensis*, *E. delegatensis*, *E. diversicolor*, *E. grandis*, *E. pilularis* and *E. regnans*. Throughout these forests two habitat factors, water availability and the level of soil fertility, strongly influence species composition and growth. The interplay of these factors and the great number of eucalypt and acacia species give an unusual character to the open-forests. Because the dominant eucalypts, and to some extent the acacias, are very sensitive to habitat conditions, the species change more frequently and rapidly than in open-forests elsewhere in the world (Ovington and Pryor 1983). The structure and composition of the understorey of open-forest change with rainfall, soil type, fire frequency and latitude. In tall open-forest of the wetter areas (over 1000 mm annually) there is usually a dense understorey including tree ferns and tall shrubs, but as rainfall decreases the amount of understorey also becomes less. *Acacia* species are prominent in the understorey of these forests and in the drier areas, or on particular soil types, may assume dominance.

1 Tall open-forest

Tall open-forest is capable of developing on most closed-forest sites under appropriate fire regimes, but elsewhere it is extensive in mountain areas where the annual rainfall is in the range 1000–1500 mm. Temperature conditions range from cool, with frosts and snowfalls, in the mountainous areas of southeastern Australia to mild and warm in coastal Queensland and southwestern Western Australia. Exceptionally tall *Eucalyptus* trees, often over 60 m, are characteristic of this subformation. In the subtropical areas of New South Wales and Queensland the tall open-forests are dominated by *E. pilularis*, *E. microcorys*, *E. saligna* and *E. grandis*; the more temperate southeastern forests by *E. obliqua*, *E. viminalis*, *E. fastigata*, *E. delegatensis*, *E. nitens* and *E. globulus*; and in southwestern Western Australia *E. diversicolor*, *E. calophylla*, *E. jacksonii* and *E. guilfoylei* are common (Ashton 1981). Associated smaller trees and shrubs include *Acacia dealbata*, *A. binervata*, *A. melanoxylon* and *Allocasuarina torulosa*.

Fire plays a major role in the maintenance of the tall open-forest as in its absence many eucalypts are unable to regenerate in the dim light of the forest floor (Ashton 1981). Some of the dominant eucalypts, such as *E. grandis* and *E. regnans*, are fire-sensitive and are killed in an intense fire. However, dense regeneration from seed usually follows rapidly after fire and tall open-forests are typically even-aged. Acacias regenerate and grow very quickly after fire and in some instances temporarily outgrow the eucalypts .

2 Open-forest and low open-forest

The open-forest subformation sometimes includes the same dominant tree species as tall open-forest, but usually the species and the structure of the understorey change as the tree height decreases. On very infertile soils a layer of dense low shrubs, 2 m tall or less, with hard, small leaves is present. On more fertile soils, especially where there is a high fire frequency, the understorey is largely composed of grasses and herbs with few shrubs. There are many open-forests with understoreys intermediate between these two extreme types.

Eucalypt open-forests often with an understorey of grasses are prominent in the north of the Northern Territory, where *E. tetrodonta* and *E. miniata* are dominant, either singly or in combination, and in eastern Queensland where *E. drepanophylla* extends over large areas and the mean annual rainfall is 1000–2000 mm.

Open-forests of *Acacia* tend to develop in areas where the mean annual rainfall is 400–1000 mm. *Acacia harpophylla* is the major component of many open-forests in southeastern Queensland where there are relatively fertile clay soils. *Acacia cambagei* and *A. argyrodendron* assume importance on similar sites where rainfall is 450–650 mm. In drier areas of Queensland and the Northern Territory, acacias such as *A. shirleyi* and *A. aneura* form open-forest and low open-forest on acidic, sandy and gravelly soils (Johnson and Burrows 1981).

Considerable areas of tropical and subtropical Australia with a mean annual rainfall of 500–1200 mm and sandy soils are dominated by open-forests of *Callitris intratropica* and *C. columellaris* (including *C. glaucophylla*). In tropical and subtropical coastal areas on seasonally-inundated sites and along river banks, *Melaleuca leucadendra* and *M. cajuputi*, occasionally exceeding 40 m in height, are important in open-forest formations (Stocker 1972; Brock 1988).

In contrast to the situation in tall open-forest many tree species in the drier forests are fire-resistant and recover from damage by shoot regeneration from epicormic buds on the trunk and branches. Many understorey species survive fire by shooting from underground root stocks, or regenerate readily from seed. *Acacia harpophylla* (brigalow) is one species that has the ability to produce root sucker shoots vigorously, a habit that enables it to recover from fire damage and to resist clearing for agriculture.

Low open-forests often comprise depauperate forms of communities that may exist as open-forest. The canopy level does not exceed 10 m and these low open-forests frequently occupy marginal habitats where their height growth is restricted by aridity, waterlogging, low fertility or low temperatures throughout the year (Specht 1970). *Acacia harpophylla* forms extensive areas of this subformation in the drier parts of south-eastern Queensland, while in cool temperate montane areas *E. pauciflora* occurs in a similar form before grading into a woodland formation.

Woodland and open-woodland

Woodland and open-woodland are widespread in Australia and dominated by trees of *Eucalyptus*, *Acacia*, *Allocasuarina*, *Callitris*, *Casuarina* and *Melaleuca*. About 80% of all *Eucalyptus* species and most Australian acacias occur in these formations (Gillison and Walker 1981). Woodland trees project a foliage cover of 10–30% and usually have rounded crowns and trunks shorter in length than the depth of the crowns. Tree height in woodlands is more restricted than in open-forest being mainly 15–25 m in moister areas and 5–15 m in drier parts. Dominants rarely exceed 30 m tall so that few species are found in the tall woodland subformation. In general terms, open-woodlands may be regarded as an extension of woodlands into arid, infertile or fire-prone environments only marginally suitable for tree growth. They have an open canopy, with a projective foliage cover of less than 10%, and comprise scattered low trees, usually less than 10 m tall.

Large areas of inland Australia are covered by woodland and open-woodland. They are the most common formations in inland Queensland and New South Wales, and are extensive in northern parts of Western Australia and the Northern Territory. There are also substantial areas in Central Australia and southwestern Western Australia.

Eucalyptus species dominate woodlands in northern Australia in areas receiving more than 600 mm annual rainfall but are replaced by *Acacia* species in drier habitats. Eucalypt woodlands occur widely in more temperate parts of southern and eastern Australia to where the annual rainfall declines to 400 mm or less. Eucalypt woodlands characterised by a grassy understorey are very prominent on the heavier and more fertile soils and on alluvial flats along rivers in northern and eastern Australia. *Eucalyptus camaldulensis*, *E. tereticornis*, *E. drepanophylla*, *E. populnea*, *E. tetrodonta* and *E. alba* are common dominants in this type of woodland. On somewhat less fertile soils or where rainfall is low the eucalypt woodland may have an understorey of low trees or tall shrubs of *Acacia*, *Casuarina* or *Callitris* species.

Woodlands dominated by acacias or casuarinas usually have a lower canopy height than eucalypt woodland and where it does not exceed 10 m the association is referred to as low woodland. The structure of low woodlands is variable, consisting generally of an open low-tree layer 3–6 m in height, a sparse low-shrub layer of 1–2 m and a ground layer of ephemeral herbs or grasses. Both the size and the form of species vary with site conditions so that a species may be either a small tree or tall shrub according to the habitat.

In eastern Australia dominant species of the low woodland formation are *Acacia cambagei*, *A. excelsa*, *A. harpophylla*, *A. pendula* and *Casuarina cristata* (Johnson and Burrows 1981). The seasonally dry solodic floodplains around the Gulf of Carpentaria have extensive areas of low woodlands of *Melaleuca*, of which the most common species are *M. nervosa* and *M. viridiflora*. The woodlands to the southeast of the Gulf grade into a mixed low woodland with a wide range of dominants including *Atalaya hemiglauca*, *Lysiphyllum cunninghamii* and various *Terminalia* species.

The most abundant open-woodland type is low open-woodland in which widely-spaced small trees of *Eucalyptus* or *Acacia* grow in association with shrubs, hummock grasses or tussock grasses. A vegetation type known as 'pindan', which occurs on the sandy plains of northwestern Western Australia, is an example of low open-woodland with tall shrubs in the understorey. It is characterised by scattered eucalypts, mainly *E. dichromophloia* and *E. setosa*, over a dense layer of tall shrubby acacias including *A. ancistrocarpa*, *A. eriopoda* and *A. tumida*. Pindan communities are subject to regular burning and, while the eucalypts tolerate the fire, many acacias are killed or severely damaged and regenerate from seed or roots.

Low open-woodlands with an understorey of hummock grasses are associated with skeletal soils of rocky hills or the sandy soils of sand plains or dunes. They are usually in areas with a mean annual rainfall from 600 mm to less than 300 mm. The hummock grasses include a wide range of *Triodia* species, with *T. pungens* prominent in the north and *T. basedowii* in the south. *Plectrachne schinzii* predominates on deep, coarse sands. In typical hummock grassland the individual plants are from 1 to 6 m in diameter and 0.5 m high. Each plant branches repeatedly into a great number of culms that intertwine to form a hummock with rigid sharp leaves.

Across northern Australia low open-woodland of *E. brevifolia*, or a closely-related species, extends over large tracts of rocky, hilly country with siliceous, acidic and low fertility soils between the 350 and 650 mm isohyets. In the Northern Territory shallow or rocky soils may support stunted eucalypt communities with a dense grass layer. The canopy is often 7 m in height and dominated by *E. foelscheana*, *E. tectifica* and *E. clavigera*. On the red sand plains and dunes of Central Australia *E. gongylocarpa* reaches the remarkable height of 8–13 m in very arid conditions. It occurs as isolated trees, sometimes with the mallee *E. youngiana*, or as small pure stands with an understorey always dominated by *Triodia* hummock grasses. Also on the arid, sandy plains of the Central Australian deserts is the impressive and picturesque desert oak, *Allocasuarina decaisneana*. It is often present as small groves at the base of sand dunes in some of the hottest and driest country in Australia.

Many species of *Acacia* are found in hummock grassland but few reach a large size. In the subtropical arid and semi-arid zones *A. aneura* is the most common acacia in low open-woodland but further north species such as *A. coriacea*, *A. cowleana* and *A. holosericea* become prominent.

Open-woodland with an understorey of tussock grasses, including *Astrebla* in northern Australia and *Danthonia* species in the south, are widespread in lower rainfall areas. *Eucalyptus coolabah* subsp. *coolabah* and *E. microtheca* are a characteristic species of grassy open-woodland on the heavier clay soils of seasonally inundated country in northern and inland Australia. In western Queensland, grassy low woodland of *A. cambagei*, *A. harpophylla*, *A. excelsa*, *A. pendula* and *Casuarina cristata* give way on drier sites to low open-woodlands dominated on the heavier calcareous soils by *A. georginae* and on the more acidic sandy soils by *A. aneura*. In other parts of northern Australia grassy open-woodland and low open-woodland with *Melaleuca viridiflora* and *M. nervosa* occur on swampy, nutrient-deficient sites.

The life span and leaf features of woodland species suggest an adaptation to environmental pressures of which water stress, nutrient deficiency and fire incidence are paramount. The prominence of phyllodinous acacias and casuarinas with reduced leaves, and the deciduous species of *Terminalia* and *Lysiphyllum*, are examples of traits linked to water stress. Eucalypts and melaleucas have well-developed lignotubers, thick protective bark and the ability to produce epicormic shoots, which ensure survival and recovery after fire. Some acacias will tolerate fire but others such as *A. aneura* are relatively sensitive and can be killed by a hot burn. The more sensitive species generally produce abundant seed at an early age and the substantial bank of hard-coated seed in the surface layers of the soil ensures their regeneration after fire.

The multitude of species in woodlands and open-woodlands include trees and shrubs highly tolerant of very adverse habitats. An understanding of the different adaptive strategies they use to cope with a variety of stress conditions is important if the most appropriate species are to be selected and brought successfully into cultivation. There is, for example, a clear need to separate the opportunistic fast-growing, short-lived species, such as *A. holosericea*, from more persistent, very hardy and usually slower-growing species.

Shrublands and scrub

Shrublands are defined as having an upper stratum of shrubs with a foliage cover of 10–30%. They may be separated into tall shrublands (individuals exceed 2 m tall) and low shrublands (less than 2 m tall). The tall shrublands have *Acacia* and *Eucalyptus* as the principal genera, with *Banksia* and *Grevillea* of local importance. Low shrublands are dominated by the family Chenopodiaceae, especially the genera *Atriplex*, *Bassia* and *Maireana* (*Kochia*). They are very important rangelands but produce little woody biomass and are not considered further in this account.

Scrubs are tall shrubs with a foliage cover over 70% (closed-scrub) or in the range 30–70% (open-scrub). Closed-scrub formations, usually of *Melaleuca* or *Leptospermum* species in swamps or on coastal sand dunes, are relatively rare. Open-scrub dominated by *Acacia*, *Allocasuarina* and *Eucalyptus* species is more frequent, especially in southern Australia. Species occurring in these open-scrubs are usually also found in adjacent shrublands.

Tall shrublands dominated by *Acacia* species extend over 1.5 million km^2 of inland Australia. They are widespread in tropical areas where the mean annual rainfall is ca 400 mm but further south extend into localities where the annual rainfall is less than 150 mm. They occur on diverse soils ranging from deep siliceous sands to heavier red duplex soils. Soil reaction tends to be alkaline in southern shrublands and acid to neutral in northern occurrences.

Acacia shrublands occur in conjunction with low woodlands with some species, such as *A. aneura*, common to both formations. *Acacia aneura* is dominant in many shrublands of Central Australia but in Western Australia it is replaced by *A. grasbyi*, *A. linophylla*, *A. ramulosa*, *A. sclerosperma* and other species, largely in response to topographic and edaphic factors. The trees and shrubs in the arid shrublands of Western Australia are described by Mitchell and Wilcox (1994). *Acacia cambagei* shrubland is a typical formation in the clayey interdune areas of the eastern Simpson Desert, while further to the southeast in Queensland and northern New South Wales, *A. ligulata* and *A. tetragonophylla* form sparse shrubland. Other acacias prominent in the tall shrublands include *A. brachystachya*, *A. georginae*, *A. holosericea*, *A. kempeana*, *A. papyrocarpa*, *A. pendula*, *A. victoriae* and *A. xiphophylla*.

Tall shrublands of *Acacia* are largely used for extensive grazing by sheep or beef cattle. *Acacia aneura* shrublands are by far the most important associations utilised commercially and *A. aneura* is Australia's most important fodder shrub, not because it is the most nutritious, but because it is palatable, widespread and abundant (Johnson and Burrows 1981). In some places overgrazing, especially in severe droughts, has resulted in virtually complete destruction of the ground vegetation and the edible shrubs followed by widespread soil erosion (Chartres et al. 1982).

Eucalyptus tall shrublands have a wide distribution in southern Australia, especially between latitudes 30° and 36°S where the mean annual rainfall is in the range 200–450 mm and has a predominantly winter incidence. The eucalypts in this formation exhibit a 'mallee' form, having many stems arising from a large, underground woody swelling ('lignotuber') composed of stem tissue. Eucalypt tall shrublands are frequently referred to simply as 'mallee'. The mallee eucalypts are usually 3–9 m tall but exceptionally reach heights to 18 m (Parsons 1981). There are about 100 mallee eucalypts with most occurring in the south of Western Australia. Environmental factors may be important in inducing the multi-stemmed characteristic as many species also occur occasionally as single-stemmed trees.

Mallee formations are extensive on the somewhat undulating topography in southern and southwestern Australia on grey-brown calcareous soils and red-brown earthy sands. Soil nutrient levels and water availability are generally low and the incidence of fire is high. In southeastern Australia dominant mallees include *E. socialis*, *E. oleosa*, *E. gracilis*, *E. incrassata* and *E. viridis*. In arid areas of Western Australia the mallee formation is dominated by *E. pyriformis*, *E. kingsmillii* and *E. oleosa*. The mallees tolerate a variety of soil conditions but rainfall seems to be the most important factor influencing overall distribution. Eucalypt tall shrubland can be regarded as occupying the most arid habitat of the eucalypt-dominated communities in temperate Australia. There are, however, a few eucalypts with the mallee habit, such as *E. odontocarpa*, *E. pachyphylla* and *E. normantonensis*, growing in drier tropical localities.

The mallee eucalypts have been used for fuel and farm timbers in Australia for many years but have not been at all widely planted as exotics. It may be that the special attributes of these eucalypts will enable plantings of them to contribute to solving the wood shortage in some of the harsher environments of the warm temperate and subtropical areas of the world. However, those species that have been tried have generally been slow-growing and unappealing for large–scale cultivation.

ADAPTIVE TRAITS

The more recent evolution of the Australian flora has frequently taken place under environmentally stressful conditions of which water scarcity, low nutrients, recurrent fires and high levels of salinity appear to have been paramount. The woody perennial vegetation has in consequence acquired adaptive traits that facilitate survival and reproduction under the various natural environmental stresses. Although apparent adaptive characteristics are often discussed in isolation it is evident that they may have evolved in response to several environmental stresses. Many plants occurring in dry regions or in wetter regions on soils of low fertility or high salinity exhibit xeromorphic features including small hard leaves, thick cuticles, sunken stomates, hairiness, rolled leaves and in some cases succulence (Beadle 1981). Xeromorphism is also seen in alpine plants so it appears to be a response to one or a combination of environmental extremes, viz. reduced water supply or low fertility or both.

Australian woody plants adapted to a range of harsh habitats have potentially a very valuable role in revegetating environments modified by human action to such a degree that species native to the area are unable to thrive. The account that follows is intended to highlight salient biological features of Australian trees and shrubs rather than be a comprehensive review of adaptive strategies.

Water stress

Australia is often described as the world's driest continent outside the Polar regions with about 50% of the land area receiving 300 mm or less of rain annually. Marked seasonal variation in rainfall can considerably reduce soil moisture availability through evaporation and transpiration in the dry season, in winter in the north and summer in the south. Rainfall may vary considerably between years; in the drier areas of Australia variability is about 10% greater than the global mean for regions having the same average rainfall (Williams 1979), and long droughts are common.

The effect of transpiration is to reduce the leaf water content and potential. The balance is restored by drawing water from soil through the roots. If the soil water is not replenished, insufficient water reaches the leaves and irreversible damage to the leaf tissues can occur. As far as is known there is nothing fundamentally different in the way native Australian species cope with water stress (Cowan 1981) but the great extent of arid and semi-arid areas in Australia has meant most species in the country exhibit a high tolerance to periodic severe moisture stress.

Growing plants cope with water deficiency by either minimising internal water deficits by various mechanisms such as stomatal closure, and/or by having the ability to tolerate much reduced water potential in their tissues. Australian woody plants have a wide range of mechanisms that enables them to avoid or tolerate drought conditions. Many of the life forms and leaf features of plants suggest xeric influences acting in concert with low soil nutrient levels. Sclerophylly is well developed in many woody genera in the form of thickened cuticles, increased glaucousness, rolled leaf margins, dense indumentum, high specific leaf weight and an increase in the volatile oils (Walker and Gillison 1982). Eucalypt leaves are commonly pendulous and isobilateral with a high oil content; *Casuarina* and *Allocasuarina* have highly reduced leaves and photosynthetic cladodes; Australian acacias are principally those that develop phyllodes, and phyllode-like leaves are a feature of *Melaleuca* species. Reduced leaf size is characteristic of plants in arid zones and in the seasonally very dry regions of northern Australia a deciduous habit exists in some species of *Acacia* (subgenus *Acacia*), *Eucalyptus*, *Erythrina*, *Lysiphyllum* and *Terminalia*.

Acacia is the dominant genus in the drier zones with eucalypts often restricted to moister habitats along watercourses and around depressions. The distribution suggests that acacias are generally better adapted to withstand extremes of water stress than are eucalypts. Large areas of open-forest, woodland and shrublands of inland Australia are dominated by *A. aneura* and *A. harpophylla*. Both possess phyllodes that exhibit extreme resistance to desiccation (Tunstall and Connor 1975), exceeding that of eucalypts (Connor et al. 1977). *Acacia harpophylla* will form forests on heavy-textured soils with adverse water relations and some salinity or alkalinity in the profile.

Acacia aneura has hairy, resinous, compact phyllodes held vertically to minimise heat absorption and water redistribution. The plants stop growth when drought occurs and may even shed some of their phyllodes during the greatest stress, but they can rapidly resume growth when water becomes available. Rainwater often flows along their phyllodes and stems so that it is concentrated at the base of the trunk (Slatyer 1965). In the more arid parts of its range *A. aneura* frequently occurs in groves that receive run-on water from sparsely vegetated intergrove areas, and many of the *A. harpophylla* stands are in areas where the microrelief inhibits runoff and accumulates surface moisture. The development of extensive root systems by acacias to tap both surface water and that accumulating at depth above the hard pan assists in sustaining the plants during drought periods (Winkworth 1983).

In general, the Australian arid zone is well vegetated and even areas classed as desert almost always possess a plant cover of some kind. Despite its great extent the Australian arid zone is not as arid as some parts of the world, with even the driest localities having a mean annual rainfall of about 100 mm, and hence the flora of these areas has attributes enabling it to tolerate and/or avoid the corresponding level of water stress.

Low nutrient availability

There is probably no continent with soils so critically low in essential plant nutrients as Australia and in consequence a large part of the indigenous flora is likely to be adapted in one way or another to cope with these deficiencies (Bowen 1981). Instances of extreme nutrient deficiencies are especially common on acidic light sandy podzolic soils derived from siliceous rocks, sandstones and quartzites or lateritic residues. Information on nutrient concentration ranges and critical nutrient concentrations is very limited for Australian trees and shrubs. Diagnosis of nutrient disorder from visual symptoms can be verified by chemical analysis of affected plant tissue (Dell et al. 1995). Typically phosphorus and nitrogen are lacking, and most known specialised mechanisms of nutrient uptake are related to these elements.

Nutrient uptake and the subsequent nutrient use by the plant are key stages in mineral relations of plants. The sources of plant nutrients are organic and inorganic materials in the soil and, in some plant groups, atmospheric nitrogen. The production of fine roots with well-developed root hairs may be adequate for some plants to obtain nutrients in a soil of moderate fertility, but this in unlikely to be the case in less fertile soils. Where nutrients are scarce, some species enhance uptake by allocating a much greater proportion of their assimilate to root growth, thereby tapping a larger volume of soil. However in the very infertile Australian soils many trees and shrubs increase their access to nutrients by altering their root morphology, usually in association with microorganisms such as mycorrhizal fungi or soil bacteria.

1 Nitrogen fixation

Leguminous plants, such as *Acacia*, *Albizia* and *Cassia* spp., and some non-legumes, especially the family Casuarinaceae, overcome the problem of limited nitrogen availability by forming symbiotic nitrogen-fixing associations with bacteria. The bacterial symbiont is *Rhizobium* or *Bradyrhizobium* for the legumes and the filamentous soil actinomycete, *Frankia*, for the casuarinas. Roots are infected by the soil bacteria and form specialised lobes on the root surface called 'nodules'. Plant sugars are utilised by the bacteria, which convert atmospheric nitrogen (N_2) to ammonium nitrogen. This symbiotic relationship is widespread in leguminous subfamilies of Mimosoideae and Papilionoideae but is much less common in Caesalpinoideae (Allen and Allen 1981; Halliday 1984). In Casuarinaceae the association with the actinomycete genus *Frankia* appears to be much better developed in the genus *Casuarina* than in *Allocasuarina*, possibly related to moister sites that *Casuarina* species usually occupy.

The rate of nitrogen fixation varies according to species and environmental conditions. Estimates of nitrogen fixation from the atmosphere are often unreliable because the figures quoted frequently include the contribution of soil nitrogen. Nitrogen fixation rates within the range 20–50 kg/ha/year appear to be reasonable and are comparable with estimates for herbaceous annuals (MacDicken 1994). Orchard and Derby (1956) calculated that a dense stand of *A. mearnsii* in South Africa fixed 180 ± 40 kg N/ha/year but studies of small native acacias in Australia have indicated fixation at rates from 3 to 16 kg/ha/year (Langkamp et al. 1979). In Senegal, the annual rate of accumulation of nitrogen under plantations of *Casuarina equisetifolia* was estimated at 12–80 kg N/ha depending on water availability (Dommergues et al. 1990)

Australian acacias and casuarinas when grown as exotics have generally formed nodules from bacteria present in the soil but the question as to whether these associations are as effective as could be achieved by inoculation with selected symbionts remains unresolved. Research suggests that selected *Frankia* will be beneficial in improving the early growth of *Casuarina* species.

2 Mineral uptake

Mycorrhizas are symbiotic associations between plant roots and soil fungi that provide a means of improving nutrient absorption from the soil. It is likely that most Australian native plants, including *Acacia*, *Casuarina*, *Eucalyptus*, *Melaleuca* and others, are mycorrhizal (Bowen 1981). The fungi hyphae are narrower, longer and more flexible in their direction of growth than root hairs, providing greater access to the nutrient-holding soil pores and particles. Most mycorrhizal studies have pointed to the crucial role of mycorrhizas in phosphate uptake but they appear to also improve the availability of poorly mobile ions of zinc, copper, molybdenum, and possibly ammonium.

There are two major types of mycorrhiza: the general vesicular arbuscular (VA) and the host-specific ericoid, orchid or ecto-mycorrhizas. The VA mycorrhizas are the most widespread. They infect and enter plant roots and form intracellular structures so are collectively known as endomycorrhizas. Many plant species have VA mycorrhizas although they are notably rare or absent in Proteaceae (e.g. *Banksia*, *Hakea*, *Persoonia*) (Malajczuk et al. 1981). The ectomycorrhizal fungi form a sheath around the rootlets of the host; they grow between the root cells but rarely penetrate them. In the Australian flora ectomycorrhizas are found mainly on woody species including *Acacia*, *Allocasuarina*, *Casuarina*, *Eucalyptus*, *Leptospermum* and *Melaleuca*, most of which also form endomycorrhizal associations.

Large differences occur between strains of ecto- and endo-mycorrhizal fungi in the extent of their stimulation of plant growth on particular soils. The differences may be due to different strains of fungi being less effective for the host species on that site (Bowen 1981). Such observations suggest there is considerable scope for the selection and matching of efficient fungal strains with hosts. More comprehensive accounts of the role of mycorrhizal fungi are provided by Bowen (1981), Lamont (1984), Reddell and Warren (1987) and Malajczuk et al. (1994).

An alternative mode of enhancing nutrient uptake is provided by bunches of hairy rootlets produced on the root systems of some plant groups. Several types of root 'clusters' are recognised with the best known being the proteoid roots. In this type a very large number of rootlets are packed in rows along the parent root providing a surface area at least five times that of 'normal' roots (Lamont 1984). Proteoid roots form dense mats of lateral rootlets generally in the upper 10 cm of the soil. They are induced by soil microorganisms and enhance the absorption of ions such as phosphate from phosphorus-deficient soils (Lamont 1982). Most species in the family Proteaceae and some in the genus *Casuarina* have proteoid roots (Bowen 1981; Diem and Arahou 1996). Under cultivation many proteaceous species (e.g. *Banksia*, *Grevillea*) are sensitive to phosphorus toxicity caused by excessive fertilizer application, a situation possibly due to the inability of the proteoid roots to exclude the over-abundant ions (Reddell 1984). (Additional information on nitrogen-fixation and mineral uptake in relation to silvicultural techniques is given in Chapter 4).

Fire

Fire caused by lightning has been a natural environmental stress in most regions of Australia for millions of years. Since Aboriginal people arrived on the continent some 40 000 years ago the fire regime has been modified to more frequent but generally less intense burns.

For woody perennials the threat of extinction by an untimely fire prior to the age of seed production is high. It is then highly probable in an environment where there have been recurrent fires for a long period that surviving species are those that evolved traits that enhance the persistence of populations when burnt. Many apparent fire-adaptive traits may however have evolved principally as a response to other selective forces. For example, evolution of the eucalypt lignotuber may have been in response to low soil-nutrient levels (Beadle 1968). It has therefore been suggested that adaptive traits ascribed to fire may well be of multipurpose use, enabling a species to persist by tolerating various types of environmentally induced physiological stresses (Hodgkinson and Griffin 1982), such as drought or excessive competition from other plants. In practical terms the origin of the particular traits is of less importance than the fact that they exist and enable species to grow in fire-prone environments.

The survival of established trees and shrubs in a fire varies considerably according to the intensity of the fire and the stage of development of the plants. Hot summer burns can be far more damaging than those in the cooler conditions of spring, and mature plants may be highly resistant to fire but their seedlings highly vulnerable. Such variation needs to be taken into consideration when assessing the fire tolerance of any species.

The ability to coppice or resprout is an important trait that enables woody plants to survive fire damage. The degree to which individuals will recover by resprouting is partly dependent upon the extent to which vegetative buds are protected by bark or soil during the fire. Some arid zone species of *Acacia*, *Allocasuarina*, *Grevillea* and *Hakea* have thick protective bark that affords protection to buds but others such as *Acacia aneura* and *Dodonaea viscosa* subsp. *angustissima* have bark thicknesses less than 3 mm (on shrubs 2.5 m tall), which offers little protection. These thin-barked species are relatively sensitive to fire damage, although they often have the capacity to resprout readily from subsurface stem tissue when cut off at ground level (Hodgkinson and Griffin 1982).

Most eucalypts and many other species will regenerate from 'lignotubers'. These structures are particularly well-developed in the mallee eucalypts. Many eucalypts, such as *E. tetrodonta*, reproduce from root suckers. However, rhizomes, root suckers and lignotubers are not confined to *Eucalyptus* but occur in many other trees and shrubs in tropical savannas. Adventitious buds on lateral roots are especially evident in acacias (such as *A. coriacea*, *A. dealbata*, *A. harpophylla* and *A. murrayana*), *Atalaya hemiglauca* and *Ventilago viminalis* which can send up a thicket of root suckers when the main stem is fire-damaged.

Aerial buds protected by bark in the upper parts of a tree or shrub ensure rapid regeneration of the crown following fire in some eucalypts and melaleucas and to a lesser extent in casuarinas and acacias. In eucalypts, bunches of shoots emerge from epicormic buds on the trunk and major branches. Acacias as a whole appear to be better equipped than eucalypts to withstand extremes of water stress rather than fire. While many acacias such as *A. lysiphloia* and *A. monticola* are highly flammable, with some exceptions, e.g. *A. inaequilatera* and *A. hemignosta*, they lack the thick, protective bark of the eucalypts.

Species lacking vegetative traits useful to survive fire often have reproductive features to ensure rapid regeneration of their offspring. Fire triggers the release of seeds from the serotinous 'cones' of *Allocasuarina* species and from the woody capsules of many eucalypts. The release of seed from abundant crops present on *Melaleuca quinquenervia* during fires has been largely responsible for the rapid spread of this species and its weed status in Florida.

Heavy seed production and early reproductive maturity are features of many Australian species with low to moderate resprouting ability. It is not unusual for species such as *Acacia holosericea*, *A. colei* and *Dodonaea viscosa* to set viable seeds within three years of establishment. With few exceptions, Australian acacias are hardseeded and need some sort of physical change in the seedcoat to stimulate germination. Fire is one agent that does this effectively and abundant regeneration may follow the passage of a fire through a stand of acacias. The ability of seeds of *Acacia*, *Cassia*, *Dodonaea* and other hardseeded genera to remain dormant in the soil for long periods is an adaptive trait to ensure survival in the event of loss of the parent trees due to fire, drought or other catastrophe.

The persistence of many Australian species in the face of periodic fire suggests that they may have considerable value for planting in fire-prone environments where it is necessary to retain vegetative cover. They offer good possibilities for providing cover in water catchments or on steep slopes likely to be subject to severe erosion in the event of fire. Detailed reviews of plant traits adaptive to fires and the general response of species to fire have been provided by Gill (1975, 1981b), Noble and Slatyer (1981) and Hodgkinson and Griffin (1982).

Salinity

Almost one-third of the Australian landscape has salt-affected soils. In a broad survey, Northcote and Skene (1972) estimated that there are 39 million ha of naturally saline soils and 200 million ha of sodic soils with a high level of adsorbed sodium. In addition the long coastline has salt marshes, estuarine and tidal flats, and mangroves either under regular tidal influence or subject to occasional inundation by sea water. It is reasonable to expect that vegetation that occurs naturally over such extensive areas of salt-affected lands will have acquired a significant degree of tolerance to high levels of groundwater salinity. In addition the woody vegetation of coastal sand dunes and other littoral associations above high tide level are frequently exposed to substantial amounts of salt in windborne spray.

Halophytes, i.e. plants that grow and complete their life cycles on saline soils, have evolved specialised physiological adaptations for coping with high salinity levels. Most evidence suggests that once salt enters the plant it is the control of salt transport to the leaf and the final compartmentation of salt within that leaf that are the principal factors determining salt tolerance (Winter et al. 1981). It appears that halophytes transport salt rapidly to their shoots, preferentially accumulating it in the vacuoles where it does not interfere with cytoplasmic metabolism, but contributes to osmotic adjustment. The relative importance of this particular adaptive trait in conferring salt tolerance of Australian woody plants growing on saline soils is difficult to assess but it is certainly very important in mangroves (Adam 1990).

Saline sites may have other features that make them stressful for plant growth. On many sites high salinity levels are associated with waterlogging, and thus tolerance of relatively anaerobic, saline conditions in the root zone for at least part of the year may be essential. *Casuarina glauca* and *Melaleuca* species in the brackish water of coastal swamps combine tolerance of these conditions. Not all species of *Casuarina* are salt-tolerant, but *C. equisetifolia*, and especially *C. glauca* and *C. obesa* will grow on saline sites. A similar situation prevails amongst *Melaleuca* species. *M. halmaturorum*, *M. lanceolata* and *M. styphelioides* are adapted to saline sites and will withstand moderate exposure to salt-laden winds. *Melaleuca quinquenervia* is regarded as only moderately salt-tolerant, but will tolerate salt-laden coastal winds. In the dry interior of Australia, species such as *M. bracteata*, *M. glomerata*, *M. nervosa* and *M. pauperiflora* occur on the margins of salt lakes (Midgley et al. 1986). Other genera, including *Eucalyptus* and *Acacia*, also have a limited number of species that grow in saline environments. Salt-tolerant acacias, such as *A. ampliceps*, *A. maconochieana* and *A. stenophylla* are described in the species' digests later in this book. A more comprehensive description of trees suitable for planting on salty lands is given by Marcar et al. (1995).

REPRODUCTIVE BIOLOGY

The reproductive processes of Australian woody plants are not dissimilar to those of many species in other parts of the world, but an understanding of the reproductive biology can be important when introducing exotic species for trial. The potential of a species to set fertile seed, produce hybrids or inbreed is a significant aspect of seed collection and controlled seed production. The following brief account does no more than draw attention to the variety of mechanisms for pollination and the relative importance of inbreeding, outcrossing and hybridisation in a selection of Australian genera.

Mimosaceae

When conditions are favourable acacias produce flowers in great profusion. Flowering usually commences at an early age; *A. monticola* can flower in its first year, but many species such as *A. holosericea* and *A. simsii* flower in their second year and produce mature seed from the third year. *Acacia mearnsii* in plantations begins to flower at about age 20 months and, while providing some ripe seed from the third year, it is not until the fifth or sixth year that appreciable quantities of seed are produced (Sherry 1971).

Acacia flowers are small, regular and usually bisexual (male and female parts on the same flower). Each flower contains basically 4 or 5 sepals and petals. The sepals may be free or united into a calyx and the petals free or united into a corolla. The stamens are numerous and arise from under or just above the base of the ovary. A thread-like style protrudes beyond the stamens. The structure and histochemistry of the stigma and style in some Australian acacias has been described by Kendrick and Knox (1981). The ovary is sessile or has a short stalk and its outer surface may be smooth or covered in minute hairs. Each flower is subtended by a small bracteole the shape of which varies according to species (Doran et al. 1983). Except in the degree of division of the calyx, degree of hairiness, or ratio of corolla to calyx, all *Acacia* flowers look very much the same.

Flower colour is mostly due to the colour of the projecting filaments of the stamens; almost all Australian acacias have white to orange-yellow flowers. The flowers are arranged in either heads (compact spherical clusters of flowers) or in spikes (compact cylindrical clusters of flowers) commonly made up of 10–50 individual flowers.

Insects are the main pollinating vectors of acacias, wind having a very minor role. It also seems likely that birds, seeking insects or attracted to extra-floral nectaries on the phyllodes or on the rachis of true leaves, play a part in pollination (Ford and Forde 1976). There is very little information available on *Acacia* pollination and, although there is a general belief that insect pollinators are nonspecific, the constancy of flower colour of most acacia species implies that there could be some pollinator specificity (New 1984).

After pollination, the ovary matures within the flower to form the pod characteristic of species in the Mimosaceae family. Although there is usually a large number of flowers in each acacia inflorescence, relatively few pods are formed. At maturity the pods usually split longitudinally along both margins to release the seed. Seed dispersal from the pod is usually by gravity or in some instances the drying pods dehisce and propel the seeds with some force. Ants may be involved in short-distance dispersal of seeds on the ground and in a few cases dispersal of seeds by birds appears to be a regular strategy. Some acacias, for example, produce seeds with bright red or orange arils which may be attractive to birds especially when they remain suspended by their funicles from open pods. Glyphis et al. (1981) report the distribution of *A. cyclops* by birds.

The breeding system appears to be one of preferential outcrossing. The mating systems have been determined for four Australian acacias (*A. auriculiformis*, *A. crassicarpa*, *A. mangium* and *A. melanoxylon*) and in all there were high levels of outcrossed progeny. In other species high levels of self-incompatability have been found (Kendrick and Knox 1989). However, experimentally manipulated selfs of two species from the dry zone, *A. cowleana* and *A. holosericea*, resulted in good seed set and germination of almost 100% (Moran et al. 1992). Substantial inbreeding may therefore occur and could reach high levels in some species.

Some natural interspecific hybrids are known to occur. Intermediates between *A. auriculiformis* and *A. mangium* have been observed in natural stands in Papua New Guinea and occur occasionally in plantations in Sabah. Artificial hybridisation techniques for these species have been developed by Sedgley et al. (1992). A hybrid swarm of *A. brachybotrya* and *A. calamifolia* in Victoria has been studied by Leach and Whiffin (1978) and in Western Australia fertile natural hybrids of *A. ampliceps* and *A. bivenosa* and of *A. ancistrocarpa* and *A. trachycarpa* have been reported. Natural hybrids may be a relatively common occurrence but the full extent of hybridisation and introgression in Australian acacias is not known. Most Australian acacias that have been examined are diploid with $2n$=26 (Vassal and Lescanne 1976). However, three species in the *A. holosericea* complex are diploid, tetraploid and hexaploid while *A. cowleana* is tetraploid (Moran et al. 1992).

Casuarinaceae

Casuarinas flower annually and usually begin to produce seed before they are five years old. They are mainly dioecious, but some are monoecious, and both conditions may occur in some species — the flowers are unisexual and greatly reduced. The male flowers consist of a single stamen after anthesis and occur in whorls on cylindrical spikes, which are terminal or lateral on the branchlets. The female flowers terminate short lateral shoots and form dense compact globular heads. Each flower consists of a unilocular ovary containing two ovules, only one of which forms a seed. There is no perianth. The ovary is subtended by two lateral bracteoles which form a single bract. Flower structures are described in more detail by Beadle (1980) and Barlow (1983).

The pollen is disseminated by wind and after fertilisation the inflorescence enlarges to form a woody, cylindrical fruiting body. Aspects of the floral biology of *Allocasuarina verticillata* have been described by Moncur and Boland (1996). The individual fruit is a one-winged samara surrounded by two bracteoles (‘valves’) and a single bract. The samara is single-seeded and has a membranous terminal wing. It is released when the valves retract and is dispersed initially by wind, further dispersal sometimes being assisted by water and ants. Many Australian casuarinas in the genus *Allocasuarina* have serotinous fruits and fire or extreme desiccation may be necessary to release the seeds. Species in the genus *Casuarina* usually shed their seed annually (Turnbull and Martensz 1982).

As the family comprises wind-pollinated, predominantly dioecious species, the plants are primarily obligate outbreeders. The taxonomy, breeding system and genetic variation of casuarinas have been reviewed by Turnbull (1990). In *Casuarina* polyploidy has not been recorded. There are no indications of extensive hybridisation although occasional natural hybrids of *C. cunninghamiana* with *C. glauca* and *C. cristata* are known. In *Allocasuarina* polyploidy is sometimes frequent. Hybridisation between some closely related species occurs and at least one species has obligate apomixis, producing populations consisting entirely of females (Barlow 1983).

Myrtaceae

Many species of the Myrtaceae family flower prolifically and at an early age. Within the family there are many types of inflorescences including much-branched panicles and a variety of reduced forms, including umbels and spikes, down to single flowers. In *Eucalyptus* the umbel comprises 1, 3, 7, 11, 15 or more individual flowers and in some species the individual clusters form compound branching structures. *Melaleuca* and *Callistemon* flowers are arranged in a spike-like inflorescence, the ‘bottlebrush’, with new shoot growth often extending from the axis. Solitary flowers are found commonly in genera such as *Leptospermum*. Within the family there is a great diversity in flower appearance; in eucalypts and melaleucas the mass of stamen filaments, often brightly coloured, is the showy part, while other genera have flowers deeply enclosed within coloured bracts and yet others such as *Leptospermum* have more conventional flowers with prominent petals. Pollination is by insects, birds, or sometimes mammals including bats and possums. Eucalypts and melaleucas with brightly coloured flowers show adaptations for bird pollination. Some species produce large quantities of nectar that attracts both insects and birds.

Eucalyptus the best known genus in the Myrtaceae, has bisexual flowers. An individual flower bud consists of a hollow receptacle, the hypanthium. This is surrounded by the operculum, which is an organ formed by the fusion of the sepals or petals or of both structures. On the rim of the hypanthium is a ring of stamens some of which may be sterile. This ring may be continuous or in the subgenus *Eudesmia* the stamens are grouped in bundles. Inside the staminal ring is a band of tissue, the disc or nectary, which descends to the top of the ovary. The ovary chambers themselves are surmounted by the style and stigma. At flowering the operculum is shed, the stamens spread and the pollen is released from the anthers. Detailed descriptions of the eucalypt reproductive cycle can be found in Boland et al. (1980).

The stigma does not become receptive until some days after the pollen is released, a sequence which impedes self-pollination. While this mechanism is largely effective in preventing self-pollination of a single flower it is less so over a whole tree because of the varying time of pollen shed in different flower clusters. There is little doubt that although eucalypts are preferential outcrossers a degree of self-fertilisation does take place. In *E. obliqua* this has been estimated as high as 24% (Brown et al. 1975) and in *E. pauciflora* 37% (Phillips and Brown 1977).

Individual interspecific hybrids between closely related species of *Eucalyptus* occur under natural conditions but are probably more common in plantations where geographic barriers to hybridisation are broken down by planting compatible species in the same neighbourhood (Eldridge et al. 1993). Large hybrid swarms or areas of introgression are found under natural conditions involving species such as *E. saligna* and *E. botryoides*, and *E. camaldulensis* and *E. tereticornis*.

After pollination the ovary matures to form a woody capsule and seed shed depends on the separation of the seed from the placenta and opening of valves on the top of the fruit. As the fruit dries out the locules open and the seed falls out under the influence of gravity and agitation by wind. Wind is probably the only important agent of seed dispersal in eucalypts, melaleucas and the majority of the dry-fruited Myrtaceae genera. The fleshy berries of some Myrtaceae including *Acmena*, *Eugenia* and *Syzygium* species are attractive to birds and animals, and the seeds may be dispersed over long distances.

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Chapter 3

SELECTION OF SPECIES AND PROVENANCES FOR PLANTING

D.J. Boland

The selection of species and provenances for planting is still a very subjective process. It is largely reliant on personal knowledge, judgement and experience augmented by literature reviews. This situation has improved somewhat in recent years with the development of computer-assisted decision support systems. Field surveys of the planting site, assessment of required end-uses of the trees and a desk survey of the range of potentially suitable species available should be conducted before final decisions are made on species to be short-listed. Ideally this phase should be followed by a research phase involving field tests of short-listed species, seed sources and management options. Only when such steps have been followed can we be confident that we have selected the best species for the site and intended end use. Although there have been some instances where a single species has been chosen and planted widely from the start, one should be aware that new 'miracle' species often have not been adequately tested and may not meet expectations.

Perhaps the most exciting new development in recent years has been the emphasis placed on the selection of non-industrial trees for farm (agroforestry) and environmental use in both developed and developing countries. This has considerably expanded the range of species to be considered and has really tested the capacity of forestry professionals to give accurate advice on choice of species. There has also been an increased call for the greater use of indigenous species to avoid the reliance usually placed by professionals on a small number of well-tried exotics. The problem we all face is that reliable information on ecological, growth, silvicultural and utilisation characteristics of many potentially valuable species is still difficult to obtain. Many lesser-known species with potential for agroforestry, e.g. native fruit trees, have been described by Leakey (1994) as 'Cinderella' species. When detailed knowledge of lesser-known indigenous species is acquired it may also be possible to trade-off species with rapid growth for those indigenous species with slower growth but with greater resistance to drought, fire and pests. Such species may have lower water and nutrient requirements, or may provide more valuable wood products than common exotics, albeit over a longer time.

The modern development of agroforestry as a scientific discipline has brought with it a very special focus on the use of certain tree species, and their special properties, for use in particular farming systems (see Sanchez 1995). From a species selection viewpoint the objective is to choose species that are compatible with farm crops, produce valuable products and provide environmental services, e.g. improved soil fertility. While it is possible to recommend certain species for certain products we still lack the capacity to quantify the effects of tree growth on the growth of companion crops. In this sense our scientific knowledge of trees and their interaction with crops is still in its infancy and our selection procedures primitive.

Young (1989) took account of much of ICRAF's pioneering work on categorising agroforestry technologies when proposing 19 such technologies (Table 3.1). Most of these technologies are based on information gathered worldwide on existing indigenous agroforestry systems. Categorisation only serves to focus our attention on how trees can be used on farms in a technological sense. One can divide all 19 technologies into two time-related types, viz. simultaneous and sequential agroforestry systems. From the point of view of this book, our long-term vision is to evaluate all lesser-known Australian species for use in each technology. Two technologies of special interest to current agroforestry practice are improved sequential systems such as fallows (e.g. the role of tree species in improving soil

Table 3.1. Agroforestry technologies (adapted from Young 1989).

MAINLY AGROSILVICULTURAL (trees with crops)	
Rotational	
	Shifting cultivation
	Improved tree fallow
	Taungya
Spatial mixed	
	Trees on cropland
	Plantation crop combinations
	Multistoried tree gardens
Spatial zoned	
	Hedgerow intercropping (barriers, alleys)
	Boundary planting
	Trees on erosion-control structures
	Windbreaks and shelterbelts
	Biomass transfer
MAINLY OR PARTLY SILVOPASTORAL (trees with pastures and livestock)	
Spatial mixed	
	Trees on rangeland or pastures
	Plantation crops with pastures
Spatial zoned	
	Live fences
	Fodder banks
TREE COMPONENT PREDOMINANT	
	Woodlots with multipurpose management
	Reclamation forestry leading to multipurpose use
OTHER COMPONENTS PRESENT	
	Entomoforestry (trees with insects)
	Aquaforestry (trees with fisheries)

chemical and physical properties) and improved simultaneous systems such as mixed plantings of trees and crops where the issues are tree–crop interactions (usually below ground) and competition between or complimentarity of components of mixtures. For example, in the context of this book it would be useful to know which Australian *Acacia* species have potential for use in improved fallows and how valuable the contribution from each would be. It would also be useful to know if other *Grevillea* species besides *G. robusta* have desirable tree–crop interactions and what special characteristics they possess to allow such complementarity. It is only by systematically researching and assembling such knowledge that we can make real progress in the more precise selection of species for agroforestry development. Our databases are only as useful as the information we feed into them.

The aim of this chapter is to provide an historical overview of tree species introduction and then cover traditional and modern techniques for species and provenance selections. Some details are given on social issues that affect species selection and appreciation by people. The qualities required of tree species to provide fuelwood, roundwood (poles and posts), fodder, live fences, windbreaks, shade, soil improvement and protection are briefly examined as these are the major products from or uses for tree species within the scope of this book. These products and uses can be produced within particular agroforestry technologies (as outlined in Table 3.1) or in other systems. The processes used in the selection of species and provenances for traditional forestry and agroforestry are compared.

HISTORICAL PERSPECTIVE OF SPECIES INTRODUCTION

Much is known of the introduction of new annual crop plants. The introduction and domestication of cereal crops such as wheat from the Old World and fruit crops like tomatoes from the New World are reasonably well known, but the equally long history of tree crop introduction is often overlooked. Food tree crops were initially important. Chestnuts (*Castanea sativa*) and figs (*Ficus carea*) were introduced to Britain by the Romans some 2000 years ago and at least six varieties of figs were grown in Britain before the Christian era (Anon. 1977).

There are similar examples of the introduction of food tree crops in tropical regions. Baob trees (*Adansonia digitata*) were reputedly introduced into India from Africa by either Arab traders or Indian seafarers in the 7th or 8th century (Vaid 1978) while the Makassan trepangers (Indonesian fishermen) brought tamarind (*Tamarindus indica*) to the northern coasts of Australia before European colonisation

(Macknight 1976). The Indonesian clove tree (*Eugenia aromatica*), a food spice whose properties were known from early times (at least 300 BC in China), has been cultivated outside Indonesia for 200–300 years (Cobley 1956). The oily seeded candlenut (*Aleurites moluccana*), *Canarium* spp. and the breadfruit (*Artocarpus incisor*) are examples of species that were probably spread widely by the Pacific Islanders prior to European settlement. Most of these species have been subjected to some degree of domestication.

By comparison, tree introduction for non-food purposes is much more recent. The Romans are believed to have introduced the shrubby plant *Rhus coriarea* into Spain to produce leaves as a tannin source (Gonzalez 1982), while in East Africa Arab dhow captains arranged for the planting of *Casuarina equisetifolia* to mark harbour entrances (Perry and Willan 1957). Though native trees were used *in situ* for a wide range of non-food uses such as shelter, weapons and handicrafts, it was not until the 19th century that scientifically managed industrial plantations of native and exotic species were established. These plantations provided wood products such as sawn timber, fuel for railways and more recently pulp for paper and other products. Extensive areas of exotic pines and eucalypts were planted during the 20th century for industrial wood; this development overshadowed the need, especially among developing nations, to cultivate non-food trees for non-industrial purposes.

By the 1970s there was a growing realisation of the detrimental impact that the exploding world human population was having on the woody vegetation in many countries. Excessive cutting of fuelwood, overgrazing and more-widespread shifting cultivation for agriculture led to the serious degradation of the native tree flora in many parts of the tropics. The emphasis now is on conserving remnant vegetation and revegetating degraded areas with planted material. Social and community forestry became the rallying calls of the time. In these plantings the emphasis was still mostly on a limited number of well-tried exotics.

In the 1970s attention moved to agroforestry as a means of encouraging farmers to plant trees on their own lands rather then relying solely on government planting programs (Bene et al. 1977; Steppler and Nair 1987). This focus brought a realisation that research was needed in order to explain better the merits of many traditional agroforestry practices around the world and to justify the emphasis placed on this form of land use. This international movement led to the establishment of ICRAF (International Council, later Centre, for Research in Agroforestry) in 1982. In the years since, ICRAF's attention has shifted progressively from agroforestry systems documentation, technology description and categorisation, survey of farmers' practices and prescribing agroforestry interventions and proselytising, to intensive research on pertinent agroforestry research questions (see Sanchez 1995).

The 1970s also brought increased attention to the selection of tree species which could biologically fix atmospheric nitrogen (such as legumes with rhizobia and non-legumes with *Frankia*, e.g. *Casuarina*, *Alnus*). This attention arose in part from the agricultural sector where improved mixed pastures with legumes and legume fallows were common technologies, but also as a result of the rise in oil prices which increased the price of nitrogenous fertilizers. This in turn led to the exploratory work of the International Rice Research Institute (IRRI) on a range of organisms that fixed atmospheric nitrogen, and included work on small shrubs such as *Sesbania rostrata* for improved fallows in rice paddies. In addition the leaves of many legumes, e.g. *Leucaena* and *Chamaecytisus*, were high in nitrogen and hence valuable leaf protein for animal feeds. In retrospect it is not surprising that considerable attention was given to biological nitrogen-fixing plants, but the downside was that other tree species that accumulate nitrogen (e.g. *Cassia siamea*) and other plant elements in luxury amounts have not been well studied.

Given these historical trends, the question to be addressed is how has the science of species and provenance selection kept pace with and adapted to these new demands. Fortunately many of the scientific methods employed in species selection and domestication for industrial plantations can be adapted for selecting trees and domesticating tree species for non-industrial uses. A major difference will be in assessment techniques, which depend on whether we are selecting trees for agroforestry, village woodlots or environmental purposes. It is in the agroforestry domain that more research is needed, and in particular a better understanding of species characteristics in relation to companion crops is required.

There is no doubt that it is in the non-industrial plantings that the range of species available for selection has increased. This is because of the range of agroforestry technologies and due to the diversity of products that can be produced. In addition, tree size, stem straightness and wood quality are often not constraints to selection. Small rapidly growing trees and shrubs are often more suitable than large trees for village or farm planting. The ICRAF MultiPurpose Tree (MPT) database contains information on about 1100 mostly non-industrial species (von Carlowitz et al. 1991), and this number could easily be expanded to 2000. Many of these species are still poorly known outside the areas where they are locally appreciated. It is often impressive to see in the field the skill with which local people have successfully exploited and managed indigenous tree species in their farming systems.

Research involving several scientific disciplines will be required to evaluate lesser-known species for use in various agroforestry technologies. Simple on-research-station field trials should be established to assess basic attributes of new species such as survival, growth rate and form characteristics. There is a real need for rapid tests to assess the competitive and complementary aspects of tree crop interaction. This can be addressed via either genetic or management studies, e.g. pruning and coppicing, or through combinations of these approaches. At the same time it is wise to quickly move promising species to on-farm trials that are farmer-managed to allow some empirical experimentation. This allows farmers to comment on the performance of species. This phase will also benefit from the involvement of social scientists and economists who can document and assess farmers' opinions and needs. There is no point in continuing classical domestication pathways until it is certain that a promising species is worthy of further research investment. Methods for the careful selection of priority species for tree improvement with a focus on farmer opinions have been explored by Jaenicke et al. (1994) and Franzel et al. (1995).

SOCIAL ISSUES HAVING IMPACT ON SPECIES SELECTION

Despite the benefits that can be derived from planting exotics there exists in some countries a belief, mainly among environmental groups, that only native trees should be planted. Many of these groups are motivated by nationalistic, spiritual and other worthy motives. Sometimes the opposition to planting exotics is not based on accurate information. Examples include general opposition to planting eucalypts in India and Myanmar because of their supposed excessive extraction of soil water, and in Spain because of the putative poisonous effect of leached leaf oils on soil micro-organisms. Such criticisms create considerable uncertainty amongst tree-growing organisations and the community in general. The real issue is to find the right species for the product required on the site available for planting. Correct siting of trees on farms to avoid conflict with neighbours, especially on small farms, is essential and is practised in many countries, e.g. in Ethiopia with *E. camaldulensis*.

Criticisms of exotics may be justified on other grounds, especially in cases where a poorly adapted species has been used for large-scale planting. In southern Spain, for example, the drought-susceptible *E. globulus* has been widely planted in dry areas where the stressed plants are attacked by the longicorn beetle (*Phoracantha semipunctata*), causing widespread growth retardation and even death. Black wattle (*Acacia mearnsii*), an otherwise valuable tree for tannin, roundwood, fuelwood and pulp, has escaped from cultivation and become a weed in certain parts of Africa and elsewhere. These examples suggest that species must be chosen wisely by species introduction officers and plantation planners who have a social responsibility for the long-term consequences of their decisions. This fact was stressed by Hughes (1994) in relation to the testing of weedy legumes and the damage that can be caused, especially to indigenous flora on small oceanic islands. While it is highly desirable to promote native trees in cultivation and to include them in trials, the long history of successful exotic introduction suggests that one should not be too timid in searching for and testing a wide range of new and potentially valuable species. Midgley et al. (1995) also alluded to this in their report of tree species used in three communities in Vietnam, provocatively subtitled ‘Do trees need passports?’.

Tree and land tenure issues can have a dramatic positive or negative impact on species selection and tree planting. In Kenya *G. robusta*, being an exotic species, was widely adopted initially to mark permanently individual farm boundaries. Landowners also had the right to harvest tree products, and the management of *G. robusta* developed in a surprising way. Farmers adopted management techniques in which trees are treated as ‘milking cows’, i.e. trees are climbed, pollarded and branches lopped regularly for fuelwood and other products. Leaves are used for mulch and cattle bedding materials and the residual tree stems eventually used for sawlogs. In contrast, tree planting in Ethiopia and Eritrea has virtually ceased on farms as the State owns most land and controls tree products that grow on them. In this situation there is little incentive for private citizens to plant any tree species. In addition the combination of high population density, small farm size, roving cattle after crop harvest and use of wooden ploughs (for which tree roots are a problem) to cultivate annual crops curtailed the use of agroforestry.

Gender issues are also important in species selection. In much of Africa, tree planting is seen as ‘men’s work’. One reason for the lack of success of alley farming is that women are reluctant to lop hedges as this heavy work is in the male domain. In some rural surveys in East Africa, ICRAF found that women prefer some tree species more than men if they contain medicines of value to them, e.g. for breast complaints (S. Franzel, pers. comm.). ICRAF staff also pioneered the use of the traditional African Mbao board game to assist in species selection when dealing with farmers. In a Rapid Rural Appraisal survey of bush mango (*Irvingia gabonensis*) in Gabon, West Africa, Boland et al. (1996) found that women have a better knowledge of genetic variation within the species (as they are major gatherers). They could more accurately predict the fruit properties (really cooking properties of the cotyledons) of closely related species, i.e. the species preferred for cooking were consistently better known to women.

SITE ASSESSMENT

This section provides an account of the data that are required to assess or characterise a site before species are selected. The larger the area where the site characteristics remain the same, the greater the practical impact of a successful introduction. Greater emphasis is given to traditional forestry approaches, but the modifications necessary for providing species to small-scale, resource-poor farmers are described. In recent years the development of Geographical Information Systems (GIS) has revolutionalised rural land-use planning appraisals. Land use planning can be assisted by flexibility of scale and the ability to isolate and mix different maps. The eco-regional approach to species testing can be refined more rigorously and comprehensively when GIS technology is used.

Procedures for evaluating the planting site

Once the characteristics of the species required have been established, and before species are actually chosen, the specific conditions of the planting site need to be evaluated. This stage involves a description of the physical, edaphic and climatic factors of the site. This stage can be as comprehensive as required and may involve a considerable amount of work. The aim is to divide the area into categories with each category having uniform conditions. The ultimate unit may be termed a ‘site’ that Coile (1952) defines as ‘an area of land with a characteristic combination of soil, topographic, climatic and biotic factors’. This evaluation sets the limits for species selection and also enables a realistic appraisal of where trial sites for particular species should be located so that the results can be extrapolated accurately. Some scientists refer to this process as site characterisation.

1 Physical, edaphic and vegetational factors of the land

On a large scale it is often useful to have vegetation maps, soil maps and perhaps aerial photographs to determine the overall land patterns. In some countries, e.g. Zimbabwe and the Republic of South Africa, major silvicultural zones based on elevation, climate, vegetation and past experience with exotic trees and crops have been delineated. These broad-scale appreciations are a desirable prerequisite to more detailed mapping.

In the agricultural sector similar maps exist which show 'agro-ecological zones'. Such zones often have colloquial names attached to them such as the 'coffee-based' land-use system.

Maps of the planting area at a scale of at least 1:50 000 or 1:20 000 are essential. These should indicate latitude, altitude and small topographical detail, e.g. aspect, slope, swamps, rivers, rocky hilltops. Other maps showing soil type, native vegetation and land use should be obtained or compiled. Special biotic characteristics, e.g. in South Africa snout-beetle (*Gonipterus*) attack on eucalypts, more common at higher altitudes, can be noted. In other areas, the occurrence of termites which eat the roots of newly planted seedlings is a serious pest and should be noted.

2 Climatic factors

Meteorological stations are rarely located at proposed plantation sites, and some extrapolation is commonly needed. Burley and Wood (1976) suggest that the following data should be assessed for each site type.

(1) Mean annual total precipitation.
(2) Mean monthly precipitation.
(3) Mean monthly relative humidity percentage.
(4) Mean annual temperature.
(5) Mean monthly temperature.
(6) Mean daily minimum temperature for the coldest month.
(7) Absolute minimum temperature.
(8) Mean daily maximum temperature for the hottest month.
(9) Absolute maximum temperature.
(10) Mean range of temperature.
(11) Mean monthly wind speed at 2 m above ground level.
(12) The number of years of observation for each of the above.

On a broad scale some climatic indices can be applied to indicate climatic types (homoclimes). Thornthwaite and Koppen are the most commonly used homoclimes. In the Thornthwaite system, potential evaporation and transpiration are estimated as a function of mean monthly temperature with a day-length adjustment to account for effects of latitude and for seasonal variation. The main advantage of these systems is that they can be applied worldwide and hence broad-scale climatic comparisons can be made.

In recent years more complex climatic indices indicating likely or anticipated crop growth have been developed so that more precise matches can be made between a plant in its natural range and its performance in an exotic situation. This has been applied to crops (Hutchinson et al. 1992) to determine suitable areas for cultivation.

3 Mapping site types

Once the physical, edaphic, vegetational and climatic factors have been established, the various site groupings can be drawn on topographic maps. Positions for species trials can then be selected in advance of actual species introductions. These positions may be located randomly within each site type, or determined subjectively because of constraints, such as ease of access, availability of land for trials, ease of protection, the fragmented nature of the planting area. These practical considerations are almost always overriding factors in any introductory work.

Site assessment for agroforestry

Site assessment procedures for forestry are equally applicable to agroforestry. Perhaps the major difference between the two is that foresters are usually looking for uniformity of the site to ensure, if possible, uniformity of production. There is ultimately greater management control in the whole production process in forest plantations than is possible in agroforestry. In agroforestry, greater interaction between the site and the users, i.e. farmers, is necessary.

In an agroforestry context it is also necessary to include a social component in the site characterisation process. This should include census of population, household income, farm size, labour availability and willingness to grow trees. Details of preferred tree species are also vital. Unfortunately it is only in recent times that the value of this kind of preliminary social survey has been fully appreciated. Rapid Rural Appraisals can be used to gather this kind of data.

TRADITIONAL TECHNIQUES TO SELECT SPECIES AND PROVENANCES

This stage should proceed in a logical and systematic manner once the required species' qualities and site conditions have been determined. The two main problems that impede progress are lack of knowledge of suitable species and availability of seed for planting.

Local appraisals of species near the planting site

Previous native and exotic plantings at or near the planting site should be carefully examined. All relevant local literature should be consulted and knowledgable people contacted for useful information.

Indigenous tree species

Suitable native trees should be examined for their potential. Both local and non-local seed sources should be examined for suitability. The best native species should always be included in species trials so that scientific assessments can be made on the relative merits of natives versus exotics.

Local exotics

It is rare for any country these days not to have some successful exotic trees. Often these may be found in botanic gardens, on farms, alongside streets, in parks and around old established farmhouses. A survey of these trees should be made as early as possible. This should provide information on species to plant, countries where suitable species may be found, or taxonomic groups of species worthy of further study, e.g. if one member of a particular genus is performing well then others should be tried, particularly closely-related species from similar environments. This naturally presupposes that evolutionary relationships amongst species in the genus are known, e.g. by prior cladistic analyses.

Selection of exotics

The method most commonly employed for selection of exotics for introduction is environmental matching. This may involve examining native trees in their home climatic environments and/or their performance in trials as exotics in other countries with similar environmental conditions. It is preferable that this latter step be taken first. For example, information on exotics can be gathered from Streets (1962) for a wide range of species grown in the British Commonwealth, from Poynton (1979) and FAO (1979) for eucalypts and from NAS (1979) for tropical legumes. For information on specific topics one can consult NAS (1980, 1983) for fuelwood species or FAO (1963) for tree species and planting practices in arid zones. Webb et al. (1980) produced a valuable data set when they compared up to 82 characters for about 125 of the world's most important forest trees.

Climatic matching

This technique involves comparing the climate of the planting area with other equivalent climatic areas around the world (see Chapter 1). Species are then selected from these areas with adjustments for soil types or special features, e.g. salt tolerance. This technique has been used for many years e.g. by Robertson (1926) when he compared Australian climatic zones with those in South Africa in selecting species. In Brazil Golfari et al. (1978) demarcated climatic zones and matched them with similar zones in Australia in order to select eucalypt species and provenances for trial.

One serious disadvantage of climatic matching is that some species perform well outside their natural climatic range, e.g. *E. robusta* grows well from tropical to near-temperate parts of Brazil. Past events such as fire or climatic squeezes may have severely restricted the current natural range of the species, and thus the natural range may not indicate the full potential of a species.

Information exchange

Arguably the most practical method is for the plant introduction officer to send environmental data and information on planting objectives to appropriate scientists in other countries having similar climatic conditions requesting their comments on species selection. Special advisers may also be consulted or visits arranged to bring them to the plantation site. Such practices are common in many parts of the world.

Selection of provenances for planting

The concept that provenance has a genetic and evolutionary basis has dominated forestry thinking for some time; it implies that genetic variation is associated closely with the ecological conditions in which the species evolved. Application of the concept involves recognition of intraspecific variation in particular characteristics and classification of forest reproductive material according to its geographical origin (Turnbull and Griffin 1985). The term 'provenance' is applied frequently to the original geographic source of seeds or propagules. Most provenances are labelled by locality names but often regions are confused with provenances, e.g. Coffs Harbour *Eucalyptus grandis* covers a huge region and many provenances. There is a definite international need to standardise the nomenclature of provenance.

In arboreta or species elimination phases great care must be taken to get representative seed sources. One view is that seed should come from the part of a species range where growth is optimal. Namkoong (1969) reasoned that outlying populations have evolved conservative survival strategies at the expense of fast growth, while those populations in optimal sites have developed under more intense competition for light and nutrients, thus favouring rapid growth over survival strategies.

A different view for provenance selection has been espoused by Edwards (1963). He suggested for an unknown species that at least three provenances should be used. These are the optimum, the closest climatic match, and one marginal provenance from the boundary of the distribution that extends the range in a given preferred direction, e.g. drought tolerance. Overall this approach is recommended, and it is important that each provenance be treated as a single testable unit for a species.

NEW TECHNIQUES FOR SPECIES SELECTION (COMPUTER-ASSISTED DECISION SUPPORT SYSTEMS)

The development of computers and database software has made possible the storage, retrieval and comparison of large data sets on individual tree species. This development has gained considerable momentum over the past 20 years and has been helped considerably by the advent of more powerful desktop computers. Most databases on species consist of two main types of data sets. These can be summarised as: (a) documentation of the physical characteristics of species, and (b) documentation of growth performance of tree species in a range of environments. One advantage of combining such data is that we have the essential components necessary to select species for a particular end-use and then predict their growth response on a particular planting site. This may also involve including additional information on climate and soils and also other environmental factors. The development of these decision support systems has made species selection simpler. Today we are in the fortunate position of being able to assess the value and use of several databases developed in Australia and other countries.

One of the earliest databases to assist in species selection was INSPIRE, developed by Oxford Forestry Institute (OFI) and based on a compendium of tropical species compiled by Webb et al. (1980). INSPIRE made use of the six climatic parameters given for each species in the compendium and searched for species that fulfilled specified climatic conditions. Although valuable, the limitations of INSPIRE were absence of soil data, no ability to predict growth rates or growth performance and no provision for users to add extra datasets.

Many advances in the use of climatic datasets for tree species selection have been promoted by Booth (1985, 1996). Underlying these new approaches has been the ability to interpolate climatic data for sites where no weather station records are available. Climatic surfaces at the country and continental levels have been developed for the continents of Australia and Africa, and for China, Vietnam, Indonesia and the Philippines. The power of this modelling approach has resulted in several new uses. At its simplest level one takes the climate at a particular planting site in, say, Thailand and then circumscribes the part of Australia that best matches the Thai site. This enables selection of species and provenances from that part of Australia for trial in other countries (Booth et al. 1987).

Another approach involves a circumscription of the climatic parameters for a particular species in its natural distribution in Australia and then the interrogation of a climatic database to determine where the species will grow in corresponding areas in, say, Africa (see Booth 1991). This procedure is appropriate when a species has not been widely tried outside Australia. However, it is well known that many species may grow successfully in plantations in conditions which are somewhat different from those within their natural distribution. The assumption is that factors such as competition with other species and fire and pest and disease problems have limited the natural distribution of species. One can assess this adaptability by examining the planted distribution of an Australian species outside its natural range and then redefining its climatic requirements. For example, *A. mearnsii* is grown successfully in plantations outside Australia in areas that tend to be both wetter and warmer than locations where the species is found naturally in Australia (Booth and Jovanovic 1988).

One facet of climatic modelling that has not yet been well embraced is the concept of climatic region of provenance within species. In papers on *Acacia mearnsii* (Booth et al. 1989) and *Acacia auriculiformis* (Boland et al. 1990), cluster analysis techniques were used to defined subregions of the natural distributions with similar climatic conditions. Artificial limits are usually set for the number of subregions that are required. This has the potential advantage of defining a climatically-based seed collection program so that the whole climatic range of a species is adequately sampled. Alternatively this technique can more sharply define where trees from a region or provenance of a species in Australia can be grown in other countries.

A major limitation of the climatic approach is that other environmental variables (e.g. soil properties) are also important in the species/provenance prediction process. In addition there is no modelling capability for predicting rates of growth of a species at a particular site. This decision support system will also be considerably enhanced once climatic surfaces are available for all countries.

Recognition of the importance of multipurpose trees (MPTs) to resource-poor farmers in tropical ecosystems worldwide brought the accompanying realisation that very little was known of their special physical characteristics, how they could be managed and conditions under which they grew best. Many of these species were shrubs, that occur spontaneously in fallow land, weedy trees and indigenous fruit species and were not well known to foresters, horticulturalists or agriculturalists. The International Centre for Research in Agroforestry (ICRAF) recognised this problem and sought to address it by developing an MPT database. The first release contained data on about 1100 species (von Carlowitz et al. 1991). The database is largely descriptive in character. A special feature for agroforestry is the coding of species for particular agroforestry technologies and end-uses. The database enables all species to be searched for particular end-uses, soils, agroforestry technologies, climatic regions (using Koppen codes) and other properties. The data are somewhat limited by the small number of field records for most species. Major technical limitations are the lack of modelling capability to predict species growth at particular sites, and the difficulty for users of adding new records. The database is continually being improved and there are hopes for graphic capabilities and electronic data capture techniques for use by field observers. Users of the database are encouraged to send new records to ICRAF to update the database.

Two recent Australian systems of note with predictive capability are TREDAT and PLANTGRO. The former database was developed jointly by Queensland Department of Forestry and Division of Forestry, CSIRO (Brown et al. 1989); work first commenced in 1983. The underlying concept was the recognition that considerable numbers of field trials had been conducted in the past in many parts of Queensland, but often results existed as 'grey literature' that had not been adequately documented. The TREDAT database permits the results from field trials of species or provenances to be stored and selectively retrieved to assist in the choice of planting material for particular sites. The database made early use of relational database technology. Information on species was divided into six categories (files or modules) with links between them. These categories were site description, management history, performance record, botanical identity and project description. A more recent description of TREDAT was given by Vercoe and Clarke (1995). A key advantage of TREDAT is that it allows actual mean values from trials to be included so that comparisons in growth performance for species/provenances across sites are possible.

When TREDAT was initially developed it could only be run on a mainframe computer but now it is possible to run it on desktop personal computers (PCs). While the original purpose was to serve Queensland users, the system has potential to accommodate information on trials of trees from other Australian States as well as those growing in other countries. Limitations to the database include lack of graphic capability and no real capacity to model plant growth.

MPTDAT is usable on PCs and was developed under the USAID F/FRED project. MPTDAT is based on a minimum dataset which was taken from TREDAT. Its main purpose was initially to underpin the F/FRED fuelwood trials in Asia and to develop the capability of modelling growth responses of trees at any particular site. The main dataset were based on priority species used in the F/FRED field trial program established at several sites in Asia. There was an initial vision that users could network and share data files on species growth in trials within the region. This database has also been used by the Division of Forestry and Forest Products, CSIRO for recording responses of Australian native trees to salinity.

PLANTGRO is a software package on PC for predicting the growth of crops, forest trees, and other species (Hackett 1991). The database comprises plant, soil and climate files, with the soil and climate data being based around widely used descriptors. Each plant file contains quantitative relationships which describe the plant's responses to 11 soil and 11 climate factors. By using a generic prediction engine whose output includes dynamic information about growth rates and water balance, predictions can be made for almost any higher plant and for a very wide range of locations. The current version (V2.1) provides starter sets of files for ca 35 forest trees, 100 crops, 50 soils, and 100 climates, any of which can be upgraded or adapted by use of the editor provided in the package. Programs are provided for making further such files, with the handbook providing expert systems for estimating the relationships for plant files. A recent new additional system called INFER (Hackett 1995) enables starter plant files to be made from records of the conditions a species is known to experience; data in the MPTDAT, TREDAT, and similar databases can be used by INFER to help estimate species' environmental relationships, which can then be improved by making predictions for various combinations of soil and climate conditions. Connections are provided too with GISs and flat-file plant databases, and two special programs enable multi-species systems to be constructed and tested. PLANTGRO passed extensive testing for crops in 1993 at Wageningen Agricultural University in the Netherlands and was used successfully by international forestry consultants for the recent construction of Indonesia's National Masterplan for Forest Plantations. 'Matching Trees and Sites' (Booth 1996) includes several papers summarising recent forestry work with the PLANTGRO model. Current research with the package is focused on demonstrating formally that the model's predictions for forest trees are reliable for the uses envisaged. Some 80 files exist in all for forest trees, covering many species important in tropical and subtropical regions. It is hoped that all these files will ultimately become publicly available.

Another database of international significance is MIRA developed by CATIE, Costa Rica, to monitor the results of the Madelena project in Central America. This has many of the elements of TREDAT (Ugalde 1988).

One of the major difficulties of all databases is the need for continued funding to upgrade records and improve interface capabilities. There has been a rapid increase in the number of species databases being developed around the world. One must recognise that different organisations require databases for different purposes and may wish to develop their own customised products. It is clear, however, that there is a need to achieve easy access to a range of databases, and the development of platforms to permit this is desirable.

STAGES OF SPECIES INTRODUCTION AND IMPROVEMENT (THE CLASSICAL APPROACH)

The stages (phases) developed for the selection of species and provenances for industrial plantations are: an arboretum phase, a species elimination phase, a species testing phase, a species proving phase and a species provenance phase. In sophisticated programs a tree-breeding phase involving individual tree selections and controlled crossing can be developed after the provenance phase. Some of the phases can be conducted simultaneously.

Arboretum phase

This is one of the most interesting and stimulating phases of tree introduction but unfortunately it is usually the most poorly setup and understood. The aim is to test a few individuals of a wide range of species.

The demonstration value of arboreta is important, so siting the trial near roadsides or towns is desirable. These trials have long-term value and must be properly maintained for many years. Few new arboreta have been established in the tropics in recent years, despite there being interest in a greater number of species than ever before, and many organisations move straight into the species elimination phase.

Species elimination phase

The aim is to examine a large number of the most promising species in small plots to eliminate unsuitable candidates. These trials are usually of relatively short duration. If several species do well, more tests with a selected few over a wider range of sites may be useful in establishing the most versatile species. Care should be taken to use appropriate and well-documented seed sources.

The main conceptual issues for these trials are trial purpose and trial design. Once thoughts are clear on the former, the latter issue can be determined with assurance. In general the aim is to field-test a wide range of accessions (species and provenance) and assess survival, initial growth rate and species capacity to provide the type of product wanted, e.g. fodder or thorniness for fencing. Duration of the experiment may be as short as three years. Once the best species have been identified we can move onto other related trials. By three years, spacing, competition and gaps through death of accessions are usually a major problem in the trials. Given these potential limitations it is sensible to plant line plots and use incomplete block designs (Williams and Matheson 1994).

Details of trials of Australian species in China, Thailand, Kenya and Zimbabwe are given in Boland (1989).

Species proving phase

This involves examining all possible methods of propagation (e.g. is propagation by cuttings possible if seed is difficult to obtain?), methods of ground preparation, planting techniques, spacing, thinning, pruning, fertiliser, weed control, etc.

Many introductions fail because seed is difficult to collect, hard to store and loses viability rapidly. These factors can have a dramatic influence on the choice of species. Species that are difficult to germinate, are susceptible to disease in the nursery, are slow-growing or need special inoculation with fungal or bacterial organisms to maintain thrifty growth are seldom included in later plantations. Vegetative propagation can play an important part in providing planting stock of improved varieties of many valuable multipurpose species.

Species provenance phase

Once an important species has been identified a provenance trial can be commenced. This trial may be limited to provenances from a favoured region, or there may be one or more wide-ranging trials involving all possible provenances.

This stage can be considerably enhanced by participation in international provenance trials for a particular species. Such trials have been organised by CSIRO (e.g. *Casuarina equisetifolia* trials), OFI (e.g. *Gliricidia sepium*), IUFRO (e.g. *Eucalyptus grandis*), FAO (e.g. *E. camaldulensis* and *Azadirachta indica*) and DANIDA (e.g. *Tectona grandis*). Such participation can be very rewarding in finding provenances well suited to particular ecozones or, conversely, determining whether there are very significant site–genotype interactions, a situation which makes selection of superior provenances very difficult.

Final testing stage

This stage will vary with the end uses involved. Small pilot plantations, agroforestry plots, etc. can be established.

In all of these stages identifying best seed sources is vital. As the program develops, considerable thought has to be given to establishing seed stands or seed production areas to ensure the production of high-quality improved seed in sufficient quantities to meet current and anticipated demand. Procedures for eucalypts are documented by Boland et al. (1980) and Eldridge et al. (1994).

Diffusion of germplasm of selected or improved seed to users

This phase is probably the most important in getting selected and/or improved seed to users (Turnbull 1984). In industrial forestry the clients traditionally have been either government organisations or large forestry companies. For these clients it was relatively easy to assess demand and get seed to the user. Social forestry and agroforestry has a more diffuse client base with, in many cases, a very poor appreciation of the value of improved seed. This difficulty has to be tackled through education and careful analyses of the diffusion pathways. Both sociologists and economists are needed for this work.

STAGES OF SPECIES INTRODUCTION AND TREE IMPROVEMENT (for simultaneous agroforestry technologies)

The process of selecting species/provenances/clones for simultaneous agroforestry technologies is based mainly on the classical approach with modifications to allow for input from other scientific disciplines and from farmers, the real users of trees in agroforestry. Table 3.2 gives details of the issues involved and sequencing of research activities that must all come together to select species for domestication for simultaneous agroforestry technologies.

TREE PRODUCTS AND SERVICES (qualities required when selecting species for use)

This section highlights some of the uses to which species in this book are put. Table 3.3 indicates how these products and services are related to some agroforestry technologies.

Fuelwood

Fuelwood is required by both industrial and non-industrial nations but the need is much greater in developing countries where domestic fuelwood is often essential for cooking and heating. Charcoal has an advantage over wood as a fuel in that larger-diameter logs can be utilised in its production, and that it is much lighter and therefore easy and cheaper to transport long distances to city markets. Charcoal production is, however, wasteful of fuelwood resources and has been banned in some countries, e.g. Eritrea. Native people, who traditionally obtain fuelwood from indigenous species whose burning and smoke properties are well known, are often extremely reluctant to change to exotic unknown woods. These preferences must be considered in the selection of species for fuelwood.

The qualities needed for fuelwood can be divided into the physical properties of the wood and silvicultural or environmental properties of the species. Thornless trees or shrubs with small-diameter stems are easy to cut with primitive implements and to transport. The wood should be easy to split and have a low moisture content or be relatively fast-drying, as considerable heat is lost in burning moist wood. For health reasons, smoke should be minimal and non-toxic (Poynton 1984) as ventilation is traditionally poor in most native houses. Sherpas in Nepal suffer respiratory problems resulting from home fires in confined spaces (S. Midgley, pers. comm.). In these same homes, however, the smoke has extended the life of beams and thatched roofs by inhibiting insect attack. For safety reasons wood should not spit nor spark while burning. Calorific values are not available for most species but there is usually a positive correlation between high wood density and heat produced per unit weight (calorific value). The best firewood burns slowly producing good heat from glowing coals. Some acacias have particularly good burning properties, and casuarinas are also highly regarded as firewood species. The fuelwood value of Australian species has been explored experimentally by Gardner (1989), Gough et al. (1989) and Groves and Chivuya (1989).

Desirable silvicultural and environmental properties of fuelwood species are given by Burley (1978) and NAS (1980). These include rapid growth, even on poor soils; ability to stabilise and improve the environment; minimal management requirements; disease and pest resistance; ability to coppice; hardiness to survive drought and other environmental stresses; and suitability for multiple use. Most of these qualities are not related solely to the use of trees for fuelwood.

Roundwood (poles, posts and stakes)

Poles and posts are very important for home building and fences in many developing countries. Despite the importance, little has been written about the management of trees for roundwood production or the use of roundwood timbers.

Table 3.2. A guide to the processes involved in the selection of species/provenances/clones for simultaneous agroforestry technologies based on exploitation of natural variation in wild tree species.

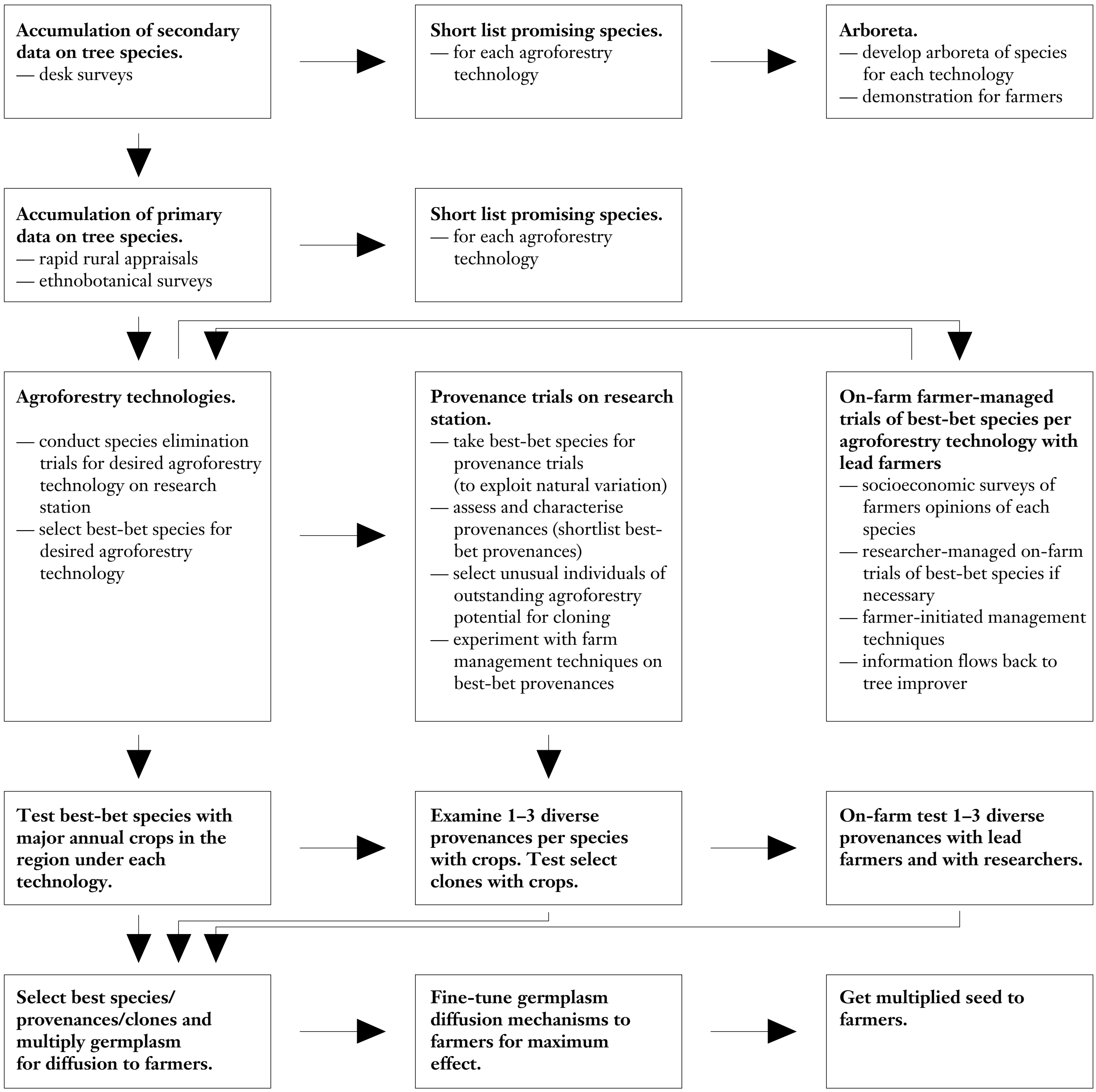

Table 3.3. Some agroforestry technologies (after Young 1989) together with some products and services that can be produced within them.

Agroforestry technologies	*Products*	*Services*
Improved tree fallows	Fuelwood, poles	Improved soil physical and chemical properties Reduction in quantity of invasive weeds
Trees on cropland	Fruits, poles, fuelwood,	Improved soil fertility, leaf fodder for animals Soil erosion control
Multistoried tree gardens	Fruits, poles, sawlogs	Increased biodiversity of plants and animals, shade
Hedgerow intercropping	Fodder (cut and carry), mulch to improve soil fertility	Soil erosion control
Boundary planting	Poles, sawlogs	Confirm land title claims, windbreaks, live fences

Commonly poles and posts are taken as saplings from native forests or are by-products of forest plantations grown for other purposes. Eucalypt plantations for sawlog production in Africa often have the first thinnings used for fence posts and later thinnings for telephone or electrical transmission poles, depending on size. At Ntabazinduna in Zimbabwe, a small plantation of *E. tereticornis/E. camaldulensis* is managed as a pole crop from coppice, with fuelwood as a by-product. Clump development of culms of *Dendrocalamus strictus* and other bamboos is encouraged in India and much of Asia to yield poles (Anon. 1980a) for scaffolding and house construction.

Poles are in great demand for rural house construction, especially as rafters that can bear heavy cross loads. In Africa, black wattle (*Acacia mearnsii*) or eucalypts are often used as house poles. In urban areas poles are required for scaffolding and it is not uncommon in India and other Asian countries to see tall buildings surrounded by a maze of bamboo, eucalypt or casuarina poles. There is a major market for eucalypt poles in the Ethiopian highlands for house construction. The shortage of poles is such that individual poles are split longitudinally to produce more. In Kenya both eucalypt and *Acacia mearnsii* stakes are used in the construction of woven wall frames for houses. These frames are then plastered with mud.

Poles and stakes are often required in mining areas. In Zimbabwe thin eucalypt poles are used to ram explosives into drilled holes, and there is an extensive use for poles for 'mat-packs' (solid piles of logs wired together and stacked horizontally) in South African gold mines. In China an important use for eucalypt poles has been to provide props in mines.

Stakes are widely used for support for agricultural crops. In Rwanda *Sesbania sesban* stakes are used to support climbing beans. In West Africa supports are required to carry trailing yam vines and allow easy weed removal around the tubers.

In developing countries wooden posts are required for house walls and supports and are widely used for fencing. The wood of many Australian acacias is very durable and suitable for fencing. *Acacia acuminata*, for example, is extensively used as fence posts across the southwest of Western Australia. Underground piles is the principal use of *Casuarina junghuhniana* in Thailand.

Both wood and silvicultural characteristics influence the suitability of species for poles. Poles should be durable, light, capable of taking high cross-loads (high strength to diameter ratios for a given length is vital), have minimal spirality, be resistant to termites and other wood borers, or be capable of taking preservatives easily. The tree should be straight, with strong apical dominance, few or thin branches and preferably self-pruning without leaving knots that cause weakness, little taper from bottom to top, and the bark should strip easily. For a discussion of the utilisation of eucalypt roundwood see Hillis and Brown (1978).

Similar properties are required of posts. Logs of larger diameter are usually required and they should be durable in the ground or in water, and be able to take high end-loads, e.g. if used as house bearing posts. For in ground use, the resistance to a wide range of termite species is essential.

Fodder

In dryland areas, especially, trees may be required as an emergency fodder supply during drought periods. Ideally the foliage should be palatable, nutritious and digestible. Details of useful Australian fodder species for dry areas are provided by Chippendale and Jephcott (1963), Askew and Mitchell (1978) and Vercoe (1989). One should guard against introducing trees that are poisonous to livestock, especially species with palatable foliage.

For many species management requirements have not been examined. Fodder trees have to be carefully protected during their early years from all forms of livestock, especially goats. Trees should produce large crowns above the reach of livestock. The crowns must be capable of severe lopping during periods of high environmental stress. Alternatively in intensively managed agricultural areas, trees can be grown totally protected and the leaves then harvested and fed to livestock, e.g. *Leucaena leucocephala*.

By world standards Australia does not have many useful fodder tree species. Most Australian species are used only in emergencies, although *A. saligna* is widely cultivated as a fodder species in North Africa. Acacias, while having high protein content are very high in condensed tannins and other anti-nutritional properties, e.g. cyanogenic glucosides.

Human food

Tree foods for human beings come in such forms as fruits, nuts, vegetables and honey. The domestication of Australian tree species to produce these products has not been remarkable to date. Australian Aboriginal people made use of nuts (*Macadamia*), fruits (*Eugenia*, etc.), vegetables (heart of palm, e.g. *Livistona*) and honey from wild bees. So far only *Macadamia* has been developed into a commercial crop, while the Australian honey industry is a significant rural industry largely based on nectar harvest from wild indigenous trees. The quandong, *Santalum acuminatum*, is emerging as a small plantation industry in South Australia. In nearby Papua New Guinea and the Pacific islands, tree nuts have been traditional important foods (Bourke 1994), being replaced in recent times with high-yielding root tubers such as sweet potato. Nevertheless nut trees are important food security in many Papua New Guinea villages and some have considerable potential for commercial production, e.g. *Canarium*. Tree vegetables (leaves) such as *Gnetum* are locally important but probably not to the same level as those harvested from a related species, *Gnetum africanum*, in West Africa.

In the context of this book acacia seeds offer some exciting possibilities for human food. The most promising are desert species like *Acacia colei*, *A. cowleana* and *A. tumida* (Harwood 1994). These species have performed well in trials in Niger and are seen primarily as drought security food. Good quality honey is produced from eucalypts and many other species. In Ethiopia honey from *E. camaldulensis* is highly regarded, as nectar production is greatest in seasons when nectar production from indigenous species is quite poor. Australian acacias are an excellent source of pollen for bee protein.

Live fences

Fences created with trees or shrubs are common in many developing countries because of their low establishment cost. Few are totally effective and gaps created by dying plants have to be plugged by either replanting or more commonly by using dead branches.

Species with prickles or spines, or having stiff branches, both with non-edible leaves, are preferred. In some instances trees capable of root-suckering can be usefully employed. Ideally species should be fast-growing, of medium height, long-lived and be capable of growing under adverse conditions and close together. Minimal maintenance is essential although some trimming can be undertaken.

In dryland Africa many temporary fences are erected by lopping thorny branches from bushes and trees and constructing barrier lines to restrict animal movement. These dry fences are often severely attacked by termites.

Shade

Species selection will depend on the degree of shade required. Trees growing close to agricultural crops need to cast very light shade; for example, in India *Casuarina equisetifolia* is preferred on rice bunds because the thin narrow crowns cast minimal shade. Trees giving dense shade throughout the year are needed in many hot arid areas to relieve stress on grazing animals during the hottest part of the day.

A good shade tree should be evergreen, especially in the tropics, and have a wide spreading crown with a dense canopy. The amount of canopy closure is often determined by the branching pattern. Preferred species are fast-growing, long-lived, unpalatable and capable of tolerating soil compaction by animals camping beneath them.

Windbreaks

Ideal windbreak trees should be bushy and capable of withstanding strong wind (hot or cold), or the effects of salt-laden wind in coastal areas or wind-borne sand in desert areas. Wind can desiccate crops and reduce body heat in animals, causing loss of productivity or even death.

There are several outstanding examples of successful windbreaks around the world. Since 1949 a windbreak of *Casuarina equisetifolia*, 3000 km long, has been established in China along the coast bordering the South China Sea. This has provided shelter for crops growing on the leeward side and has also stabilised drifting sand in the area (Turnbull 1983). In Egypt, casuarina shelterbelts have also been grown to protect agricultural land mainly from wind erosion (El-Lakany 1983). In New Zealand windbreaks of *Pinus radiata* effectively provide shelter for stock from cold winds. The windbreaks may be trimmed on their sides and tops to prevent too much shading of pastures and selected trees are sometimes pruned for sawlog production. By comparison the extensive windbreaks of *Eucalyptus cladocalyx* in southern Australia and of *E. diversicolor* in parts of South Africa have only a limited useful life because of the shedding of the lower limbs. These examples suggest that species selection is important and that the effectiveness and value of windbreaks can be improved by appropriate manipulation.

Some of the qualities required are tolerance of harsh environmental conditions, a crown which is bushy and deep but allows some wind penetration, delayed shedding of lower limbs, wind firmness of roots, rapid growth if early protection is required, long life, and pest and disease resistance. They also should not harbour pests of neighbouring crops, and the roots should not compete excessively for water and nutrients with adjacent crops.

Soil protection — erosion control

Trees are often required to prevent soil loss through wind or water action and often very hardy trees are sought for poor sites . The basic idea is to prevent soil movement by root-binding the soil, preventing direct impact of raindrops or by increasing the percolation of water through the soil. Leaf fall also provides ground cover to further protect the soil. The role of trees in preventing soil losses from agricultural lands in high-intensity tropical storms can be very significant (see Sanchez 1995) but species differ greatly in their effectiveness.

Casuarina equisetifolia has helped to stabilise coastal sand dunes in India by binding the sand with numerous fine roots and preventing sand movement by the heavy and continuous shedding of branchlets that form a thick and slowly decomposing interlocked mulch on the sand surface (Kondas 1983). In South Africa, North Africa and the Middle East *Acacia saligna* was introduced and used extensively and successfully to control sand drifts, but in South Africa it has now become a noxious weed (Anon. 1980b). In Argentina *Casuarina cunninghamiana* has been used successfully to control streambank erosion in the delta region of the Parana River (Mendonza 1983). In high-rainfall areas of Java, *Acacia auriculiformis* produces dense foliage thus providing ground cover while the extensive root system helps bind the soil (NAS 1980). *Melaleuca quinquenervia* was planted in swampy bog areas of Hawaii, resulting from clearing of the natural vegetation, to help stabilise the soil surface and to increase water penetration.

Common tree qualities sought for erosion control are: fast and healthy growth under adverse conditions; spreading crowns; vigorous root systems with soil binding properties; either vigorous vegetative reproduction, e.g. root suckers, or heavy natural seed fall and natural seedling development *in situ* without the tendency to become a weed; and trees having roots with high strength values — especially in areas prone to land slip; and fire tolerance.

Soil improvement (including use of improved fallows)

This usually involves planting trees to increase the fertility (usually nitrogen content) of the soil. Nitrogen-fixing species form associations with nitrogen-fixing organisms (rhizobia or *Frankia)* in their roots and have the ability to return atmospheric nitrogen to the soil through root decomposition or leaf fall. Such species may be rotated with other crops or grown as mixtures such that one may benefit from nitrogen and the other perhaps from shade.

In agroforestry in the tropics, rotational fallows (sequential agroforestry systems) are used in the highlands of Papua New Guinea. Here *Casuarina oligodon* is planted amongst cash crops such as coffee to provide shade and to improve soil fertility in the fallow period of bush gardens (Thiagalingam 1983). This technology has been widely adopted by local farmers and is spreading rapidly (Bourke 1985; M. Bourke, pers. comm. 1995). On Iwa Island, Papua New Guinea, a tree legume *Schleinitzia novo-guineensis* and another tree *Rhus taitensis* are said to be planted after the yam harvest to improve soil fertility (Hide et al. 1994). Green manure is popular in some countries and leaves of *Leucaena leucocephala* are said to rival animal manure in nitrogen content (NAS 1980) and can be collected and dug into fields to benefit subsequent agricultural crops.

Sesbania sesban has been tried in several research farming systems in Africa by ICRAF and local farmers (see Ndungu and Boland 1994). In western Kenya individual trees are left (or seed is broadcast) to provide scattered trees on farms. Farmers are very much aware that after trees die, or are harvested, the yield of the subsequent crop is much enhanced. In Zambia and Malawi research has been conducted on relay cropping (maize–sesbania relays) and use of *Sesbania* as an improved fallow (Kwesiga and Coe 1994). This technology is currently being taken up by resource-poor farmers in the region and *Sesbania sesban* has proved, so far, to be effective.

There is considerable international interest in growing mixtures of leguminous and non-leguminous species. Trials established in Hawaii showed increases in total biomass productivity with mixtures of *E. saligna* and various legume tree species, e.g. *Paraserianthes falcataria* (Binkley and Giardina 1997). Research is currently ongoing in Australia on eucalypt-acacia mixtures to assess the benefits each may derive from such mixtures (Khanna 1995). A critical factor in the long-term use of mixtures is the fate of the biomass of the N-fixing component. If this is removed from the site, the long-term impact of the mixture may be adverse because of the hastened removal of nutrients other than N.

Soil improvement can also occur through the transfer of nutrients from the lower solum (that may move there through leaching or be released by decomposing parent materials) to the soil surface where they are available to crop and pasture plants. Certain plant mycorrhizal associations are also able to tap refractory phosphate, thus improving available phosphorus levels in phosphorus-fixing soils. In western Kenya recent research has shown that *S. sesban*, as well as being a legume and hence able to fix atmospheric nitrogen, can also tap pools of nitrogen trapped deep in the soil profile below the reach of annual crops (Sanchez 1995).

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Chapter 4

SEED, NURSERY PRACTICE AND ESTABLISHMENT

J.C. Doran

The purpose of this chapter is to compile existing germination and plant propagation information of the tree species described in this book. Guidelines for establishment are suggested as a basis for the small-scale planting operations necessary for trials and pilot plantations of these species. Included is information on seed procurement, laboratory germination, presowing treatments, nursery practice and establishment techniques. More detailed accounts of techniques and alternative methods that may be better suited to large-scale operations are available elsewhere; the reader is directed to these through citations in the text.

EXPERIMENTAL PLANNING AND LAYOUT

Practically all phases of the domestication process are represented in the work that is taking place on the species described in this book. At one end of the process, seed collections for first-stage species' elimination trials of little-known species have still to be planned (e.g. with some of the *Acacia* and *Terminalia* spp.). At the other end work incorporating conventional (e.g. with *Eucalyptus camaldulensis* in Thailand) and advanced breeding (e.g. with *Acacia mangium* in Malaysia) methodologies is in progress.

The phase reached in the domestication process will influence the choice of design for the trial, the type and number of seedlots represented, the number of seedlings to be included in each experimental plot and trial duration. A suitable trial site needs to be chosen. The design must use blocking to accommodate site heterogeneity, and appropriate randomisation must be incorporated.

It is only after these decisions are made that seedling numbers can be calculated and seed requested to ensure adequate numbers of seedlings are raised in the nursery to meet the trial requirements. Advice on experimental design is beyond the scope of this chapter. However, two books published recently cover this requirement admirably. The first, by Eldridge et al. (1993), includes a chapter on testing species and provenances. The second, by Williams and Matheson (1994), is particularly appropriate as it is a practical guide to design, analysis and interpretation of tree improvement trials. Many aspects of the practical management of multipurpose tree trials have been described by Briscoe (1990).

SEED PROCUREMENT

The availability of authentic, well-documented seed is a critical factor in all stages of species and provenance testing. The Australian Tree Seed Centre (ATSC) of CSIRO Forestry and Forest Products, Canberra collects and supplies high quality seed of Australia's woody flora, with special emphasis on range-wide provenance collections and lots from widely-spaced individual trees for research purposes. Currently seed from more than 1200 species, mainly of Australian origin, is held in store. Most species described in this book are well represented. New collections to obtain sufficient provenances for first-stage trials of those species not in the seed bank are planned.

Researchers wishing to procure seed should first provide basic information about objectives and the physical and environmental conditions at their planting site(s). Notes to facilitate this task are given in Appendix 1. The ATSC in consultation with the researcher will prepare a short list of species and provenances for trial, and provide the required seedlots with accompanying documentation on origin (source name, latitude, longitude, and altitude), number of mother trees in each collection and seed viability. It is recommended that researchers contact the ATSC at least three months in advance of their proposed sowing date to ensure timely arrival of seed.

SEED CHARACTERISTICS

Knowledge of the seed characteristics of individual species is important if trees are to be raised efficiently from seed. The plant propagator must know the number of plants to expect from a given weight or number of seeds, and appropriate methods to make every viable seed germinate as quickly as possible.

Data on seed viability, treatments to break dormancy, recommended laboratory germination temperatures and typical periods in the nursery to reach plantable size are given in Table 4.1 for most of the selected species. The information is based mainly on seed testing records of the Australian Tree Seed Centre, some of which have been published previously, e.g. Boland et al. (1980); Doran et al. (1983); Turnbull and Martensz (1982) and Turnbull and Doran (1987), but most are taken from internal files. Figures for some species are based on only a small number of tests but, used with discretion, they can be a useful guide until more comprehensive data are available. A summary of the more important attributes of seed of individual genera is given below.

Legumes

Species of the leguminous genera *Acacia*, *Albizia*, *Cassia*, *Dendrolobium*, *Lysiphyllum*, *Paraserianthes* and *Sesbania* dominate Table 4.1. Their seeds are extremely variable in size, shape and weight; even within a species marked differences can occur. The range in viability of the species given is 1194 germinants per 10 g for *A. mangium* from Indonesia to less than 20 germinants per 10 g for *Dendrolobium umbellatum*.

The seedcoat of many legumes is hard and impervious to water. This causes seed dormancy so that germination of a seedlot may extend over months or years. In order to propagate this seed efficiently in the nursery some form of presowing treatment is needed to permit water absorption through the seedcoat and ensure not only a high final germination percentage but rapid and uniform germination after sowing. A few *Acacia* species such as *A. cambagei* and *A. harpophylla* have a soft seedcoat and pretreatment is unnecessary or may be lethal.

Within many legume seedlots, not all the seeds are equally 'hard'. The proportion of hard seed in a sample depends on the environmental conditions during the growth of the plant, the degree of maturation of the seed when collected and the length of the storage period. Variation in hardseededness will occur within a sample, between samples of the same species, and between species. This makes it impossible to prescribe a standard presowing treatment that will be optimal for all seeds. With most techniques in common usage there is a danger of injury to the embryos of some seeds. Two techniques commonly employed for breaking seedcoat dormancy are described below under 'Conditions for Germination'.

The storage of seed of most of the legumes included in this book presents few problems by virtue of their hard seedcoat. The recommended treatment is to store them dry in airtight containers in a cool, secure location. Soft-coated species require more attention to storage conditions to maintain viability. *Acacia harpophylla*, for example, must be kept in airtight containers at –20°C (Coaldrake 1971). If necessary, seed that has undergone presowing treatment can be safely stored for at least short periods (e.g. 1 year) if kept cool and dry.

Myrtaceae

The myrtaceous genera *Asteromyrtus*, *Eucalyptus*, *Lophostemon*, *Melaleuca*, *Neofabricia*, *Syncarpia*, and *Syzygium* are the next largest group of species given in Table 4.1.

Asteromyrtus, *Eucalyptus*, *Lophostemon*, *Melaleuca*, *Neofabricia and Syncarpia*

Seed of these genera is usually stored and sown as a mixture of viable seed and chaff (mainly unfertilised ovules) that are difficult to separate in many species. Some features of their seedlots are the very small size of the seed of most species, the high proportion of chaff (from 80 to 97% by weight for the eucalypts), and the similarity in size, shape and colour of the chaff and viable seed of many species. Seed of the species in Table 4.1 germinate readily (5–20 days) without presowing treatment when given appropriate conditions of temperature, moisture and light. The range in seed size of these species is very great, varying from 65 000 germinants per 10 g for *M. arcana* to 360 germinants per 10 g for *E. oxymitra*.

The seed of these genera is relatively easy to store. The mature seed of most species remains viable for a decade or more when stored at a moisture content below 10% in sealed containers at 1–4°C.

Syzygium

A distinctive feature of the three species described is their colourful fruits. For example, *S. suborbiculare* has large, succulent red fruit each containing a large, single, transversely oblong seed (Boland et al. 1984). Each seed of *S. suborbiculare* weighs about 10 g and germination commences quickly after release. Preliminary data suggest that storage in airtight containers at 1–4°C is an effective means of delaying germination and keeping the seed healthy in the short term.

Casuarinaceae

Table 4.1 includes nine species of Casuarinaceae, i.e. four *Allocasuarina* and five *Casuarina* species. The winged seed of casuarinas germinate readily (7–35 days) without presowing treatment. They vary greatly in size between and within species. The desert oak, *A. decaisneana*, has the largest seed with an average of 320 germinants per 10 g, while at the other extreme *C. cunninghamiana* averages 6800 germinants per 10 g. The testa of the *Allocasuarina* species takes up water rapidly and produces a hygroscopic mucilaginous gel that appears to be an adaptive trait for rapid germination in conditions where the water supply may be transient.

The casuarinas listed in Table 4.1 retain seed viability at a high level for many years with minimal attention to storage conditions. Recommended treatment is to store them dry, in airtight containers in a cool secure location. Refrigerated storage (1–4°C) is desirable in the tropics. A review of aspects of seed collection, storage and germination of the casuarinas is given by Turnbull and Martensz (1982). Additional information can be found in papers given at two international casuarina workshops (see Midgley et al. 1983 and El-Lakany et al. 1990).

Proteaceae

Twelve species in the proteaceous genera *Banksia*, *Buckinghamia*, *Grevillea*, *Hicksbeachia*, *Macadamia* and *Persoonia* are covered in the book. The germination of all except *Persoonia* is problem-free under the right conditions. The germination of some of the grevilleas, e.g. *G. parallela*, *G. pteridifolia* and *G. striata*, is stimulated by a 24-hour soak in cold water prior to sowing. Work is still needed to define the germination requirements of *Persoonia falcata*.

Other species

Of the remaining species, germination of seed of *Alstonia scholaris*, *Brachychiton diversifolius*, *Callitris endlicheri*, *Capparis mitchelli*, *Davidsonia pruriens*, *Melia azedarach*, *Pleiogynium timorense*, *Santalum album* and *Ventilago viminalis* is usually problem-free under appropriate conditions, although *Callitris endlicheri* exhibits inherently low germination (8%) (Scott 1970; Turnbull 1972), which must be catered for in sowing procedures. Seed requiring pretreatment includes *Alphitonia* spp., *Atalaya hemiglauca*, *Dodonaea viscosa* subsp. *angustissima*, *Elaeocarpus* spp. and *Eremophila bignoniiflora*. Work is still needed to define the germination requirements of *Geijera parviflora*, *Parinari nonda*, *Petalostigma pubescens*, *Terminalia* spp. and *Ventilago viminalis*.

Seed of most species appears to be relatively easy to store, the recommended regime being airtight containers at 1–4°C.

CONDITIONS FOR GERMINATION

Temperature, moisture and light

These are important factors controlling the germination of seed of many species. While the detailed investigations required to stipulate optimum germination conditions remain to be carried out for most of the species covered in this book, Table 4.1 provides details of temperatures that have been found to give satisfactory germination under laboratory conditions.

The availability of good quality water is, of course, one of the major factors affecting the germination of seed. Ideally, nursery water should be soft and clean, slightly acid or neutral in pH and low in

Table 4.1. Summary of seed viability, pretreatment, suitable temperatures and periods for laboratory germination, and time in the nursery to reach plantable size.

Species	*Number of tests*	*Number of viable seeds per 10 g (mean ± S.D.)*[a]	*Average germ. (%)*	*Pretreatment*[b]	*Temp. (°C)*[c]	*Laboratory germination period (days)*[d]	*Nursery life span (months)*	*Source*[e] *(additional remarks)*
Acacia adsurgens	15	1116 ± 318	81	C or E	25	4, 21	2–3	1
A. ammobia	2	981	80	C or E	25	5, 21	4	1
A. ampliceps	30	339 ±97	91	C or E	25	9, 30	–	1
A. ancistrocarpa	19	233 ±55	78	C or E	30	4, 21	4	1
A. aneura	129	658 ±326	79	C or G	25	4, 21	3	1
A. argyrodendron								(no data available)
A. aulacocarpa	83	433 ±168	65	C or E	25; 30	5, 21	3–4	1
A. auriculiformis	174	716 ±108	71	C or E	25; 30	4, 26	3–4	1
A. bancroftii	3	154	73	C	25	4, 21	–	1
A. bidwillii	4	48	68	C or H	25	7, 21	2–3	1
A. blakei	3	998	70	D	25	4, 21	–	1
A. brassii	3	1045	81	C or E	25	5, 21	–	1
A. burrowii	1	1125	83	C or E	25	5, 21	–	1
A. calcicola	2	224	80	C or E	25; 30	4, 17	4	1
A. cambagei	15	209 ±60	98	A	25	5, 21	–	1 (boiling water and acid are lethal)
A. cincinnata	17	824 ±77	83	C or E	25; 30	4, 21	4	1
A. citrinoviridis	8	202	86	C or E	25	2, 24	–	1
A. colei	46	738 ±108	90	C or E	25	5, 21	–	1
A. concurrens	4	902	74	C or E	25	3, 25	–	1
A. coriacea	6	107	68	C or E	25	5, 25	3–4	1
A. cowleana	9	752	80	C or E	25	5, 21	3–4	1
A. crassa	2	801	71	C or E	30	7, 36	–	1
A. crassicarpa	123	364 ±80	69	C or D	25; 30	5, 25	3–4	1
A. cretata	1	1053	83	C or E	25; 30	4, 25	–	1
A. dealbata	46	534 ±141	74	C or E	25	4, 21	–	1
A. deanei	4	454	82	C or E	25	3, 25	–	1
A. difficilis	10	429 ±88	87	C or E	25; 30	4, 21	–	1
A. distans	1	416	75	C or E	25	3, 10	–	1
A. doratoxylon	2	956	86	C or E	25	5, 21	–	1
A. elata	24	217 ±31	76	C or E	25	5, 25	2–3	1
A. eriopoda	10	594 ±125	88	C or E	25	4, 25	4	1
A. falciformis	4	187	84	C or E	25	4, 29	–	1
A. fasciculifera	3	139	83	C or E	25	4, 25	–	1
A. filicifolia	4	643	80	C or E	25	4, 26		1
A. flavescens	7	255	60	C or E	25	5, 25	2–3	1
A. glaucocarpa	6	380	73	C or E	25	3, 21	–	1
A. harpophylla	2	189	97	A	25	5, 14	3	1 (boiling water and acid are lethal)
A. holosericea	49	929 ±206	86	C or E	25; 30	3, 17	3–4	1
A. hylonoma	1	408	76	C or E	25	5, 14	–	1
A. irrorata	11	1011 ±230	85	C or E	25	5, 21	–	1
A. julifera subsp. *gilbertensis*	2	213	61	C or E	25	6, 28	–	1
A. julifera subsp. *julifera*	6	609	78	C or E	25	3, 24	–	1
A. latzii	2	465	58	C or E	25	3, 21	–	1
A. leptocarpa	25	838 ±195	73	C or E	25	3, 21	3	1
A. leucoclada	3	516	65	C or E	25	3, 21	-	1
A. ligulata	12	260 ±67	76	C or E	25; 30	3, 25	4	1

continued over

Table 4.1 continued

Species	*Number of tests*	*Number of viable seeds per 10 g (mean ± S.D.)[a]*	*Average germ. (%)*	*Pretreat-ment[b]*	*Temp. (°C)[c]*	*Laboratory germination period (days)[d]*	*Nursery life span (months)*	*Source[e] (additional remarks)*
A. longispicata	3	876	79	C or E	25	5, 21	-	1
A. macdonnelliensis								(no data available)
A. maconochieana	2	410	78	J	25	4, 21	3-4	1 (high proportion of soft seeds)
A. maidenii	4	582	82	C or E	20; 25	3, 21	-	1
A. mangium Aust/ PNG	231	636 ±181	79	C or E	25; 30	6, 35	3	1
A. mangium Indonesia	12	1 194 ±137	86	C or E	25	8, 17	-	1
A. mearnsii	123	719 ±185	82	C or E	25	5, 21	-	1
A. melanoxylon	53	640 ±287	75	C or G	25; 30	3, 35	-	1
A. monticola	6	238	75	C or E	25; 30	3, 37	2-3	1
A. murrayana	5	199	66	C or E	25	4, 21	3-4	1
A. neriifolia	3	223	70	C or E	25	4, 25	-	1
A. oraria	7	427	49	C or E	25	5, 26	4	1
A. orites	1	853	60	C or E	25	4, 21	-	1
A. pachycarpa	3	49	74	C or E	25	3, 21	-	1
A. pendula	8	292	68	C or E	25	5, 21	3	1
A. platycarpa	7	43	75	C or E	25	4, 30	4	1
A. plectocarpa	13	598 ±223	80	C or E	30	4, 21	3	1
A. podalyriifolia	2	280	88	D or E	25	6, 28	2-3	1
A. polystachya	8	601	80	C or E	25; 30	5, 21	3	1
A. pruinocarpa	3	262	82	C or D	25	3, 21	4	1
A. rothii	4	33	52	C or E	30	4, 21	2-3	1
A. salicina	18	152 ±48	69	C or D	25	4, 31	3	1
A. saligna	26	457 ±136	74	C or E	15	5, 35	-	1
A. sclerosperma	9	33	95	C or E	25	5, 25	3	1
A. shirleyi	2	592	56	C or E	25	5, 25	3–4	1
A. silvestris	5	374	73	C or E	25	5, 25	-	1
A. simsii	6	817	60	C or E	30	3, 21	3	1
A. stenophylla	9	106	73	C or G	25	3, 25	3	1
A. stipuligera	13	808 ±88	85	C or E	25	5, 21	-	1
A. tephrina	1	233	40	C or E	25	5, 21	-	1
A. torulosa	24	267 ±143	80	C or E	25	5, 21	4	1
A. trachycarpa	6	121	68	C or E	25	5, 39	-	1
A. trachyphloia	5	678	63	C or E	25	4, 25	-	1
A. tumida	52	152 ±50	77	C or E	25	4, 30	2–3	1
A. victoriae	30	251 ±83	76	C or E	25	3, 21	2–3	1
A. xiphophylla	4	135	80	C	25	4, 11	-	1
Albizia lebbeck		70	70	C;D;H	25	14		2, 7
A. procera	4	166	63	E	25	3, 16	3–4	1
Allocasuarina campestris	6	3463	76	A	20; 25	8, 30	-	1
A. decaisneana	9	340	55	A	30; 35	4, 28	-	1
A. littoralis	13	2590 ±929		A	25; 30	5, 28	-	1
A. luehmannii	4	1576		A	25	6, 21	-	1
Alphitonia excelsa	7	45	27	C; D; H	25; 30	6, 21	3–4	1
A. petriei	1	684	60	C or E	25	4, 16	-	1
Alstonia scholaris								(no data available)
Asteromyrtus brassii	5	1710		A	25	5, 14	-	1
A. symphyocarpa	9	3118		A	25	5, 14	-	1
Atalaya hemiglauca	4	108	64	C	25	7, 21	3–4	1

continued over

Table 4.1 continued

Species	*Number of tests*	*Number of viable seeds per 10 g (mean ± S.D.)*[a]	*Average germ. (%)*	*Pretreat-ment*[b]	*Temp. (°C)*[c]	*Laboratory germination period (days)*[d]	*Nursery life span (months)*	*Source*[e] *(additional remarks)*
Banksia integrifolia	2	523	82	A	25	3, 21	-	1
Brachychiton diversifolius				A			4–5	1
Buckinghamia celsissima				A			4–5	1
Callitris endlicheri	2	130	8	A	20	7, 28	-	1
Capparis mitchellii				A				1
Cassia brewsteri	2	60	78	C	25	5, 48	4	1
Casuarina cristata	5	1119		A	25	7, 21	-	1
C. cunninghamiana	22	6072 ±2889		A	25; 35	5, 21	3	1
C. equisetifolia	77	2682 ±1572		A	30	4, 17	-	1
C. glauca	16	4149 ±2713		A	25	4, 28	-	1
C. obesa	7	3678		A	30	4, 22	-	1
Davidsonia pruriens		16		A				4, 5
Dendrolobium umbellatum	1	2125	85	A or C	30	5, 24	-	1
Dodonaea viscosa subsp. *angustissima*	1			C or D	25	4, 11	4-5	1
Elaeocarpus angustifolius			12	J				4, 6 (slow germination)
E. bancroftii								(no data available)
Eremophila bignoniiflora				J	30	18, 38	-	7 (16 hour soak in warm water)
Eucalyptus argophloia	4	12 978		A	25	5, 25	-	1
E. brevifolia	11	4408 ±3509		A	25	5, 18	4	1
E. camaldulensis	588	7035 ±4453		A	30	5, 14	2-3	1
E. gongylocarpa	9	764		A	25	7, 25	-	1
E. jensenii	12	1729 ±133		A	25	4, 18	-	1
E. ochrophloia	16	830 ±380		A	25	5, 14	4	1
E. odontocarpa	5	525		A	25	5, 14	-	1
E. oxymitra	5	403		A	25	7, 21	4	1
E. pellita	53	2660 ±1487		A	25; 30	5, 21	-	1
E. socialis	15	1242 ±874		A	15; 20	7, 25	3	1
E. thozetiana	7	4093		A	25	5, 14	-	1
E. trivalvis	4	1670		A	20	11, 26	3	1
E. urophylla	138	4499 ±2906		A	25;30	5, 14	-	1
Flindersia maculosa	1	568	90	A	30	4, 16		1
Geijera parviflora	1	480	50	A	30			1
Grevillea baileyana		480	50	A	25	15, 30	-	1 (syn. *G. pinnatifida*)
G. glauca	2	120	78	A	25	5, 15	-	1
G. parallela	1	293	85	J	25	11, 29	-	1 (24 hour cold soak improves germination)
G. pteridifolia	6	149	50	J	25; 30	13, 25	-	1(24 hour cold soak improves germination)
G. robusta	35	425 ±96	66	A	20; 25; 30	5, 25	-	1
G. striata							-	(no data available)
Hicksbeachia pinnatifolia				A				1
Lophostemon suaveolens	5	7700		A	20	6,23	-	1
Lysiphyllum carronii								(no data available)
L. cunninghamii	3	24	78	D or H	25	3, 8		1
Macadamia integrifolia				A				8 (24 hour cold soak improves germination)
Melaleuca arcana	1	39 000		A	25; 30	6,17	-	1
M. argentea	6	7783		A	25; 30	5,21	-	1

continued over

Table 4.1 continued

Species	Number of tests	Number of viable seeds per 10 g (mean ± S.D.)[a]		Average germ. (%)	Pretreat-ment[b]	Temp. (°C)[c]	Laboratory germination period (days)[d]	Nursery life span (months)	Source[e] (additional remarks)
M. bracteata	5	105 000			A	25; 30	5,18	4–5	1
M. cajuputi	8	26 925			A	30	5,15	-	1
M. dealbata	8	44 463			A	30	10,35	-	1
M. leucadendra	23	18 256	±10 270		A	25; 30	5,31	2–3	1
M. nervosa	2	59 500			A	25; 30	5,21	4	1
M. quinquenervia	9	26 614			A	30	5,22	3	1
M. stenostachya	1	52 000			A	25; 30	5,31	-	1
M. viridiflora	18	24 811	±11 231		A	25	5,21	3–4	1
Melia azedarach var. *australasica*	1	7		32	A or J	25	40,100	4	1 (Use only fresh seed; careful cracking of endocarp may assist germination)
Neofabricia myrtifolia	3	2180			A	25	5,21		1
Paraserianthes lophantha	3	100-150			C or E	25	5,21		7
P. toona									(no data available)
Parinari nonda	1	0.3		7	A	25	40,120	3–6	1
Persoonia falcata									(no data available)
Petalostigma pubescens	2	6		17		30	11,32		1
Pleiogynium timorense									(no data available)
Santalum album		45		70	C or J			8	9 (Gibberellic acid may enhance germination, species is hemiparasitic)
Sesbania formosa	14	309	±92	81	C or E	25; 30	5,19	-	1
Syncarpia hillii	1	670			A		4,30	-	1
Syzygium paniculatum									(no data available)
S. suborbiculare	1	0.7		76	A	25	40,120	4	1
S. tierneyanum									(no data available)
Terminalia arostrata	1	0.3		5	A	25	40,120	6	1
T. oblongata subsp. *volucris*									(no data available)
T. sericocarpa									(no data available)
Ventilago viminalis	1	219			J	25	4,11	-	1 (1/2hour soak in warm water improves germination)

[a] *For species with less than 10 seedlots tested only the mean number of viable seeds per 10 g is given, but where the number of lots tested exceeds 10 both the mean and standard deviation are given.*

[b] *A = no pretreatment required.*
C = manual scarification.
D = boiling water, pour and soak until cool (use 10 times the volume of water to seed volume).
E = boiling water, immersion for 1 minute (use 10 times the volume of water to seed volume).
G = immersion in hot water (90°C) for 1 minute (use 10 times the volume of water to seed volume).
H = concentrated sulfuric acid.
J = other pretreatment as specified, or as given in references.

[c] *The temperatures given have been found to be satisfactory for germination, however, except in a few instances, a full range of temperature tests has not been made.*

[d] *The figures given are average numbers of days from test initiation that first and final counts of germinance are made in standard germination tests at suitable temperatures.*

[e] *Primary sources of information on seed germination.*
1. Seed testing records of Australian Tree Seed Centre, CSIRO Forestry and Forest Products.
2. Hocking (1993).
3. Bonney (1994).
4. Floyd (1989).
5. Wrigley and Fagg (1988).
6. Nicholson and Nicholson (1988).
7. Langkamp (1987).
8. Trochoulias (1991).
9.Gjerum et al. (1995).

dissolved salts (saline water should be avoided). Germinating seed should be kept continuously moist, though not soaking wet, as this may affect oxygen supply and encourage pathogens.

A knowledge of the light requirements of individual species is important in sowing seeds in the nursery; the deep sowing of species requiring light may result in poor germination and, conversely, species inhibited by light should be well covered. It is anticipated, however, for most species in Table 4.1 that the best germination will be achieved if the seeds are sown near the surface where some light penetrates.

Presowing treatments to break seedcoat dormancy

The hard seedcoats of *Acacia*, *Albizia*, *Alphitonia*, *Cassia*, *Dendrolobium*, *Dodonaea*, *Lysiphyllum*, *Paraserianthes* and *Sesbania* species must be treated to make them permeable to water and oxygen so germination can take place. While soaking in concentrated sulfuric acid is a most effective method for pretreating seeds of many African species (e.g. acacias), it can be applied without adverse effects on germination only to a small number of Australian species (e.g. *A. bidwillii*).

Two of the most successful presowing treatments to overcome seedcoat dormancy in Australian species follow.

Manual Scarification

The recommended technique for small and valuable research seedlots.

Piercing, chipping, nicking or filing the seedcoat of individual seeds with a mounted needle, knife, scalpel, handfile or abrasive paper is usually considered to be the most reliable method of breaking seedcoat dormancy. As germination of a seedlot following this operation may closely approximate its full germination potential, this technique is especially suitable for the pretreatment of small and valuable research seedlots.

The steps to follow in manually scarifying each seed as illustrated in Figure 4.1 are:

(1) locate the scar on the shoulder of the seedcoat (hilum) that was once the point of attachment of the funicle (the umbilical cord between seed and pod). The scar is often to be seen as a tiny light-coloured spot at one end of the seed. Avoid damage to this end of the seed during pretreatment as this is where the root (radicle) will emerge on germination;

(2) focus attention on the shoulder of the seedcoat at the end opposite the scar (the distal or cotyledonary end) and cut off (nail scissors often provide a convenient tool for this purpose) or abrade a small piece (1 mm) of the shoulder in this area to expose the white tips of the cotyledons. While the accidental removal of a small portion of the cotyledons will not adversely affect germination, removal of too much of the seed content will influence initial growth and should be avoided;

(3) sow in the laboratory or nursery bed.

Boiling water

A reasonably effective method for many species once suitable prescriptions have been determined.

Immersion of seed in boiling water for 1 minute provides an effective means of breaking dormancy in a wide range of hard-coated seeds. The method is easy to apply and reproduce with a minimum of equipment. However, in *Acacia* and possibly also in other genera, there are some species with ‘semi-hard’ seedcoats which may be damaged by the severity of this treatment. There are also some species with a ‘soft’ coat, which require no pretreatment and which in fact would be killed by even a mild heat treatment. *Acacia mearnsii*, *A. pachycarpa*, *A. pendula*, *A. tephrina* and *A. xiphophylla* are examples of species with ‘semi-hard’ seedcoats (see Table 4.1 for recommended pretreatments), while *A. argyrodendron*, *A. cambagei*, *A. harpophylla*, *A. latzii* and *A. maconochieana* are species with ‘soft’ seedcoats.

The steps to follow in applying the 1-minute boiling water treatment are:

(1) select a container large enough to contain 10 times the volume of seed. Fill the container with water and bring to the boil over a heat source;

(2) once the water is boiling vigorously, pour in the seed and allow the water to boil for 1 minute;

(3) remove the container from the heat source and allow the seed to soak in the gradually cooling water for several hours;

(4) sow the treated seed in the containers.

If it proves impossible to sow the treated seeds immediately, they may be stored safely for periods of a year or more in airtight containers in a cool location (preferably under refrigeration). Wet seed should be gently dried before storage.

Variations on the above technique using boiling water that have proved successful for several tropical acacias such as *A. auriculiformis*, *A. crassicarpa* and *A. mangium* are reported by Bowen and Eusebio (1981, 1982).

NURSERY PRACTICE

Discussion in this section is confined to the raising of seedlings in nurseries. Nurseries provide the means to control moisture, light, and physical and chemical soil constituents in such a way as to produce the healthy, hardy and uniform seedlings necessary for species and provenance trials.

Of the two different methods available for raising tree seedlings (open-rooted compared to containerised), container methods are generally preferred as they conserve valuable seed, give greater versatility to the planting program and, most importantly, improve the chances of plants surviving difficult conditions following planting. For more detailed discussions of using either containers or bare-root stock see Evans (1992) and World Bank/AGRNR (1993).

In adopting a container system a decision has to be made whether the seed will first be sown into germination trays or beds and the seedlings later transplanted, or whether the seed will be sown directly into the nursery containers.

Choice of container

Types and sizes of container vary greatly (Tinus et al. 1974; FAO 1979; Figure 4.2) and local preference depends largely on cost and convenience. For example, the use of local materials for producing pots and tubes, e.g. clay, mud-dung, bamboo, tin and wooden veneer is often preferable to importing expensive alternatives made of peat, plastic, paper or polystyrene. It is also standard practice, especially where labour costs are high, to aim for the smallest container size compatible with satisfactory survival and growth to reduce handling and transport costs. Evans (1992) discusses

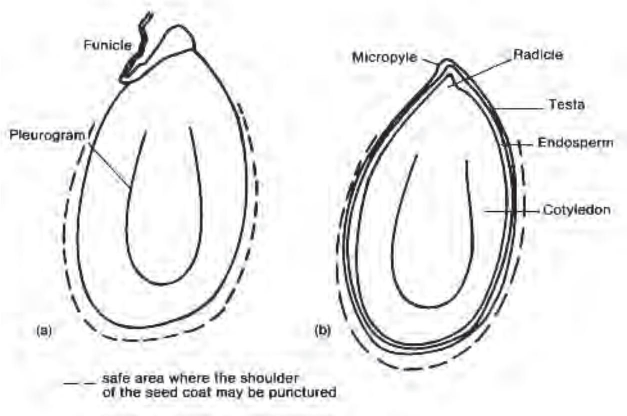

Figure 4.1. Area where the shoulder of the seedcoat is punctured to promote germination. (a) an *Acacia* seed with funicle; (b) an *Acacia* seed without funicle showing relative position of strophiole, hilum and micropyle.

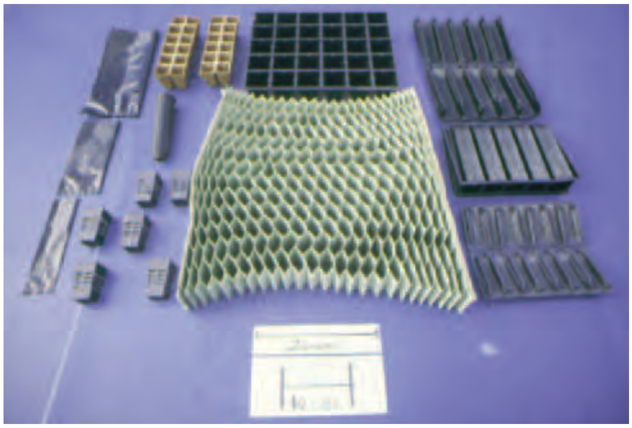

Figure 4.2. Container types and sizes vary considerably.

the relative advantages and disadvantages of the main types of container available today.

Perforated polythene bags and tubes are in widespread use in forest nurseries and are likely to be the main containers used for the propagation of the species described in this book. The following discussion is limited to aspects of their use but in no way infers superiority to other container types. All types have their own advantages and disadvantages.

The decision on the most satisfactory size of tube or bag is often a compromise. Larger sizes with their greater soil volume give added safety to plants in difficult conditions but are costly and difficult to transport. As trials of many of the species covered in this book will generally be on harsh sites and nursery periods may be long for some species (e.g. *Parinari nonda*), medium to large sizes are recommended to produce sturdy plants with substantial root volumes. Examples of polythene container sizes (medium) for the mass production of seedlings of a wide range of Australian species are given in Table 4.2.

It should be noted that it will not always be optimal to use the medium-sized containers described above. For example, in the arid areas of Spain, Italy, Greece, and Israel, polythene bags with capacities up to 1600 cm^3 are used to improve survival while tubes up to 30 cm deep are used where seedlings are intended for sand dune stabilisation (le Roux 1975).

Polythene bags and tubes, like all impervious containers, have two disadvantages. First, time must be taken to remove the bag or tube at planting otherwise root growth is inhibited, which leads to the instability of the tree. Second, seedlings left too long in the container suffer from root balling and circling, which are characteristics that reduce plant survival and growth. In this situation, care must be taken at planting to gently tease the side and basal roots until they hang loosely and if the tap root springs back into a coil, remove it by cutting.

NURSERY SOILS

In the germination trays loose, friable, sterilised soil mixed in equal proportions with weed-free medium-grade sand, or a 1:1:1 by volume mix of peat, perlite and washed sand, are commonly used. The germination medium should be free of particles more than 2 mm in diameter (larger particles could impede the germination of small seeds). In some instances, when using pure sand, it has been found necessary to add artificial fertilizers (particularly N) if satisfactory early growth is to be obtained. Good drainage and ventilation of the trays are paramount to avoid fungal problems. The trays must have holes at their base; a layer of coarse gravel or charcoal to prevent these being clogged by soil promotes good drainage.

For the nursery containers, a light, permeable, non-calcareous soil or mixture that has adequate water-holding capacity whilst still allowing good drainage is generally recognised as the most suitable medium in which to grow Australian trees. It should not contain a high content of organic matter, and it must not compact into a hard crust or clod, nor be so loose and sandy as to dry quickly and fall from the roots when the plant is handled. All potting mixes should be sieved to remove particles larger than 5 mm diameter.

Table 4.2. Some examples of high-impact black polythene container sizes for the mass production of seedlings of Australian species.

Polythene thickness (μ)	*Type*	*Manufacturing size diam. (mm)*	*Manufacturing size length (mm)*	*Filled size diam. (mm)*	*Filled size length (mm)*	*Total volume when filled (cm^3)*	*Genera commonly grown*	*Time to reach plantable size (months)/ (size at planting)*	*Location (reference)*
50	Tube	100	200	65	160	547	*Acacia*, *Callistemon*, *Casuarina*, *Eucalyptus*, *Leptosperum & Melaleuca*	3-5/ (up to 50 cm)	Australia (Grossbechler 1982)
50	Bag	70 [a]	185 [a]	50–70	160–200	314–770	*Acacia*	5/ (30–60 cm)	Malaysia (NAS 1983)
50	Bag	95	235	95 [a]	150 [a]	1063 [a]	*Casuarina*	5/ (30–60 cm)	India (Kondas 1983)
50	Bag	68 [a]	205 [a]	50.8	177	359	*Eucalyptus*	12/ (100 cm)	Pakistan (Qadri 1983)
50	Tube	57	178	50.8	165	334	*Eucalyptus*	3–5/ (30 cm)	Nepal

[a] *Estimated by author.*

The soil that is favoured in a particular locality will usually depend on cost and availability and will be identified through experience. Sand is frequently used in containers because it is cheap, readily available and is usually weed- and pathogen-free. Its low moisture-holding capacity, however, has excluded its use in many areas. There is considerable diversity in the practice of adding organic matter to the soil. Animal manure, leaf mould and peat are the most common additives.

A simple prescription for a soil and organic matter mix suitable for eucalypt seedlings is given by the Wattle Research Institute (1972):

Nursery soil should be stock-piled at the nursery and allowed to weather for at least 6 to 12 months before it is used. It should consist of friable topsoil, i.e. the first 15 cm of soil below any organic material mat, which is first scraped away, preferably similar in nature to the soil of the site on which the transplants are to be established, with the addition of topsoil collected from under well-rotted slash lines in eucalypt plantations. These two components should be sieved separately through 6 mm mesh and then mixed together thoroughly at the rate of 3 parts of ordinary topsoil to 1 part of slash line topsoil and stock-piled. If slash line topsoil is unavailable, a similar proportion of well-rotted, sieved manure may be used.

Other examples of suitable soil mixtures for eucalypts are given by FAO (1979).

Potting mixes in use with the other genera covered in this book are not well-documented. A porous (15%) potting mix used at CSIRO Forestry and Forest Products and found suitable for a wide range of Australian woody-plant species (M. Mill, pers. comm.) is given below. Although somewhat complex, it will serve as a guide. The potting mix comprises — composted pine bark 60%, coarse washed sand 20% and peat moss 20%. The following nutrients are mixed in after sterilisation and shortly before use: coated iron (0.5 g/L), Micromax (0.2 g/L) and a total of 4 g/L of slow release NPK fertilizers of variable release rate.

Fertilizer and insecticides in nursery soils

In many instances satisfactory growth is achieved without artificial fertilizers. However they better ensure the production of healthy, vigorous planting stock and their use is recommended if suitable fertilizers are readily available.

In forest nurseries in Australia a complete, slow-release fertilizer is often placed in the bottom of the container or mixed directly into the potting medium. The amount of fertilizer applied depends on the medium used and is usually determined after local experimentation. Today inorganic fertilizers such as magnesium ammonium phosphate ('Magamp') and 'Osmocote' are commonly used for this purpose and are usually added to the mix at the rate of 1.5 kg/m^3 (Doran 1990).

A soluble complete fertilizer ('Aquasol') is commonly applied regularly and frequently (e.g. twice weekly) through the watering system or by hand spray in Australian nurseries to stimulate the growth of young seedlings. There are several disadvantages in relying solely on soluble fertilizer to provide the nutrient requirements of containerised plants, so they are more commonly used in conjunction with a solid fertilizer dressing incorporated into the potting mix.

In some situations and especially in the tropics it is necessary to add insecticides either directly to the nursery soil or as a surface application to control termite attack in the nursery, in transit and when the containers are left in the field awaiting planting. Use of dangerous chemicals such as dieldrin, aldrin and chlordane (LARP 1972; Jackson 1975; Nair et al. 1984; Carter 1987) for the protection of seedlings against termites is being phased out in most countries. Carbosulfan, a non-persistent carbamate insecticide, is being used as an effective replacement for the organochlorine insecticides in several African countries (e.g. Canty 1991; Chilima 1991; Mazodze 1992).

Sterilisation

While it is recognised that soil sterilisation to control weeds, insects, and fungi in nursery soils may not be feasible or, in fact, necessary in some cases, there is little doubt that the chances of raising a greater quantity of quality seedlings are enhanced if it is done. Soil sterilisation techniques are described in detail by Baker (1979). Some methods commonly applied in forest nurseries include the following.

Methyl bromide fumigation

Treatment of nursery soil 2 to 3 weeks before use by injection of methyl bromide at the rate of 1 kg/2 m^3 of soil is effective in controlling weeds and pathogens. The gas is applied to moist soil either in made-up beds or in heaps, which are kept sealed by plastic sheets for 24–48 hours while being fumigated; the soil is then left uncovered for 5–7 days before sowing or pricking out into it (Wattle Research Institute 1972).

Methyl bromide is very poisonous and safety precautions require strict attention. Operators should wear appropriate protective clothing at all times.

Heat sterilisation

The pasteurisation of nursery soil either by burning wood on it in a hot fire (Wattle Research Institute 1972) or by 'cooking' the moistened soil in large metal containers is claimed to be effective in stimulating germination and initial growth and in reducing losses from fungi. If employing these techniques, local trials should be undertaken to determine the temperature and duration of treatment necessary for effective control. In Bangladesh, the recommended way of sterilisation is to heat the nursery soil, with nine litres of water added, in a halved 44-gallon drum at 104°C for 15–20 minutes or at 60°C for 30 minutes (Das 1984).

The solar heating of nursery soil is a promising technique for the control of pathogens and weeds. Pioneered in Israel, the method involves spreading moistened nursery soil on a suitable surface and covering with thin sheets of clear plastic with the edges sealed tightly. Long periods of intense irradiation and high ambient temperatures (above 25°C) are needed to achieve temperatures high enough to kill soil pathogens. This technique is therefore restricted to areas of the world with high summer temperatures. Moistening the soil increases its thermal conductivity and may stimulate saprophytic microbial growth inimical to the survival of pathogens (Katan et al. 1976). One month of treatment during mid-summer in Australia appears to give successful control to varying depths of some serious pathogens, but local trials should be undertaken to gauge the effectiveness of the technique.

Inoculation of nursery soils

Symbiotic relationships have developed between many Australian plants and certain soil bacteria and fungi. These relationships assist the plants to cope with infertile soils. Planting species such as acacias, casuarinas and eucalypts at trial sites where their symbionts are absent results in poor performance and invalid provenance comparisons. The seedlings should be inoculated with the appropriate symbiont to avoid these problems.

Nitrogen fixation

Many legumes and casuarinas are able to convert nitrogen gas from the air into ammonia, a soluble form of nitrogen that after conversion to nitrate is readily utilised by plants. This conversion is achieved by bacteria of the genera *Rhizobium* and *Azorhizobium* (fast-growing in culture) and *Bradyrhizobium* (slow-growing in culture) in the case of the legumes, and an actinomycete, *Frankia*, in casuarinas (NAS 1979, 1984; Sprent 1994).

Rhizobium and *Frankia* infect roots and the plant reacts by forming swellings (nodules) on the root surface (Fig. 4.3). Within these nodules the micro-organisms proliferate, absorb air from the soil and 'fix' the nitrogen. The nitrogen-fixing plants may grow vigorously only if they have functioning nodules and this depends on their roots encountering appropriate strains of symbiont in the soil.

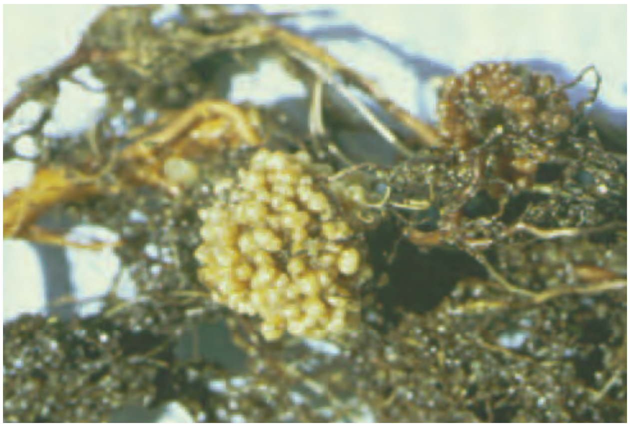

Figure 4.3. Nodules on 1–year–old *Casuarina equisetifolia*. Casuarinas form large root nodules. These house symbiotic micro-organisms that provide the plant with usable nitrogenous compounds. Although casuarinas can grow without the helpful microbes, the development of nitrogen-fixing nodules fosters faster growth, enriches soil with nitrogen, benefits growing plants, and helps casuarina trees become established on previously unproductive lands.

In acacia and casuarina there is often a high degree of host × strain microorganism specificity, both for nodule formation and more particularly for symbiotic effectiveness (i.e. the degree to which nitrogen fixation can meet the nitrogen demands for plant growth relative to the growth of plants with adequate N-fertilizer) (Dreyfus and Dommergues 1981; Dart et al. 1991). For example, *Acacia holosericea* nodulates effectively with a wide range of strains, whereas *Acacia mangium* shows provenance × strain specificity (Millar et al. 1991; Sun et al. 1992) as do *A. melanoxylon*, *A. shirleyi* and many other species (A. Gibson pers. comm.). A similar situation pertains to species of *Casuarina* and *Allocasuarina* (Coyne 1983; Reddell 1990; Sanginga et al. 1990).

By inoculating *A. mangium* and *A. auriculiformis* with appropriate strains of rhizobia the growth of the trees has been remarkably improved in the Philippines (Dart et al. 1991). A similar result has been achieved by applying appropriate *Frankia* strains to various *Casuarina* species. For example, inoculation increased wood production of *C. cunninghamiana* by up to 100% (Reddell 1990), increased tree height by 50–300% (Reddell et al. 1988), and inoculation of *C. equisetifolia* increased biomass production at 1, 2 and 3 years after transplanting by 45%, 36% and 40% respectively (Sougoufara et al. 1989).

The rhizobia nodulating acacias (i.e. *Rhizobium* and *Bradyrhizobium*) also nodulate other legumes and the occurrence of acacias is not necessary for these bacteria to be present in the soil. However, they are not ubiquitous. A recent examination of the roots of a number of tropical and temperate acacias growing in plantations in southern China revealed that most species were nodule-free; the occasional nodules found were small, white and presumably ineffective (A. Gibson, pers. comm.). It is likely in this case that the introduction of a suitable bacteria through inoculation will be beneficial to plant growth. However, the symbiont must be able to survive, function and compete with other microbes for nutrients and with other symbionts for infection sites in the particular environment if it is to be effective.

Any factor that limits tree vigour and health probably also limits symbiotic nitrogen fixation (MacDicken 1994). The following conditions are likely to promote effective nodulation in most nitrogen fixing tree species.

(1) *Well-aerated soils* — an abundant supply of oxygen is necessary; poor nitrogen fixation in heavy clay or waterlogged soils can be attributed to lack of oxygen.

(2) *Water availability* — high or low soil moisture can be limiting to both nodulation and fixation. The optimum level is about 60–75% of soil water-holding capacity.

(2) *Soil pH* — the critical pH for nodulation of most legumes is above pH 4.5–5.5. Low soil pH generally inhibits nitrogen fixation. For example, symbiosis of *A. mangium* in the Philippines was improved by liming acid soils to pH 6.5 (Umali-Garcia et al. 1988) and *A. auriculiformis* nodulation on the acid-sulfate soils of the Mekong Delta in Vietnam was restricted to the undecomposed litter layer rather than the highly acid mineral soil (MacDicken 1994).

(4) *Micro-nutrients* — additional supplies of cobalt, iron and molybdenum may be necessary for fixation (Co and Fe availability is lowest in alkaline conditions and Mo lowest in acid soils).

(5) *Macro-nutrients* — high levels of combined soil nitrogen may reduce nodulation and fixation. The level of inhibition varies within and between species and also depends on the symbiont. In some species nodulation is enhanced by a starter dose of nitrogen, phosphorus and potassium in the nursery soil, but in other species it has a detrimental effect.

(6) *Environmental stresses* — a wide range of environmental stresses affect symbiotic nitrogen fixation but many of these effects are both extremely complex and temporary. For example, saline conditions can depress nitrogen fixation. However, symbionts tolerant to highly saline conditions have been found.

(7) *Plantation spacings* — nitrogen fixation tends to respond to plant density in a way similar to above-ground biomass production. Intermediate spacings appear best.

(8) *Temperature* — select a time for application of micro-organisms when temperature is optimum for tree growth.

(9) *Age of tree* — senescent trees should be avoided as hosts for symbionts.

Few forest nurseries employ methods to ensure that the most effective organism for nodule formation is present in the soil. Fortunately most introductions of tree legumes and casuarinas seem to have located functional root nodule organisms. There is a growing pool of data, however, to suggest that chance inoculation may not optimise the nitrogen-fixing ability of particular species because of the specificity between plant species and root nodule organisms.

As the presence of an effective symbiont may be crucial to the successful establishment of these trees, especially when they are first introductions of the genus into a new area, arrangements must be made to introduce the required micro-organisms into the nursery soil. The time-honoured method of providing inoculum in a new nursery is to add some surface soil or leafy litter collected from around effectively nodulated plants of the same genus to the potting mix. Spores from the introduced material then infect the seedlings. The disadvantages of this approach include the risk of introducing undesirable pathogens and weeds, exacerbated by the fact that sterilisation cannot then be applied for fear of killing the desirable micro-organisms.

It can be more reliable and efficient to introduce suitable rhizobia or *Frankia* to the nursery through an aqueous preparation of the micro-organism applied to the roots of seedlings, once they are 2–3 cm tall, or injected into the soil near the seedlings. The procedure is as follows: first obtain some root nodules from beneath a healthy young tree of the required species and soak them in 70% ethanol for a few seconds (to reduce the risk of contamination from microbes on the outside of the nodules). If both rhizobial and *Frankia* nodules are being collected, take care to keep them completely separate. The nodules are then washed and ground to a fine paste. They are then added to water and the resulting suspension is applied by watering can or sprayer (Torrey 1983; NAS 1984). About 10 g of nodules should be adequate to nodulate at least 1000 plants. Nodules should appear within 3–5 weeks of planting and the success of the treatment should be monitored. If unsuccessful it may be necessary to seek alternative sources of the symbiont or alter nursery techniques to promote nodulation.

Of course these methods are very crude and do not ensure that the most effective strain of the symbiont is supplied to the particular tree. Sophisticated techniques involving inoculation of seed with spores and use of pure cultures are being developed in Australia and elsewhere (see papers in El-Lakany et al. 1990 and Turnbull 1991). Already limited numbers of tested symbionts are available. These specialised methods will gradually replace the rather hit-or-miss techniques in common use today.

Mycorrhizas

Many Australian native plants, including species of *Eucalyptus*, *Leptospermum*, *Casuarina* and many legumes including acacias, form endo- (vesicular-arbuscular or VA) and ecto-mycorrhizal associations with various fungi (Warcup 1980; NAS 1984). Endomycorrhizas are by far the most important and widely distributed (geographically as well as within the plant kingdom) type while ectomycorrhizas are restricted almost entirely to trees and are found in association with most forest tree species (McNicoll 1993). Ectomycorrhizas are characteristic of such genera as *Eucalyptus* and *Pinus*.

Through their roots, to which the fungi are attached, the trees derive certain nutrients (especially phosphorus) from the fungi and these, in turn, benefit from other nutrients made available to them by the tree. Many exotic plantations are devoid of mycorrhizal associations since compatible fungi are not always present in the soil. The introduction of suitable mycorrhizal fungi with the trees into exotic plantations may increase tree resistance to environmental stresses as well increasing timber yields. The screening of diverse fungi to select isolates most suited to specific conditions is the key to successfully introducing mycorrhizal fungi into exotic plantations.

In Australia, inoculation of *Eucalyptus globulus* seedlings with ectomycorrhizal fungi has given up to 30% growth increases on recently cleared sites in Western Australia (Malajczuk 1995). *E. globulus* is an introduction from Tasmania. The fungal mycelia are applied in a beaded gel ('Mycobeads') during the fluid drill sowing of the seed directly into the pots. NAS (1984) states that the association of casuarina roots with both types of mycorrhizas significantly enhances the trees' 'adaptability' as well as their ability to grow in harsh environments. Dual inoculation using *Rhizobium* and VA mycorrhizal fungi has shown positive responses in growth in a wide range of acacias including *A. holosericea* (Cornet et al. 1985).

Nurseries growing Australian trees, especially where the soils are deficient in phosphorus, should attempt to introduce appropriate mycorrhizas to the nursery soil. Soil, spores, sporocarps, vegetative mycelium and mycorrhizal mother-tree seedlings are primary sources of ectomycorrhizal and VA mycorrhizal inoculum for containerised seedlings in nurseries (McNicoll 1993). Each method has its own set of advantages and disadvantages —

(1) *Soil inoculum* — this is done by adding soil collected from existing healthy stands of the particular species to the potting mix. Usually, about 10–20% of soil inoculum is added to the nursery soil before potting-up but this may result in uneven spread of the symbiont. Alternatively 2 tablespoons (about 40g) of soil inoculum can be added to each container. Soil inoculum should be used fresh, or at least within two weeks of collection, to ensure viability and should not be exposed to direct sunlight. Although the method is simple, major disadvantages include importation of pests and diseases to the nursery, lack of control over the symbionts introduced and the high cost of transporting soil.

(2) *Pot-cultured inoculum* — this is the recommended method for the handling of VA mycorrhizal fungi which cannot be grown in pure culture. The fungi are obtained from healthy plants in the field, cleaned and sterilised, and then multiplied on host plants in sterile growing medium. The entire growing medium with the mycelium, spores and roots (macerated) is commonly used as the inoculum.

(3) *Spores* — basidiospores from macerated fruiting bodies of some ectomycorrhizal mushrooms, puffballs or tuffles provide good inoculum. They can be dusted onto soil around seedlings and leached into the root zone, or mixed with a carrier like sand or vermiculite and added to the potting mix. The advantage is that the inoculum is light and can be stored between seasons. However, difficulty in testing for viability, slowness of infection and variation in effectiveness are significant disadvantages of the technique.

(4) *Mycelial inoculum* — pure cultures of ectomycorrhizal fungi provide the most biologically sound material. However, this technique has been rarely used in large-scale nursery operations because of difficulty in mass-producing quality inoculum (Sangwanit 1993). This situation is changing with research on the production and use of pure culture inoculum and several fungi are now available commercially, including one that is effective on *E. globulus* (see above).

(5) *Mycorrhizal mother-tree seedlings* — vigorous mycorrhizal seedlings are planted in seed beds at regular spacings (1–2 m) before sowing seeds. These serve as the source for infection of new germinants in the bed. This method is used for *Pinus merkusii* in Indonesia.

Selected strains of ectomycorrhizal inoculum for a limited number of the species described in this book are just coming available commercially. For example, Professor Rey Dela Cruz's BIOTECH group at University of the Philippines, Los Baños, College, Laguna 4031 Philippines supplies pellitised tablets containing ectomycorrhizal fungi suitable for inoculating eucalypts and acacias in the nursery. However, until more strains are tested and produced, the most common sources of inoculum are likely to remain soil or pot-culture.

Time of sowing

Careful timing is important as it is essential that seedlings of the many trial species reach the desirable size (usually 15–30 cm) at the optimal time for planting-out. There will be considerable variation between species and between nurseries in the time required to reach the optimum size. As a guide the nursery life-spans of many of the species covered in this book, as determined by the Queensland Department of Forestry (P. Ryan, pers. comm.), are given in Table 4.1. If species having markedly different nursery requirements are to be grown in the one trial, sowing at different times may be necessary in order to be able to plant the field trial in a single operation.

Sowing seeds

There are two main methods of producing container-grown seedlings. Seeds can first be sown into germination trays or germination beds and the seedlings later transplanted (an operation called pricking out, i.e. the two-stage method), or they are sown directly into individual containers. The two-stage method usually ensures the maximum production of seedlings from a seedlot and will be the method most commonly applied when propagating small research seedlots. However, direct sowing has a role, particularly in the propagation of the larger-seeded species such as the acacias where there is some sensitivity to the shock of transplanting.

Sowing in germination trays

Choose a germination tray of convenient size and depth to permit rapid growth of germinants and to facilitate the transplanting operation. Trays 14 × 8 cm are suitable for 50–70 seedlings of the fine-seeded species and 53 × 20 cm if larger numbers of seedlings are required. For small seeds, such as eucalypts, sowing densities of 3000 to 10 000 seeds/m^2 of germination tray are commonly used (average spacing 1–2 cm), and it is usual that 25–50% of the seed sown will reach the pricking-out stage (FAO 1979). Fill the trays with the preferred germination medium, apply water and sprinkle or direct-sow the seed evenly over the surface (Fig. 4.4). Care is necessary to avoid sowing too closely as this will result in unsatisfactory spindly seedlings.

Directly following sowing, a covering layer of sand, vermiculite or similar inert material, free of weed seeds, not prone to caking or capping and near-neutral in reaction, should be applied so that the seed is less likely to be disturbed by watering and be prone to drying out. Other materials used for this purpose include sieved soil or organic matter, e.g. peat moss, well-rotted sawdust, rice husks and dead pine needles. For larger seed, a rule of thumb for the depth of cover is up to three times the thickness of the seed itself (Grossbechler 1982) while for smaller seed (e.g. eucalypts and melaleucas) only a very thin cover should be applied.

The germination trays should be kept in a warm shaded area (50–80% shade). A glasshouse is preferable but a protected shadehouse can also be used. The trays should be watered at frequent intervals with a fine spray, so that the sowing mix is kept moist at all times but not saturated. Sub-irrigation (i.e. watering from below) of the trays may be preferable to overhead watering if fine sprays are not available. Another variation is the Bog Method sometimes used for very fine-seeded species such as melaleucas that are adapted to swampy conditions in their natural habitat. The seed of these species is very susceptible to drying-out and damage by overhead watering. In this method the germination trays are constantly sub-irrigated by placing them in a larger tray filled with water. The level of this water should be maintained at 2 cm. This will allow the soil mix in the tray to be kept constantly moist, but not saturated at the surface. An inflated plastic bag is fitted over the trays to keep the moisture in. About one month after germination, the germination tray should be removed from sub-irrigation and handled normally. Hygiene is especially important with this method because of the risk of disease.

If using a nutrient-free germination medium a twice-weekly application of a liquid fertilizer such as ‘Aquasol’ (4 g/10L of water) is recommended. If damping-off (the rotting of seedlings by soil pathogens attacking at soil level) becomes a problem (most common soon after germination), regular fungicidal treatment may be necessary. A suitable treatment is recommended in the section on protection against insects and fungi.

Direct sowing

Take the seeds to the prefilled and moistened containers suitably arranged in the shadehouse. Place the required number of seeds either onto the surface of the potting

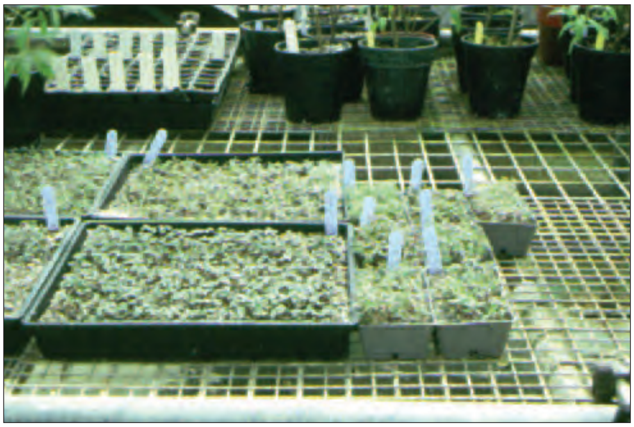

Figure 4.4. Germination containers.

mix and cover with fine sand or, with larger seed only, dibble with a stick or finger to the required depth. The aim is to sow two or three viable seeds per container; so it is essential to know the viability of the seed beforehand. Water the containers and monitor germination.

When direct-sown seedlings have reached the one or two leaf-pair stage it is time to thin down to one seedling per container. It may be worthwhile transplanting seedlings from overstocked containers to empty ones if a significant number of containers are left empty because of irregular germination.

Transplanting

Transplant when the seedlings have 1–2 pairs of leaves above the cotyledons. The technique is:

(1) fill the separate containers with potting mix and water thoroughly;

(2) collect the appropriate germination tray from the greenhouse and place near the containers;

(3) take each container and prepare a hole 1–2 cm in diameter and 2–3 cm deep in the mix with a 'dibbler' (a pointed tool such as a meat skewer);

(4) using the dibbler, carefully prise a group of seedlings out of the sowing container ensuring, by placing them in a container of water if necessary, that their roots always remain moist. Handle seedlings by their leaves only; avoid squeezing the stem, growing tip or roots (Fig. 4.5). Long roots should be pruned to a length of 2–3 cm. Prevent the root system folding upwards as it is placed in the hole. Hold the seedling at the side of the hole so that the topmost roots are a few millimetres below the soil surface and gently firm the soil around the root system with the dibbler;

(5) water gently immediately after transplanting to ensure complete soil contact with the roots.

Avoid air pockets near the roots and too-deep or too-shallow placement of the transplants in their holes (roots bent upwards in a too-shallow planting hole cause retarded growth and instability after planting).

After pricking-out, keep the seedlings under shade (and if possible under automatic mist spraying) for about four weeks and store in bays until required for field planting (Fig. 4.6).

Damping-off is unlikely if prescribed sterilisation measures have been taken, but if suspected, spraying with

Figure 4.5. Transplanting

Figure 4.6. Seedlings are stored in bays until required.

an appropriate fungicide is recommended. Twice-weekly applications of a liquid fertilizer ('Aquasol') should continue, gradually increasing the strength to 12 g/10L of water.

Pregermination and transfer to containers

A variation of the traditional two-stage method described above is as follows.

First sow the seed between sheets of blotting paper (hessian can be used for large seed) kept moist in a controlled environment; when the radicle has just appeared (usually 2–5 days), germinants are progressively transferred to the nursery containers until germination is complete. This technique has been employed successfully with acacias, eucalypts, pines and some other genera (Sirikul 1975; Hodgson 1977; Grossbechler 1982) with the stated advantages of speed of transfer, saving space, improved uniformity of plants and high utilisation of available seed, and disadvantages including the need for careful management of the sowing rate so that the nursery staff are not overloaded.

Shade and shelter

Shade screens made from a variety of materials including reeds, bamboo, woven coconut fronds, hessian and 'Sarlon' (a special plastic shade cloth) are used in some nurseries to protect young seedlings from excessive heat. The screens are most frequently set up over seed beds prior to germination and for one to four weeks after transplanting. For example, in Pakistan, screens made of kana reeds (60% shade) are placed over the seed beds and containers when the maximum daily temperature exceeds 35°C (Qadri 1983). Shade is used in some Australian nurseries (Doran 1990) and elsewhere (Hocking 1993), but its use is far from universal and there are many examples of successful nurseries where shade is not used at all.

Protection of young seedlings against heavy rain, hail and frost is important particularly in the tropics where violent storms can cause considerable damage to all types of nursery stock. Undesirable waterlogging may also occur with frequent heavy storms. Materials in common use for this purpose include polythene sheeting, heavy duty clear plastic or simply employing the local material used for shading.

Many nurseries require some protection from the wind. In new nurseries artificial screens may be erected at right angles to prevailing winds. Later these may be replaced by live hedges.

Nursery watering

The amount and frequency of watering is largely a matter for judgment under local conditions of climate and nursery practice (container size, nursery soil, etc). As a general rule the pots should be kept moist but not saturated and never allowed to dry out. This often requires watering twice a day, morning and evening. The normal tendency is to over-water and it is for this reason that sub-irrigation is sometimes preferred to overhead watering (Jackson 1975). Overwatering and watering young seedlings during the heat of the day when they are susceptible to scalding must be avoided.

Protection against insects and fungi

Insects, pathogenic fungi and other injurious agencies can cause problems in nurseries. Often it has been found necessary to pretreat the nursery area before sowing to control ants and beetle larvae (FAO 1979; Qadri 1983). Ants will quickly destroy the seed and the larvae attract birds, which can cause considerable damage. Insecticides applied between sowings will give effective control (Cremer et al. 1984). Thrips and other insect pests can also cause damage to young seedlings and the non-toxic pyrethrum derivatives (e.g. 'Bioresmethrin', Cooper) are most useful in their control (Cremer et al. 1984).

Damping-off caused by soil-borne pathogens such as *Rhizoctonia*, *Phythium* and *Phythopthora* can be responsible for heavy losses in nurseries. Baker (1979) emphasises that the best way to avoid problems is to prevent the introduction of such diseases into the nursery through sterilisation of soil and equipment, and to minimise the build-up of inoculum by general cleanliness. Handreck (1985) recommends several procedures to promote cleanliness in the nursery, viz. wash hands before potting; use clean tools and containers (disinfect used items by removing surface dirt then immersing them for 5–10 minutes in bleach solution of 125 ml domestic bleach of 4.5% strength diluted to 1:1); do not allow muddy water to splash into pots; do not let the ends of hoses drag along the ground before watering plants; do not sit pots on bare soil or on any surface on which water can pond. Rather, use benches with tops of slats or mesh or, outdoors, stand pots on gravel. A clean sloping concrete or asphalt surface can also be suitable, so long as water does not pond on it, or runoff from soil flow over it; never re-use mix from pots in which plants have died unless it has first been sterilised.

Fungicide sprays will nevertheless continue to be an important method of prevention and control of damping-off and foliar diseases such as powdery mildews, *Botrytis* rots and *Penicillium* moulds. Carter (1987) recommended the use of propamocarb ('Previcur') against phycomycete fungi, mainly *Pythium* spp. but also *Phytopthora* spp. and downy mildews and iprodione ('Rovral') against *Botrytis* spp. and fungal leaf spots. Fungicides may retard plant growth, so frequent applications should be avoided.

Weed control

Weeds can seriously retard the growth of containerised plants and must be removed promptly. Soil sterilisation gives early protection but wind-blown seeds can quickly invade and necessitate weeding. Hand weeding is the principal method of control because of the susceptibility of Australian native plants to chemical herbicides, and it should be undertaken when weeds are seen to be competing with the seedlings.

Root-pruning

For good survival after planting, seedlings need a balanced root to shoot ratio. Container-grown seedlings in contact with the ground will readily send roots into the soil rather than develop a compact fibrous root system in the container. As these fibrous roots are the main feeder roots of the seedling once it is planted, root growth into the ground must be prevented and the formation of feeder roots stimulated. This is done by standing the containers on material impervious to roots, keeping them off the ground to air-prune the roots or by regular root-prunings.

Root-pruning of container-grown stock is usually done either by 'lifting' to break off the protruding roots or by undercutting using a steel wire that is drawn through the soil close to the base of the container. A simple undercutting tool used in Malawi is illustrated by Evans (1992). Regular (every 2–4 weeks) root-pruning should commence from the time the seedlings are as tall as their containers, which must be well watered immediately before and after each pruning (Poynton 1979).

Hardening off

A few weeks before the time of planting out it is regular practice to harden off the nursery stock by reducing the amount of water and frequency of foliar fertilizer doses. This is aimed at slowing down growth, reducing lush foliage, encouraging 'woodiness' and generally making seedlings sturdier and better able to withstand planting shock.

Experimental design in the nursery

Since there may be systematic differences between nursery bays it is important in species and provenance research to use a blocked experimental design in the nursery. Nursery blocks should be linked to blocks in the field design. That is, plants in any one field block should all come from the same nursery block. Treatment of plants within a nursery block should be as uniform as possible (Burley and Wood 1976).

VEGETATIVE PROPAGATION

In the first instance, trees described in this book will be grown from seed. In commercial forests, however, simple, robust methods of vegetative propagation are very attractive; examples of trees grown by these means are the poplars and willows from temperate climates, and *Casuarina junghuhniana* and some eucalypts (e.g. *E. camaldulensis*, *E. grandis* and *E. urophylla*) from the tropics. Methods of mass vegetative propagation of tropical eucalypts by cuttings are described by Eldridge et al. (1993).

TREE ESTABLISHMENT

General considerations

In species and provenance research it is important to give the plants under trial every opportunity to show their reaction to site factors not under human control (Burley and Wood 1976). The following discussion, therefore, is biased towards intensive methods of tree establishment including adequate ground preparation, addition of fertilizer and control of weeds aimed at achieving good survival and rapid early growth. We recognise that less intensive but nevertheless successful methods are desirable when planting is scaled up to an operational level, but a high level of care is justifiable in preliminary investigations. If there is any doubt that cultural practices are going to be adequate, it is better to delay expensive species and provenance trials until suitable practices have been developed (Burley and Wood 1976).

It is important that sites chosen for species and provenance trials are representative of the areas that are most likely to be planted in the future. This includes coverage of the extremes in environmental conditions likely to be encountered. Stratification of sites or the grouping of areas with similar growth conditions together in a single stratum on which the performance of different species can be validly compared, and between which the site × species interactions can be determined, may be pertinent. A detailed system of site classification is given by Burley and Wood (1976). For an effective trial the site chosen should have sufficient uniformity in soil conditions to allow all the plots within each block of the statistical layout to have approximately the same environment (Eldridge et al. 1993). Thus it is important to avoid sites with extreme variability.

Species selection is dealt with in Chapter 3. Table 5.1 gives a guide to the species recommended for trial in the different environments and for particular end uses (see Chapter 5).

In preparing this section frequent reference has been made to information in publications by FAO (1979), Evans (1992) and Wattle Research Institute (1972).

Site preparation

The effect of ground preparation on tree establishment and growth can be very marked and last throughout the life of the crop. Site treatments that ensure high survival and rapid early growth are essential in trial establishment in order to reduce as far as possible the chance of establishment methods masking genetic and other differences. These 'optimum' treatments usually involve some or all of the following:

(a) control of competing vegetation,
(b) removal of physical obstruction to tree growth,
(c) cultivation to improve soil structure, primarily to aid rooting but also nutrient availability,
(d) modification of natural drainage either to improve drainage on wet sites or retain moisture on dry sites, and
(e) control of leaf cutting ants, termites or other local hazards.

Clearing

The control or removal of any grass, shrubs or trees is an essential first step in preparing the land for planting. Ways of clearing vegetation (manual and mechanical methods and by fire and chemicals), their application and specific examples are given by Chapman and Allan (1978) and Evans (1992).

Cultivation

The need for and intensity of cultivation will vary greatly between sites. For example most logged-over rainforest sites support good growth without soil cultivation, whereas tree growth is possible on some infertile compacted soils only after first subsoiling and mounding or ploughing (Evans 1992). A detailed examination of the site and soil profiles as well as a review of routine plantation practice in the area will give an indication of what is required. Mechanical rather than hand cultivation offers most scope for soil improvement and should be the preferred treatment where feasible.

Evans (1992) describes three main types of cultivation.

(1) Openings of narrow channels into the subsoil, to depths of up to 1 m, to improve downward rooting by breaking impermeable barriers and aiding drainage — ripping, subsoiling, tining, etc.
(2) Cultivation of the topsoil to 20–30 cm depth either completely over the site or on strips to form furrows and ridges, or mounds— ploughing.
(3) Complete surface cultivation of the top 10 cm to keep the soil surface friable and to discourage weeds — discing, harrowing, rotovating.

Recommended ground preparation practices by site types as outlined by FAO (1979) are given below.

(1) Following a previous plantation crop — The site should be ripped, ploughed and disced if practicable. If the planting lines of the previous crop were regular and straight, and if the proposed new espacement is similar to the old, the new crop may be planted along the same line as the old, with the trees placed midway between the old stumps. This will allow maximum cultivation between the rows of old stumps.

    If the old stumps are irregular, or if the new espacement is to be different from the old, some of the old stumps must be removed or sawn flush with the ground to permit mechanical cultivation. Preparation of planting pits may be necessary, as an alternative.
(2) On former agricultural land — If agricultural land has been cultivated for a considerable period it is likely that there will be a compacted

layer just below plough depth. Because of this, ripping (preferably when the soil is dry) as well as ploughing and discing is advisable and will result in better growth. Ripping should be to a depth of 30–45 cm and should be along the proposed planting lines. The best way to control grass and promote good plantation tilth is by complete ploughing to a depth of at least 10 cm. Ploughing should be done while the soil is moist and if practicable the soil should be allowed to lie fallow for at least three months before it is further broken up with disc harrows.

(3) On difficult sites — On stony or very steep sites, complete cultivation may be impracticable. It is then necessary to prepare planting pits. It is preferable, but not essential, that these be prepared before the actual planting season. For good results the planting pits should be centred in well-cultivated patches of at least 1 m diameter, and preferably larger. Grass can be killed by herbicides such as glyphosate or by manual screefing.

On very wet sites it is desirable to establish a drainage system by ploughing deep furrows parallel to the direction of runoff. Two or more furrows ploughed in opposite directions are desirable so as to form a raised mound into which the seedlings are planted.

Dry-country plantations involve deep ripping, ploughing and mounding along the contours, followed by discing. The seedlings are planted on the tops or preferably on the slopes of the mounds.

Spacing

The initial espacement of a plantation is one of the most important silvicultural decisions in plantation establishment, as it greatly influences patterns of growth, weed suppression, water requirements and the economics of planting and tending. To calculate the optimum stand density, it is necessary to know the growth habits of the tree species, the potential productivity of the site, the length of the rotation and the average size of stem desired. If thinning is possible the picture becomes more complex (Cremer et al. 1984). Another important factor which should influence a grower's decision on spacing is the likely use of mechanical equipment for cultivation and harvesting (FAO 1979).

For most of the species described in this book the data needed to determine the optimum spacing for trial plantings are unavailable. The current management practice in the region of the trial is a good guide but, in the absence of this, recommended spacings for short rotation fuelwood, shelter and light pole plantations of most species are listed in Table 4.3.

Table 4.3. Recommended spacings for short rotation fuelwood, shelter and light pole plantations.

Initial espacement	*Trees/ha*	*Objectives*
2 × 2m	2500	Short-rotation crop for fuelwood, shelter and light poles.
2 × 3m	1670	Unequal spacing primarily to allow access for mechanical cultivation.
3 × 3m	1110	For plantations on poorer site types, where mortality is a problem at the closer spacings, and where agri-silviculture and grazing are additional land-use requirements.

Marking the planting spots

In order to promote uniform growth and facilitate mechanical tending, the lines of trees should be regular and the spaces between the trees even. Careful espacement is of particular importance in experiments and has the added benefit of assisting in the identification of plot boundaries if plot markers are lost or misplaced.

With some forms of mechanical site-preparation, planting rows are clearly defined (e.g. ridging) so it is only necessary to space the trees along the row using a pole of suitable length. On even ground all methods start by laying out baselines, usually with a compass, 50–100 m apart. Spacing from baselines can be done with long ropes with markers at fixed intervals. The planting holes are clearly indicated on the ground by starting the holes with a hoe or mattock or by inserting thin wooden stakes.

Time of planting

In general, planting should be done as early as practicable in the wet season so that the plants can take full advantage of residual warmth in the soil in winter rainfall regions and of the available moisture in summer rainfall regions. In both cases there is occasionally a dry spell of two or three weeks between the first rains and the more general rains. One great advantage of containerised stock is that the moist soil in the container should carry the plant over difficult periods such as this. The medium container size recommended earlier (300–800 cm^3) should achieve this, but there may be difficulties with small pots sometimes having as little as 60 cm^3 of soil. It is preferable to delay the planting of small pots until the main rains have started. In cold areas planting after the last frosts may be necessary.

Transport of plants to the field

A heavy watering is recommended immediately before the plants leave the nursery. In transport extreme care must be taken to avoid excessive transpiration and mechanical damage resulting from exposure to wind (e.g. in an open truck) or loss of soil from the roots. Plants must be completely shielded from the wind in transit but, as closed vehicles may heat up excessively, the plants should be transported in the cool of the evening or in the morning. Containers should be packed so they cannot move and the vehicle driven carefully so the seedlings are not shaken up.

There should be minimum delay between delivery and planting of plants; they must be carefully labelled at all times, and if possible each nursery replication should be transported and planted together (Burley and Wood 1976). If it proves necessary to store the seedlings in the field before planting they should be kept in a sheltered spot protected from the wind, frost, excessive heat and vermin, and watered regularly.

Planting method

For trial establishment great care is needed in distributing the carefully labelled seedlings to their appropriate planting positions, taking into account the need to have nursery and field replications corresponding if possible. Rechecking at each stage of the operation is essential.

Once correctly positioned, impervious containers should be removed carefully so as not to dislodge the soil around the roots. If root balling or circling is evident, the side and basal roots should be gently teased so they hang loosely and, if the tap root springs back into a coil, it should be cut off. Plants should be inserted up to the root collar in a hole dug with a spade, mattock or similar implement. The field soil is firmed against the soil of the container by heeling or foot pressure. Firming of the soil and elimination of air spaces are vital to the success of planting.

Fertilisation after planting

Most of the land available for tree growing in the subhumid and humid zones is comparatively infertile and may be deficient in both major and minor elements. Nitrogen, phosphorus, calcium, zinc, boron and magnesium are commonly lacking. To achieve reasonable production and yet maintain soil fertility on poor soils, some fertilizer will be a necessity. For species and provenance trial establishment, the application of a 'starter' dose of balanced mixed fertilizer 1–3 months after planting is highly recommended as this often has a dramatic effect on early growth and survival.

The application of fertilizer in order to increase production or to replace nutrients lost as a result of management can only be done with any degree of precision after a great amount of research in a number of related fields, continuously validated by carefully designed, maintained and managed field experiments (Waring 1984). Data of this type are largely unavailable for the species covered in this book, so growers must look to routine plantation or agricultural practice on a particular site as a guide to the amount and composition of fertilizer required. Examples of fertilizer requirements and schedules in use with different genera in different parts of the world are given below.

Fertilising may be done by hand, tractor with spreader, or aircraft. Hand application, because it ensures proper placement of fertilizer near each tree, is the most appropriate method for species and provenance trials. Placement of the fertilizer dose is important; it should not be placed so close as to cause root scorch or so distant to be unavailable to the young plant. Regular practice is to apply the dose in a circle or in small holes and 15–30 cm from the plant.

Fertilizer requirements and examples of schedules

Legumes

Critical elements for fertilising leguminous trees are phosphorus, sulfur, potassium, calcium, and magnesium, especially in acid soils. At transplanting, a mixture of rock phosphate (about 40%), dolomite (40%) and potassium sulfate or a mixture of calcium sulfate and potassium chloride (20%) is suggested. A small amount (0.5%) of mixed molybdenum, zinc, copper and boron elements is also likely to be beneficial (information from E.M. Hutton, cited in NAS 1983).

(1) Malaysia — Use of fertilizer with *Acacia mangium* depends on the site. Ex-jungle sites when broadcast burnt do not require fertilizer but trees on semi-mechanically prepared sites benefit from two applications of triple superphosphate (TSP) per tree; 100 g shortly after planting and 150 g at 5–6 months. On less fertile *Imperata* sites nitrogen and a general trace element mix (NPK) are added to the TSP for the first application; 120 g of a 1:1 mixture of TSP and NPK blue (12:5:14 + TE) (Mead and Millar 1991).

(2) South Africa — For seedling establishment of *Acacia mearnsii*, apply 40 g single superphosphate (10.5% P) at the time of planting followed by a further 40 g three to four months later, or before the trees are 1 m tall. In the southeastern Transvaal these rates are doubled. No response has been found to N, K or trace elements (Stubbings and Schonau 1982).

(3) India — *Acacia auriculiformis* responds to NPK applied one month after planting. Best combination is 60 g N, 25 g P and 8 g K per plant (Banerjee 1973).

Eucalypts

On many sites young eucalypts respond quickly to fertilisation, especially with phosphorus and/or nitrogen. The following examples are taken from FAO (1979). Other schedules may be found in Cremer et al. (1984) and elsewhere.

(1) Australia (New South Wales) — Apply 50 g per plant of N 15/P 30 fertilizer. Neither element alone gives much response, but in combination they give a dramatic response. Positive interaction between N and P has also been reported from Nigeria and other countries.

(2) New Zealand — On pumice soils, 60–80 g of urea per plant, followed by 200 kg urea/ha in the second year are used. No response to P or Mg.

(3) Sri Lanka — Normally planted without fertilisation. If nutrient deficiencies appear, 57 g NPK (15:15:15) are applied 2–3 years after planting.

(4) Zambia — Apply 90 g per plant of NPK (11:12:11) plus 60 g boron per plant. NPK may be discontinued because research has indicated it has little effect.

(5) Malawi — Apply 50–75 g NPK compound 3:2:1(25) plus 25–50 g boron per plant. Dosage is adjusted according to the climatic zone.

(6) South Africa — Apply 150 g NPK (3:2:1) per plant.

(7) Portugal — On sandstones *E. globulus* is fertilised with NPK. On schists, the K is omitted and replaced with Ca.

(8)Brazil — Apply 70–200 g per plant of either NPK (6:14:5) + Ca + S, or NPK (9:30:5) + micronutrients.

Casuarinas

The following recommendations are from papers in Midgley et al. (1983).

(1) India — *C. equisetifolia* was found to have a high requirement for Ca. On poor sites normal fertilizer application is 25–50 g per plant of NPK at planting. The addition of Ca, N, K, Mg and P in ratio 4:4:2:1:0.5 has been recommended by some workers.

(2) Philippines — N and P are required for increased growth of seedlings planted in grasslands.

(3) Senegal — Applications of soluble phosphate or rock phosphate (plus elemental S inoculated with thiobacilli) to *C. equisetifolia* planting on P-deficient sand dunes are recommended.

(4) Papua New Guinea — Boron should be applied to *C. oligodon* plantations in grassland at 56 g per tree during a two-month period (28 g one month after planting and another 28 g one month later).

Boron may be in low supply in some tropical savanna soils. Experiments carried out in Zambia, Nigeria and elsewhere have confirmed the necessity of applying boron fertilizers in such cases. Not only are the symptoms of boron deficiency completely eliminated, but considerable increase in plant growth is usually produced. Up to 60 g of boron fertilizer per plant is now applied as standard practice to eucalypts in countries such as Malawi, Nigeria, and Zambia.

A comprehensive account of fertility issues in tropical plantations is available in Nambiar and Brown (1997).

Finally there is evidence to show that there is a positive interaction between fertilisation and weed control; canopy closure is hastened when both are applied. Fertilisation therefore should be regarded as an integral part of tending operations rather than an isolated operation.

Weed control

Weed control is an essential part of initial and post-establishment practice in plantations. Failure to keep young plants free from weed competition can lead to high mortality, delayed canopy closure and increased fire risk. As species differ in their tolerance to weed competition and it is desirable to avoid this source of variation, complete weed control is the ideal practice for species and provenance trials.

The frequency and timing of weeding operations will depend very much on site, climate and method of suppression. The first year of growth is the most important in a plantation that has been well prepared and well fertilised. Six or even eight weedings may be necessary in the first year where weeds grow profusely and there is year-round rainfall. However, tree growth in such sites is usually fast and weeding, though demanding, is often necessary only in the first year. Fewer weedings are needed on sites where the growing season is short, but the associated slower tree growth often requires weeding to be continued for several years (Evans 1992). Once the canopy of a stand begins to close, weeds become suppressed by shading and the frequency of weeding can usually be dramatically reduced. The removal of weeds before they flower and seed reduces subsequent weed growth.

Because of the susceptibility of most of the project species to herbicides this method of weed control, though effective, is often inappropriate at least once the trial seedlings are planted. This leaves two main alternatives, i.e. mechanical and manual weeding, and three levels of coverage on a site, i.e. complete control, line weeding, and spot (or patch) weeding around the trees.

The importance of clean weeding for maximum survival and early canopy closure cannot be overstressed; this is usually achieved by mechanical disc-harrowing between rows combined with hand hoeing between plants. The discs are usually pulled by tractor so rows must be at least 3 m apart to avoid damage to the plants.

Despite the value of complete weed control, practical considerations may work against mechanical weeding in many instances, leaving partial manual weedings either in lines or spots as the only feasible but nevertheless valuable alternative. On former forest sites in the tropics, the growth of vines, lianes and climbers is often profuse and will quickly smother the young trees unless controlled in early weeding operations by uprooting.

Planting on ex-*Imperata* grassland poses special problems, as the grass grows in dense stands and will compete for light, water and nutrients with small seedlings and creates a serious fire risk during the dry season. It must be eradicated from the trial site as best as possible. Herbicides, particularly glyphosate, are very effective while other common methods of control such as cultivation, mulching and pressing, and shading with tree species give varying success (Turvey 1994).

Protection of newly planted trees

Damage to small trees by animals including goats, camels, sheep, cattle and a wide range of vermin that relish the new growth of young plants can be very serious. Erection of fences and/or the employment of forest guards may be the only means of successful establishment in areas where browsing pressure is high.

Insects can be a serious source of damage to young plantations. Termites cause problems, particularly in Africa, and leaf-cutting sauva ants are particularly damaging in South America. Control measures include insecticidal treatment in the nursery and at the planting site, and the laying of poison powder or bait.

Young plots are most susceptible to fire, and protection measures such as fire breaks and 'green belts' may be particularly important on dry grassy sites. Good weed control, as recommended earlier, will minimise this problem.

Watering and replacements

If new plantings are subjected to abnormally dry conditions before they have become established, and if the trial site is readily accessible, the application of two or more litres of water to each plant may be practicable and could carry the plants on to the next rainfall and perhaps save the experiment. Replacement of casualties is not a recommended practice in species elimination trials.

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APPENDIX 1. SEED AVAILABILITY

Limited stocks of seed are available for purchase or exchange by researchers affiliated with government, education or research organisations.

Requests for seed should be sent to:	**From (give full postal address for seed despatch)**
Officer-in-Charge, Australian Tree Seed Centre	....
CSIRO Forestry and Forest Products	....
P.O. Box E4008, Kingston	....
Canberra, ACT. 2604, AUSTRALIA.	....
Tel (Aust. 06) (Internat + 616) 281 8211	....
Fax (Aust. 06) (Internat + 616) 281 8266	....
email tim.vercoe@ffp.for.csiro.au	....

1. Description of Research Project

Proponent/Manager ....

Project location ....

(*Country*) (*State*) (*Nearest town/village*)

Latitude: o '(N/S) Longitude o '(E/W) Altitude (m)

Objectives

Agroforestry	☐	Pulp	☐	Amenity	☐
Fodder	☐	Fuelwood	☐	Posts and poles	☐
Shade and shelter	☐	Soil conservation	☐	Sawn timber	☐

Other

Indicate species of special interest. ....

....

....

....

Indicate results if Australian species have already been tested on the areas concerned, or similiar sites nearby................

....

....

....

Project size

Experimental design ....

Proposed number of trial sites .... Spacing ....

Area of each trial in hectares ....

Approximate number of plants required from each seedlot ....

....

....

Preferred date for the receipt of seed samples ....

Arrangements for provision of import permits, if required for research seed ....

....

....

2. Site Details

Climate

Nearest representative weather station
Name ....
Latitude: o '(N/S) Longitude o '(E/W) Altitude (m)

Rainfall regime

Summer ☐ Uniform ☐
Winter ☐ Bimodal ....
Mean annual rainfall ....(mm)
Dry season (< 40 mm/month) ....(months)
Mean rainfall in the driest quarter ....(mm)

Temperature

Mean annual (°C) Mean daily min. of coldest month (°C)
Absolute minimum (°C) Mean daily max. of hottest month (°C)
Number of frosts (days/year)

Topography

Flat ☐ Hollow ☐ Gentle ☐
Ridge top ☐ Intermediate ☐ Steep ☐
Aspect ....

Soil

Parent material ....
Texture ....
Depth to water table, Colour, Stoniness ....
Drainage (free draining, waterlogged etc) ....
pH very acid (< 4.5) ☐ Neutral (6.0–7.0) ☐ Very alkaline (> 9.0) ☐
Acid (4.5–6.0) ☐ Alkaline (> 7.0) ☐
Salinity (if applicable) ....

A summary of the principal factors affecting tree growth ....
....
....
....

3. Proposed Management Regime

Site preparation, weed control, fertilizing, irrigation, protection, evaluation schedule, etc.
....
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Chapter 5

INTRODUCTION TO THE SPECIES' DIGESTS

J.C. Doran, J.W. Turnbull, P.N. Martensz, L.A.J. Thomson and N. Hall

The first version of this book (Turnbull 1986) introduced 100 lesser-known Australian tree and shrub species with potential value for planting in countries with environmental conditions similar to those of Australia. The species described were those judged by a group of experienced botanists and foresters as having the potential to provide fuelwood, fodder, posts, poles, shade and shelter, ground cover, or other desirable products and influences. There was then, as today, a great need to identify multipurpose woody perennials suitable for reforestation or integration into farming systems in tropical arid and semi-arid areas where soil fertility levels are low and salinity problems not uncommon. For this reason drought-tolerant, nitrogen-fixing trees and shrubs, especially *Acacia* species, comprised the majority of the species described. Other species selected included those suitable for tropical areas where rainfall is abundant, but often highly seasonal, and where infertile soils, waterlogging or other environmental constraints limit species choice. The choice of species was primarily restricted to those that had rarely been tried as exotics and for which information was not readily available. Well-known and widely-planted Australian trees, especially eucalypts, were deliberately excluded.

The same criteria have been used in selecting the species for inclusion in this edition with the addition of some species selected specifically for their human food value (e.g. *Macadamia* and *Davidsonia*). Several experts of appropriate experience were consulted in developing a list of candidate species. Of course it was not possible to include all nominated species and a consensus approach was adopted in refining the list. For continuity, this edition includes information on all 100 species from Turnbull (1986) as well as information on an additional 64 species thought to have considerable potential to provide the required goods and services. Eleven better-known species from five genera (i.e. *Acacia*, *Casuarina*, *Eucalyptus*, *Grevillea* and *Melaleuca*) have been given a longer treatment so that the information available on them could be presented more fully and used as a guide for handling lesser-known species. Ninety-nine two-page treatments cover 101 species. Use was made of the extensive literature now available on performance and utilisation of many of the species from the first edition to rate their potential. If the early performance of a particular species in trials was below expectations, it still appears in the book but joins a small new group of other promising species in the quarter-page treatments. Fifty-two species are given quarter-page treatment, including 38 species from the first edition. The promising new species in the quarter-pages are there mainly because they are little-known and there was insufficient detail available to warrant a two-page treatment. Information on the performance of species from the first edition has been provided mainly by papers and reports from several ACIAR-supported projects undertaken since 1986 and concerned with the domestication of Australian trees (e.g. see papers in Boland 1989; Turnbull 1991 and Brown 1994).

A book of this type cannot describe adequately all aspects of such a large number of species, so literature references are given to enable the reader to seek more detailed information. Where references are not cited the information is based on personal observation, informal advice and field notes accompanying the botanical specimens consulted in herbaria.

NOMENCLATURE

In preparing these digests the latest accepted botanical nomenclature has been used. Synonyms are given where species names have been changed recently or earlier names are still in common use. Some species have many common names applied to them; other lesser-known species have no local name. No attempt has been made in these digests to select the most appropriate common name or to invent a suitable name. When the species is included in the Australian Standard

02-70, Nomenclature of Australian Timbers (Standards Association of Australia 1970), which provides 753 standard trade common names and lists over 1000 species of trees and large shrubs, the standard common name is indicated in the digests.

In view of the confusion that can arise from using common names alone, particularly when the same name is applied to more than one species, botanical names are recommended as the primary means of reference.

ILLUSTRATIONS

Most of the photographs of species described in this publication have been taken by staff of the CSIRO Forestry and Forest Products but many other organisations and individuals have cooperated. Every effort has been made to ensure the illustrations are true to name and where possible they are plants from which botanical material was collected and identified.

SPECIES DISTRIBUTION MAPS

Records of authenticated specimens held in Australian herbaria are the primary source of information used to plot the natural distribution of each species. In a few instances this information was supplemented by personal observations and published records. Doubtful records were referred to specialist botanists. The scale of the maps precludes individual records from being plotted. Only the boundaries of the natural occurrence in Australia are shown unless the occurrences outside of Australia could be plotted with confidence.

SPECIES DIGESTS

The digests on the 164 species include reference to the following points.

Botanical features

The correct identification of trees and shrubs is of great importance but often presents problems for the non-specialist farmer or forester. Many Australian species of *Acacia*, *Eucalyptus* and *Melaleuca* can be accurately identified only by competent botanists. The botanical features are an outline only and should not be regarded as a full description of a species. They are intended only as a guide to assist field workers to check on the identity of trees and shrubs in their trials.

Natural occurrence

Not all species described are confined to Australia — several extend from northern Australia into Papua New Guinea and Indonesia, and a few, such as *Dodonaea viscosa*, have a much more extensive distribution. *Eucalyptus urophylla* occurs soley in Indonesia.

Ecological conditions

The ecological conditions of the natural habitat are described under ‘Climate’, ‘Physiography and Soils’ and ‘Vegetation Type’.

The climatic classification of Thornthwaite (1948) is used to define climatic zones. Rainfall is cited in terms of percentile values. The 10 percentile value means that on average one year in 10 will be less than the amount shown. The 50 percentile is the median value and indicates that in 5 out of 10 years the rainfall will be higher than the stated amount and in the remaining 5 years it will be lower. The number of frost days is based on 0°C in the screen; ground temperatures are usually several degrees lower.

Physiographic regions are based on the Jennings and Mabbutt (1977) classification (see Chapter 1) and soil nomenclature mainly follows Stace et al. (1968). For describing the structural vegetation forms the classification of Specht (1970) is used and is supplemented by that of Webb (1959) for types of closed-forest (rainforest).

Utilisation

The main purposes for which the species has been used in Australia or elsewhere is reported under the headings ‘Fodder’, ‘Fuelwood’, ‘Wood’ and ‘Other Uses’. The potential of species for these purposes is also noted where appropriate.

Silvicultural features

Many of the species described have been planted only rarely and little information is available on nursery and plantation methods. Data and observations on seed characteristics, coppicing ability, growth rate, and yield are included when available.

Pests and diseases

Known pests and diseases of the species are listed but much of the information is from Australian observations and may not be relevant when the species is introduced into a new environment.

Limitations

Attention is drawn to features of the species that may make it undesirable in certain circumstances. Many of the trees and shrubs selected are aggressive and fast-growing. Such trees are appropriate for cultivation in areas of extreme fuelwood deficit, particularly where soil and climatic conditions are unfavourable. However, in more equable or fire-prone environments such potentially invasive plants should be introduced and monitored with great care. A valuable tree or shrub in one environment may prove to be an invasive weed in another.

Related species

Close relatives of the species described are listed as this information can provide insights into the potential of the species for hybridisation or suggest other species that might be included in trials.

EXPLANATION OF TABLE 5.1

This table (pp 93–99) lists described species and their more important characteristics and uses. In such a table it is not possible to qualify each classification and, hence, amplification should be sought from the digests on individual species.

Climatic zone (column 2) based on C.W. Thornthwaite's universal system indicates the range of climatic zones where the species occurs naturally. The zone in which the species most commonly occurs is listed first. The zones used are arid, semi-arid, sub-humid and humid.

Rainfall (columns 3–4) gives the range of median annual rainfall in the area of natural occurrence of the species. Abbreviations for the season of greatest rainfall are W=winter, U=uniform, S=summer. The values given are general indications of rainfall requirements and allowance must be made for temperature, soil type and depth, and topography. Some species, especially in the arid and semi-arid zones, grow only in situations where they receive additional moisture as run-on from slopes or in drainage channels. Under these circumstances the median rainfall value may underestimate the water requirement of the species.

Frosts (column 5) are based on screen temperatures (0°C).

Soil texture (column 6) of the sites where the species most commonly occurs is indicated by the abbreviations Sa=sand, L=loam, and C=clay. The abbreviation Sa–C indicates the species occurs over a wide range of soil textures, from sand to clay.

The occurrence of the species on *saline or alkaline* (pH 7–10) *soils* (column 7) is indicated by the abbreviations Sl=saline and A=alkaline. Occurrence on seasonally or permanently waterlogged sites (column 8) is indicated by the symbol X. These species tolerate waterlogged sites.

Tree habit (columns 9 and 10) is denoted by the range of tree height attained by the species under natural conditions. The form of the tree is indicated by Sh=shrub, St=small tree, T=tree. Shrubs are distinguished from small trees in being multistemmed from or near the ground. Some species are found both as shrubs and as small trees and this is indicated by Sh-St. Trees are single-stemmed forms of the species reaching a height of over 10 m.

The ability to fix *atmospheric nitrogen* (column 11) is assumed for all species of *Acacia*, *Albizia*, *Allocasuarina*, and *Casuarina* even though confirmation that they individually nodulate and fix nitrogen may be lacking. The symbol X indicates the ability to fix atmospheric nitrogen.

Symbol X is also used in columns 12–21 to indicate that the species is used, or has the potential to be used, for the purpose shown. When given in lowercase (x) this indicates that the species has limited value for that particular attribute.

Shelter/windbreaks (column 12) includes the taller trees suitable for single or multi-rowed belts and shrubs or small trees with a bushy habit from ground level that provide satisfactory low shelter without recourse to pruning. The shrubs may be used in the lower storey of windbreaks formed by trees that do not retain branches near ground level.

Soil protection (column 13). This category includes trees and shrubs that serve to prevent soil erosion by forming a dense canopy or having an extensive shallow root system that binds the soil.

Any tree can provide some *shade* (column 14) but species particularly suitable for this use must develop a moderately broad and relatively dense crown.

Ornamental species (column 15) includes trees and shrubs that are suitable for public and private amenity planting. Species with attractive foliage, showy flowers or unusual bark characteristics are noted in this category.

Animal fodder (column 16) is a general category that indicates that the foliage or other parts of the plant may be eaten by stock. Some plants are grazed regularly and constitute an appreciable part of the food intake at all times, whereas others are eaten only under stress when alternative forage is scarce or lacking during severe droughts.

The categories included under *Timber* (columns 17–21) are intended only as general indications of suitability for the various uses shown. To be classified under *sawlog*s (column 17) the trunks should normally attain at least 25 cm diameter and lengths of over 3 m, whilst the wood should be suitable for use as boards or framing timber. In the case of *poles* (column 18) stem form and natural durability of the heartwood are requisites. Smaller-sized material possessing natural durability is also necessary for the *post* classification (column 19). Species listed as suitable for *turnery* (column 20) possess special wood qualities, such as figured grain. Nearly all the species in the table make good or satisfactory *firewood*, including charcoal, but the few that have unsatisfactory characteristics have been excluded from column 21.

Under '*Other uses*' (column 22) are listed species that can be used for tannin (Ta), food (F), nectar (N) and pollen (P) sources for bees, or possess medicinal properties (M) or provide other non-wood products.

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Table 5.1. A list of 164 Australian trees and shrubs with potential for use in land rehabilitation and farm planting, with a summary of certain characteristics.

		Environment						Tree habit		Uses											
		Rainfall			Soil											Timber					
Botanical name	Climatic zone	Range of annual 50 percentile values (mm)	Season	Frosts (no./year)	Texture	Saline or alkaline	Water-logged	Range of mature height (m)	Form	Ability to fix atmospheric nitrogen	Shelter/windbreak	Soil protection	Shade	Ornamental	Animal fodder	Sawlogs/pulp	Poles	Posts	Turnery	Firewood	Other uses
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Acacia adsurgens	Semi-arid – arid	200–500	S–W	0–11	Sa–L			2–4	Sh	X	X	X								X	F
A. ammobia	Arid	200	S	5–15	Sa–L			3–6	Sh–St	X	X	X		X				X		X	f
A. ampliceps	Semi-arid – arid	250–700	S	0	Sa–C	A–Sl		3–9	Sh–St	X	X	X	X		X			X		X	F
A. ancistrocarpa	Arid – semi-arid	200–700	S	0–11	Sa			2–4	Sh	X	X	X								X	f
A. aneura	Arid – semi-arid	200–500	U	1–12	Sa–L			2–15	Sh–St	X	X	X	X	X	X			X	X	X	f
A. argyrodendron	Semi-arid – sub-humid	450–650	S	0–2	C	A		12–20	T	X	X		X	X	X		X	X		X	
A. aulacocarpa	Humid – sub-humid	500–1500	S	0–5	Sa–L			3–40	T	X	X		X	X	x	X	X	X	X	X	
A. auriculiformis	Humid – sub-humid	1000–2000	S	0	Sa–C	A–Sl	X	8–30	T	X	X	X	X	X	x	X	X	X		X	P, Ta
A. bancroftii	Sub-humid	500–700	S	2–5	Sa			2–6	Sh–St	X				X				X		X	
A. bidwillii	Sub-humid – semi-arid	380–850	S	0–5	C–L			6–12	St–T	X	X		X	X	X				X	X	
A. blakei	Sub-humid – semi-arid	650–900	S	5–40	Sa–L			6–13	St	X	X		X		x					X	
A. brassii	Humid	1150–1800	S	0	Sa			4–10	Sh–St	X	X	X						X		X	
A. burrowii	Sub-humid – semi-arid	500–675	S	2–12	Sa–C	A		2–13	Sh–St	X			X		X		X	X	X	X	
A. calcicola	Arid	150–250	S–U	1–12	Sa–C	A		3–5	Sh–St	X	X	X	X							X	
A. cambagei	Semi-arid – arid	300–600	U–S	1–5	C–L	A		5–15	St	X	X		X		x			X	X	X	P
A. cincinnata	Humid – sub-humid	1100–3500	S	0–5	Sa–L			10–25	St–T	X	X		X			X	X	X	X	X	
A. citrinoviridis	Arid	200–310	S–U	0–5	Sa–C	A		6–18	St	X	X	X	X	X		x		X	X	X	f
A. colei	Semi-arid	230–725	S	0–2	Sa–C	A		4–9	Sh–St	X	X	X	X	X					X	X	F
A. concurrens	Humid – sub-humid	900–1200	S	0–2	Sa–C			2–10	Sh–St	X	X	X			X					X	
A. coriacea	Arid – semi-arid	200–500	S	0–12	Sa	A		3–10	Sh–St	X	X	X	X	X						X	F
A. cowleana	Arid – semi-arid	250–400	S	0–12	Sa			2–7	Sh–St	X	X	X		X	x					X	F

continued over

Table 5.1 continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A. crassa	Sub-humid	560–705	S	2–20	Sa			3–10	Sh–St		X			X						X	
A. crassicarpa	Humid – sub-humid	1000–3500	S	0	Sa–C	A		5–30	T	X	X	X	X	X		X	X			X	
A. cretata	Sub-humid – humid	750–845	S	2	Sa			2–8	Sh–St	X	X						X	X		X	
A. dealbata	Sub-humid – humid	600–1000	S–W	2–80	L–C			2–30	Sh–T	X	X	X	X	X	x	X	X	X		X	P
A. deanei	Semi-arid – sub-humid	480–680	S	2–22	Sa–Ca			2–9	Sh–St	X	X	X		X				X		X	P
A. difficilis	Sub-humid – semi-arid	650–1100	S	0	Sa–L			5–10	Sh–St	X	X	X						X		X	P
A. distans	Arid	200–260	S–W	0–2	L–C	A		5–8	St	X	X	X	X							X	
A. doratoxylon	Sub-humid – semi-arid	400–600	S–U	9–52	Sa–L			3–10	Sh–St	X	X			X	X		X	X		X	P
A. elata	Sub-humid – humid	1000–1250	S	5–40	Sa–L			15–28	T	X	X			X		X		X		X	Ta
A. eriopoda	Semi-arid – arid	325–535	S	0–3	Sa–L			4–8	Sh–St	X	X	X						X		X	
A. falciformis	Sub-humid – humid	600–900	S–W	5–50	Sa–C			5–24	Sh–T	X	X	X					X	X		X	Ta
A. fasciculifera	Sub-humid – humid	675–850	S	0–5	L–C			8–20	St–T	X			X	X		X	X	X		X	
A. filicifolia	Humid – sub-humid	750–1000	S	0–65	Sa–C			2–14	Sh–St	X			X	X			X	X		X	
A. flavescens	Sub-humid – humid	1000–2150	S	0–2	Sa–L			4–10	Sh–St	X		X			x			X		X	Ta
A. glaucocarpa	Sub-humid	650–850	S	0–5	L–Sa			6–10	St	X			X	X	x		X	X		X	Ta
A. harpophylla	Sub-humid – semi-arid	500–750	S	2–18	C–L	A–Sl		12–24	St–T	X	X		X	X	X	X	X	X	X	X	
A. holosericea	Sub-humid – semi-arid	300–1100	S	0–10	Sa–L	A		4–9	Sh-St	X	X	X		X						X	f
A. hylonoma	Sub-humid	2150	S	0	L–C			15–25	T	X				X	x		X	X		X	
A. irrorata	Humid – sub-humid	750–1100	S	0–40	L–C			5–20	Sh-T	X	X	X	X	X			X	X		X	Ta
A. julifera	Humid – semi-arid	800–1100	S	0–20	Sa			2–10	Sh–St	X	X			X			X	X		X	
A. latzii	Arid	160–250	S	5–10	L–C	A–Sl		2–6	Sh–St	X	X									X	
A. leptocarpa	Humid – sub-humid	750–1750	S	0	Sa–C			3–12	Sh–St	X		X	X	X			X	X	X	X	
A. leucoclada	Humid – sub-humid	575–990	S–U	0–61	Sa–C			4–20	Sh–T	X	X	X	X	X		X	X	X		X	
A. ligulata	Arid – semi-arid	100–700	S–W	0–12	Sa–L	A–Sl		1–5	Sh	X	X	X			X						
A. longispicata	Semi-arid – sub-humid	475–800	S	0–23	Sa–C			3–10	Sh–St	X	X	X	X	X			X	X		X	
A. macdonnelliensis	Arid	200–300	S	8–12	Sa			2–5	Sh–St	X	X							X		X	f
A. maconochieana	Arid	225–350	S	1–2	L–C	A–Sl		3–12	St	X			X	X	X		X	X		X	f
A. maidenii	Humid – sub-humid	900–1300	S–U	0–10	Sa–L			4–16	Sh–T	X	X		X	X					X	X	Ta

continued over

Table 5.1 continued

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
A. mangium	Humid	1500–3000	S	0	Sa–L			7–30	St–T	X	X	X	X		X	X	X	X	X	X	P
A. mearnsii	Sub-humid – humid	440–1600	W–U	0–80	L–C			6–20	St–T	X	X	X	X	X	x	X	X	X		X	Ta
A. melanoxylon	Humid – sub-humid	750–1500	W–S	1–40	Sa–L			10–40	Sh–T	X	X	X	X	X	x	X			X	x	
A. monticola	Semi-arid – arid	150–800	S	0–12	Sa–C	Sl		2–8	Sh–St	X	X			X	X			X		X	
A. murrayana	Arid – semi-arid	200–300	S–U	1–8	Sa–C	A		2–8	Sh–St	X	X	X			X				X	X	P, F
A. neriifolia	Sub-humid	600–800	S	13–60	Sa–C			2–15	Sh–St	X	X			X	x		X	X		X	Ta
A. oraria	Humid – sub-humid	1750–2150	S	0	Sa	Sl–A		3–15	Sh–St	X	X	X		X			X	X	X	X	
A. orites	Humid	1500–2500	S–U	0–5	L–C			8–30	St–T	X	X			X		X	X	X		X	
A. pachycarpa	Arid	225–350	S	0–5	C–Sa	Sl		3–6	Sh–St	X	X				X					X	F
A. pendula	Arid – sub-humid	400–650	W–S	1–20	C–Sa	A–Sl		8–12	St	X	X		X	X	X				X	X	
A. platycarpa	Humid – semi-arid	450–950	S	0–3	Sa–L			6–10	Sh-St	X	X	X	X	X						X	
A. plectocarpa	Sub-humid – semi-arid	600–1600	S	0	Sa	Sl		3–10	Sh–St	X	X	X			X		X	X		X	
A. podalyriifolia	Sub-humid – humid	700–1150	S	1–5	Sa–C			2–6	Sh–St	X	X			X				X		X	P, Ta
A. polystachya	Humid – sub-humid	1150–2150	S	0	Sa–L	A–Sl		3–25	Sh–T	X	X	X	X				X	X		X	
A. pruinocarpa	Arid	200–275	W	1–12	Sa–L	A		5–12	St	X			X	X	x		X	X		X	
A. rothii	Humid – sub-humid	1400–1700	S	0	Sa–L			6–12	Sh–St	X	X	X								X	
A. salicina	Sub-humid – semi-arid	375–550	S–W	1–12	Sa–C	A–Sl		7–20	Sh–T	X	X	X	X	X	X	X			X	X	
A. saligna	Sub-humid – humid	300–1000	W–S	0–6	Sa–C	A–Sl	X	2–9	Sh–St	X	X	X	X	X	X		X	X		X	Ta
A. sclerosperma	Arid – semi-arid	175–325	W–S	0–6	Sa–C	A–Sl		2–6	Sh–St	X	X	X		X						X	
A. shirleyi	Semi-arid – sub-humid	500–750	S	0–2	Sa–L			7–18	St–T	X	X	X	X	X	X		X	X	X	X	
A. silvestris	Sub-humid	800–1100	U	5–60	Sa–L			8–30	St–T	X	X	X	X			X	X	X	X	X	Ta, P
A. simsii	Humid – semi-arid	1000–1800	S	0–2	Sa–C			2–7	Sh	X	X	X		X						X	
A. stenophylla	Arid – semi-arid	125–600	S	1–20	C	A–Sl	X	4–10	St	X	X	X	X	X	X			X	X	X	F
A. stipuligera	Arid – semi-arid	300–700	S	0–1	Sa–L			2–5	Sh–St	X		X		X						X	F
A. tephrina	Semi-arid – sub-humid	400–550	S	1–15	C	A–Sl		4–20	St–T	X	X		X		X		X	X		X	
A. torulosa	Sub-humid – semi-arid	700–1150	S	0–2	Sa–L	A–Sl		5–12	Sh–St	X	X		X	X				X		X	f
A. trachycarpa	Arid – semi-arid	230–400	S	0–5	Sa–C	A		1–8	Sh–St	X	X	X			X					X	
A. trachyphloia	Humid – sub-humid	700–950	S	0–66	L–C			3–18	Sh–T	X	X			X			X	X		X	

continued over

Table 5.1 continued

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
A. tumida	Semi-arid – sub-humid	450–1000	S	0–2	Sa	A		3–12	Sh–St	X	X	X		X	X					X	F
A. victoriae	Arid – semi-arid	100–1000	S–W	0–11	Sa–C	A–Sl		1–8	Sh–St	X	x	X			X					X	P, F
A. xiphophyllla	Arid	200–350	S–W	1–5	C	A–Sl		2–5	Sh	X	X	X								X	
Albizia lebbeck	Humid	1030–1755	S	0	Sa–L	Sl–A	X	15–30	T	X		X	X		X	X	X	X	X	X	N, Ta
A. procera	Humid – sub-humid	1000–1750	S	0	Sa–L			7–30	St–T	X	X	X	X		x	X	X	X	X	X	Ta
Allocasuarina campestris	Semi-arid	220–400	W	0–12	Sa–C			1–5	Sh	X	X	X								X	
A. decaisneana	Arid	200–250	S	1–12	Sa			9–12	T	X	X		X	X			X	X		X	
A. littoralis	Sub-humid – humid	650–1250	S–W	0–70	Sa–C			3–12	Sh–St	X	X	X		X				X	X	X	
A. luehmannii	Sub-humid – semi-arid	425–650	S–W	0–50	Sa–L	Sl	X	6–15	St		X			X			X	X	X	X	
Alphitonia excelsa	Humid – semi-arid	650–1250	S	0–18	Sa–C			8–35	Sh–T		X		X	X	X	X		X	X	X	M
A. petriei	Humid – sub-humid	1100–1650	S	0–4	L			10–40	St–T		X	X		X	X	X				x	M
Alstonia scholaris	Humid	1200–2400	S	0	L–Sa			20–40	T					X		X			X	X	M
Asteromyrtus brassii	Humid	1400–1950	S	0	Sa–C			3–25	Sh–T			X		X			X	X		X	m
A. symphyocarpa	Sub-humid – humid	850–1300	S	0–1	Sa–C		X	2–12	Sh–St			X		X			X	X		X	M
Atalaya hemiglauca	Arid – sub-humid	250–650	S	0–18	Sa–C			3–9	Sh–St		X			X	X						
Banksia integrifolia	Humid – sub-humid	850–1200	S	0–65	Sa–L			2–25	Sh–T		X	X		X		X			X	X	N
Brachychiton diversifolius	Humid – sub-humid	440–1500	S	0	Sa–L			5–18	St			X	X	X	X	X					F, M
Buckinghamia celsissima	Humid	1300–1800	S	0–2	Sa–L			10–30	St–T				X	X		X	X			X	
Callitris endlicheri	Semi-arid – humid	550–900	S–W	1–80	Sa–L			6–12	Sh–St		X			X			X	X	X	X	Ta
Capparis mitchellii	Sub-humid – arid	120–630	S–W	1–23	Sa–C	A		4–10	Sh–St		X	X	X	X	X				X	X	F
Cassia brewsteri	Humid – semi-arid	1100–1350	S	0–4	Sa–C	A–Sl		4–30	Sh–T				X	X		X				X	
Casuarina cristata	Semi-arid – sub-humid	310–1180	S–U	2–50	Sa–C	A–Sl	X	10–20	St–T	X	X			X	x			x	X	X	
C. cunninghamiana	Humid – semi-arid	600–1100	U–S	0–50	Sa–L	Sl	X	12–35	T	X	X	X	X	X	x	x	X	X	X		P
C. equisetifolia	Humid – sub-humid	1000–2150	S	0–3	Sa	A–Sl		6–35	Sh–T	X	X	X	X	X		X	X	X		X	Ta, M
C. glauca	Humid – sub-humid	900–1700	S	0–5	Sa–C	Sl	X	2–20	Sh–T	X	X	X		X	x	X	X	X	X	X	
C. obesa	Sub-humid – arid	250–500	W	0–12	Sa–C	Sl		2–14	Sh–St	X	X			X				X	X	X	

continued over

Table 5.1 continued

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
Davidsonia pruriens	Humid – sub-humid	1265–2035	S	0–2	L–C			2–10	Sh–St					X			X	X	X	X	F
Dendrolobium umbellatum	Sub-humid	850–1750	S	0–1	Sa–L	A		1–7	Sh–St	X		X			X			X		X	
Dodonaea viscosa subsp. *angustissima*	Arid – humid	120–1580	S–W	0–93	Sa–L	A–Sl		1–5	Sh–St			X		X	X				X	X	
Elaeocarpus angustifolius	Humid	1200–2400	S	0–5	Sa–L			35–40	T							X				x	F
E. bancroftii	Humid	2000–3600	S	0–1	L			15–30	T							X					F
Eremophila bignoniiflora	Arid – semi-arid	120–940	S–W	0–12	C	A–Sl		1–8	Sh–St		X				X				X		N, M
Eucalyptus argophloia	Sub-humid	660	S	10–15	C–L			20–40	T		X		X	X		X	X	X		X	
E. brevifolia	Semi-arid – sub-humid	450–700	S	0	Sa–L	A		6–12	St		X	X		X				X		X	
E. camaldulensis	Sub-humid – semi-arid	250–1250	S–W	0–20	Sa–C	A–Sl	X	20–45	T		X	X	X	X		X	X	X	X	X	N
E. gongylocarpa	Arid	150–250	S	0–5	Sa–L			8–20	St		X			X				X		X	
E. jensenii	Semi-arid – sub-humid	550–1550	S	0	Sa–L			6–18	St–T				X				X	X		X	
E. ochrophloia	Arid – semi-arid	250–450	S–U	1–10	C	A		6–20	St–T		X		X		X			X		X	N
E. odontocarpa	Arid – semi-arid	250–570	S	0–10	Sa–L			1–4	Sh		X	X								X	
E. oxymitra	Arid	150–250	S	1–12	Sa–L	A		1–6	Sh–T		X			X						X	
E. pellita	Humid	1000–4000	S	0	Sa–L–C			15–40	T		X	X				X	X	X		X	P
E. socialis	Arid – semi-arid	150–500	S–W	0–20	Sa–L	A		2–9	Sh–St		X	X						X		X	N
E. thozetiana	Arid – sub-humid	256–650	S	1–15	L–C	A		8–25	St–T				X			X	X	X		X	
E. trivalvis	Arid	150–300	S–W	1–15	Sa–L	A		3–10	Sh		X	X								X	
E. urophylla	Humid – sub-humid	800–2200	S	0	L			15–45	T		X		X			X	X	X		X	
Flindersia maculosa	Semi-arid – sub-humid	275–474	S	0–12	C–Sa	A		6–13	Sh–St				X	X	X	X	X	X		X	N, M
Geijera parviflora	Semi-arid – sub-humid	175–715	S–W	1–52	Sa–C–L	A		5–10	Sh–St		X		X	X	X					X	P, N
Grevillea baileyana (syn. *G. pinnatifida*)	Humid	1500–2150	S	0	L			6–30	St–T					X		X				X	
G. glauca	Humid – semi-arid	490–2090	S	0–2	Sa–L			2–15	Sh–St					X			X	X		X	

continued over

Table 5.1 continued

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
G. parallela	Semi-arid – humid	600–1150	S	0–1	Sa–C			5–15	Sh–St					X	X			X	X	X	N
G. pteridifolia	Humid – sub-humid	800–1600	S	0–5	Sa–C		X	2–18	Sh–St		X	X		X	x					X	N
G. robusta	Humid – sub-humid	700–1700	S	1–5	L			20–37	T		X	X	X	X	x	X	X	X		X	N
G. striata	Arid – sub-humid	200–500	S–U	0–12	Sa–C–L	A		3–15	Sh–St					X	X	X		X	X		N, M
Hicksbeachia pinnatifolia	Humid – sub-humid	1200–1700	S	0	L			8–12	St					X							F
Lophostemon suaveolens	Humid – sub-humid	650–2100	S	0–10	Sa–C		X	5–15	Sh–St							X	X				N
Lysiphyllum carronii and *L. cunninghamii*	Semi-arid – sub-humid	340–965	S	0–4	Sa–C	A		2–12	Sh–St		X		X	X	X		X	X	X	X	N
Macadamia integrifolia and *M. tetraphylla*	Sub-humid – humid	1130–1670	S	1–4	L			10–20	St–T				X	X					X		F
Melaleuca arcana	Humid	1700–1900	S	0	Sa–L		X	1–12	Sh–St			X					X	X		X	N
M. argentea	Humid – semi-arid	300–1500	S	0–10	SL–C			5–20	Sh–St		X			X			X	X		X	N
M. bracteata	Arid – humid	250–1150	S	1–12	C–L	Sl–A		5–20	Sh–St		X	X		X			X	X			P, E
M. cajuputi	Humid – sub-humid	1300–1750	S	0	C		X	15–40	T		X		X	X			X	X		X	M, N
M. dealbata	Humid – sub-humid	1135–1750	S	0	Sa–C	Sl		5–25	St–T		X	X		X			X	X		X	N
M. leucadendra	Sub-humid – humid	650–1500	S	0–2	L–C	Sl	X	15–40	T		X		X	X		X	X	X		X	N, E
M. nervosa	Sub-humid – semi-arid	700–1150	S	0–3	Sa–C	Sl	X	1–10	Sh–St			X		X			X	X		X	
M. quinquenervia	Sub-humid – humid	900–1250	S	0–5	L–C	Sl	X	4–25	St–T		X	X		X		X	X	X		X	M, N
M. stenostachya	Humid – sub-humid	750–1750	S	0–3	Sa–L		X	4–25	St–T			X					X	X		X	
M. viridiflora	Humid – semi-arid	325–1750	S	0–2	Sa–L	A	X	5–25	St–T					X			X	X		X	P, E
Melia azedarach var. *australasica*	Sub-humid – humid	800–2100	S	0–15	Sa–C	Sl		10–45	T		X		X	X	X	X				X	N
Neofabricia myrtifolia	Humid – sub-humid	1600–1750	S	0	Sa–L			3–13	Sh–St					X						X	N
Paraserianthes lophantha	Humid – sub-humid	670–1120	W	0–4	Sa–L	A–Sl	X	4–15	Sh–St	X	X	X		X	X						
P. toona	Humid – sub-humid	1000–1750	S	0–2	Sa–L			5–30	Sh–T		X				X		X	X	X	X	
Parinari nonda	Humid – sub-humid	1150–1725	S	0	Sa–L	A		6–34	St–T			X				X	X	X	X	X	F
Persoonia falcata	Sub-humid – humid	600–1300	S	0–4	Sa–L			2–9	Sh–St					X				X	X	X	M
Petalostigma pubescens	Semi-arid – humid	600–1200	S	0–5	Sa–L			5–12	St					X				X		X	M
Pleiogynium timorense	Humid – sub-humid	800–2090	S	0	L			15–20	St–T				X								F

continued over

Table 5.1 continued

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
Santalum album	Humid	1000–1500	S	0	Sa–C–L			4–20	Sh–St		X			X	X				X	X	E
Sesbania formosa	Arid – humid	230–1570	S	0	Sa–C	A–Sl	X	8–20	St–T	X	X	X		X	X	X				X	F
Syncarpia hillii	Humid	1100–1700	S	0	Sa		X	20–40	T		X					X	X	X			M
Syzygium paniculatum	Humid	760–1160	S	0	Sa			10–20	St					X		X					F
S. suborbiculare	Humid – sub-humid	880–1760	S	0	Sa			9–12	St				X	X						X	F
S. tierneyanum	Humid	1715–3560	S	0	Sa–L			10–25	T		X	X		X		X					F
Terminalia arostrata	Semi-arid	400–650	S	0	C	A		6–12	St					X	X			X		X	F
T. oblongata subsp. *volucris*	Semi-arid – sub-humid	650–850	S	0	C			2–8	Sh–St						X			X		X	
T. sericocarpa	Humid	850–2100	S	0	Sa–L			10–30	T		X			X		X				X	F
Ventilago viminalis	Semi-arid	400–700	S	1–12	C–Sa			4–10	Sh–St		X		X	X				X			M

A = alkaline; C = clay; E = fragrant essential oil; F = food; L = Loam; M = medicinal properties; N = nectar; P = pollen; S = summer season; SL = sandy loam; Sa = sand; Sh = shrub; Sl = salinity; St = Small tree; T = tree; Ta = tannin; U = uniform season; W = winter season; lower case letter represents limited value for that particular characteristic.

SPECIES' DIGESTS

List of Major Species

Acacia adsurgens

Main attributes. A moderately fast-growing, nitrogen-fixing, multi-stemmed large shrub. It is suitable for soil stabilisation and amenity plantings on well drained, infertile, acidic and neutral sands and loams in hot dry zones. Its wood makes an excellent charcoal, while its seeds have potential as a source of human food.

Botanical name. *Acacia adsurgens* Maiden and Blakely was first published in *J. Roy. Soc.* 13: 28 (1927). The generic name comes from the Greek *akazo* — I sharpen, in allusion to the spiny stipules of many African and Asiatic species. The specific name is derived from the Latin *adsurgens* — ascending or rising up, possibly an allusion to the erect growth habit or ascending branches.

Common name. Mintilpi.

Family. Mimosaceae.

Botanical features. *A. adsurgens* is a multi-stemmed large shrub or shrubby tree, 2–4 m tall and up to 8 m across. Young plants are often bushy, but tend to become open with age. Maximum basal diameter of stems is 10–15 cm. Branch habit is typically ascending. The bark is grey to reddish brown and mostly smooth, but may be rough and somewhat fibrous towards the base on large specimens.

Phyllodes are grey-green to olive green, narrow-linear to linear, 6–20 × 2–4 mm, coriaceous, resinous, with many fine longitudinal nerves and a slightly more prominent central nerve. Flowering occurs between April and June. The dense, perfumed, light golden flower spikes, 10–20 mm long, are on long peduncles 5–15 mm. The pods are sweetly scented and mature between September and November. They are linear 8–10 cm × 2.5–3 mm, raised over the seeds and contracted between them (Pedley 1978). For some time after pod dehiscence the seeds dangle by their long pale yellow arils, no doubt facilitating their dispersal by birds. The seeds are longitudinally arranged, oblong 3–4 × 1.5–2 mm, brown or black. The funicle is folded several times to form a large, oil-rich, helmet-like aril.

The species is described by Pedley (1978) and illustrated by Thomson and Hall (1986).

Natural occurrence. *A. adsurgens* is widespread, but not especially abundant, over a large part of inland

northern Australia. Its main range is inland north-western Australia, central-southern parts of the Northern Territory and northwest Queensland. Outlier populations occur near Jericho and Windorah in central Queensland (Pedley 1978).

- Latitude. Range: 18–26°S
- Altitude. Range: 100–700 m

Climate. This species occurs in warm to hot, semi-arid and arid zones. Summers are hot with the mean maximum temperature of the hottest month (November to February) 36–39°C. The mean temperature of the coldest month is 5–11°C. The more northern localities are frost-free, but over much of the range there is an average of 1 to 11 frosts per year.

The 50 percentile rainfall is 200–500 mm, the 10 percentile 64–340 mm and the lowest annual rainfall recorded ranges between 22–200 mm depending on site. Rainfall is distributed with a weak to moderate summer maximum (mostly from November to February), but in the most southern localities there may be substantial winter (May–June) rainfall.

Physiography and soils. *A. adsurgens* is mostly found on sandplains, interdunal plains and sandy rises, but may also occur in rocky habitats and on gravelly rises and sandy alluviums within floodout zones. The soils are typically deep, well drained, infertile, acidic red sands and sandy loams. Gravel or ironstone fragments are often present. Rocky habitats include lateritic gneiss outcrops, gravel and quartzite slopes; the soils are skeletal, stony sandy loams and loams. Very infrequently it has been recorded on shallow clay loams and clay.

Vegetation type. *A. adsurgens* typically occurs in open plant communities, e.g. open shrubland, open scrub and low open-woodland, with a spinifex (*Triodia* and

Plectrachne)-dominated groundcover. The woody vegetation mainly comprises *Acacia* spp., especially *A. aneura* and *A. tenuissima*, with some eucalypts. Other associated acacias include *A. ancistrocarpa*, *A. atkinsiana*, *A. cowleana*, *A. drepanocarpa*, *A. laccata*, *A. pruinocarpa*, *A. coriacea* and *A. stipuligera*. Associated eucalypts include bloodwoods (e.g. *E. polycarpa* and *E. terminalis)* and mallees (e.g. *E. gamophylla*, *E. odontocarpa*, and *E. oxymitra*). Other associated woody genera include *Senna*, *Codonocarpus*, *Eremophila*, *Grevillea* and *Hakea*.

Utilisation.

Fodder: The species is recorded as palatable to cattle (Chippendale 1958), but it does not appear to be grazed to any extent in its native habitat. Its phyllodes contain cyanogenic glycosides (Conn et al. 1985). However, cyanide levels are low and the species does not appear to possess an endogenous enzyme capable of hydrolyzing the glycosides, and is therefore unlikely to be dangerous to stock (Maslin et al. 1987).

Fuelwood: The wood is very dense (1030 kg/m^3), with a dark brown heartwood and a narrow irregular band of pale sapwood. It is suitable for firewood and for conversion into charcoal. Investigations by the Division of Chemistry and Energy of the CIRAD Forêt (France) indicate its wood produces one of the best charcoals of Australia's tropical arid-zone acacias, giving an adequate yield (35%), high proportion of fixed carbon (90%), high upper calorific value (7960 kcal/kg) and a low ash residue (2.9%).

Wood: The wood is mostly too small for uses other than fuelwood.

Other uses: The species has an excellent potential for amenity plantings, including low shelter and sand stabilisation. Its small seeds and oil-rich arils have potential as a subsistence or famine food source for humans. The seeds are easily harvested and were a traditional aboriginal food source (O'Connell et al. 1983). Aborigines roasted the seeds and then ground them to a paste prior to consumption.

Silvicultural features. This multi-stemmed shrub has been infrequently planted and there is little information on its silvicultural characteristics. Plants flower at

an early age (14–22 months) and produce heavy seed crops during good seasons. It is not especially long-lived (8–20 years), but appears to have a moderate coppicing ability.

A. adsurgens failed on a dry (300–400 mm rainfall) sodic site in northwest Pakistan (Marcar et al. 1991b).

Establishment: The species is readily propagated from seed, and there are about 111 600 viable seeds/kg with an average germination rate of 80%. Seedcoat dormancy is removed by immersing the seed in a large volume of boiling (100°C) water for 30–60 seconds. A nursery phase of 2–3 months is recommended (Ngulube 1988).

Yield: Field observations suggest this species is moderately fast growing. In trials in southeast Queensland (Ryan and Bell 1989) and Niger (L. Thomson pers. comm.) plants grew to 2 m tall in 18–24 months.

Pests and diseases. Although some damage by termites has been recorded in Africa the problem is not serious (Mitchell 1989).

Limitations. Its small size will restrict its use to fuelwood, sand stabilisation and amenity plantings. Its fodder value, including its possible cyanide toxicity to livestock, and human food potential require further investigation.

Related species. *A. adsurgens* is a member of section Juliflorae and appears most closely related to *A. tenuissima* (B.R. Maslin, pers. comm.). Populations intermediate between *A. adsurgens* and *A. stowardii* are present in the Hamersley Ranges of Western Australia.

Acacia ammobia

Main attributes. A small tree, frequently multi-stemmed, suitable for planting on sand dunes or other sandy sites in hot, arid areas. It has potential for soil stabilisation, low open shelter, ornamental planting and fuelwood. It is also a potential source of edible seed, although it is not regarded as a principal species for this purpose.

Botanical name. *Acacia ammobia* Maconochie was first described in *J. Adelaide Bot. Gard.* 1(3): 180 (1978). The specific name appears to be from the Greek *ammobius* — which means dwelling on sand, in reference to the common occurrence of this species on sand dunes.

Common names. None known.

Family. Mimosaceae.

Botanical features. A shrub or small tree 3–6 m tall, with single or several stems, up to 8 m wide. The species is regarded as being relatively morphologically homogeneous. The bark is grey-black in colour. The phyllodes and branchlets are often pruinose. Phyllodes are yellowish green, rigid, flattened, leathery, linear or broad linear with many fine veins, 12–22 cm long by 4–9 mm wide, erect on the branchlets. The inflorescence is a cylindrical spike 2–4 cm long, sessile or with a short stalk. The pod is linear, 12–22 cm long by 4–9 mm wide, slightly raised over and constricted between the seeds. The seeds are longitudinal in the pod, 3–5 mm long by 1–2 mm wide, shiny, dark brown-black with a pale yellow-white terminal folded funicle. Mature seeds have been collected in November.

It is illustrated and more fully described by Maconochie (1978).

Natural occurrence. *A. ammobia* has a very restricted natural distribution in the southwest of the Northern Territory within a radius of about 100 km of Uluru (Ayers Rock).

- Latitude. Range: 23–26°S.
- Altitude. Range: about 450–600m.

Climate. The distribution is in the warm arid climatic zone with hot summers and cool winters. The mean maximum temperature of the hottest month is 37–38°C and the mean minimum of the coolest month 3–4°C. The number of frost days is probably in the range 5–15 per year.

Two meteorological stations within the area have a mean annual rainfall of 182 and 262 mm. The estimated 50 percentile value is about 200 mm, the 10 percentile is near 100 mm, and the lowest on record is 50–75 mm. The maximum rainfall occurs in the summer and there is measurable rain on 30–40 days annually. Drought is a feature of the climate and no month has a mean rainfall above 30 mm.

Physiography and soils. This species occurs in the southwest of the Central Australian Ranges physiographic province. It is limited to the Amadeus Lowland consisting of dunefields and scattered sandstone ranges with some calcrete plains. *A. ammobia* is generally found on the dunes and will grow on dune crests. It occurs less commonly on stony ridges and hills. The soils are shallow sands or deep red earthy sands.

Vegetation type. The main occurrence is in low open-woodland where tree cover is very sparse. *A. ammobia* may be the dominant small tree or shrub in localised areas, or associated with *Allocasuarina decaisneana* in groves between the sand hills. There is a lower stratum of hummock grasses, mainly species of *Triodia* and *Plectrachne*.

Utilisation.

Fodder: Not known to have any value as fodder.

Fuelwood: No data are available, but the wood should be suitable for firewood or charcoal.

Wood: A potential producer of small, round timber for use as posts, poles, or rails.

Other uses: The common occurrence of this species on sand dunes suggests it may have a role in sand stabilisation and erosion control in arid areas. It has potential for low open windbreaks and is an attractive ornamental shrub.

It is rated as a species whose seeds have some food potential (Thomson 1992). *A. ammobia* was used as a source of food (seed and wood-boring grubs) by the Pitjantjatjara aborigines of Central Australia (Devitt 1992).

Silvicultural features. This small, multi-stemmed tree from a remote part of central Australia has been seldom planted. Little is known of its silvicultural characteristics. It is reported to be of moderate longevity (10–50 years). *A. ammobia* flowered early (15 months) and produced a moderate seed crop when planted near Gympie, Queensland (Ryan and Bell 1989). Under natural conditions *A. ammobia* is killed by fire but regenerates profusely from seed in the ground. It is a poor coppicer.

Establishment: There are about 98 100 viable seeds/kg giving 80% germination rate after routine treatment to break seedcoat dormancy.

Yield: A. ammobia has a moderately fast growth rate. Although giving poor survival (30%) when planted on a relatively high rainfall site near Gympie, Queensland, surviving trees attained heights of 5–6 m and basal diameters of 6–8 cm at 4.5 years (Ryan and Bell 1991). Height growth of 1 m in 18 months and survival of 56–83% has been recorded on two sites in Zimbabwe (Gwaze 1989).

Pests and diseases. None are recorded.

Limitations. The small size of this species will limit its use for wood production to fuelwood, small posts and poles.

Related species. *A. ammobia* is related to *A. dorotoxylon* of eastern Australia and *A. lasiocalyx* of Western Australia. *A. dorotoxylon* has phyllodes that are shorter and more falcate than *A. ammobia*, while *A. lasiocalyx* has longer and more flexible phyllodes with prominent central nerve (Maconochie 1978). *A. ammobia* is also related to *A. shirleyi* and *A. petraea*. It is similar to *A. macdonnelliensis* but larger in all respects (Latz 1995).

Acacia ampliceps

Main attributes. A shrub or small tree suitable for warm to hot, semi-arid to arid tropical areas. It is fast-growing and tolerates alkaline, highly saline and sodic soils. Useful for fuel, low windbreaks, sand dune and saline wasteland rehabilitation, and fodder. Seed is edible.

Botanical name. *Acacia ampliceps* B.R. Maslin was first published in *Nuytsia* 1(4): 315 (1974) and is derived from the Latin *amplus* — large, great, an allusion to the large flower heads.

Common names. Salt wattle, jila jila, nyarlka.

Family. Mimosaceae.

Botanical features. A large dense shrub or small tree, 3–9 m tall with 1–4 stems, branches often pendulous and a spreading canopy, 6–12 m wide. The bark is rough grey-brown for 1–2 m from the base, becoming smooth light green-brownish. The canopy is distinctively dark green in colour, the branchlets glabrous and yellowish. Phyllodes are variable in shape, linear to lanceolate, sometimes narrowly obovate, 7–25 cm long and 7–30 mm broad, straight to shallowly incurved, with a prominent yellow midrib, the marginal vein less prominent. A prominent gland is present on the upper margin towards the base of the phyllode.

Inflorescences are arranged in axillary or terminal racemes of globular flower heads. The white or cream flower heads, 7–10 mm in diameter, are produced from May to August (Maslin 1974a). The pods are hard, greyish-brown, 7–9.5 cm long and 5 mm wide, slightly constricted between the seeds, the margins yellow and not thickened. The seeds are longitudinal in the pod, ovate to elliptical or oblong, greyish-brown to black, shiny, 4.5–6.5 mm long by 3–3.5 mm wide, with a scarlet funicle, slightly widened at the apex of the seed, beneath a twisted scarlet aril, which is orange before maturity. The pods mature from late August to November.

The species is described and illustrated by Maslin (1974a), Craig (1983) and Wheeler et al. (1992).

Natural occurrence. Restricted to northwestern Western Australia and the Northern Territory. It occurs along the coast and in scattered localities throughout arid and semi-arid inland areas, including the southern Kimberleys and northern parts of the Northern Territory.

- Latitude. Range: 14–26°S.
- Altitude. Range: near sea level to about 400 m.

Climate. It is found mainly in the warm semi-arid, hot semi-arid and arid zones. It rarely extends to the sub-humid zone. The mean maximum temperature of the hottest month is 32–42°C and that of the coolest 11–14°C. The temperature exceeds 32°C on 44–280 days each year. The area is frost-free.

The 50 percentile rainfall is mainly 250–700 mm, the 10 percentile 60–450 mm, and the lowest on record 15–300 mm. Rainfall distribution has a well developed summer maximum and rain is recorded on an average of 25–110 days. The dry season is 5–9 months but *A. ampliceps* almost invariably occurs on sites that receive additional run-on water.

Marcar et al. (1995) provided the following climatic profile for successful growth; mean annual temp. 21–28°C, mean min. coldest month 8–15°C, mean max. hottest month 29–41°C, mean annual rainfall 225–1360 mm occurring mainly in summer with 0–10 month dry season.

Physiography and soils. *A. ampliceps* occurs in the Western Plateau physiographic division. It is found on the plains and sand dunes of the Western Australian coast. Inland, it is found on sandplains and floodplains and along drainage lines or low-lying plains among rough hilly country (Thomson 1992). The soils are chiefly alluvials, either sandy or clayey (Maslin 1974a) and typically strongly alkaline. The soil types include calcareous earths, grey loams, red earthy sands, and grey, brown, or black cracking clays. One of the most salt-tolerant of northwestern Australian acacias, it grows very close to the tidal zone and in and around inland salt lakes. It will colonise coastal flats in associations with shrubby grassworts (*Halosarcia* spp.).

Vegetation type. *A. ampliceps* is most frequently found in fringing communities along drainage lines associated with *Melaleuca bracteata*, and species of *Lysiphyllum*, *Terminalia* and *Eucalyptus*. It is also found in chenopod shrublands in coastal Western Australia and in acacia-dominated open-shrubland elsewhere in Western Australia and the Northern Territory. It also grows in eucalypt woodland and open woodland.

Utilisation.

Fodder: Potential supplement for cattle, goats (Pakistan) and sheep (Marcar et al. 1995).

Fuelwood: It is a good fuel burning with great heat and leaving a fine grey ash.

Wood: Hard and tough with an air dry density of 660 kg/m^3. Has potential for posts and small poles.

Other uses: It has been used extensively for secondary dune rehabilitation and on rocky coastal sites in north-western Western Australia (B. Hastings, pers. comm.). Has potential for reclamation of salt-affected sites and as a low windbreak. The seeds are utilised for food by Australian aboriginal people in northwestern Australia (Devitt 1992). The seed is generally ground to paste, but the rather soft-coated mature seeds may be chewed without preparation (Thomson 1992).

Silvicultural features. A moderate to fast-growing small tree, which may have a short life span.

A. ampliceps has a shallow root system. It is intolerant of frost, acid soils and waterlogging but establishes well in highly saline, sodic and alkaline soils. Marcar et al. (1995) advise to expect reduced growth at EC_e about 10–15 dS/m with reduced survival above about 20 dS/m on saltland.

It can spread by root-suckering (C. Malcolm, pers. comm.) and coppices well. Flower buds were observed on planted specimens in Queensland as early as 11 months and small seed crops were produced in the second year (Ryan and Bell 1989). Mature specimens can yield about 0.5–2 kg of seed/year.

Establishment: There are 33 900 viable seeds/kg of about 90% germination rate after routine treatment to break seedcoat dormancy (Craig 1983). Direct seeding has been successful on saline and other sites in Pakistan. Inoculation with a salt-tolerant rhizobia strain may improve N-fixation under saline conditions (Zou et al. 1995).

Provenance variation in growth rate, form, survival and salt tolerance (Aswathappa et al. 1987) has been recorded (N. Marcar, pers. comm.).

Yield: In species' trials in several countries (Turnbull 1991), *A. ampliceps* gave an mean annual increment (MAI) for height of 1 m/year (range 0.36–1.88) and an MAI for diameter of 1.3–4.9 cm. On saline, sodic soils in northwest Pakistan it reaches 3.1 m in height in 28 months from sowing (Hussain and Gul 1991). Survival, however, was often disappointing (< 50%) indicating that the species requires a well-matched site for best development. The survival and growth of *A. ampliceps* was greatly enhanced by the addition of mulch, gypsum and fertiliser to a saline site in northeast Thailand (Marcar et al. 1991b).

Pests and diseases. This species seems to be particularly susceptible to insect attack in Australia (Maslin 1974a). A range of stem-borers, sap suckers and defoliators were reported to cause minor to occasional severe damage to young trees planted near Gympie, Queensland (Ryan and Bell 1991). Older specimens are prone to mite and spider mite attack (B. Hastings, pers. comm. 1984).

Limitations. The small size of the tree will limit the utilisation of the wood to fuel, posts, and small poles. Grows poorly in acid soils.

Related species. *A. ampliceps* hybridises naturally with *A. bivenosa*. This hybrid has performed exceptionally well in a trial on a very harsh site in Sumba (Indonesia). It is also allied to a group of species including *A. ligulata*, *A. rostellifera*, *A. salicina*, *A. sclerosperma*, and *A. xanthina* (Maslin 1982).

Acacia aneura

Main attributes. A bushy nitrogen-fixing shrub or small tree up to about 15 m, which grows in arid and semi-arid areas on a range of well drained, infertile soils. It has potential for erosion control, shelter, animal forage, fuelwood and ornamental purposes.

Botanical name. *Acacia aneura* F. Muell. ex Benth. The species name was first published in *Linnaea* 26: 627 (1855) and comes from the Greek words *a* — not and *neuron* — a nerve, in allusion to the absence of conspicuous veins on the phyllodes.

Common names. The standard trade name is mulga. 'Mulga' is an Aboriginal word for a long narrow shield made from acacia wood.

Family. Mimosaceae.

Botanical Features. *A. aneura* occurs as a tree 10–15 m tall, often single stemmed in higher rainfall areas, but is a stunted low shrub 2–3 m tall in very dry situations or where it occurs on very shallow or calcareous soils. Its form and phyllode morphology are exceptionally variable (Midgley and Gunn 1985). Some of the variants appear to be associated with polyploidy, others with particular habitats.

The bark is dark grey and fissured and the branchlets are angular and occasionally resinous and shiny. Phyllodes 2–25 cm long and 1–12 mm broad, terete to flat, often silvery scurfy, straight or curved, leathery, with many fine, obscure parallel nerves. Flowers in dense cylindrical spikes, 1.5–2 cm long. Pods are flat, papery, thin, very obtuse, usually with an obvious wing along the edge, 2–5 cm long and 7–15 mm wide. Seeds ovate, longitudinal or slightly oblique in the pod, more or less flattened, 3–5 mm long and 2–4 mm wide, dark brown with a small, pale membranous aril. Flowering depends upon favourable weather conditions and only late summer flowering followed by winter rain leads to seed set (Davies 1976). The seed is shed October–December.

The species was described by Pedley (1978) and illustrated by Maslin (1981). Examples of variation in growth form are depicted by Boomsma and Lewis (1980) and Whibley and Symon (1992).

Natural occurrence. The major distribution is in central and southern Australia near the coast of Western Australia to western areas of Queensland and

New South Wales; it is absent or sparse in the Simpson and Great Victoria Deserts.

- Latitude. Range: 21–33°S.
- Altitude: Range: near sea level to about 1000 m.

Climate. The distribution is mainly in the arid climatic zone, although in southern Queensland and northern New South Wales it extends over much of the semi-arid zone. For the principal occurrence, the mean maximum temperature of the hottest month is 36–40°C, with the mean minimum temperature of the coolest month 5–8°C. In the hottest parts, the average number of days per year over 32°C exceeds 150, and there are 50–75 days above 38°C. None of the area is frost-free. The average number of frosts per year is 1–12 and the temperature can fall to −7°C on rare occasions. The duration of frost and its frequency is greater in the south.

The 50 percentile rainfall in the arid zone is mainly 200–250 mm, the 10 percentile about half that and the lowest on record mainly 50–60 mm. The corresponding values for semi-arid areas are 300–500, 175–300, and 100–135 mm. In many of the drier parts of its distribution *A. aneura* receives substantial run-on water (Winkworth 1983). Seasonally rainfall shows a summer maximum on northern boundaries, but southern margins have a well-defined winter maximum. Drier inland localities have a more or less uniform distribution.

Physiography and soils. Mulga grows most plentifully on flood and erosional plains and in broad valley heads, and only occurs scattered on hill slopes and ridges. In sandridge deserts it may occur in the sand in the dune swales. Soil types vary but the denser stands are usually found on red earths and sands or red clayey sands and, sometimes, on sandy gravels. It is found only scattered on less favourable soils such as lateritic and calcareous crusts or those of a markedly skeletal nature.

Vegetation type. *A. aneura* is a dominant species of the woody vegetation in arid and semi-arid zones (Williams 1979). Most stands are in low open-woodland or in tall open-shrubland. Scattered specimens are also found in grassy open-scrub or open-shrubland, with mallee-form eucalypts.

Utilisation.

Fodder: Mulga forms a significant part of the dry-range diet of sheep in Australia but without supplementary high quality feed it is barely sufficient for maintenance (Goodchild and McMeniman 1987). Phyllodes have a high crude protein level (11–16%) and good palatability (Vercoe 1987). Excessive grazing may result in the death of mulga.

Fuelwood: It makes excellent firewood and charcoal (Bateman 1962).

Wood: The heartwood is dark brown with contrasting markings of golden yellow; the sapwood is white. The wood is hard, heavy, and durable in the ground; it turns well and takes a high polish. It is easy to work when green but becomes hard when dry and rarely splits. It has been used extensively for fence posts.

Other uses: Mulga can be used in arid areas to provide shelter and shade; its attractive silvery grey foliage makes it a popular choice for amenity plantings. The Australian Aborigines ground the mulga seed for flour (Caffin et al. 1980). Aborigines also used the resinous phyllodes of the desert mulga form as an adhesive resin.

Silvicultural features. A long-lived (50 years) but slow-growing species. *A. aneura* is sensitive to fire (Gill 1975). *A aneura* forms nodules with rhizobia with which it exhibits a degree of specificity (Roughley 1987). Ectomycorrhizal associations have been observed and there is almost certainly VA mycorrhizal symbiosis (Reddell and Warren 1987). Careful attention to seed sources is required and co-ordinated provenance trials are in progress in several countries (Midgley and Gunn 1985).

Establishment: For good germination, seed (65 800 viable seeds/kg) should be scarified mechanically or immersed in hot water (90°C) for 1 minute (Doran and Gunn 1987). In 10 days germinated seedlings can be transplanted into pots (Kube 1987).

In the nursery seedlings often take 6–8 months to reach 20 cm tall. When transplanted to the field the seedlings usually require several months without severe moisture stress to survive and in arid areas may need supplementary irrigation. Established seedlings have the ability to survive severe drought. They develop a long tap root and an extensive lateral root system in the top 30 cm of the soil. *A. aneura* needs to be protected from browsing animals while young.

Yield: Growth rate is generally slow but is related to moisture conditions. In central Australia planted specimens receiving an average of 370 mm of rainfall a year grew in 10 years to multi-stemmed shrubs 3 m tall and 2–4 cm dbh with a crown diameter of 2 m (Kube 1987). Cultivated specimens receiving regular irrigation have reached 10 m tall and 10 cm dbh in 10 years. In trials where rainfall is relatively high, the Charleville (Queensland) provenance, a broad phyllode form, has grown more rapidly than provenances from central Australia (Ryan and Bell 1989).

Pests and diseases. In its natural habitat *A. aneura* is subject to partial defoliation by a range of insects and root damage by termites. Termite damage was light (4% mortality) to moderate (30%) for two provenances aged 18 months in a trial in Zimbabwe (Mitchell 1989).

Limitations. The slow growth rate and a very limited capacity to regenerate vegetatively after fire, and excessive browsing or cutting may limit the use of *A. aneura*. It is unlikely to become a weed.

Related species. *A. aneura* is closely related to *A. ayersiana* and *A. catenulata*. The *A. aneura* complex is presently under revision and several new taxa are to be formally described from forms that are presently recognised as *A. aneura* (L. Pedley, pers. comm.).

*Acacia aulacocarpa**

Main attributes. A hardy, fast-growing, nitrogen-fixing tree capable of tolerating a wide variety of infertile sites. It has shown great potential for wood production in the humid–sub-humid tropics. The wood is attractive for joinery. It makes a good fuel and appears suitable for chemical pulping.

Name. *Acacia aulacocarpa* A. Cunn. ex Benth. was published in the *London J. Bot.* 1: 328 (1842). The specific name is from the Greek *aulakos* — a furrow and *carpos* — fruit and refers to prominent furrowing and thickened transverse bands on the pod.

Common names. Brown salwood (standard trade name), brush ironbark wattle, Papua New Guinea brown wattle, hickory wattle, black wattle.

Family. Mimosaceae.

Botanical features. Two varieties are presently recognised. Var. *fruticosa* is a bushy shrub to 3 m tall and var. *aulacocarpa* is usually a tree 10–20 m tall but ranges from a shrub of 4 m on xeric sites to a large tree to 40 m tall and 1 m diameter often with a somewhat fluted trunk, in tropical rainforest. Young bark is greyish and relatively smooth but later becomes darker grey and deeply furrowed. Var. *aulacocarpa* has phyllodes grey-green or dull grey, 7–15 cm long and 1–3 cm wide, usually sickle-shaped tapering to a point at the tip and gradually into a stalk at the base. There are 3–7 conspicuous longitudinal nerves of which the lower ones merge with the margin. The closely-packed finer veins are parallel. The flowers are pale to bright yellow in spikes 2–7 cm long, singly or up to three on short stalks. The pods are up to 10 cm long, 1–2 cm wide, oblong, woody with prominent, oblique veins and twisted when old. Seeds are transverse in the pod, black and shiny, 3–7 mm long by 2–4 mm wide, with a pale, creamish terminal aril. In the tropics peak flowering time is April–July and in the subtropics it is August–September. The fruits mature September– December.

Species descriptions are given by Pedley (1978), Floyd (1979) and Boland et al. (1984). Thomson (1994) has proposed five informal subspecies from what is presently called var. *aulacocarpa*. The raising of var. *fruticosa* to specific rank was also recommended.

* *A. aulacocarpa* is presently undergoing taxonomic revision. Therefore, the understanding of taxa within this complex will change.

Natural occurrence. The species extends from northern New South Wales through eastern and northern Queensland, the Top End of the Northern Territory and northwestern Australia, and into southern New Guinea. A map showing the distribution of the different subspecies/variants is given by Thomson (1994). Var. *fruticosa* has a restricted distribution in southeastern Queensland.

- Latitude. Range: 6–31°S
- Altitude. Range: near sea level to 950 m.

Climate. The main distribution is in the warm to hot, humid and sub-humid zones of the tropics and subtropics. The mean maximum temperature of the hottest month is in the range 28–39°C and the mean minimum of the coolest 4–22°C. Frosts are absent from most of the area but at the highest altitudes, especially in the south, there may be 1–5 per year.

The 50 percentile rainfall is mainly in the range 900–1500 mm, but may be as low as 500 mm in the driest northern area, the 10 percentile is 550–1100 mm and the lowest on record 375–500 mm. The northern areas of occurrence have a strongly-developed monsoonal pattern with rainfall concentrated from December–March; southern areas have a more uniform distribution but with a well-developed summer maximum.

Pysiography and soils. This species grows on a wide range of topography including undulating highlands, ridges, and steep rocky slopes, but most commonly on the flats and gently undulating terrain of coastal plains and foothills. The soils include deep sands, stabilised lateritic sand dunes, lateritic podsols, hard gravelly clays, red earths, friable loams and humus-rich loams. The soils are freely to imperfectly drained, usually acid or very acid and of low to moderate fertility.

Vegetation type. *A. aulacocarpa* is one of the few acacias found in rainforest. In the wet foothills and uplands of north Queensland it occurs as a tall emergent over an understorey of rainforest species or on rainforest margins. It is often associated with *Eucalyptus pellita*, *E. intermedia*, *Acacia cincinnata*, *A. mangium* and *A. polystachya*. On the swampy coastal plains of northeastern Australia and southwest Papua New Guinea it occurs with monsoon vine forest species and acacias such as *A. mangium* and *A. crassicarpa* between wet depressions dominated by *Melaleuca* spp. On drier sites in northern Australia it occurs in open-forest, low open-forest or woodland.

Utilisation.

Fodder: Foliage has low levels of dry matter digestibility and protein (Vercoe 1987) giving it limited potential as a fodder species (Berger 1971).

Fuelwood: The wood dries rapidly (Gough et al. 1989), splits easily and is an excellent fuel.

Wood: The narrow sapwood is pale yellow-brown and the heartwood pale olive-brown, grey brown, or golden brown. It is hard, strong and moderately heavy with basic density of about 570 kg/m^3 and an air-dry density of 645–720 kg/m^3 (Eddowes 1978; Keating and Bolza 1982). The sapwood is susceptible to attack by *Lyctus* borers and the heartwood has low to moderate durability in ground contact. It is suitable as light structural and flooring timber, for boat building, furniture and cabinet work, joinery and turnery (Keating and Bolza 1982). It has excellent potential as a source of fibre for pulping and papermaking industries (Clark et al. 1991).

Other uses: Woodland forms cast a light to moderate shade, which makes it useful for amenity and ornamental plantings in the tropics.

Silvicultural features. This is a relatively long-lived (> 30–40 years) acacia. Provenance variation is substantial. Tropical provenances are likely to be of most interest commercially. Provenances in the Northern Territory and on harsh sites on Cape York display a more stress-adapted growth habit than origins from more mesic sites in north Queensland and New Guinea. The latter sources have shown potential for plantation development on both *Imperata* grasslands and ex-forest sites in Southeast Asia where the species prefers deep

loamy soils and high rainfall (>1500 mm). *A. aulacocarpa* does not coppice well, but there are reports that trees from Queensland coppice better than those from Papua New Guinea (Visaratana 1991). Woodland forms may sucker from the roots (Berger 1971).

Establishment: Propagation is generally by seed although air layering and rooted cuttings are also possible. There are 43 300 viable seeds/kg. A germination rate of about 65% is usual after dormancy-breaking treatment. Nursery and silvicultural treatments described for *A. mangium* apply.

Yield: A. aulacocarpa has shown considerable variation in growth and yield. In general, provenances from Papua New Guinea grow much faster than those from Australia. At a planting site in southern Thailand, a seedlot from Oriomo, PNG produced above ground biomass of 103 dry t/ha in three years, twice as much as that produced by Queensland provenances (Visaratana 1989). PNG provenances have also shown satisfactory growth in Sabah. Trees attain 12–16 m in height and 11–14 cm in diameter in four years (Sim and Gan 1991).

Pests and diseases. There are no records of serious damage by pests and diseases.

Limitations. Sensitive to frosts and damage by cyclonic winds. Its tendency to have fluted stem may reduce its value for some purposes.

Related species. Closely related to *A. crassicarpa* and *A. wetarensis*. Occasional natural hybrids with *A. mangium* and *A. crassicarpa* have been recorded in New Guinea (L. Thomson, pers. comm.).

Acacia auriculiformis

Main attributes. Few other species can match the ability of *A. auriculiformis* to grow on harsh sites in the tropics. Its rapid early growth rate, ability to fix nitrogen, tolerance of infertile, acid, alkaline, saline or seasonally waterlogged soils and moderate dry seasons make it a very useful species for the rehabilitation of degraded lands. It has been widely planted for fuel-wood production, erosion control, ornament or shade mainly in Asia but also in Africa and South America. The stem form can be improved significantly by selection and breeding, providing outstanding prospects for industrial plantations to produce paper pulp and other timber products.

Botanical name. *Acacia auriculiformis* A. Cunn. ex Benth was published in Hooker's *London J. Bot.* 1: 377 (1842). The specific name comes from the Latin *auricula* — external ear of animals, *forma* — form, figure or shape, in allusion to the shape of the legume.

Common names. Northern black wattle (Australian standard trade name); others include: ear-pod wattle, Darwin black wattle, tan wattle; ngarari, unar (Papua New Guinea); kasia (Indonesia); Australian babul (India) and Japanese acacia (Philippines).

Family. Mimosaceae.

Botanical features. On favourable sites in its natural habitat *A. auriculiformis* grows into a tree 25–30 m tall with a straight bole dominant for a greater part of tree height. More commonly it is a tree of 8–20 m, heavily branched and with a short bole. Bark is grey or brown, smooth in young trees, becoming rough and longitudinally fissured with age.

The phyllodes are straight or falcate, 8–20 cm long and 1.1–4.2 cm wide. There are 3 prominent longitudinal nerves running together towards the lower margin or in the middle near the base, with many fine crowded secondary nerves, and a distinct gland at the base of the phyllode (Pedley 1975, 1978). The bright yellow flowers are in spikes to 8 cm long in pairs in the upper axils. The pods are flat, flexible but hard, rather woody, glaucous, transversely veined with undulate margins. They are initially straight or curved, but on maturity become very twisted and irregularly coiled, about 6.5 by 1.5 cm. Flowering is usually from June–July, and ripe seed is available September–October. The seeds, held transversely in the pod, are broadly ovate to

elliptical, 4–6 mm long by 3–4 mm wide, and each is encircled by a long red, yellow or orange funicle.

The botanical characteristics are illustrated in Little (1983), Boland et al. (1984) and Brock (1988) and fully described by Pedley (1978). Pinyopusarerk (1990) provides an annotated bibliography.

Natural occurrence. Natural stands of *A. auriculiformis* are found in Australia, Papua New Guinea, and Indonesia. In Australia it occurs on Cape York Peninsula and in Torres Strait, Queensland, and in the north of the Northern Territory including several off-shore islands (Boland et al. 1990). In Papua New Guinea it occurs in Central and Western Province and extends into Irian Jaya and the Kai Islands of Indonesia.

- Latitude. Main occurrence: 8–16°S.
  Range: 5–17°S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 400 m.

Climate. The natural occurrence is in the hot humid and hot sub-humid climatic zones. The mean maximum of the hottest month (November or December) is within the range 32–34°C and the mean minimum of the coolest month is 17–22°C. In general, there are many days over 32°C but very few over 38°C. There are no frosts.

In Indonesia and Papua New Guinea *A. auriculiformis* occurs where the mean annual rainfall is about 1400 mm but with a high of 3400 mm at one site in PNG (Boland et al. 1990). In Australia the 50 percentile rainfall is 1000–1500 mm with the 10 percentile about 700–1000 mm. A lowest-on-record rainfall of 450–500 mm has been recorded. The average number of days where there is measurable rain is 89–100 per year. The rainfall has a monsoonal pattern, with most falling (November) December– March (April).

Physiography and soils. In Australia *A. auriculiformis* grows on dissected lateritic lowlands and alluvial coastal plains. Occurrences in the Northern Territory are along drainage channels just above the tidal range, on the edges of sand dunes, behind mangrove swamps, and along river levees. In Queensland it is mainly restricted to river banks and drainage lines. The soils are frequently yellow earths but vary from dune sands and sandy loams to alluvials with a high clay and humus content. It can also tolerate highly alkaline and saline soils.

The occurrences in western Papua New Guinea and Irian Jaya are mainly on the relict alluvial plain known as the Oriomo Plateau. They are on shallow well drained sandy loam overlying heavy clay or imperfectly drained soils subject to temporary or prolonged flooding in the wet season. These soils are strongly acid and of poor fertility with low values for nitrogen, exchangeable potassium and available phosphorus (Bleeker 1983).

Vegetation type. *A. auriculiformis* in Australia tends to grow in very narrow belts where it may be dominant or one of the principal species. It also occurs in small pockets in depressions or along drainage lines in open-forest dominated by various eucalypts and acacias. It is found in littoral rainforest behind either mangroves or coastal dunes.

On the Oriomo Plateau of PNG this acacia is common on the floodplains and levees of Bensbach and Morehead Rivers. Elsewhere it occurs as scattered trees in the riparian habitats, tall savannah woodland and in tall open-forest (monsoon forest). It is a component of swamp forest, dominated by *Melaleuca* species, usually on the less poorly drained sites. It is also common in littoral forest. Regular associates in these forests include *Acacia mangium*, *A. aulacocarpa* and *Melaleuca cajuputi* (Boland et al. 1990; Paijmans et al. 1971; Skelton 1987).

Utilisation.

Fodder: Not recognised as a fodder species but in India and Fiji trees may be browsed by cattle (Banerjee 1973; L. Thomson pers. comm.). Preliminary study of fodder values has shown that *A. auriculiformis* meets the minimum requirements for certain nutrients and warrants further investigation (Vercoe 1989).

Fuelwood: It has a high basic density and a calorific value of 4700–4900 kcal/kg, which make it ideal for firewood and charcoal. The charcoal is not too heavy, and glows well with no smoke or sparks (Wiersum and

Ramlan 1982). The physical properties, calorific value and burning properties are described by Yantasath et al. (1993). In Asia and Africa it is planted for fuelwood. The annual fall of leaves, twigs, and branches can amount to 4–6 t/ha, which is useful as household fuel (NAS 1983).

Wood: The sapwood is yellow and the heartwood light brown to dark red; the timber is fine-grained, often attractively figured and finishes well (Keating and Bolza 1982). The basic density is 500–650 kg/m^3. The fibre is relatively short, about 0.85 mm in length and 0.2 micron in width. The wood of *A. auriculiformis* makes attractive furniture. It is also suitable for construction work (e.g. framing, flooring), wood turning and carving. Boards may sometimes split when sawn. The crooked and multiple stems which are a common feature of the species largely restrict its use as poles or other forms of timber that require reasonable length. The heartwood is typically hard and durable, but the sapwood is highly susceptible to termite and borer attack and requires preservative treatment when in contact with the soil.

Plantation-grown trees have been found to be very promising for the production of unbleached kraft pulp (for bags, wrapping paper, linerboard) and high quality neutral sulfite semichemical pulp (for corrugating, medium and higher-grade packaging-type products) (Logan 1987). The sulfate process with 13% alkali yields up to 55% of screened pulp. It is less suitable for high-yield mechanical type pulps (Phillips et al. 1979) although there is very significant variation in pulp-making properties between provenances (Logan

1987). Large-scale plantations have already been established in Karnataka, India for the production of paper pulp. The chemical composition of wood is 59% cellulose, 24% lignin, 19% pentosan and 0.4% ash. Flavinoid substances are also present.

Other uses: The bark has sufficient tannins (about 13%) for possible commercial exploitation (Abdul Razak et al. 1981). A natural dye, used in the batik textile industry in Indonesia, is also extracted from the bark. Lac insect culture using the species as host plant is possible. Edible mushrooms occur in plantations in Thailand and Vietnam. Its flowers are a source of bee forage and contribute to honey production (Moncur et al. 1991a).

Though not widely used in agroforestry systems because of its spreading and competitive surface rooting habit, intercropping *A. auriculiformis* with peanut, rice and kenaf has proved to be successful. It has been used satisfactorily as a nurse tree in tea plantations. *A. auriculiformis* is sometimes planted in mixture with eucalypts and other trees which do not fix nitrogen to maintain or improve soil fertility. Its leaves (phyllodes) are good for soil mulching.

This species is planted to provide shelter along the sea-front and to revegetate mining spoil heaps. The spreading, densely-matted root system stabilises eroding land. It has been used widely in revegetation of degraded land and rehabilitation of grassland in India, Indonesia and Vietnam. This acacia is used for shade and ornamental purposes in cities where its hardiness, dense foliage and bright yellow flowers are positive attributes.

Silvicultural features. A fast-growing species adapted to a wide range of soil types from light sands to heavy clays, often of low fertility. It has a superficial root system, which enables it to grow satisfactorily on shallow soils, and it will tolerate prolonged flooding due to its ability to cope with an oxygen deficiency (Verhoef 1943). Pot trials over a pH range 4.3–8.0 indicated that seedlings grow equally well in acidic, neutral, or alkaline soils (Hu et al. 1983) and in northern Australia and the Philippines it has grown on acid mine spoil (pH 3) and sand dunes with an alkaline (pH 9) reaction (NAS 1980). In West Timor it is one of the best species for cultivation on highly alkaline soils (McKinnell and Harisetijono 1991). It is also amongst the best performing acacias on low to moderately saline seasonally waterlogged soils in southeastern Queensland, and northeastern Thailand (Marcar et al. 1991b). On these sites annual height growth ranges from 0.5–1.5 m and survival from 20–100% depending on site quality.

A. auriculiformis can fix nitrogen after nodulating with a range of *Rhizobium* and *Bradyrhizobium* strains in many tropical soils. In the Philippines, 52–66% of nitrogen uptake was shown to be derived from nitrogen fixation (Dart et al. 1991). This nitrogen-fixing potential may only be realised in many soils if adequate fertiliser, especially phosphorus, is applied. *A. auriculiformis* has associations with both ecto- and endo-mycorrhizal fungi. The ecto-mycorrhizal fungus, *Thelephora* spp., forms a beneficial association, and several species of vesicular arbuscular mycorrhizas including *Glomus etunicatum* and *Gigaspora margarita* have been shown to be effective (Dart et al. 1991; dela Cruz and Umali-Garcia 1992).

A. auriculiformis exhibits marked genetic variation. Isozyme studies indicate that weight should be given to both intra- and inter-population genetic variability in initial selections in domestication programs of this species (Wickneswari and Norwati 1991). Estimates of genetic distance between populations show three distinct groups of populations corresponding to the geographic distribution of the species in Queensland, Northern Territory and Papua New Guinea. These regional groupings were also apparent in differences in seedling morphology (Pinyopusarerk et al. 1991). The poor stem form of *A. auriculiformis* is a major drawback limiting wider utilisation of the species. Provenances from Queensland appear to have a higher proportion of straight stems. The 3-year performances of 25 provenances in trials on 7 sites in 4 countries was reported by Awang et al. (1994). Of the 8 provenances with high vigour and good form, 4 were from Queensland, 2 from the Northern Territory and 2 from Papua New Guinea. Several countries have genetic improvement programs which aim to produce better quality seed for future planting programs. A seed orchard has been established on Melville Island in the Northern Territory of Australia. Results of this work are promising (Harwood et al. 1994). Provenance variation in salt and waterlogging tolerance has been noted in pot trials (Marcar et al. 1991a).

Establishment: It produces large quantities of seed at an early age; flowering usually starts within 2–3 years. The species is predominantly outcrossing (Khasa et al. 1993; Moran et al. 1989c). The yellow flower spikes are found on the tree throughout the year but there is a distinct peak flowering season. Pollination is by insects and the fruits mature 4–5 months after flowering. There are about 71 600 viable seeds/kg. Mature seeds require a pregermination treatment, such as mechanical scarification of the seedcoat or immersion in boiling water (1 minute immersion is suitable), to break dormancy (Doran and Gunn 1987). Germination is rapid after suitable treatment and typically exceeds 70%. Nursery methods are described in Chapter 4. In general, 3–4 months are needed to raise seedlings to plantable size (25 cm in height). Inoculation with appropriate rhizobia may be beneficial especially when seedlings are raised in sterilised media or planted on highly degraded soils or minespoil. Research into vegetative propagation of *A. auriculiformis* has been carried out, but results to date are still preliminary (see papers in Carron and Aken 1992 and Turnbull 1991).

Plantations can be established using containerised seedlings or by direct sowing, although the latter has achieved only limited success (Banerjee 1973; Wiersum and Ramlan 1982). Containerised seedlings generally give higher survival especially in areas where there is heavy weed competition. Aerial seeding has sometimes been successful but appropriate site preparation prior to sowing is required. Profuse natural regeneration may appear after fire or on disturbed sites in the absence of severe weed competition.

The optimum spacing for *A. auriculiformis* depends on the product required and management considerations. Most current plantings employ spacings of 1 × 1 m to 4 × 4 m. Spacings of 1 × 2 m and 1.5 × 1.5 m are favoured by farmers in China producing fuelwood and poles.

A. auriculiformis has the ability to coppice; however, it is not a vigorous or prolific sprouter so careful management is required to get good results. Stump height has been shown to be an important factor in sprouting; better results are obtained when stumps are cut 60–100cm from ground. Age or stump diameter and season of cutting also effect coppicing ability (Huang and Zheng 1993). The species also responds well to pollarding. Removal of lower branches of young plants has been suggested as a means of improving stem form.

Yield: A. auriculiformis has shown excellent growth under plantation conditions and an increment in height of 2–4 m per year in the first few years is common even on soil of low fertility (see papers in Boland 1989 and Turnbull 1991). Under optimal conditions, *A. auriculiformis* is very vigorous and reaches 15–18 m tall and 15–20 cm diameter at age 10–12 years. On relatively fertile Javanese soils receiving over 2000 mm annual rainfall, a mean annual increment (MAI) of 15–20 m^3/ha is possible but on less fertile or highly eroded sites the increment is reduced to 8–12 m^3/ha (Wiersum and Ramlan 1982). Yield is further reduced on sites where low rainfall or a prolonged dry season is a limiting factor. The expected MAI, without fertiliser, on red lateritic soils in a semi-arid area of India is 2–6 m^3/ha (Banerjee 1973). On *Imperata* grasslands and very infertile soils *A. auriculiformis* will usually grow faster than species of *Albizia*, *Eucalyptus*, *Leucaena* and *Pinus*.

Pests and diseases. There are several insect pests and diseases of *A. auriculiformis* but none is limiting to establishment on appropriate sites at present (Day et al. 1994). In Indonesia, growth rate has been impaired by a rust fungus, *Uromyces digitatus*; in India root rot caused by *Ganoderma lucidum* has been reported (Wiersum and Ramlan 1982). Seedlings in the nursery can be infested by powdery mildew, especially where there is excessive shading. A beetle, *Sinoxylon* sp., can girdle small stems or branches. This insect is of concern because if the main stem is damaged the tree will develop multiple leaders and reduce the length of clear bole. In Australia the wood is attacked by borers and termites, and scale insects are prevalent on young trees (Hearne 1975).

Limitations. The crooked stem form and tendency to multiple leaders of trees in plantations currently limit their utilisation for poles and heavy construction timber. Careful selection and introduction of better-formed provenances should minimise this drawback in the future. The relative sensitivity of young trees (< 18 months) to fire, weak coppicing ability, weed potential and susceptibility of stressed trees to insect attack are other limitations.

Related species. *A. auriculiformis* is related to *A. polystachya*, *A. cincinnata* and *A. spirobis* subsp. *solandri* and more distantly to *A. aulacocarpa* and *A. crassicarpa* (Pedley 1975). Hybridises readily with *A. leptocarpa* in cultivation (Pinyopusarerk 1993). Natural hybridisation of *A. auriculiformis* and *A. mangium* has been observed in natural stands and plantations. Many hybrids have shown commercially desirable characteristics. Aspects of seed production and vegetative propagation of the hybrids are covered in papers in Carron and Aken (1992).

Acacia brassii

Main attributes. A nitrogen-fixing small tree or shrub, which grows quickly on infertile sandy sites in tropical hot humid climates. Has potential for fuel-wood or low shelter.

Botanical name. *Acacia brassii* Pedley in *Contrib. Qd Herbarium* 15: 6 (1974). The species name honours L.J. Brass (1900–71), a notable Australian plant collector, taxonomist, and explorer.

Common names. None known.

Family. Mimosaceae.

Botanical features. This acacia is a shrub or small tree usually 4–10 m in height. The bark is dark, hard, and furrowed. The branchlets and phyllodes of young plants have a somewhat dense covering of short white hairs and sparse, shorter brown hairs.

The mature phyllodes are narrowly ovate, falcate, usually 13–19 cm long by 2–3 cm wide. There are 3 conspicuous longitudinal nerves and the remainder are faint and strongly reticulated. The flowers are in spikes about 5 cm long, either singly or in pairs in the upper axils. The pods are linear, more or less straight, acute, sometimes with long points, up to 13 cm long and 2–3 cm wide, raised over the seeds, and contracted between them. The seeds are arranged longitudinally in the pod, 3–3.5 mm long by about 1.5 mm wide with a small terminal aril. The seeds mature in September–October.

A more detailed botanical description is given by Pedley (1974a, 1978).

Natural occurrence. *A. brassii* is found primarily on the eastern side of Cape York Peninsula north of Princess Charlotte Bay. Its occurrence in association with *Melaleuca viridiflora* has been mapped by Pedley and Isbell (1970).

- Latitude. Range: 11–15°S.
- Altitude. Range: near sea level to 200 m.

Climate. Most of the area is in the hot humid climatic zone but it fringes on the sub-humid zone. The mean maximum temperature of the hottest month is 30–33°C and the mean minimum of the coolest month ranges from about 17°C for the higher inland location to about 22°C for sites near sea level. The temperature rarely exceeds 38°C and the whole area is frost-free.

The 50 percentile rainfall is mainly 1150–1800 mm, the 10 percentile 650–1200 mm, and the lowest on record 500–850 mm. There is a strong monsoonal pattern of rainfall with most rain in the period December–March. The average number of raindays each year is 85–105.

Physiography and soils. The distribution is in the Peninsular Uplands physiographic province on topography which is gently undulating or flat. It also occurs on stream banks. The soils are deep sandy bleached grey earths, gleyed podzolics and neutral solodics derived from soft sandstone or alluvium. They are low in nutrients and seasonally very wet.

Vegetation type. *A. brassii* mainly occurs in the more open areas of mixed tropical low woodland or in low open-forest. It forms distinct communities with *Melaleuca viridiflora* in which *Grevillea glauca* is also usually present. *E. polycarpa* is fairly common but other eucalypts are less frequent (Pedley and Isbell 1970). Associated small trees and shrubs include *A. flavescens*, *Allocasuarina littoralis* and *Petalostigma banksii*. In the northern part of Cape York Peninsula, *A. brassii* and *A. rothii* are the commonest acacias (Pedley 1978).

Utilisation.

Fodder: Not known.

Fuelwood: The small-sized, dense wood is potentially suitable for fuel.

Wood: Not used in Australia; properties unknown.

Other uses: It is used for mine rehabilitation work in northern Queensland (Langkamp 1987). *A. brassii* has potential to provide low shelter on appropriate sites.

Silvicultural features. A small tropical tree that grows rapidly when young and tolerates soils of low fertility, which are seasonally very wet. It tolerates a long dry-season but appears to require reasonable levels (> 1000 mm) of precipitation in the wet season to succeed. The species is a very poor self-pruner and coppicer; *A. brassii* failed to resprout when cut near the ground and at 0.5 m and gave only poor reshooting at 1.0 m (Ryan and Bell 1989).

Establishment: Flower buds were observed as early as 15 months on planted specimens (Ryan and Bell 1989). There is an average of 104 500 viable seeds/kg providing a germination rate of 81% after routine treatment to break seedcoat dormancy (1 minute immersion in boiling water is suitable).

Yield: In trials in the subtropics near Gympie in Queensland, *A. brassii* grew well and was an average of 8.7 m tall and 15.6 cm in basal diameter in 4.5 years over two sites. Survival was better than 90% (Ryan and Bell 1991). It also performed well in the seasonally dry tropics near Mareeba in Queensland where it gave 100% survival and grew to 3.6 m in 13 months (Bell et al. 1991). However, on the coarse textured red earths near Longreach in Queensland survival and growth has been poor even with irrigation. The species has shown potential in the semi-arid–sub-humid zone of Thailand where it is similar in performance to *A. holosericea*, *A. ampliceps*, *A difficilis* and *A. plectocarpa* (Pinyopusarerk 1992). Best growth was at Ratchaburi and Si Sa Ket where the species attained heights of 2.8 m and 2.6 m in 12 months of growth (Pinyopusarerk 1989). At Kadoma in Zimbabwe, *A. brassi* ranked 15th for height growth (1.9 m) and 22nd on volume index at 18 months out of 52 different species and provenances. Survival was high (76%) and it had sustained little mortality from termites (2.2%) (Mitchell 1989). It ranked fourth out of 31

Australian acacias trialed on two sites in semi-arid Kenya attaining an average height of 2.9 m in 18 months (Chege and Stewart 1991). However, the species has not done so well at Loruk, Kenya where survival at 1 year was 55% on one site and only 15% on another at 2 years (Kimondo 1991).

Limitations. The small dimensions of this species will restrict its range of uses to fuelwood, posts, and low shelter. It is unlikely to tolerate frost or severe drought.

Related species. Related to the group containing *A. tumida*, *A. difficilis*, *A. retinervis* and *A. montfordiae* (B. Maslin, pers. comm.).

Phyllodes are similar to those of *A. auriculiformis* but the two species are readily separated by pod differences. *A. auriculiformis* has a flat pod with undulate margins and transverse seeds. *A. brassii* has a long, narrow pod, constricted between the longitudinally arranged seeds.

Acacia burrowii

Main attributes. A nitrogen-fixing, small fast-growing tree or shrub with potential as a fuelwood or forage species on sandy, infertile sites in semi-arid or sub-humid subtropical climates.

Botanical name. *Acacia burrowii* Maiden was published in *J. and Proc. Roy. Soc. New South Wales* 53: 227 (1920). The specific name honours a forester, R.J.G. Burrow (1877–1957), whose collection provided the basis for the original description.

Common names. The Australian standard trade name is Burrows wattle. It is also known as yarran or currawang.

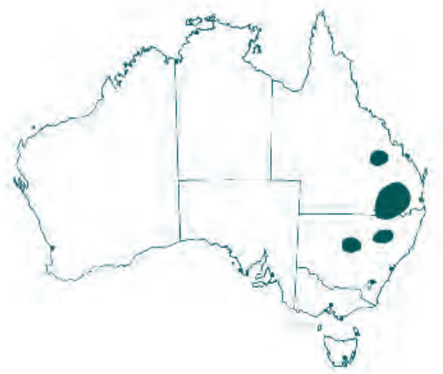
Family. Mimosaceae.

Botanical features. A small tree, usually 7–10 m tall but sometimes up to 13 m, with a stem diameter up to 30 cm. Typically has a straight main stem with light, ascending branches. A shrub form also occurs, usually 2–5 m high and often multi-stemmed. The bark is thin, tough, and fibrous. The branchlets are yellowish-brown.

The phyllodes are 4–10 cm long by 3–10 mm wide, straight or curved, narrowed at both ends, rather thick and leathery, greyish green, with many very fine longitudinal nerves, three of which are prominent. The phyllodes of young plants are broader, 7–14 mm, than those of older plants, which rarely exceed 7 mm. The flowers are bright yellow on short-stalked spikes 20–25 mm long. The spikes may be borne either singly, in pairs or in clusters. Pods are 5–8 cm long, 2–3 mm wide, straight, convex over the seeds, and contracted between them. Seeds are shiny, black, longitudinal in the pod, 4–5 mm long and up to 2 mm broad with a funicle with several folds beneath the seed and a basal aril. Flowering occurs during the period August–October with mature seed available from November onwards.

The species is described by Pedley (1978) and Stanley and Ross (1983). An illustration is given by Cunningham et al. (1981).

Natural occurrence. This acacia has its main distribution in a belt, about 800 by 350 km, across the border of New South Wales and Queensland on the inland side of the Great Dividing Range. Small disjunct stands are found in Central Queensland.



- Latitude. Main occurrence: 26–31°S.
  Range: 23–32°S.
- Altitude. Range: 175–375 m.

Climate. The distribution is mainly in the warm sub-humid climatic zone with some extension in the south of its range into the warm semi-arid zone. The mean maximum temperature of the hottest month is 33–35°C and the mean minimum of the coolest is 2–7°C. The average number of days over 32°C is 60–120, and over 38°C is mainly 8–20. Frosts, usually 2–12 each year, occur throughout the area but the screen temperature rarely falls below –5°C.

The 50 percentile rainfall is 500–675 mm, the 10 percentile 300–500 mm, and the lowest on record 200–300 mm. The rainfall distribution has a moderate to well-defined summer maximum. The average number of raindays each year is 55–70.

Physiography and soils. The species occurs mainly in the Central Lowlands physiographic province where the topography consists of plains and gently undulating country, with some tablelands and mesas. In New South Wales it is common on foothills and rocky hill-tops. *A. burrowii* occurs on solodised solonetz, solodic, and red-brown earth soils derived from a wide range of sedimentary and metamorphic rocks, alluvium, or colluvium. The surface soil is a sandy or clay loam, acid or neutral, with a clay subsoil that may be impeded and alkaline in reaction. The soils are inherently infertile, with low nitrogen, phosphorus, and calcium; they dry out in the dry season and may be somewhat water-logged in wet periods.

Vegetation type. In the drier areas *A. burrowii* occurs as single, isolated trees or in open clumps, but in higher rainfall areas it may form dense thickets. The vegetation types are low open-forest, woodland, and low woodland. Associated species include *Eucalyptus crebra* and *E. melanophloia*, with *E. populnea* on the heavier clay soils, and *E. coolabah* along drainage channels in drier areas. On some of the more sandy sites the cypress pine, *Callitris glaucophylla*, may be dominant. *Casuarina cristata*, *Allocasuarina luehmannii*, *Acacia pennin-ervis*, *A. deanei* and other small acacias may be found with *A. burrowii*.

Utilisation.

Fodder: The phyllodes are readily eaten by stock and branches may be cut for forage in some districts (Everist 1969). The flowers of *A. burrowii* have been recorded to contain hydrogen cyanide (Cunningham et al. 1981).

Fuelwood: The wood of *A. burrowii* has been used for fuel in Australia (Anderson 1968).

Wood: The wood is hard, heavy, dark brown, and easily split. Could find a use for posts, poles, and small joinery items. Maiden (1922) suggests it will make a useful furniture wood.

Other uses: None are recorded, but it will provide light shade.

Silvicultural features. A small tree for infertile sandy sites, especially in sub-humid, subtropical areas. It has not been used in plantations and has only recently been included in species trials. There is little information available on silviculture and yield.

Establishment: There are approximately 112 500 viable seeds/kg providing a germination rate of about 80% after routine treatment to break seedcoat dormancy (1-minute immersion in boiling water is suitable). *A. burrowii* showed only low to moderate (26–50%) promiscuity when tested against 38 *Rhizobium* strains suggesting a degree of selectivity in its association with its nitrogen-fixing symbiont (Roughley 1987). This suggests inoculation with a selected rhizobia strain will be beneficial when this species is planted outside its natural range.

Yield: In trials near Gympie, Queensland *A. burrowii* averaged 5.3 m in height growth and 8 cm in basal diameter at two years from planting (Ryan and Bell 1991). Survival averaged 80% over two sites. Similar to several other Australian *Acacia* species, it was reported to have grown slowly and coppiced poorly after cutting 15 months after establishment at Makoka, Malawi (Maghembe and Prins 1994). Annual rainfall at this site is 1044 mm with a six-month dry season. The authors speculate that lack of suitable rhizobia may be contributing to the unexpected poor performance of these species.

Pests and diseases. None are recorded.

Limitations. The small size of *A. burrowii* will restrict its use as a wood for fuel, posts and poles and small joinery items. It is unlikely to tolerate severe drought. The occurrence of this species in dense thickets in some higher rainfall areas suggests that it is a potential weed species on sites where conditions favour it.

Related species. *Acacia burrowii* is closely related to *A. blakei*, which has larger phyllodes usually and a more coastal and northern distribution (Pedley 1978).

Acacia calcicola

Main attributes. A small tree or shrub with a moderate growth rate, suitable for shade and shelter in harsh arid regions, particularly on calcareous soils.

Botanical name. *Acacia calcicola* Forde and Ising in *Trans. Roy. Soc. South Australia* 81: 153 (1958). The specific name is derived from the Latin, *calx* — limestone and *colo* — to inhabit, referring to the occurrence of this species on calcareous soils.

Common names. Grey myall, myall-gidgee, northern myall, shrubby mulga.

Family. Mimosaceae.

Botanical features. A small spreading tree or rounded shrub, 3–5 m high, with up to six major stems branching from the base, with a wide, bushy crown. The branchlets are angular with a dense covering of silvery-grey fine hairs; new shoots yellow. Bark is grey-black, furrowed, thick and rough on all except the smaller branches. Phyllodes linear to lanceolate, often curved, 5–11 cm long and 1.5–10 mm wide, leathery, usually with a hooked tip. They appear silvery or golden due to a covering of fine, appressed silky hairs; immature phyllodes are coated with a bronze resin. The yellowish-green young growth contrasts with darker-green old phyllodes.

The flowers are yellow, in globular heads of 30–40 or more. Each head is about 4 mm diameter borne singly on short stalks or in short racemes of 2–4 heads in the leaf axils. The thick woody pods are 5–12 cm long, 5–8 mm broad, curved not twisted, constricted between and wrinkled over the longitudinally-arranged seeds. The seeds are dark brown, about 6 mm long and 4 mm broad with a short funicle folded 1–3 times, and small, terminal, fleshy, yellowish aril. Flowering time is August–December and may be dependent on rain falling when temperatures rise during the spring and early summer. Mature seeds have been collected in October–November in Central Australia.

The species is described botanically and illustrated by Forde and Ising (1958) and Whibley and Symon (1992).

Natural occurrence. This acacia is most common in the central and southern part of the Northern Territory and northwestern South Australia. It has a

narrow distribution in Western Australia and there are a few isolated populations in the extreme northwest of New South Wales and southwestern Queensland.

- Latitude. Main occurrence: 25–28°S.
  Range: 21–31°S.
- Altitude. Main occurrence: 300–500 m.
  Range: 100–700 m.

Climate. The main distribution is in one of the hottest and driest parts of Australia. The mean maximum temperature of the hottest month is 37–39°C, with 42°C being the highest recorded. The mean minimum of the coolest month is 4–6°C. Most of the area is subject to heavy frosts with a range of 1–12 a year, with the greatest frequency in the higher altitudes of Central Australia.

The 50 percentile rainfall is 150–250 mm, the 10 percentile 50–125 mm, and lowest on record 30–60 mm. In the area of the main occurrence of *A. calcicola* the rainfall is sporadic and more or less evenly distributed throughout the year or with a moderate summer maximum. The number of raindays a year is a very low 30–37 and varies considerably from year to year. The dry season (less than 30 mm rainfall per month) is 10 months or more throughout most of the distribution.

Physiography and soils. Most of the distribution is in the Western Plateau physiographic division where there has been weathering to plains and gently undulating topography. *A. calcicola* usually occupies heavy-textured calcareous soils, often over limestone, and the banks of ephemeral watercourses and flood plains (Boomsma and Lewis 1980; Cunningham et al. 1981). It also grows on the slopes of degraded sand dunes and on the heavier soils of the inter-dune flats. In drier areas it occurs on flats and depressions receiving 'run-on' water. The soils vary from alkaline to somewhat acid and are mainly crusty alkaline and neutral red duplex, brown calcareous, or neutral red earths (Perry and Lazarides 1962; Whibley and Symon 1992).

Vegetation type. *A. calcicola* occurs in low open-woodland and tall open-shrubland formations. It is found in patches often associated with other acacias including *A. aneura*, *A. brachystachya*, *A. cambagei*, *A. georginae*, *A. kempeana*, *A. sessiliceps*, and *A. tetragonophylla*. Other associates include *Casuarina pauper*, *Hakea leucoptera*, several species of *Eremophila*, and chenopods such as *Atriplex*, *Vesicaria* and *Maireana* species (Boomsma and Lewis 1980; Perry and Lazarides 1962). Occasionally it grows along watercourses in the understorey of *Eucalyptus camaldulensis* woodland.

Utilisation.

Fodder: Not known to have any value as fodder.

Fuelwood: Should be a satisfactory fuel.

Wood: The timber is hard, very dense, with a pale yellow sapwood and an oily dark brown heartwood (Forde and Ising 1958).

Other uses: The habit of this species together with its drought-resistance and tolerance of calcareous soils make it a suitable species for shade, shelter, and windbreaks in arid areas with alkaline soils (Whibley and Symon 1992).

Silvicultural features. This is a long-lived, drought-tolerant species adapted to alkaline soils (Thomson et al. 1994). It also appears to possess some salt tolerance as it ranked amongst species of moderate tolerance of salinity in a glasshouse trial (Aswathappa et al. 1987). Coppicing ability is reported to be poor. This species has rarely been cultivated and little is known of its

establishment requirements or yield. Nevertheless, it is worthy of greater consideration as it possesses several attributes important for establishment on many soils in arid and semi-arid lands and has the capacity to provide a range of environmental benefits.

Establishment: It seeds heavily and produces 22 400 viable seeds/kg. The seeds require one of the routine treatments to break seedcoat dormancy. Average germination percentage after treatment is 80%.

Yield: It is reported to have a moderate to slow growth rate (Whibley and Symon 1992; Thomson et al. 1994).

Pests and diseases. None are recorded.

Limitations. This small tree is invariably crooked and the utilisation of its wood will be limited to fuel.

Related species. The closest relatives are *A. latzii* and *A. cana*. *A. calcicola* has been confused with *A. coriacea*, which is distinguished mainly by its longer, linear phyllodes and longer, curved, twisted and striate pods of a fibrous texture.

Acacia cambagei

Main attributes. A nitrogen-fixing, drought-tolerant long-lived tree adapted to heavy clay soils which are often alkaline. Produces excellent firewood and highly durable timber, and can be used as a shade tree.

Botanical name. *Acacia cambagei* R.T. Baker in *Proc. Linn. Soc. New South Wales* 25: 661, t.42 (1900). The specific name honours R.H. Cambage (1859–1928), a geologist with a wide knowledge of Australian plants.

Common names. Gidgee (standard trade name), gidyea, gidya, gidgea, and stinking wattle.

Family. Mimosaceae.

Botanical features. A small tree, 5–15 m tall, dividing into a few main stems at ground level or with a single trunk up to 30 cm diameter. A wide crown, usually moderately dense, and a deeply furrowed, pale to dark grey-brown bark. Phyllodes are lanceolate to linear, 4–14 cm long by 3–15 mm wide, leathery, dull green to pale grey with 1–3 prominent nerves. The flowers are in tight yellow globular heads on racemes of 4–10 heads. Pods are papery, smooth, flat, oblong, 7–13 cm long, 8–12 mm wide and slightly constricted between the seeds. Seeds are arranged longitudinally in the pod, dark brown, flat with a sharp edge, 6–8 mm long by 4–7 mm wide, with an unfolded, slender funicle, not thickened into an aril. Flowers generally in May–September but heavy flowering usually follows substantial rainfall and may be several years apart (Boomsma 1972). Mature seeds have been collected August–October (Pedley 1978).

The species is described by Hall et al. (1975) and illustrated by Whibley and Symon (1992).

Natural occurrence. *A. cambagei* has a wide distribution over more than 1.5 million square km of the drier areas of eastern Australia. It extends from central-western Queensland into the Northern Territory and in the south it occurs in northwestern New South Wales and northern South Australia.

- Latitude. Main occurrence: 18–30°S.
  Range: 17–32°S.
- Altitude. Range: 75–500 m.

Climate. This species is common in the warm, semi-arid climatic zone, but is widespread in the arid zone and less frequent in the drier parts of the sub-humid zone. Summer temperatures are hot to very hot, frequently above 38°C but in winter there are warm days and cool nights. Light frosts occur on 1–5 days per year over most of the distribution.

The 50 percentile rainfall is 300–600 mm. There is high to very high variability with the 10 percentile, which is often about half of the 50 percentile, and the lowest on record being only 60–120 mm. For much of the area there is a moderate to strong summer rainfall pattern. In the drier south and west edges, the mean monthly rainfall is more or less uniform or has a slight winter maximum, although averages have little significance due to great seasonal and annual variability. For most of the area, rain falls on 30–65 days a year and droughts may be prolonged.

Physiography and soils. *A. cambagei* occurs mainly on plains and gently undulating topography. It occupies areas subject to irregular flooding and in arid areas it follows drainage lines and forms ribbon-like communities on an otherwise treeless landscape (Boomsma and Lewis 1980). In wetter areas it is found occasionally on the upper slopes of small hills and ridges.

Communities of *A. cambagei* are most abundant on soils developed from argillaceous sedimentary and basic volcanic rocks. They also occur on fine-textured alluvial soils. The soils are generally grey and brown cracking clays, less commonly red duplex and brown calcareous and red earths. They are usually alkaline, occasionally neutral or acidic, with carbonate concretions at depth. The clays are relatively fertile although available phosphate may be low.

Vegetation type. In the more mesic areas in central Queensland, *A. cambagei* forms open-forest communities with a canopy up to 15 m high. On drier sites the formations are low woodland, low open-woodland, and shrublands.

A. cambagei usually occurs in extensive, pure, dense stands. In the moister parts of its range, it may be associated with *Atalaya hemiglauca*, *Alectryon oleifolius*, *Flindersia maculosa*, *Grevillea striata*, and *Casuarina cristata*. In open-forest *Eucalyptus cambageana*, *E. coolabah*, and *E. populnea* are associated as emergents or co-dominants. *E. terminalis*, *E. largiflorens*, and *E. ochrophloia* occur in ecotonal communities. It replaces *A. harpophylla* and *A. argyrodendron* on drier sites and is frequently found in association with *A. tephrina* on cracking clay soils and with *A. cyperophylla* on sandy soils in the south.

Utilisation.

Fodder: This species has limited value as fodder. The phyllodes, wood and bark contain toxins for ruminants (Cunningham et al. 1981) and they are generally avoided by stock. Nevertheless, in times of severe drought the phyllodes can serve as drought fodder and fallen pods are browsed (Askew and Mitchell 1978). Goodchild and McMeniman (1987) estimate dry matter digestibility at 44% (in vitro) and crude protein of 12% for phyllodes.

Fuelwood: It is regarded as an excellent firewood. The wood burns green or dry with intense heat and if burnt alone the heat may buckle firebars (NAS 1980). The ash content is high, in the range 6–8% in charcoal (Humphreys and Ironside 1980).

Wood: The wood is hard, very heavy, close-grained, often interlocked, with a dark reddish-brown or almost black heartwood and a pale yellow sapwood. It is durable and termite-resistant and has been widely used for fence posts.

Other uses: Recommended as a shade and shelter tree for dry areas (Hall et al. 1972) but it should not be planted close to where people live because the phyllodes emit a strong offensive smell during humid or wet weather. A quote from Mountford (1948 cited in Whibley and Symon 1992) describes the problem 'Gidya trees might be all right to look at, old man, though to smell them on a damp morning would spoil anyones breakfast; but gidya, after a camel has eaten it, and the beast breathed on you — oh Hell'.

Useful supplies of pollen are produced and it is of value as a source of pollen in apiculture in western Queensland and New South Wales (Clemson 1985). It has seen minor use in mine rehabilitation in northern Australia (Langkamp 1987).

Silvicultural features. *A. cambagei* is a long-lived (> 50 years) species, tolerant of drought and highly alkaline soils. It has also shown moderate tolerance of salinity in pot trials (Aswathappa et al. 1987) and has potential for cultivation on a range of harsh sites in subtropical dry-zones. It is a nitrogen-fixing species and is moderately promiscuous (51–75%) in its association with various *Rhizobium* strains (Roughley 1987). There is a dearth of published information on the silviculture of this species. The species appears sensitive to handling in the nursery and to conditions of the planting site: two seedlots failed in plantings near Gympie, Queensland (Ryan and Bell 1989). It has been observed to coppice and root sucker in its native habitat (Searle 1989).

Establishment: Unlike most acacias, the seeds have a thin seedcoat and will usually germinate without pretreatment. The use of boiling water to hasten germination can be harmful. Seeds have an average viability of about 20 900/kg and an average germination rate of 98%. Seed storage at low temperature is desirable.

Yield: Small planting trials have been established in India and North Africa but no details of performance are available. Growth rate is moderate (Whibley and Symon 1992), or slow (Chuk 1982; Thomson et al. 1994).

Pests and diseases. The seeds are often heavily attacked by seed-boring insects.

Limitations. The apparent relatively slow growth rate and offensive odour may limit its use.

Related species. *A. georginae* and *A. harpophylla* are closely allied to *A. cambagei*. *A. georginae* can be poisonous to stock so it is important that the two species are not confused.

Acacia cincinnata

Main attributes. A tall, straight, slender, nitrogen-fixing tree growing in the tropical and subtropical lowlands. It makes a good fuelwood and has excellent pulp and paper-making properties. A useful species for agroforestry purposes, casting a light shade but producing wood suitable for posts and poles.

Botanical name. *Acacia cincinnata* F. Muell. in *Fragm* 11: 235 (1878). The specific name is from the Latin, *cincinnatus* — with curls, and refers to the pods, which are spirally coiled.

Common names. None known.

Family. Mimosaceae.

Botanical features. A tree to 25 m tall and 40 cm diameter on moist sites in the tropics. On drier sites in the south of its natural range it is a small tree, little more than a large shrub, less than 10 m in height. The bark is compact, moderately hard, closely longitudinally fissured, grey-brown showing red-brown in the fissures.

Mature phyllodes are bright green, oblong lanceolate or falcate, 10–16 cm long and 1.5–3 cm wide, with three prominent longitudinal veins running into each other on the lower margin near the base. There is a prominent raised gland at the base of the phyllode. Young shoots are covered with silky, golden yellow hairs. The flowers are axillary spikes, 3–4 cm long, almost white to pale yellow and faintly perfumed. The pods are spirally and tightly coiled (like a flattened spring) and glaucous when immature. The seeds are longitudinal in the pod, 3–5 mm long by 2–3 mm wide. The areole is large and open, and a rather fine yellow funicle encircles the seed. Flowers in May–June and bears mature seed from October–November.

The botanical features are described by Pedley (1978) and illustrated by Lebler (1979). An annotated bibliography is available (Thomson 1994).

Natural occurrence. Confined to the east coast of Queensland in two main areas, in northern Queensland from Cairns to Mackay and in the south from Fraser Island to Brisbane. There are isolated occurrences on the lower slopes of the moister coastal ranges, such as the Eungella Range, between the main areas of distribution.

- Latitude. Northern occurrence: 16–18°S.
  Southern occurrence: 25–28 °S.
- Altitude. Northern occurrence: sea level to 800 m.
  Southern occurrence: near sea level to about 150 m.

Climate. The northern area of *A. cincinnata* is mainly hot humid but with a narrow coastal belt in the hot wet climatic zone, and inland is marginally hot sub-humid. The mean maximum temperature of the hottest month is 32–33°C. The temperature rarely exceeds 38°C but there are 20–40 days over 32°C each year. The mean minimum temperature of the coolest month is about 16°C at the lowest altitudes to 10°C at the highest. The area is mainly frost-free, although very light frosts may occur at the highest elevations. The 50 percentile rainfall is 2000–3500 mm, the 10 percentile 1250–2000 mm, and the lowest on record 750–1200 mm. There is a well-developed summer maximum and 140–180 raindays annually.

The southern area of occurrence is in the warm humid and sub-humid zones. The mean maximum temperature of the hottest month is 29–31°C and that of the coolest month 6–9°C. There are 4–50 days over 32°C and 2–5 days over 38°C annually. Light frosts occur 1–5 days a year, except in coastal areas. The 50 percentile rainfall in the southern area is 1100–1500 mm, the 10 percentile 700–1000 mm, and the lowest on record 400–600 mm. There is a fairly well-developed summer maximum rainfall and 110–120 raindays each year.

Physiography and soils. Occurrences of *A. cincinnata* are in the lowlands and foothills but extending to the somewhat hilly tablelands. The soils are usually red and yellow podzolics, or yellow and red earths derived from sediments, schists, granite and acid volcanics. It is also found on deep well-drained siliceous sands, peaty sands, soils associated with seasonal swamps, and leached krasnozems. The soils are of low to moderate fertility, acidic and well drained.

Vegetation type. Throughout much of its range, this acacia grows with fringing rainforest or as a constituent in rainforest regrowth areas. In northern Queensland on some sites *A. cincinnata* is codominant with *A. aulacocarpa*, *A. mangium*, and *A. polystachya* and closed-forest trees such as *Alstonia muellerana*, *Endiandra hypotephra*, and *Flindersia ifflaiana*. On other sites it occurs with *Eucalyptus pellita*, *E. intermedia*, *E. torelliana*, *E. tereticornis*, *A. crassicarpa*, and *A. flavescens*. Other associates are listed by Tracey (1982).

In the south of its range, *A. cincinnata* is a component of open-forest or tall open-forest of eucalypts including *E. intermedia*, *E. microcorys*, *E. pilularis* and *E. resinifera*. It is also recorded as a shrub growing in the drier parts of swamps dominated by *Melaleuca* spp.

Utilisation.

Fodder: Not known.

Fuelwood: The wood burns well when dry.

Wood: Dark brown, attractive figure, close-grained, hard (basic density 510–580 kg/m^3) and tough, of a somewhat greasy nature. It has been used for cabinetwork and turnery (Bailey 1900b) and in the round for posts and poles. The wood is reportedly resistant to the teredo marine borer and may be useful for some marine purposes. It has excellent potential as a source for fibre for pulp and papermaking industries (Clark et al. 1991).

Other uses: It has been grown infrequently as an exotic but appears to have excellent potential for agroforestry purposes when planted on suitable sites (e.g. in southern China, S. Searle, pers. comm.). It is suitable as a support for passionfruit and yams and shade tree for cardomom and cocoa.

Silvicultural features. A medium to fast-growing species adapted to acidic soils of low fertility in the humid tropics and sub-tropics. It is site-sensitive, being prone to premature senescence, gummosis and crown thinning when planted off-site. Best performance is achieved on deeper, loamy soils with annual rainfall about 2000–2500 mm and a short dry season. It has shown good wind resistance to tropical cyclones and typhoons. It is frost-sensitive and coppices poorly when cut close to the ground.

The stem form of *A. cincinnata* can vary markedly in field trials, from specimens with a straight tapering bole and small, horizontal branches to a bushy shrub

(Thomson 1994), indicating the importance of species-site matching and screening provenances before embarking on broadscale plantings.

Establishment: Floral buds were observed as early as 26 months in field trials near Gympie, Queensland (Ryan and Bell 1989). There are about 82 400 viable seeds/kg and germination rate averages 80%. The seeds require pretreatment with boiling water (1–2 mins) to break seed-coat dormancy. A nursery phase of 3–4 months is suitable.

Early growth and crown development is less than for some other acacias and greater attention to weed control is necessary during the first few years.

Yield: Growth rate is moderate in early years, typically 1.5–2.5 m/year height growth and a dbh of 1–2.5 cm/year, in humid parts of South East Asia. The most rapid growth has been recorded from an ex-forest site in Sabah, Malaysia where annual height growth increment was 4.1 m/year and dbh increment 3 cm/year (Anuar Mohamad 1987). On more favourable sites the rotation period for sawn timber is expected to be about 25 years. There is no published information on wood yields.

Pests and diseases. No serious pests and diseases have been reported.

Limitations. More information is required on the adaptability of the species to different sites and on provenance variation. It is senstive to frosts and drought and will not coppice readily.

Related species. Its nearest relative is probably *A. spirobis* subsp. *solandri* (Pedley 1978). It is also closely related to *A. polystachya*, *A. mangium* and possibly *A. auriculiformis*.

Acacia citrinoviridis

Main attributes. A nitrogen-fixing tree adapted to neutral and calcareous soils in the hot, semi-arid tropics. Has potential for fuelwood, small posts, shade, shelter, erosion control and ornamental purposes.

Botanical name. *Acacia citrinoviridis* Tindale and Maslin was first published in *Nuytsia* 2: 86–92 (1976). The specific name is from the Latin, *citrinus* — lemon-yellow and *viridis* — green, and refers to the yellowish-green hairs on the new shoots and pods.

Common names. River jam, milhan (Ashburton district), wantan (Murchison–Gascoyne region).

Family. Mimosaceae.

Botanical features. *A. citrinoviridis* is typically a round-crowned, multi-stemmed small tree to 6–12 m tall. Young plants have a dense, bushy habit and root suckers may form thickets following soil disturbance. On better-watered sites it may develop into an open, spreading tree to 18 m tall with a crown spread of 15 m. The bark is grey, rough and longitudinally fissured.

New shoots are densely covered in iridescent yellow hairs. These hairs become silvery white on partly expanded phyllodes and may be absent at phyllode maturity (Maslin 1982). Mature phyllodes are silvery greyish-green, narrowly elliptical, falcate, 8–12 cm long by 5–12 mm wide. There is a rather prominent midrib, two slightly less prominent veins and numerous minor parallel veins.

The bright yellow flowers are arranged in single or paired spikes 13–32 mm long. The pods are straight, hard and brittle, 35–80 mm long × 7–15 mm wide, with prominent margins 1.2–1.5 mm wide, sparsely to densely covered in yellow or silvery sericeous hairs raised over the transversely positioned seeds. The seeds are round, 3–6 mm diameter, flattened, light brown to brown-black and attached to the pod by a fine, twice-folded cream-coloured funicle. Flowering occurs between April and July, and may be especially profuse following good rains. Seeds mature between late September and early November.

A botanical description with illustration is given in Tindale and Maslin (1976).

Natural occurrence. *A. citrinoviridis* has a rather compact distribution in central-western Western Australia. It has a scattered occurrence in the Gascoyne, Ashburton and Fortescue River catchments.

- Latitude. Range: 21–26°S.
- Altitude. Range: 50–720 m.

Climate. The occurrence is in the warm to hot arid zone. Mean annual temperature is 23–27°C. The mean maximum of the hottest month (typically January) is 38–41°C. The mean minimum of the coolest month is 7–13°C. A small number of frosts (to –3°C) may occur in some years at the more elevated sites.

The 50 percentile rainfall is 200–310 mm, the 10 percentile 95–150 mm and the lowest on record 20–65 mm. It occurs in an area of very irregular rainfall incidence, both from year to year and within years. Infrequent heavier falls occur in two main periods between January–March (summer) and May–July (winter). In the north, 60% of total precipitation is received during summer, while in the south rainfall is distributed bimodally.

Physiography and soils. The distribution of *A. citrinoviridis* is wholly within the Western Plateau physiographical division. It is restricted to drainage lines. Habitats include the banks and floodplains of the major river drainages and sandy or rocky banks and beds of infrequently flooded minor creeks.

The soils are typically slightly to strongly alkaline (pH 7.5–9), stony or skeletal loams derived from ironstone, granite, sandstone and calcrete. Recorded soil types include red-brown sandy and stony loams, light reddish-brown gravelly sands, red loamy clay over an ironstone hardpan and brown sandy clay.

Vegetation type. *A. citrinoviridis* is a dominant component in riverine low woodlands and low open woodlands. The principal associated trees are *Eucalyptus camaldulensis*, *E. victrix* and *A. aneura*. Other associated trees include *E. aspera*, *A. coriacea* var. *pendula*, *A. distans* and *A. pruinocarpa*. Understorey associates include *A. bivenosa*, *A. inaequilatera*, *A. pyrifolia*, *A. sclerosperma*, *A. subtessarogona*, *A. tetragonophylla*, *A. trachycarpa*, *A. victoriae*, *Dodonaea compacta*, *Prostanthera striatiflora*, *Plectrachne* spp. and *Triodia* spp.

Utilisation.

Fodder: It has not been recorded as being grazed and is unlikely to be palatable to stock.

Fuelwood: The wood is dense (810 kg/m^3; T. Vercoe, unpublished data) and makes an excellent fuel.

Wood: The heartwood is dark brown, hard and moderately durable. Larger specimens may provide small posts and rough building timbers. It also has potential for conversion into small decorative items.

Other uses: A. citrinoviridis has a dense crown and is useful for shade, shelter and windbreaks. Its bushy, root-suckering habit makes it especially suitable for soil protection and plantings to reduce scouring of alluvial deposits during flash floods in arid and semi-arid regions. The profuse yellow flowers, silvery grey-green phyllodes, semi-pendulous habit and long life span make it a most desirable ornamental and amenity subject for town plantings in the arid–semi-arid subtropics.

In the Ashburton district of Western Australia it is recorded that Australian Aboriginal people coarsely ground the dry seeds and ate them uncooked (Scott 1972).

Silvicultural features. Seed of this species has only recently become available and it has yet to be properly evaluated in field trials. Field observations indicate that

the species has a moderately fast growth rate, long life span (>40 years), good coppicing ability and a propensity to root sucker.

Establishment: There are on average 20 200 viable seeds/kg at an average germination rate of about 86%. The recommended pretreatment to remove seedcoat dormancy is to place the seed in a large volume of rapidly boiling water for 1 minute (Gunn 1990). Manual nicking is a suitable pretreatment for smaller quantities of seed. Supplementary watering during the first year may be required for successful establishment in arid and semi-arid regions.

Pests and diseases. None recorded.

Limitations. It is likely to be poorly adapted to acid soils. Research is needed to determine its growth rate and performance in different environments.

Related species. *A. citrinoviridis* is most closely related to *A. hamersleyensis*, *A. olgana* and *A. distans* (B.R. Maslin, pers. comm.). It will hybridise with *A. distans* (L. Thomson, pers. comm.).

Acacia colei

Main attributes. This is a nitrogen-fixing shrub or small tree with excellent survival and a fast growth rate on a wide range of sites in the semi-arid tropics. It is very promising for fuelwood, charcoal, windbreaks and land rehabilitation, and has potential for human food production.

Botanical name. *Acacia colei* B.R. Maslin and L.A.J. Thomson in *Aust. Syst. Bot.* 5: 737 (1992). The species is named after a CSIRO seed collector Mr E.G. Cole (1927–), who assisted in extensive botanical and seed collections of the new species in 1984. Most populations from arid regions (< 600 mm) of northern Australia previously referred to as *A. holosericea* are now referable to *A. colei*.

Common names. Cole's wattle.

Family. Mimosaceae.

Botanical features. Typically a large spreading shrub (4 m tall × 4 m wide) with many ascending branches arising from just above ground level. On more fertile, well-watered sites it may develop into a small, single-boled tree to 7–9 m tall. The apical branchlets are acutely angular and have a dense covering of short whitish hairs. Mature phyllodes are obovate and slightly asymmetrical, 10–19 cm long and 2–5.5 cm broad, with 3 (sometimes 4) prominent and basally confluent longitudinal nerves. A prominent, nearly straight, longitudinal secondary nerve runs for nearly the length of the phyllode between the major nerves and is a useful diagnostic character for distinguishing sterile specimens of *A. colei* from *A. holosericea* and *A. neurocarpa*. A dense, mat-like covering of appressed, short hairs over the entire phyllode surface gives the plant its characteristic silvery blue appearance.

The bright yellow flowers are on spikes 3.5–6 cm long in pairs in the upper axils. In the Turkey Creek (Western Australia) population the spikes reach 8 cm in length. Mature pods commonly slightly curved but sometimes tightly, irregularly coiled, 5–10 cm long × 3.5–5 mm wide, thin-textured, constricted and raised over the seeds. Pods mature more or less synchronously and fall from the bush within 1–2 weeks in hot, windy weather. The seeds are shiny, black, rectangular, 4–5 mm long by 2.5 mm wide and longitudinal in the pod. At dehiscence the seeds are exposed, dangling from the pod by a bright yellow aril. The peak flowering period is June–July, but flowering may extend from May to September. Large masses of loosely interwoven reddish-brown pods are present September–November.

The species is described and illustrated in Maslin and Thomson (1992).

Natural occurrence. This species is widespread across inland regions of northern Australia. It extends from the Pilbara and southern Kimberley region in northern Western Australia, across the Great Sandy and Tanami Deserts (Northern Territory) to the area south of the Gulf of Carpentaria and Simpson Desert in western Queensland.

- Latitude. Range: 14–23°S.
- Altitude. Range: near sea level to 450 m.

Climate. *A. colei* is a species of the hot (annual mean temperature 25–27°C), semi-arid (270–690 mm) tropics. The mean maximum temperature of the hottest month is 34–40°C, and the mean minimum of the coolest month is 8–16°C. The area is essentially frost-free but 1–2 light frosts are experienced in most years in the more elevated inland localities, such as Nullagine (Western Australia).

The 50 percentile rainfall is 230–725 mm, the 10 percentile 60–440 mm and the lowest on record 20–350 mm. Rainfall is highly erratic between years and distributed with a strong summer maximum. Between 60 and 70% of rain falls during the wettest quarter (December–February). The dry season is both extended, typically lasting 8–9 months and severe, e.g. the average rainfall for the driest quarter is 5–30 mm. There is marked gradient in rainfall from north to south, with northern populations, e.g. Beagle Bay and

Turkey Creek (Western Australia) receiving most rainfall (650–690 mm/year).

Physiography and soils. Populations of this acacia occur on four major physiographic landforms, i.e. inland plains, hilly uplands, coastal lowlands, and dune fields. The plains are flat or undulating, typically alluvial. The uplands are hilly or undulating often in the form of dissected plateaux and ranges of granite, metamorphics, quartzites, sandstones, and basalts. Lowlands are undulating or flat plains on limestone or easily eroded sedimentary rocks. The dune fields are longitudinal east–west sand dunes.

A. colei is found most commonly along seasonally dry watercourses with sandy or gravelly banks. During cycles of wet years the species proliferates and colonises sandy plains and stony ridges especially those in close proximity to watercourses. The latter can be considered as refuge habitat.

A wide variety of soil types are colonised including red-brown stony clays, skeletal ironstone loams, deep aeolian sands, red sandy loams and fine-textured clays and silty clays. Soil are typically neutral (pH 6–7.5), but range from slightly acidic (pH 5.5) in the east (e.g. Helen Springs, Northern Territory) to alkaline (pH 8.5) in the west (e.g. Turkey Creek, Western Australia). Some populations occur on the margins of saline drainage systems, e.g. at Lake Gregory and Eighty Mile Beach (Western Australia), but salt levels are low in the upper soil profile (Electrical conductivities of the saturation extract (EC_e) 1.1–1.7 mS/cm, Vercoe and McDonald 1987).

Vegetation type. *A. colei* typically forms dense, nearly monospecific stands along seasonally dry watercourses. It is a colonising species and a component of many semi-arid tropical plant communities.

It is widespread in *Acacia*-dominated scrubs and tall open shrublands of northwestern Australia. Frequent associates in the Tanami Desert (Northern Territory) include *Triodia* species (hummock grasses), *A. adsurgens*, *A. cowleana*, *A. dictyophleba*, *A. stipuligera*, *A. tenuissima*, *Eucalyptus argillacea*, *E. brevifolia*, *E. pruinosa* and *Lysiphyllum cunninghamii*. In the Pilbara (Western Australia) the most frequently associated species is *A. tumida*; other associates include *A. ancistrocarpa*, *A. trachycarpa*, *A. translucens* and *Grevillea wickhamii*. Further north it is abundant in the near-coastal

'pindan' scrubs, where associates include *A. anaticeps*, *A. eriopoda*, *A. inaequilatera*, *A. monticola* and *A. tumida*. *A. colei* occurs with *A. holosericea* at Burketown (Queensland) and with *A. neurocarpa* at Beagle Bay (Western Australia).

Utilisation. In recent years *A. colei* has become widely planted, under the name of *A. holosericea*, in West Africa. Plantings have been undertaken for amenity (windbreak and ornamental) purposes, fuelwood production and soil improvement and erosion control.

Human food: In the past the seed of *A. colei* was a moderately important food source for central Australian Aboriginal tribes (Latz 1995). The small seeds are produced in large amounts and may be harvested easily. Processing for consumption was a rather labour-intensive process. The dry seed was ground to a coarse flour, mixed with water and either eaten as a paste or baked to form a 'cake'. The seeds are nutritious containing 21% protein, 10% fat and 57% carbohydrate (P. Maggiore and P. Latz, pers. comm.).

A. colei seeds are being investigated as a food source in semi-arid Niger, Africa, where the species has been planted extensively for windbreaks and fuelwood production. Field trials have been established to quantify seed yields (Rinaudo et. al. 1995). Local recipes have been modified to produce foods which incorporate acacia seed flour. Chemical analysis, palatability trials of acacia seed-based foods and extensive dietary experimentation with laboratory rats indicate that foods incorporating a modest proportion (up to 25%) of acacia seed flour can be safely eaten by humans as part of a balanced diet (Harwood 1994; S.R. Andewusi, pers.

comm. 1995). A medically and scientifically monitored human nutrition trial testing diets incorporating seed flour of *A. colei* will be reported in 1997.

Fodder: A. colei is not grazed to any extent by stock in Australia. Trials in Senegal indicated that fresh phyllodes of *A. colei* were not palatable to cattle and sheep, but dry foliage had greater palatability (Hamel 1980). Analyses of fodder value suggested that *A. colei* (Turkey Creek population; CSIRO Seedlot No. 14660) had potential for fodder due to its high dry matter digestibility 46% (predicted in vivo), high protein level (19%) and acceptable calcium to phosphorus ratio of 10 (Vercoe 1989). Further research is needed to ascertain its fodder potential through replicated animal feeding trials and which factors (possibly hairiness, volatiles, tannins) contribute to its low digestibility when fresh.

Fuelwood: A. colei is an excellent source of firewood and charcoal. The calorific value of the wood is 4670 kcal/kg and that of the charcoal 7535 kcal/kg (CTFT 1983).

Wood: The wood is hard with a high density of about 870 kg/m^3. The dark brown heartwood contrasts with the pale sapwood and this wood is suitable for manufacture of small decorative articles.

Other uses: It has been planted as a windbreak around fields and along roadsides in Burkina Faso, Niger and Senegal. Its bushy habit to ground level and heavy fall of large slowly decomposing phyllodes enhance its value for sand stabilisation. On sandy soils in semi-arid zones *A. colei* may be used in a wide alley cropping system (about 20 m between rows) where its benefits as a low windbreak may outweigh its depletion of soil moisture in the crop root zone. It has given very satisfactory results when planted as the lower part of windbreaks with *Eucalyptus camaldulensis* (Cossalter 1987).

A. colei has been used as an ornamental in west Africa, Thailand and northern Australia. Its silvery foliage, mass flowering and wide adaptability to different soil types are features most admired for this role.

Aborigines extracted a red dye from the lipid-rich arils by soaking them in water (Latz 1995).

Silvicultural features. Cole's wattle is a short-lived (<10 yrs), fast-growing multi-stemmed large shrub or small tree of the hot, semi-arid tropics. It has variable coppicing ability. Trials in Niger, Senegal and Australia have shown that the species can be successfully coppiced at 0.5 m or more above ground level at certain times of the year. At Dosso plants cut in April had only 4% and 38% survival at cutting heights of 5 and 50 cm, respectively. Cutting in June, at the onset of the rainy season, resulted in much higher survival rates of 51% and 95% (C. Kjellstrom, pers. comm.). High cutting (≥ 0.5 m) with retention of some foliage-bearing branches appears to effectively rejuvenate the canopy and may prolong the lifespan of this rather short-lived species.

Establishment: The mean number of viable seeds/kg is 73 800 with an average germination rate of 90%. Pretreatment of seed with boiling water is necessary to break dormancy and enhance germination. Seedling growth is rapid and a short nursery phase of 12–15 weeks is recommended. Direct seeding trials were very promising at Keur Macteur (Senegal) and the species is well suited to establishment by this method. Inoculation with a selected rhizobia strain on an alkaline site in West Timor, Indonesia, resulted in greatly improved growth, suggesting that this species may be somewhat selective of natural *Rhizobium* and that inoculation may be warranted.

Yield: A. colei from Sandfire Roadhouse, Western Australia has exhibited high survival and rapid growth on a wide range of soil types in the tropical hot, semi-arid and sub-humid (450–1000 mm) zones of West Africa. At Keur Mactar, Senegal (585 mm rainfall, 7-month dry season), height growth has been from 2.8–4.9 m at 4 years depending on soil type. At Bambey, Senegal (480 mm, 8-month dry season), a 4-year-old planting of *A. colei* produced 12 t/ha green wood and 2.7 t/ha of dry phyllodes — considerably greater productivity than the local *Acacia senegal* (Cossalter

1987). There do not appear to be major differences in growth rate between provenances: plants from Turkey Creek, Western Australia and Hooker Creek, Northern Territory have grown fastest in provenance trials in Burkina Faso (IRBET–CTFT 1989).

Early height growth has been rapid in the ACIAR series of trials, viz. 0.8–1.8 m at 18 months (southeastern Queensland, Australia; 1113–1362 mm), 2.5–6.9 m at 24 months (Thailand 934–1586 mm), and 1.5–3.5 m at 24 months (Zimbabwe; 925–973 mm) (Boland 1989).

A. colei has shown rapid early growth in trials in South Asia. Plants from Halls Creek, Western Australia grew to 1 m in less than 4 months on a difficult, highly alkaline site at Nepalganj, Nepal (K. White, pers. comm.). In Tamil Nadu (India), plants from Sandfire Roadhouse grew to 5.6 m tall, with a basal stem diameter of 9.8 cm at age 4 years (R. Jambulingam, pers. comm.).

Pests and diseases. In native stands phyllodes often show signs of insect browsing, but no serious defoliators have been observed. Minor insect pests include a chrysomelid beetle (*Dicranostera picea*) and a sap-sucking bug (*Sextius* sp.) (Ryan and Bell 1989). The species has been found to be very resistant to termite attack in Zimbabwe (Mitchell 1989). In cooler, humid climates powdery mildew (*Odium* sp.) attack may be severe (Ryan and Bell 1989).

Limitations. Its rather short life span of 6–10 years, shortened by prolonged drought, is a major limitation. In inland West Africa it dies at 2 to 3 years of age onward in extremely dry years (< 250–300 mm) when planted at the routine spacing of 4 × 4 m (Cossalter

1987). The form and size of this species will restrict its use for wood products other than fuelwood and charcoal, and its fodder potential is uncertain.

Related species. *A. colei* is hexaploid and may be apomictically reproducing (Moran et al. 1992). It is morphologically intermediate between *A. neurocarpa* (diploid race) and *A. cowleana* (tetraploid) and appears to have evolved as an allopolyploid from these two species. All three species are distinctive in the field and differ markedly in their pod characteristics (Maslin and Thomson 1992). Non-fruiting herbarium specimens of *A. colei* can usually be distinguished from the putative hybrid parents and *A. holosericea* on the basis of phyllode venation and shape. A coiled-pod variant with often narrower phyllodes and a more restricted natural range may warrant formal recognition at varietal rank (B. Maslin, pers. comm.).

Acacia coriacea

Main attributes. A long-lived shrub or small tree, tolerant of drought and fire, adapted to sandy soils that may be calcareous. Has potential for planting in arid areas for firewood, shade, shelter, erosion control, and ornamental purposes. The seeds are edible.

Botanical name. *Acacia coriacea* DC. was named by A.P. de Candolle in his *Prodr*. 2: 451 (1825). The species name is from the Latin *coriaceus* — leathery, referring to the leaf texture. Three subspecies have been recognised by Cowan and Maslin (1993), namely subsp. *coriacea*, subsp. *pendens* and subsp. *sericophylla*. Subsp. *pendens* is derived from the Latin *pendens* — pendulous, because of the drooping foliage and subsp. *sericophylla* from the Greek *sericos* — silken, and Greek -*phyllon* — leaf, in allusion to the leaf appearance.

Common names. Wirewood, wiry wattle, desert oak, dogwood, waterwood, river jam.

Family. Mimosaceae

Botanical features. A shrub 1–6 m or tree 3–10 m, with thin, grey bark, fibrous or thick and spongy. Juvenile foliage is yellow-green. The phyllodes are narrow elliptic or tongue-shaped, 10–30 cm long by 1.5–12 mm wide, leathery, variable in colour from light to silvery green, with many fine parallel nerves. The pale golden or cream-coloured flowers are in 1–2 globular heads in the axils. Pods are straight, 15–34 cm × 7–12 mm, leathery, twisted and coiled before or after dehiscence. Seeds longitudinal in the pod, widely elliptic, 4–10 × 4–6 mm, black with a large fleshy, bright orange aril.

Subsp. *coriacea*: Bushy shrubs or small trees 1–3 m, sometimes semi-prostrate. Phyllodes are erect, 10–20 cm × 1.5–10 mm. Flowering is June–July and mature pods present August–November.

Subsp. *pendens*: Trees rarely shrubs, 3-6 m. Foliage pendulous, phyllodes 15–25 cm × 1.5–5 mm. Flowering is March–August and mature seeds July–December.

Subsp. *sericophylla*: Shrubby, gnarled trees, 3–10 m. Bark grey, thick and spongy, yellow inside. Phyllodes 15–30 cm × 1.5–12 mm. Flowering is March–July and mature seeds July–December.

It is described and illustrated by Cowan and Maslin (1993), Mitchell and Wilcox (1994) and Whibley and Symon (1992).

Natural occurrence. Subsp. *coriacea*: northwestern Western Australia along coast and offshore islands. Subsp. *pendens*: northwestern Western Australia, inland from coast in the Pilbara. Subsp. *sericophylla:* all mainland states except Victoria; inland, rare on offshore islands.

- Latitude. Main occurrence: 18–26°S.
  Range: 16–31°S.
- Altitude. Range: near sea level to 750 m.

Climate. The greater part of the distribution is in the arid climatic zone with an extension in the north and east into the semi-arid zone. The mean maximum temperature of the hottest month is 32–38°C and the mean minimum of the coolest is 4–11°C. The temperature exceeds 32°C on about 90–200 days and 38°C on 30–50 days. The west coast and northern regions are frost-free, but elsewhere there are 1–12 frosts recorded annually.

The 50 percentile rainfall is 200–500 mm, the 10 percentile 50–250 mm, and the lowest on record 40–150 mm. The seasonal distribution varies from a summer maximum to a strong monsoonal pattern with dry to very dry spring months. In a few southern localities there may be a slight winter maximum. The mean number of raindays a year is 22–23 and mean monthly rainfall is often less than 30 mm.

Physiography and soils. The main distribution is in the Western Plateau physiographic division but it is also found in the Interior Lowlands and Eastern Uplands divisions. *A. coriacea* occurs principally on flats and very gently undulating plains, and seasonal watercourses in the drier parts of its range. It is also found on stony ridges and scarps where the soil is strongly skeletal.

In the Northern Territory and Queensland it grows mainly on deep red sands, earthy sands, and red and yellow earths. In Western Australia it occurs on the sand and limestone plains of the Great Sandy Desert and the Pilbara, and on white calcareous beach sand, red or brown sands, or red earthy sands of coastal sand dunes (Beard 1974, 1975). The soils are usually very low in nitrogen.

Vegetation type. *A. coriacea* is frequently a component of open-scrub or tall shrubland and, less commonly, of low open-woodland and low woodland. It is the dominant acacia in the low scrubs of some coastal sand dunes. On the sand plains of the Northern Territory and Western Australia it is one of the most common acacias in hummock grasslands. It may be associated with eucalypts including *E. argillacea*, *E. brevifolia*, *E. gamophylla*, *E. pachyphylla*, *E. populnea*, and *E. melanophloia*. Along watercourses and river flats it is found with *E. camaldulensis*, *E. victrix* and *E. coolabah*. It occurs in associations dominated by small acacias such as *A. bivenosa*, *A. colei*, *A. dictyophleba*, *A. ligulata*, *A. pachycarpa*, and *A. victoriae*.

Utilisation.

Fodder: The phyllodes and pods have moderate nutritive value but are relatively unpalatable to cattle (Askew and Mitchell 1978).

Fuelwood: It has many fine branches, more suitable for firewood than for conversion into charcoal.

Wood: The sapwood is pale yellow and the heartwood dark brown. When large enough the wood is used for fence posts.

Other uses: Subspecies *pendens*, in particular, is a most attractive ornamental and has been used for amenity and as a shade and shelter tree in arid areas. It has potential for erosion control and has been used in the rehabilitation of mining sites in the Pilbara region of Western Australia (Langkamp 1987).

Acacia coriacea appears to have high potential for planting for human food in dry tropical environments. There are many references (see list in Thomson 1992) to the utilisation of *A. coriacea* seed by Australian Aboriginal people, who roast the green pods and eat the immature seeds or grind roasted, dry seeds into an edible paste. Use at the green legume stage is highly favoured. Green pods, nearing maturity, are harvested, lightly roasted and the seeds stripped by hand. At this stage the seeds have a crude protein content of about 24% and are sweet and highly palatable (V. Cherikoff, pers. comm.). The orange arils may be squeezed in water to make a drink.

Silvicultural features. A long-lived, drought tolerant species of the subtropical dry zone. Plants of subsp. *sericophylla* have a thick bark and an ability to regenerate branches epicormically making them very fire-tolerant. It can also regenerate by root suckers and can be expected to possess a reasonable coppicing ability.

The species is highly variable, encompassing three distinct forms. The common shrubby form of the species (subsp. *sericophylla*) has grown rather slowly in West Africa (e.g. Senegal, Cossalter 1987). On the other hand, the Pilbara tree form (subsp. *pendens*) has grown rapidly in town amenity plantings in north-western Australia. Careful selection of the best provenance for the particular conditions of the planting site and the end-use required is indicated.

Establishment: Plants have flowered within two years of planting. Large bunches of pods are produced in years of above-average rainfall, and pods mature between October and November. There are about 10 700 viable seeds/kg giving 70% germination after immersion in boiling water for 1 minute to break seedcoat dormancy.

Yield: It has been tested in dry tropical West Africa. Two seed sources from Western Australia have shown good to poor survival and slow growth. Best results were in coastal areas of Senegal on alluvial soils, mean annual rainfall of 690 mm, and a dry season of 8–9 months. Here, *A. coriacea* has reached 3.0–3.6 m in 7 years and has withstood extreme droughts (CTFT 1983; Cossalter 1987).

Pests and diseases. None are recorded.

Limitations. The relatively slow growth and small-sized wood may limit the value of this species.

Related species. *A. coriacea* is related to *A. stenophylla*.

Acacia cowleana *

Main attributes. A fast-growing, nitrogen-fixing drought-tolerant species with potential to provide fuel and low shelter in hot arid regions. It is also a potential human food source.

Botanical name. *A. cowleana* Tate in *Trans. Roy. Soc. S. Aust*. 19: 81 (1895). Named after E.C. Cowle who assisted the Horn expedition on which type material was collected and described.

Common names. Halls Creek wattle.

Family. Mimosaceae.

Botanical features. A shrub 2–3 m high, or spindly tree 4–7 m. Branchlets usually hairy, angular at the ends. Phyllodes leathery, sickle-shaped, narrowed at the base with a distinct short point at the apex, pubescent with golden hairs when young, becoming glabrous later, 8–20 cm long by 9–24 mm wide, with 2–3 prominent nerves and many parallel secondary nerves. Glabrous (green) and sericeous (silvery grey-green) phyllode variants are known, and these variants may co-occur together with a small number of intermediate forms. Flowers in dense cylindrical spikes 1.5–4 cm long. Pods up to 7.5 cm long and 4 mm wide, glabrous, slightly glaucous, curved, with paper-like texture, raised over the seeds and slightly contracted between them. Seeds longitudinal in the pod, 3–4 mm long by 2–2.5 mm wide, black, oblong, shiny, with a funicle folded over the apex of the seed and terminating in a yellow cap-like aril. Flowering time is from May to August and seed is mature from September to November.

A botanical description is given by Pedley (1978) (see footnote) and the species is illustrated by Maslin (1981) and Whibley and Symon (1992).

Natural occurrence. This species has a wide distribution in northern Australia, often forming dense populations along roadsides. Common in the Northern Territory with scattered populations in the Pilbara and Great Sandy Desert regions of Western Australia and in western Queensland.

- Latitude. Main occurrence: 18–24°S.
  Range: 17–27°S.
- Altitude. Range: 100–650 m.

Climate. Most of the distribution is in the hot arid climatic zone extending to the warm semi-arid zone. A few populations close to the Gulf of Carpentaria are in the hot semi-arid zone. The mean maximum temperature of the hottest month is 35–42°C, and the mean minimum of the coolest is 7–11°C. The temperature exceeds 32°C on 150–250 days and 38°C on 50–80 days. Northern localities under 250 m altitude are mainly frost-free, but in southern and central locations at higher altitudes, up to 12 frosts have been recorded annually.

The 50 percentile rainfall is 250–400 mm, the 10 percentile is 125–200 mm, and the lowest on record 75–150 mm. The number of raindays a year is 30–45, but may be as high as 65 in some areas. A well-developed monsoonal pattern occurs over most of the area with most of the rain falling in December to March. June to September are very dry months.

Physiography and soils. Much of the occurrence is on extensive, strongly-leached sandplains or gently undulating topography. *A. cowleana* is commonly found in watercourses and better-watered parts of the sandplains, but has been recorded on sandstone outcrops, lateritic rises and on the lower slopes of sand dunes. The soils include a wide range of sands, red-brown fine sandy loams, gravels, and lithosols. It sometimes occurs on heavier soils such as red-brown clay loams. The soils are usually very low in nitrogen and phosphorus.

Vegetation type. *A. cowleana* is found mainly in tall shrubland, tall open-shrubland, or low open-woodland with eucalypts such as *E. brevifolia*, *E. dichromophloia*, *E. leucophloia*, *E. papuana*, *E. pruinosa*, *E. setosa* and

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* *A. cowleana* is presently undergoing taxonomic revision. What is now known as *A. cowleana* is to be called *A. elachantha* sp. nov., while the *A. cowleana* will refer to the species presently called *A. oligophelba* (M. McDonald and B. Maslin pers. comm.)

E. terminalis and a wide range of acacias. A description of the sandplain communities including *A. cowleana* is given by Winkworth (1967).

Utilisation.

Fodder: Although not known to be browsed, the phyllodes appear to be of good digestibility (DMD 45.8% in vivo), high in protein (16%) with a good calcium to phosphorus ratio (5:9), and may be a useful stock fodder (Vercoe 1989). The pods, which are produced in large quantities, may also be a source of protein for animals.

Fuelwood: It has good potential as a source of firewood and charcoal.

Wood: Only available in very small sizes.

Other uses: A. cowleana forms an attractive silvery tree. It has potential to provide ornament and low shelter in sandy or stony, hot arid environments.

The small seeds of *A. cowleana* were a seasonally-important part of the diet of Australian Aboriginal people (Latz 1995; O'Connell et al. 1983; Bindon and Maslin 1984). The seeds are highly nutritious containing 24% crude protein, 11% fat and 57% carbohydrate (total) (Brand and Maggiore 1992) and have low levels of known toxic and anti-nutritional factors (Harwood 1992b, 1994). *A. cowleana* appears to have high potential for planting for human food in dry tropical environments.

Silvicultural features. This species is short-lived (up to 10 years) and dies back after about 5 years. It regenerates rapidly from seed under natural conditions. Although *A. cowleana* has limited coppicing ability, younger specimens can tolerate pruning back to 50–100 cm in the wet season and recover quickly (Thomson 1992). Pollarding in this way rejuvenates the crown and extends tree life. *A. cowleana* grows quickly in seasons of good rainfall but declines rapidly in droughts. The species appears to have limited salt-tolerance (Aswathappa et al. 1987) and it is usually killed by fire and frost.

A. cowleana is a tetraploid species and may be directly involved in the evolution of several hexaploid species including *A. colei* and *A. thomsonii*. Isozyme studies have revealed only limited variation within and between populations (Moran et al. 1992). However, significant variation has been observed amongst provenances in survival and growth in field trials in Sahelian Africa (Souvannavong and de Framond 1992; Thomson 1992), and the need to screen provenances for optimum growth is indicated.

Establishment: A. cowleana flowers precociously (< 12 months). There is an average of 75 200 viable seeds/kg at a germination rate of 80% after routine treatment to break seedcoat dormancy. It produces large quantities of seed annually. Healthy plants at wide (5 × 5 m) spacing can produce an annual yield well in excess of 0.5 kg of seed per plant.

Yield: Planted specimens in Australia grow quickly with good rains and reach heights of 2–3 m in 2 years (Kube 1987). Winnecke Creek is amongst the best provenances trialed in Burkina Faso. On stony lateritic soils at Gonse (Burkina Faso), this source gave 71% survival and average height of 3.5 m at 30 months, while at Djibo it gave 61% survival and 3.5 m average height at 42 months (Souvannavong and de Framond 1992). While this is impressive growth in the harsh conditions, *A. cowleana* has generally been surpassed by *A. colei* in survival and yield in trials in Sahelian Africa. Growth in semi-arid Kenya has been variable. At Marimanti and Lanchiathurio it was amongst the best surviving (75%) and tallest (3.4 m) species at 1.5 years, while near Loruk it failed (Chege and Stewart 1991; Kimondo 1991). At Kadoma, Zimbabwe, the Tanami Bore provenance was 2.5 m in height at 1.5 years (Gwaze 1989).

Pests and diseases. A stem borer (*Ancita* sp.) caused damage by ringbarking branches (Ryan and Bell 1989). *A. cowleana* was relatively resistant to termites in a trial in Zimbabwe (Mitchell 1989).

Limitations. The small size of *A. cowleana* will limit its use to fuelwood and the provision of low shelter. Poor coppicing and sensitivity to fire and frosts are disadvantages.

Related species. Closely related to *A. colei*, *A. leptocarpa* and *A. thomsonii*.

Acacia crassicarpa

Main attributes. A very fast-growing tropical, nitrogen-fixing tree growing on a wide variety of soil types. It tolerates fire, salt-laden winds, weed competition and low soil fertility. The wood can be sawn, used in the round or pulped.

Botanical name. *Acacia crassicarpa* A. Cunn. ex Benth was published first in the *London J. Bot*. 1: 379 (1842). The name is from the Latin *crassus* — thick, and *-carpus* — fruit, and refers to the thick pod.

Common names. Northern wattle (Australia), Papua New Guinea red wattle.

Family. Mimosaceae.

Botanical features. Tree up to 20 m tall, but occasionally reaching 30 m. In Queensland, trees rarely exceed 15 m in height. Typical form is bushy with heavy crown, but single-stemmed trees with long straight or somewhat sinuous bole can be found. Bark is dark or grey-brown, hard, with deep vertical furrows; inner bark is red and fibrous.

The phyllodes are smooth, grey-green, curved 11–22 cm long and 1–4 cm wide with numerous longitudinal nerves, 3 prominent and 4 sub-prominent. Phyllodes are borne on angular, lined, scurfy branchlets. Inflorescences are bright yellow spikes 4–7 cm long on thick stalks clustered in groups of 2–6 in the axils. Pods are dull brown, oblong, woody, flat or twisted, 5–8 cm long by 2–4 cm wide, with oblique veins. Seeds are black, 6 × 3 mm arranged transversely, with the pale creamy-yellow funicle folded and thickened, forming a long aril. The main flowering period is May–June, but light flowering may occur as late as September. The peak fruiting season is October– November.

The botanical features are described by Pedley (1978) and illustrated by Simmons (1981). An annotated bibliography with species description and illustration is provided by Thomson (1994).

Natural occurrence. *A. crassicarpa* occurs in north-eastern Queensland, southwestern Papua New Guinea and southeastern Irian Jaya, Indonesia.

- Latitude. Range: 8–20°S.
- Altitude. Main occurrence: 5–200 m.
  Range: near sea level to 450 m.

Climate. The species is found in warm to hot, humid and sub-humid climates in the lowland tropics. Mean maximum of the hottest month is 32–34°C and mean

minimum of the coolest 12–21°C. Daily maximum temperature exceeds 32°C on 20–40 days each year but rarely goes above 38°C. The entire range is frost-free.

The 50 percentile rainfall is from 1000–3500 mm, the 10 percentile is 500–1000 mm and the lowest on record 500–750 mm. Rainfall follows a monsoonal pattern with December–March being the wettest period. Length of dry season ranges from 6 months at the southern limit of the distribution in Australia to 3 months in Papua New Guinea and Irian Jaya.

Physiography and soils. In Australia, *A. crassicarpa* is commonly found at the rear of coastal foredunes, on slopes of stabilised sand dunes, and on coastal plains and foothills. It occurs on a variety of soil types including calcareous beach sands, yellow earths derived from granite, red earths on basic volcanics, red-yellow podzolics over schists, and alluvial and colluvial soils. In Papua New Guinea and Indonesia it occurs on gently undulating terrain of a relict alluvial plain of the Oriomo Plateau. It is found mainly on well-drained, strongly acidic soils but also on imperfectly drained soils subject to flooding in the wet season and rapid drying-out in the dry season. The soils are infertile gleyed red and yellow earths, or red and yellow latosols.

Vegetation type. In Queensland, it occurs in the understorey of open-forest or open-woodland dominated by *Eucalyptus pellita*, *E. tessellaris*, or *E. tereticornis* (Tracey 1982) and in low woodland behind beach-front populations of *Casuarina equisetifolia*. *A. crassicarpa* is also a component of open-forest, low open-forest and woodland and low-woodland with *E. tetrodonta*, *Allocasuarina littoralis*, and *Melaleuca* spp. (Pedley and Isbell 1970). In the woodlands and open-forests of Papua New Guinea and Indonesia commonly fringing impeded-drainage swamps, *A. aulacocarpa*, *A. auriculiformis*, *A. leptocarpa* and *A. mangium*, *Melaleuca* spp. and *Lophostemon suaveolens* are associates (Paijmans et al. 1971).

Utilisation.

Fodder: Not known.

Fuelwood: A dense wood suitable for burning.

Wood: Sapwood is pale brown and heartwood golden brown with a reddish cast. The wood is strong and durable with an air-dry density of 710 kg/m^3 and basic density of 620 kg/m^3. It has been used for heavy construction, furniture, boatbuilding, flooring, hardboard and veneer. Pulp properties are promising but somewhat inferior to *A. aulacocarpa*, *A. auriculiformis* and *A. mangium* (Clark et al. 1991, 1994).

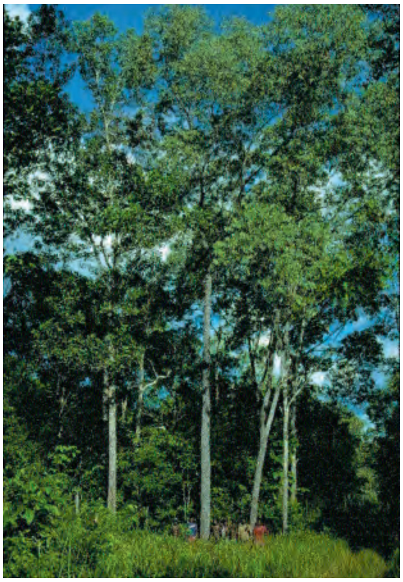
Other uses: It could be used for the revegetation and fixation of coastal sand dunes and for shelterbelts.

Silvicultural features. A fast-growing nitrogen-fixing tree suitable for planting on degraded sites in the tropics. It tolerates a wide range of infertile soils, salt winds, fire and grass competition and has potential for industrial forestry and for land reclamation. It is too competitive to grow with crops.

Significant provenance variation is reported. Papua New Guinea sources have typically a single, frequently somewhat sinuous bole with fine to moderately coarse secondary branching habit. North Queensland origins may lack apical dominance. Plants from Mata, Papua New Guinea have shown adaptation to midly alkaline soils in West Timor, Indonesia, while those from Coen, Queensland, grew poorly (McKinnell and Harisetijono 1991). Papua New Guinea sources have grown rapidly in areas with access to a shallow watertable on the margins of low-lying saline discharge areas in northeast Thailand. Plants of Queensland origin are much more resistant to damage from cyclones than the faster-growing Papua New Guinea sources (Yang et al. 1989; Casey 1993; Thomson 1994).

Coppicing ability varies with cutting height and provenance (Ryan and Bell 1989), but is not a suitable regeneration method for the species.

Establishment: There are 36 400 viable seeds/kg. A germination rate of about 70% is usual after a dormancy-breaking treatment. Inoculation of nursery seedlings with a selected strain of rhizobia is recommended. Cuttings may be successfully taken from plants up to 3 years old. Marcotting is effective on older specimens.



Spacings of 3 × 3 m to 4 × 4 m are suitable for most purposes. Early singling (several times during the first growing season) and early thinning (from year 3) may be necessary for timber production.

Yield: A. crassicarpa is one of the fastest-growing of the tropical acacias. A total above-ground biomass of 207 dry t/ha at 3 years was recorded for a Papua New Guinea provenance in Thailand (Visaratana 1989). On a drier site at Ratchaburi, Thailand it was as productive as other *Acacia* species tested with a total above-ground biomass of 40 dry t/ha at 3 years. In Sabah, Malaysia, *A. crassicarpa* is preferred for planting on rocky, shallow and sandy soils infested with *Imperata cylindrica*. It has attained a mean height of 15–23 m and 10–16 cm dbh in 4 years, outperforming *A. auriculiformis* and *A. mangium* (Sim and Gan 1991). Papua New Guinea provenances have consistently grown faster than Queensland sources in trials in Australia, China and Thailand (Harwood et al. 1993).

Pests and diseases. Susceptible to a stem borer beetle, *Platypus* sp., in Sabah (Sim and Gan 1991). Young trees are also attacked by a stem girdling beetle, *Sinoxylon* sp.

Limitations. Although total biomass production is often great, planted trees are frequently of poor form. Care in the selection of the most suitable provenance will be necessary to ensure optimal results.

Related species. *A. crassicarpa* is closely related to and often confused with *A. aulacocarpa*. The pods of *A. crassicarpa* are broader, woodier and less conspicuously veined than those of *A. aulacocarpa*.

Acacia dealbata

Main attributes. *A. dealbata* is a fast-growing, nitrogen-fixing shrub or tree adapted to cool climates. It is of ornamental value, and is used on farms for windbreaks and erosion control. The wood is excellent for pulping and is a satisfactory fuel.

Botanical name. *Acacia dealbata* Link was described in *Enum. Hort. Berol.* 2: 445 (1822). The specific name is derived from the Latin *dealbatus* — 'covered with white powder', in allusion to the whitish or silvery appearance of the canopy.

Common names. Silver wattle.

Family. Mimosaceae.

Botanical features. Silver wattle is a slender shrub of 2–3 m to an erect tree 6–30 m tall. The canopy is glaucous and often rounded. The bark is dark grey to almost black, smooth on young growth but may be moderately fissured at the base of old trunks. The branchlets are angled or flattened, more or less hairy and with a waxy bloom that can be rubbed off (pruinose). The foliage is bipinnate with a 4–10 cm long midrib. There are 10–26 pairs of pinnae and a raised gland on the upper surface at the junction between each pair of pinnae. Pinnae are 2.5–5 cm long, with 20–50 pairs of linear oblong pinnules, 2–5 mm long by 0.4–0.7 mm wide. Mature foliage is greyish-green in colour. The golden-yellow flowers are in globular heads with 25–35 flowers, on an extended axillary inflorescence 6-10 cm long, on stalks 4-6 mm long. The pod is straight or slightly curved, flat but raised over the seeds, 5–10 cm long by 7–12 mm wide, light purplish brown, sometimes pruinose. The brown to blackish-brown, ellipsoid seeds, 5–6 × 3–3.5 mm, are arranged longitudinally in the pod with a short funicle expanded into a small aril.

The species is illustrated in many texts including Boland et al. (1984) and Whibley and Symon (1992).

Natural occurrence. *A. dealbata* has a natural distribution mainly on the tablelands and in the foothills of the Australian Alps from northern New South Wales to mid-western Victoria and between 50–600 m elevation in Tasmania. It is naturalised in South Australia and southeastern Queensland.

- Latitude. Main occurrence: 33–38°S.
  Range: 29–43°S.
- Altitude. Main occurrence: 250–900 m.
  Range: near sea level to 1500 m.

Climate. The distribution is in the cool to warm sub-humid climatic zones, sometimes into the humid zone. For most of the mainland occurrence the mean maximum temperature of the warmest month is 26–28°C. The mean minimum of the coolest month is mainly –2°C. The average annual number of frosts is 20–80. In coastal regions of Tasmania frosts decrease to 2 per year. The average number of days when 32°C is exceeded is 1–15.

The 50 percentile rainfall is 600–1000 mm, the 10 percentile 350–600 mm and the lowest on record 300–500 mm. Seasonal distribution varies from a summer maximum in northern New South Wales to a winter maximum in western Victoria and Tasmania. The average annual number of raindays is 85–120, but increases to 130–170 in Victoria and Tasmania.

Physiography and soils. *Acacia dealbata* is confined to the Eastern Uplands physiographic division. It has been recorded on basalt plateaus, granite tablelands and sandstone formations. It grows mainly in hilly country, often on steep slopes and also along stream banks.

Soil types range from deep and fertile forest podsolics, clays and gravelly clays of moderate drainage to well-drained stony slopes, volcanic brown earths and lateritic krasnozems.

Vegetation type. This species grows mainly within open-forest or tall open-forest, and the largest specimens are nearly always found in sheltered sites of tall open-forest. As a small shrub it may extend to low vegetation on sandstone ridges. It grows amongst tall eucalypts such as *E. fastigata*, *E. regnans*, *E. delegatensis* and *E. viminalis*.

Utilisation.

Fodder: The species is not especially known in Australia for its animal fodder value, although it is reportedly used for this purpose in the Nilgiri Hills of southern India.

Fuelwood: A. dealbata is a satisfactory fuelwood, although wood density is relatively low for an acacia.

Wood: The sapwood is susceptible to *Lyctus* attack. The heartwood varies from light-brown to pinkish. Green density of the wood is about 800 kg/m^3 while air-dry density ranges from 540 to 720 kg/m^3 (Bootle 1983). It has good glueing properties. *A. dealbata* is recognised as a very good quality pulpwood in temperate regions in Australia (Logan 1987). The wood has furniture applications and minor usage as clothes pegs, shoe heels, wood wool and poles.

Other uses: Widely cultivated as an ornamental or farm tree where it is useful in windbreaks and in erosion control. *A. dealbata* is the 'Mimosa' of southern Europe, where it has been used for cut flowers since early times. In southern France it is also a source of aromatic oils for perfumery (Poucher 1984). It produces a gum arabic substitute and is sometimes used for tanning, but the yield and quality of the tannin is poor compared to *A. mearnsii*. Wool may be dyed with *A. dealbata* leaves to yellow-fawn or green depending on the mordants used (Martin 1974). It is a valuable source of pollen for bees.

Silvicultural features. This species grows best in cool climates with annual rainfall in the range 750–1000 mm. Mid-winter frost tolerance of *A. dealbata* in controlled environment chambers was –7.5°C (Pollock et al. 1986). On open and somewhat harsh sites it has a limited life before deterioration begins (20–40 years). It typically shows very fast early growth. Pulpwood rotations of 15–20 years are considered feasible on suitable sites in Australia.

Inoculation of seedlings with appropriate symbionts should be undertaken when introducing the species to new areas. The species is known to be associated with various rhizobia and mycorrhizal strains (Hopmans et al. 1983; Roughley 1987; Reddell and Warren 1987).

Establishment: Propagation is by seed previously immersed in boiling water for 1 minute to break seedcoat dormancy. Germination rate averages 74% and there are about 53 400 viable seeds/kg. *A. dealbata* suckers extensively and can coppice from cut stumps.

Yield: In China, *A. dealbata* has adapted well to poor sites, resists cold and is able to colonise bare ground (Wang and Fang 1991). Biomass production was estimated to be 15–21 t/ha of dry matter at 5 years. In a species trial in subtropical Guangdong, China, *A. dealbata* provenances averaged 5 m in height at 18 months (Yang et al. 1991). In New Zealand, a stand of *A. dealbata* averaged 16 m in height and gave an estimated volume (under bark) growth of 46 m^3/ha/year at eight years (Frederick et al. 1985). In a 4-year-old stand of *Acacia dealbata* in Japan the net production was 17–30 t/ha/year (Takashi and Ikuo 1973).

Pests and diseases. Lee (1993a) provides a summary list of diseases recorded on *A. dealbata* in several parts of the world. Various fungi have been reported as causing serious losses to *A. dealbata* stock in the nursery (Ito and Shibukawa 1956; Terashita 1962). The species is subject to fireblight beetle (*Pyrgoides orphana*) in Australia (Simpfendorfer 1992), a defoliator which limits its use as a plantation species.

Limitations. *A. dealbata* is a serious pest in South Africa where it has escaped cultivation by means of its prolific seed production and vigorous vegetative growth (Henderson 1989; Campbell et al. 1990). Chemical controls are available but expensive (Fagg and Cameron 1989; Fagg and Flinn 1983). Silver wattle is also considered to be a weed in parts of India (Matthew 1965).

Related species. *A. dealbata* is similar to *A. nano-dealbata* from Victoria which is distinguished by having shorter, closer, glabrous leaflets and broader pods. It is sometimes confused with *A. mearnsii*, *A. silvestris* and *A. leucoclada*.

Acacia deanei

Main attributes. A nitrogen-fixing shrub or small tree resistant to drought and frost. It has a role in windbreaks, for soil protection and in amenity plantings. The timber is of small size with potential for fuelwood and small posts.

Botanical name. *Acacia deanei* (R. Baker) Welch, Coombs & McGlynn in *J. Roy. Soc. New South Wales* 65: 227 (1932). The name honours Henry Deane (1847–1924), a noted amateur botanist who collected the type specimen. Two subspecies, subsp. *deanei* and subsp. *paucijuga* (F. Muell. ex Wakef.) Tindale, are recognised.

Common names. Deane's wattle, green wattle.

Family. Mimosaceae.

Botanical features. *A. deanei* is typically a bushy shrub or small tree, usually freely branched from near ground level in open situations and in the height range 2–9 m. The bark is smooth, grey-brown, becoming somewhat rough at the base of mature plants. This species is a bipinnate acacia with relatively small leaves and few pinnae in comparison to other bipinnate species. The midrib is 3–10 cm long and supports 4–10 pairs of pinnae, 1.5–5 cm long. Each pinna has 15–30 pairs of linear to oblong leaflets, 2–11 × 0.5–1 mm, glabrous or sparsely hairy, dull green to whitish-green in colour, yellow-green when young. Glands are numerous and irregular. There is usually a raised gland on the stalk at the junction of pairs of pinnae or of leaflets, and 1–2 glands between them.

The inflorescence consists of globular heads of 15–30 golden-yellow or almost white flowers on slender peduncles, with a fine whitish-yellow appressed pubescence. The 10–30 flower heads are clustered in terminal and axillary racemes and panicles. The pod is more or less straight, flat, 8–15 cm long by 6–10 mm wide, the margins sometimes thickened, dark brown to almost black. Seeds are longitudinal in the pod, 5.5 mm long, almost 4 mm broad, with a large open areole; aril cupular beneath the seed. *A. deanei* has an extended flowering period and may flower at any time of the year, probably in response to rain. Mature seed of subsp. *deanei* was collected in November–December in Queensland (Searle 1989).

Subsp. *paucijuga* is distinguished from subsp. *deanei* in the field by its longer leaflets (5–11 mm cf. 2–5 mm) which are more sparsely arranged on the 'leaf branches' in a fishbone pattern (Cunningham et al. 1981). Other differences are revealed by microscopic examination of the flowers.

The species is described by Pedley (1979) and subsp. *paucijuga* by Tindale (1966b). It is illustrated in Cunningham et al. (1981) and Tame (1992).

Natural occurrence. The species occurs on the western side of the Great Dividing Range and extends from central Victoria through central New South Wales to southern inland Queensland. Subsp. *deanei* has the more northerly distribution and extends into Queensland. It is rare in Victoria. Subsp. *paucijuga* is found from western Victoria to central New South Wales where intermediates occur.

Subspecies *deanei:*

- Latitude. Main occurrence: 24–35°S.
  Range: 20–35°S.

Subspecies *paucijuga:*

- Latitude: Main occurrence: 30–35°S.
  Range: 30–38°S.

For both subspecies:

- Altitude. Main occurrence: 160–360 m
  Range: about 100–1000 m.

Climate. The distribution is mainly in the warm semi-arid climatic zone, but with some extension to the warm sub-humid zone for subsp. *deanei*. The same applies to subsp. *paucijuga*, but with a greater extension into the warm sub-humid zone in the southeast of the distribution. The mean maximum temperature of the hottest month is 32–34°C and the mean minimum of the coolest month 3–5°C. There are 60–100 days over 32°C and 5–20 days over 38°C. There are 2–22 days of heavy frosts annually.

The 50 percentile rainfall is 480–680 mm, the 10 percentile 300–475 mm and the lowest on record

240–400 mm. Rain is recorded on 54–70 days per year. Maximum precipitation occurs in summer, usually January, and the minimum in August–September.

Physiography and soils. A large part of the distribution is in the Interior Lowlands, but *A. deanei* also grows on the inland side of the Eastern Uplands. The topography consists mainly of gentle slopes and plains. A disjunct occurrence of subsp. *paucijuga* is found in mountainous country in southeastern New South Wales and Victoria. It occurs on a wide range of soils including sands, red sandy loams, red soils, solodized-solonetz soils, acidic siliceous sands, gravelly clays and black soils.

Vegetation type. *A. deanei* is a component of a lower tree or shrub layer beneath dominant trees in woodland which to the north may be classified as low open-forest or low woodland and tall shrubland. *Eucalyptus crebra*, *E. melanophloia*, *E. populnea*, *E. pilligaensis* and *Callitris glaucophylla* may comprise the overstorey of such woodlands, but there are many others. Acacias are present in most of the area and include *Acacia buxifolia*, *A. aneura*, *A. hakeoides* and *A. spectabilis*.

Utilisation.

Fodder: It has been browsed by sheep in harsh times (Cunningham et al. 1981). This generally causes no ill effects, although cases of cyanide poisoning of sheep and cattle have been attributed to this species (McBarron 1978). Maslin et al. (1987) reported that *A. deanei* contained relatively low amounts of cyanogenic glucoside. Vercoe (1987, 1989) estimated the in vivo digestibility of *A. deanei* phyllodes at 35–44% with a crude protein level of 14% and a Ca to P ratio of 7.8–13.4. These are below animal maintenance requirements.

Fuelwood: Should be satisfactory fuelwood.

Wood: No information available. Stem size rarely exceeds 1–2 × 0.15 m, and this will limit its use to posts and other small round timbers.

Other uses: Suitable for quick-growing windbreaks, soil protection and amenity plantings. It is of value as a source of pollen in apiculture.

Silvicultural features. *A. deanei* is a drought-tolerant species suitable for cultivation on a variety of soils in warm semi-arid and warm sub-humid climatic zones. It can withstand periodic waterlogging. Provenances from higher altitudes or higher latitudes from inland sites are the most frost-tolerant (Pollock et al. 1986). It forms nodules with a wide range of rhizobia strains

(Roughley 1987). Coppicing performance is poor (Ryan and Bell 1989).

Establishment: There are about 45 400 viable seeds/kg. Germination rate is typically 82% after pretreatment to break seedcoat dormancy (immersion in boiling water for 1 minute is suitable).

Yield: *A. deanei* had grown rapidly (2.9 m/year and 4.9 cm/year) when assessed at 2 years in subtropical Queensland. On drier sites it showed promise on coarse-textured soils where it averaged 0.9 m in height at 7 months and was in excellent health (Ryan and Bell 1991). It has also shown promise on degraded mountainous sites in low rainfall areas in India (Relwani et al. 1988). *A. deanei* gave modest growth rate (3.0 m tall and 1.9 cm dbh at 2.5 years) relative to several other Australian acacias when trialed in the dry intermediate zone of mid-country Sri Lanka (Weerawardane and Vivekanandan 1991). Similarly, in subtropical China three provenances of *A. deanei* were 2.8–4.2 m tall and 1.5–2.4 cm in 1.5 years compared to *A. dealbata* which was 5.4 m tall and 3.6 cm dbh (Yang et al. 1991).

Pests and diseases. It has suffered minor defoliation from an insect, *Myllocerus* sp., when planted near Gympie, Queensland (Ryan and Bell 1989).

Limitations. The small size will limit use of its wood. It regenerates profusely from seed on disturbed areas in its natural range and has potential to be a weed species.

Related species. May be confused with *A. mearnsii* or *A. parramattensis*, both of which have more pairs of pinnae and pinnules.

Acacia difficilis

Main attributes. A fast-growing, multi-stemmed shrub or small single-stemmed tree with potential for fuelwood, low shelter and erosion control in semi-arid–sub-humid environments.

Botanical name. *Acacia difficilis* Maiden in the *Flora of the Northern Territory* 344 (1917) by A.J. Ewart and O.B. Davies. The species name is from the Latin *difficilis* — difficult. Maiden did not give an explanation as to why this name was used.

Common names. None known.

Family. Mimosaceae.

Botanical features. A much-branched, multi-stemmed shrub or small tree 5–10 m with a straight trunk up to half the total height. Bark dark grey and fibrous on the trunk and base of main branches, upper branches are smooth brownish-bronze, branchlets yellowish. Phyllodes curved, oblique at the base, numerous parallel veins (3–4 prominent, 4–5 are subprominent), the young phyllodes densely covered by short soft hairs, mature phyllodes mostly glabrous, 8–10 cm long by 1.5–3 cm wide. Flowers in bright yellow cylindrical spikes 2.5–5 cm long, in the phyllode axils. The pod is straight to curved, more or less twisted, nearly circular in cross-section, 12–14 cm long and about 4 mm wide. Seeds shiny black, longitudinally arranged in the pod, 5 mm long by 2.5 mm broad, with a small terminal aril. Flowering is from May to August and the seeds mature from August to October.

The species is described and illustrated by Brock (1988) and Wheeler et al. (1992).

Natural occurrence. This acacia has a fairly limited occurrence in the north of the Northern Territory. It extends into Western Australia and is found in the extreme northwest of Queensland.

- Latitude. Main occurrence: 12–15°S.
  Range: 11–18°S.
- Altitude. Range: near sea level to about 200 m.

Climate. The distribution is mainly in the hot sub-humid zone but it also is found in hot humid and hot semi-arid zones. Mean maximum temperature of the hottest month is 38–39°C, decreasing to 33°C in coastal areas. The mean minimum of the coolest month is 12–13°C increasing to 19°C near the coast. The inland localities have 200–280 days over 32°C and about 70 days over 38°C. The temperature rarely exceeds 38°C in coastal areas. The area is frost-free, though at a few of the most southern localities at moderately high altitudes, the temperature may fall as low as 2–3°C.

The 50 percentile rainfall is 650–1100 mm, the 10 percentile is 400–800 mm, and the lowest values recorded are 230–600 mm. There is a well-developed monsoonal pattern, with January to March being the wettest months; the driest months of the year are from June to August. The average number of raindays a year is 50–90, and there is a dry season of 4–5 months.

Physiography and soils. *A. difficilis* occurs in the Western Plateau physiographic division in areas where the topography is gently undulating. It is often found on riverain flood plains or adjacent to watercourses. It occurs along creeks in dissected laterite country and at scattered locations on the rugged sandstones of the Arnhem Land Plateau. The soils are mainly sandy alluvium or loams. Elsewhere it grows on truncated lateritic soils, deep sands at the base of scarps, and gravelly sands.

Vegetation type. *A. difficilis* is found as an understorey species in open-forest and woodland dominated by eucalypts that include *E. argillacea*, *E. miniata*, *E. nesophila*, *E. phoenicea*, *E. ptychocarpa*, and *E. tetrodonta*. It also occurs in low open-woodland and in open-scrub and is associated with other acacias, such as *A. holosericea*, *A. latescens*, and *A. platycarpa*.

Utilisation.

Fodder: No data available but of doubtful fodder value.

Fuelwood: Has good potential for firewood.

Wood: The wood of *A. difficilis* has a basic density in the range 730–770 kg/m^3 (Davis 1994). It may provide a source of small posts.

Other uses: It is suitable for low shelter and erosion control in sandy soils. It is used by some mining companies in Australia in their mine rehabilitation activities (Langkamp 1987). It flowers heavily and has potential as a source of pollen for bees.

Seed of the species is recorded as being an Aboriginal food source (Cherikoff and Isaacs 1989). The legumes split open elastically at maturity, making the seed difficult to harvest, but the seed is more easily cleaned than for other *Acacia* species.

Silvicultural features. *A. difficilis* is capable of fast growth in sandy soil in semi-arid–sub-humid conditions. It is intolerant of saline conditions (Aswathappa et al. 1987; Marcar et al. 1991b). The species seeds heavily and has a moderate life-span (10–50 years). Coppicing of *A. difficilis* was poor when trees were cut at 0.1 m and 0.5 m from the ground and only fair at 1.0 m (Ryan and Bell 1989).

The performance of the species when planted has been variable and there has been speculation that a contributing factor to several unexpected failures may be the lack of the desired root symbionts in the soil. Inoculation of seedlings in the nursery with effective rhizobia strains is a worthwhile precaution until more is known.

Establishment: Flower buds have been observed on planted specimens as early as 9 months (Ryan and Bell 1989). There are about 42 900 viable seeds/kg. A germination rate of 85% may be achieved after pretreatment to break seedcoat dormancy: 1 minute immersion in boiling water is suitable.

Yield: In trials near Gympie in subtropical Queensland, *A. difficilis* gave good survival and mean annual increments of 1.6 m in height and 3.1 cm in diameter at ground level over 4.5 years (Ryan and Bell 1991). However, performance of the species on other harsher sites in Queensland has been poor with complete failure recorded on a non-irrigated site on coarse textured soils (Bell et al. 1991). Performance of the species outside Australia has been variable. *A. difficilis* has grown rapidly in trial plantings in Thailand where it averaged over 8.0 m in height growth in three years on two sites (Chittachumnonk and Sirilak 1991). It has also grown well in Burkina Faso and Niger (Thomson 1992). In trial plantings in Tamil Nadu in India, *A. difficilis* averaged 5.1 m in height at two years, resisted browsing by

livestock and was considered a very promising fuelwood species for local farms (Arulmozhiyan et al. 1992). However, in semi-arid Kenya its survival and growth was unremarkable (Chege and Stewart 1991; Kimondo 1991). When assessed at 26 months in Malawi, *A. difficilis* showed good growth (MAI > 1.5 m; biomass > 6 t/ha) but survived and coppiced poorly (Maghembe and Prins 1994).

Pests and diseases. When planted near Gympie, Queensland *A. difficilis* was subject to attack by various sap-sucking, bud-chewing and defoliating insects (Ryan and Bell 1991). In Zimbabwe, it was amongst the species least susceptible to attack by the termites *Ancistrotermes latinotus* and *Macrotermes michaelseni* (Mitchell 1989).

Limitations. The small size of this species will limit its use to fuelwood, small posts, and non-wood applications such as low shelter and erosion control. Its poor coppicing ability is a disadvantage for fuelwood production.

Related species. Closest relative is *A. tumida* and it has some affinities with *A. torulosa* (Anderson et al. 1983). *A. difficilis* naturally hybridises with, and is morphologically similar to, *A. tumida*. The latter has larger and generally more glabrous phyllodes, and pods that are much broader, with fleshier valves and seeds arranged obliquely. Pedley (1978) notes that Queensland specimens of *A. julifera* subsp. *gilbertensis* have been misidentified as *A. difficilis*.

Acacia distans

Main attributes. A nitrogen-fixing, small tree adapted to neutral and calcareous soils in the hot, semi-arid tropics. It has potential to provide fuelwood, low shelter and erosion control.

Botanical name. *Acacia distans* Maslin in *Nuytsia* 4(3): 386 (1983). The specific name is from the Latin *distans* — standing apart, in reference to the more or less well-spaced clusters of flowers on the spike.

Common names. None known.

Family. Mimosaceae.

Botanical features. *A. distans* is typically a small tree with a single trunk or else sparingly divided near ground level, and a rather sparse rounded canopy. In the Pilbara region (Western Australia) it is a spreading or upright, round canopied, multi-stemmed small tree (5–8 m tall and 5–8 m wide), with moderately dense foliage to near ground level. In old specimens the trunk may reach a basal diameter of 40–50 cm. The bark is dark grey, rough and longitudinally furrowed. Phyllodes are silvery light green, almost linear, curved, 6–11 cm long by 4–11 mm wide, with numerous fine, parallel nerves. Young phyllodes have a covering of appressed, silky-yellowish hairs.

Numerous small yellow flowers are arranged in clusters on long (11 cm) spikes. The pods are linear, slightly raised over the seeds and constricted between them, gently curved, 8–14 cm long × 4–6 mm broad, obscurely longitudinally nerved, light brown and covered in short, appressed, whitish hairs. The longitudinally positioned seeds are shiny, brown, flattened, obloid, 5–7 mm long × 3–4 mm wide. Flowering occurs between late March and May. The pods develop about 5–6 months later in September–October.

A botanical description and illustration is given by Maslin (1983).

Natural occurrence. *A. distans* has a scattered occurrence in central-western Western Australia and the Pilbara region of Western Australia. It is associated with the Murchison, Gascoyne, Lyndon and Fortescue River systems.

• Latitude. Range: 22–27°S.
• Altitude. Range: 140–500 m.

Climate. The occurrence is in the warm to hot arid zone. Mean annual temperature is 22–25°C. The mean maximum of the hottest month is 38–41°C. The mean minimum of the coolest month is 7–11°C. The distribution is essentially frost-free, with one or two light frosts (–1°C) in some years in the southern part of the range.

The 50 percentile rainfall is 200–260 mm, the 10 percentile about 100 mm and the lowest on record about 60 mm. Mean annual rainfall is 195–315 mm but there is very irregular rainfall, both from year to year and within years. Infrequent heavier falls occur in two main periods January–March (summer) and May–July (winter). In the north 60% of total precipitation falls during summer, while in the south rainfall is distributed bimodally.

Physiography and soils. *A. distans* occurs only in the Western Plateau physiographical division. It is confined to low-lying alluvial plains where it is intimately associated with the major drainage systems of the region. It has also been observed on a degraded gilgai complex on slightly elevated ground.

The soils are typically neutral to alkaline (pH 7–9) alluvial loams. Recorded soil types include red and red brown sandy clays, light brown loamy clays, aeolian-derived white clay and well-drained sandy loams. A shallow calcareous hardpan may be present at some sites.

Vegetation type. *A. distans* typically occurs in dense, almost monotypic stands in the mid-upper reaches of the Murchison and Gascoyne Rivers. Associated species include *Acacia aneura*, *A. citrinoviridis* and *Melaleuca* spp. In parts of the mid-upper reaches of the Fortescue River, *A. distans* is a dominant component of low open woodland, together with *A. aneura*, *A. victoriae*, *A. tetragonophylla* and *Eucalyptus victrix*.

Utilisation.
Fodder: Not known.
Fuelwood: The moderately dense wood is an excellent fuel.
Wood: The heartwood is dark brown and hard, and has potential for conversion into small decorative items. The bole is usually rather short and crooked, and not especially suitable for posts.
Other uses: It has considerable potential for shelter, shade and soil protection.
Silvicultural features. This species has yet to be evaluated in field trials, and little is known of its silvicultural requirements, management and growth rate. Field observations suggest that the species has a moderate growth rate and is long-lived.

There are 41 600 viable seeds/kg. The recommended pretreatment to remove seedcoat dormancy is to place the seed in ten times its volume of boiling water, and allow the seeds to soak for 24 hours in the cooling water (Gunn 1990). Manual nicking is suitable for smaller quantities of seed. Supplementary watering during the first year may be required for successful establishment in arid and semi-arid regions.
Pests and diseases. None recorded.

Limitations. It is likely to be poorly adapted to acid soils. The small size and form of the tree will restrict the use of its wood to mainly fuelwood. Research is needed to determine the growth rate, coppicing ability and forage value of this species.
Related species. *A. distans* is most closely related to *A. citrinoviridis* and may rarely hybridise with the latter (L. Thomson, pers. comm.). In the field *A. distans* bears a resemblance to *A. citrinoviridis* and broad phyllode variants of *A. aneura*, but is readily distinguished from these species by its very long flower spikes bearing numerous small flowers arranged in well-spaced clusters, and by its long, linear pods (Maslin 1983).

Acacia elata

Main attributes. A tall, straight, very fast-growing, nitrogen-fixing tree suited to moist sites in warm temperate zones and tropical highlands. A useful tree for windbreaks and ornamental purposes. Its wood is suitable for fuel and small posts (after preservative treatment) and has potential for production of pulpwood.

Botanical name. *Acacia elata* A. Cunn. ex Benth in *London J. Bot*. 1: 383 (1842). The specific name is derived from the Latin, *elatus* — exalted or tall, in allusion to its tall-tree habit. Formerly incorrectly referred to as *A. terminalis*.

Common names. Cedar wattle (Australian standard trade name), mountain cedar wattle.

Family. Mimosaceae.

Botanical features. *A. elata* is typically a single-boled tree reaching 15 to 25 m. There are many small lateral branches at right-angles to the main bole, and in open habitats these are retained to near ground level. Under optimal (moist, fertile, well-drained) conditions it may reach impressive proportions, 28 m tall with a breast height diameter of 90 cm. The bark on smaller trees and branches is smooth, brown-grey becoming roughened, flaky and dark brown on the lower bole in older specimens.

The bipinnate leaves are the largest of any Australian acacia, reaching overall dimensions of 50 × 35 cm. There are 2–6 pairs of pinnae 12–30 cm long, and 8–20 pairs of leaflets per pinna. Leaflets are lanceolate, 2.5–7 cm long × 4–10 mm wide, dark green above and paler beneath, with one main and one minor nerve. Short white hairs are present on the leaflets and rachis. New shoots are covered in golden hairs and young leaves may be reddish-bronze or light green. A prominent gland is present below the lowest pair of pinnae.

The flowers are in large, pale yellow globular heads in axillary racemes or terminal panicles. The pods are flattened, straight or slightly constricted between the seeds, 7–15 cm long and 10–14 mm wide, brown with a sparse covering of short white hairs. The seeds are black or very dark brown, 5–6 mm long by 4–4.5 mm wide, with a small whitish aril. Flowering takes place from late December to March, and pods mature in late November–early December.

The species is described and illustrated by Armitage (1977), Costermans (1981) and Simmons (1988).

Natural occurrence. *A. elata* has a restricted distribution extending from southwest of Sydney to central and northern New South Wales. It is locally common on sandstone ranges in the southern and central part of its occurrence.

- Latitude. Main occurrence: 30–35°30'S.
- Altitude. Main occurrence: 100–750 m.
  Range: 50–1200 m.

Climate. The occurrence is in the warm, sub-humid and humid zones. Mean annual temperature is 11–17°C. The mean maximum temperature of the hottest month is 23–29°C. The mean minimum of the coolest month is –2°C–5°C. The number of heavy frosts per year varies from less than five on lowland sites to more than 40 on the tablelands at altitudes over 650 m. Snowfall may occur at the highest elevations.

The 50 percentile rainfall is 1000–1250 mm, the 10 percentile 625–750 mm. The lowest recorded values are 500–625 mm, which in some localities decrease to 400 mm. The pattern is a moderate summer–autumn maximum, with September (spring) being the driest period of the year. The average rainfall of the driest month is at least half that of the wettest month. The number of days when there is measurable precipitation is 100–130 per year. At the lower rainfall sites it favours sheltered areas near streams.

Physiography and soils. *A. elata* grows chiefly in valleys and basins of moderate to steep relief, although it is sometimes found on gently sloping lowlands. Major substrates are sandstones and shales.

The soils include acid and neutral yellow earths, hard acid duplex soils, acid and neutral red earths. It also grows on slightly acidic (pH 5.5) shallow sandy soils over sandstone. Soils are deeper in gully locations and accumulation of leaf litter and humus has often been significant in such sites.

Vegetation type. *A. elata* is usually found in sheltered gullies, creeks and drainage lines, and attains its best development in sheltered riparian habitats. Commonly associated tree species include *Eucalyptus microcorys*, *E. saligna*, *Syncarpia glomulifera* and *Lophostemon confertus*. In the sandstone country it occurs as a mid-storey component of tall open-forest with *Angophora costata*, *E. agglomerata*, *E. deanei*, *E. gummifera*, *E. oreades*, *E. piperita* and *E. sieberi*. On shales it is found with *E. macarthurii* and with *E. viminalis* along streams in hilly country. In the northern parts of its distribution it grows at high elevations as an understorey in tall open-forest of *E. obliqua* and *E. campanulata*.

Utilisation.

Fodder: Not known.

Fuelwood: It is considered a most desirable species for the production of firewood and the denser wood (about 670 kg/m^3, Logan 1987) of older trees should make an excellent fuel. Gough et al. (1989) have investigated the firewood properties of 2.5-year-old saplings. The wood is very easily split and dries rapidly to 24% moisture content after 4–6 weeks. This young fast-grown wood (450 kg/m^3) produced some crackling and sparks in the early flaming phase and considerable fly ash during the flaming phase.

Wood: The pale-coloured wood has been reported to be soft and lack durability (von Mueller 1888), but may be suitable for packing cases (Anderson 1968). It should prove amenable to preservative treatment and treated posts would make a suitable fencing material. The wood has excellent potential for pulpwood: the only sample evaluated produced a very high pulp yield (59%) at a low Kappa number, 13 (Logan 1987).

Other uses: The species is well-suited to ornamental and windbreak purposes, although plants can develop a considerable spread in open situations and this may limit their utility. The bark has potential for tannin production, with young trees producing a light-coloured liquor and high (28–31%) tannic acid yields (von Mueller 1888). The leaves and flowers have been used for producing dyes (Simmons 1988).

Silvicultural features. A very fast-growing species adapted to fertile acidic and neutral soils in warm temperate zones. Young plants of *A. elata* are reported to be frost-tender (Streets 1962), but seedlings of high elevation provenances should withstand temperatures down to −5°C. It is one of the longer-lived bipinnate acacias and life expectancy should exceed 20 years (Boland 1987). Saplings cut at 0.5 m displayed some coppicing ability (Ryan and Bell 1989), but it is likely that old specimens will coppice only poorly or not at all.

Establishment: There are about 21 700 viable seeds/kg, at an average germination rate of 76%. *A. elata* seed requires a routine treatment to break seedcoat dormancy. Seedlings grow fast and a brief nursery phase of 10–12 weeks is recommended.

Yield: Plants have grown very rapidly in southeast Queensland attaining heights of 5.5–7.4 m after 41 months (Ryan and Bell 1989). Basal diameter increment was also impressive at 12–21 cm. Annual height increment has been 1.2 m in the highlands (>1300 m) of Uganda (Streets 1962).

Pests and diseases. Stem borers can be important pests, frequently shortening the lifespan of unthrifty or stressed trees. The leaf rust fungus *Uromycladium notabile* has been recorded (von Mueller 1888).

Limitations. Rapid, healthy growth will be achieved only on moist (> 900 mm), well-drained, moderately fertile sites, and this will restrict the choice of planting sites. Provenance variation is likely to be significant and careful attention to selection of seed source is required.

Related species. *A. elata* is in the section Botrycephalae, but does not appear to have close relatives.

Acacia eriopoda

Main attributes. A moderately fast-growing, nitrogen-fixing shrub or small tree. It is suitable for fuelwood production and sand stabilisation on well-drained, infertile, neutral–alkaline sandy soils in hot dry zones.

Botanical name. *Acacia eriopoda* Maiden and Blakely in *J. Roy. Soc.* 13: 27 (1927). The specific name is derived from the Greek *erio* — woolly, and *podo* — foot, and may be a reference to the woolly or tomentose peduncles.

Common name. Broome pindan wattle. Known as 'Irgul' by Australian Aboriginal people on the Dampier Peninsula.

Family. Mimosaceae.

Botanical features. *A. eriopoda* is an erect branching shrub or small tree to 4–8 m tall, commonly forking at or near the base. The bark is grey or grey-brown, smooth on the upper branches becoming fibrous and longitudinally fissured near the base. The phyllodes are linear, 10–23 cm long × 2–5 mm wide, ascending or spreading, dull pale green, glabrous and somewhat resinous. There are numerous fine longitudinal nerves and one prominent central nerve.

Fragrant, short (2–4 cm) yellow flower-spikes are produced from April to July. The spikes are arranged in axillary clusters of 3–4 spikes. The pods are very narrow, linear-terete, 5–20 cm long by 3–4 mm wide, distinctly constricted between the seeds, woody glabrous. The seeds are light greyish to red brown or almost black, ellipsoid, longitudinal in the pod, 4–6.5 mm by 2–3 mm wide, flattened with an extensive central depression. The funicle is expanded into a folded, creamy-white aril. Pods mature in October and November.

The species is illustrated by Petheram and Kok (1983) and a botanical description is given by Maslin (1981) and Wheeler et al. (1992).

Natural occurrence. *A. eriopoda* has a fairly restricted distribution associated with the Great Sandy Desert and its surrounds in northwestern Australia. It extends into the southern Kimberley region and eastern edge of the Pilbara. It is confined to Western Australia.

- Latitude. Range: 16–24°S.
- Altitude. Range: near sea level to 600 m.

Climate. This species occurs in warm to hot (annual mean temperature 24–28°C), semi-arid and arid (230–755 mm) zones. Summers are hot with a mean maximum temperature of the hottest month (November to February) between 34 and 41°C. The mean temperature of the coldest month is between 7 and 18°C. The main distribution is frost-free, but inland, high elevation locations may experience temperatures down to –1°C on a few nights per year.

The 50 percentile rainfall is 325–535 mm, the 10 percentile 120–455 mm and the lowest on record 22–310 mm. Rainfall distribution has a strong summer maximum with 55–70% falling in the wettest three months between December and March. Rainfall incidence is highly variable from year to year and the average annual number of raindays is 28–49.

Physiography and soils. *A. eriopoda* is restricted to the Western Plateau physiographic division. It is abundant on the gently undulating sandplains or pindan country around Broome. In more arid inland locations its favoured habitats are the stony and/or sandy beds and banks of infrequently flooded minor watercourses and the lower slopes of longitudinal dunes. In the eastern Kimberley it grows along minor creeks and among sandstone outcrops in the Bungle Bungle National Park. Near Broome it colonises the sheltered side of coastal dunes and sandplains immediately inland from coastal saline claypans.

The soils are freely draining infertile sands and loams, mostly neutral to slightly alkaline with a recorded pH range of 5.5–8.5. They are frequently stony and skeletal drainage line occurrences in hilly terrain. Recorded soils include white, light orange-brown, red-brown and red sands and earthy sands, shallow stony earthy loams and yellow sandy earths.

Vegetation type. *A. eriopoda* regenerates from seed and/or coppice following disturbance, and dense thickets may form after fire. It is a major component of the pindan scrubs around Broome. These plant communities consist of a tall shrub layer of various acacias (*A. anaticeps*, *A. ancistrocarpa*, *A. colei*, *A. monticola* and *A. tumida*) with scattered trees of bloodwood eucalypts (*E.* aff. *papuana*, *E. terminalis* and *E. zygophylla*) and *Lysiphyllum cunninghammii*. Spinifex, especially *Triodia pungens*, and other grasses are frequent groundcover associates.

In the southern Kimberley region it co-occurs with low eucalypts (*E. argillacea* and *E. bleeseri*) and other shrubs (*A. monticola* and *A. tumida*). Further east near Gordon Downs it occurs as small pure stands in a very open low woodland of *E. aspera* and *E. leucophloia* and scattered shrubs of *A. ancistrocarpa* and *A. cowleana*. On the eastern edge of the Pilbara it grows in rocky gorges with *E. camaldulensis*, *A. cyperophylla*, *A. tumida* and *Grevillea wickhamii* subsp. *aprica*, and in open shrublands (with *A. maitlandii*, *A. orthocarpa*, *A. trachycarpa* and *A. tumida*) on sand plains adjacent to minor drainage lines.

Utilisation.

Fodder: It does not appear to be grazed in its native habitat, and is unlikely to have any importance for fodder production.

Fuelwood: The dense wood (900 kg/m^3) should make an excellent fuel, and may be suitable for conversion to charcoal.

Wood: The wood from larger specimens may provide small posts or be turned into small decorative items.

Other uses: Its multi-stemmed bushy habit make it suitable to provide low shelter and sand stabilisation.

Silvicultural features. *A. eriopoda* is a slender tall shrub or multi-stemmed small tree of the subtropical dry zone.

It has a strong coppicing ability, and root suckers have been observed on major lateral roots near the trunk.

Establishment: This species is readily propagated from seed, and there are about 59 400 viable seeds/kg at an average germination rate of 88%. Seedcoat dormancy is removed by immersing the seed in a large volume of boiling (100°C) water for 30–60 seconds. A nursery phase of 4 months is recommended.

Yield: A. eriopoda grows at a steady and moderate growth rate in the dry tropics. Early height growth was slow at Dosso (Niger), but plants reached more than 5 m in 7 years at Keur Mactar, Senegal (585 mm rainfall, 7 months dry season) (L. Thomson, pers. comm.).

Pests and diseases. None are recorded.

Limitations. The small size of *A. eriopoda* will restrict its use to fuelwood, small posts and non-wood uses such as shelter and sand stabilisation. Its probable low frost-tolerance will restrict its planting to warmer arid areas.

Related species. *A. eriopoda* is closely related to *A. torulosa*. It hybridises with *A. tumida* (e.g. at Nullagine) and *A. monticola* (e.g. on Dampier Peninsula), and possibly *A. trachycarpa* (e.g. on Mt Edgar).

Acacia fasciculifera

Main attributes. A small nitrogen-fixing tree adapted to infertile sites in sub-humid, subtropical areas. Potential for fuelwood, posts, poles and shade.

Botanical name. *Acacia fasciculifera* F. Muell. ex Benth. was first described in *Fl. Aust*. 2: 361 (1864). The specific name is from the Latin *fasciculus* — bundles or clusters, and refers to the flower heads which are clustered in the phyllode axils.

Common names. Rose wattle (standard trade name), scaly bark, rose spearwood, rosewood wattle, rosewood, scrub ironbark.

Family. Mimosaceae.

Botanical features. A small tree, commonly 8–10 m, but on fertile, moist soils it can attain 20 m and have a stem diameter of 60 cm. When growing in open situations on less favourable sites, the main stem may only be dominant for half tree height and is frequently crooked. The crown is usually dense with stout, zig-zag drooping branchlets which are angular with yellowish ribs, mainly glabrous and with no stipules. The bark is dark grey, rough and fissured.

The phyllodes are pendulous, leathery, bright or dark green, shiny, with a prominent mid-vein and margin. They are narrowly oblong or elliptic, straight or slightly curved, 5–13 cm long, 7–20 mm wide with phyllodes on young growth broader, up to 30 mm wide. There is a raised gland on the upper margin at the phyllode base or 2–2.5 mm above. The flowers are pale cream, in globular heads on peduncles up to 2 cm long, clustered in the phyllode axils or arranged in a condensed raceme. The flowers have a sweet scent. The pods are 10–13 cm long, 10–13 mm wide (sometimes only 8 mm), straight or curved, flat with the seeds arranged longitudinally. The seeds are flattened, nearly orbicular, 6–7 mm long by 5–6 mm wide. The funicle thickens gradually from the edge of the pod to the base of the seed. It is undulate but not folded. This is a summer–autumn flowering species, principally in March, but pods may be found on some trees throughout the year (Swain 1928a; Pedley 1979).

The species is described by Pedley (1979) and Stanley and Ross (1983), and illustrated by Lebler (1981).

Natural occurrence. The main distribution of *A. fasciculifera* is in the coastal areas of Queensland from near Townsville south to the New South Wales border. Most occurrences are within 150 km of the coast but in places it extends inland for 250 km.

- Latitude. Main occurrence: 23–26°S.
  Range: 19–29 °S.
- Altitude. Main occurrence: near sea level to 150 m.
  Range: near sea level to 500 m.

Climate. *A. fasciculifera* grows mainly in the warm subhumid climatic zone but extends to the warm humid zone in a narrow coastal strip in the south of its distribution. The mean maximum temperature of the hottest month is 31–34°C. There is a mean of 50–80 days over 32°C and 4–5 days over 38°C each year. The mean minimum temperature of the coolest month is 5–10°C. Most northern and coastal occurrences are in frost-free areas but elsewhere there are 1–5 frosts annually.

The 50 percentile rainfall is 675–850 mm, the 10 percentile 450–750 mm, and the lowest on record 300–460 mm. There is a moderate- to well-defined summer maximum with 60–90 raindays annually and a dry season rarely greater than 3 months.

Physiography and soils. The distribution is confined to the Eastern Uplands physiographic division in which *A. fasciculifera* occurs mainly in undulating to hilly country. The largest trees are often in valleys, along watercourses, and on the lower slopes of hills, situations where soil moisture conditions are favourable and there is protection from strong winds. Plants growing on ridge tops and on sandstone plateau sites are more shrubby in form. It has been recorded on a range of soils including alluvials, loams, clay loams, and shallow stony soils. The soil types are mainly soloths with some areas of solodized solonetz and solodics, soils that have a strong texture contrast in the profile, low to very low fertility, and poor moisture relationships. They may be acidic throughout the profile or become alkaline in the subsoil. *A. fasciculifera* also occurs on brown and grey clays where soil fertility may be somewhat higher.

Vegetation type. This acacia occurs in a range of vegetation structure types. It is found in open-forest with eucalypts such as *E. citriodora* and *E. maculata*, and in low open-forest or softwood scrub often dominated by *Acacia harpophylla* or *Macropteranthes leichhardtii* (bonewood). Occasionally it grows in deciduous vine thickets or on the margins of closed-forest in the deeper valleys of large hills, usually where the soils are of low fertility. It is one of the few acacia species occurring in rainforest (Johnson and Burrows 1981).

Utilisation.

Fodder: Not recorded as a fodder species in Australia.

Fuelwood: The wood has a high air-dry density of 1120 kg/m^3 (Cause et al. 1974) and should make satisfactory fuel.

Wood: The heartwood is red-brown, very hard, heavy, tough and close-grained but easily worked (Maiden 1889). Only under favourable conditions does this species attain dimensions large enough for sawmilling. In the late 1800s in Australia it was sawn and considered a useful building timber. It has potential as a producer of posts and poles.

Other uses: It casts a relatively dense shade and could also be suitable for ornamental planting.

Silvicultural features. *A. fasciculifera* has been planted in Australia in only very recent times and its growth has not yet been reported in field trials outside Australia. Information on the potential of the species in plantations is therefore tentative, but it is likely to be relatively slow-growing. This species has been observed to coppice and root sucker (Searle 1989).

Establishment: Propagation is by seed that has been first immersed in boiling water for 1 minute to break seedcoat dormancy. Seedlots give an average germination rate of 83% which provides about 13 900 viable seeds/kg.

Yield: Early indications are that *A. fasciculifera* is adaptable, survives well but grows slowly. Trees of a single provenance of *A. fasciculifera* averaged only 1.2 m in height and 2.8 cm in basal diameter at 2 years in field trials near Gympie in southeastern Queensland. The same provenance survived very well on coarse soils in semi-arid central Queensland where it reached 40 cm in height at 7 months (Ryan and Bell 1991).

Pests and diseases. None recorded.

Limitations. This species appears to be relatively slow-growing and is probably only moderately drought-tolerant and frost-resistant.

Related species. *A. fasciculifera* is related to *A. crombiei*, *A. penninervis* and *A. macradenia*, species that sometimes have very similar phyllodes. It differs from these species and all other phyllodinous acacias in its very condensed racemes (Pedley 1979).

Acacia filicifolia

Main attributes. A fast-growing, nitrogen-fixing bipinnate acacia of moderate size, *A. filicifolia* has potential to produce fuelwood, posts and poles and provide amenity in warm humid to cool sub-humid zones. It should prove to be frost-tolerant and moderately drought-tolerant, depending on the provenance used.

Botanical name. *Acacia filicifolia* Cheel & Welch was described in *J. Roy. Soc. N.S.W.* 65: 232–234 (1932). The species name is derived from two Latin words, *filic* — relating to ferns, and *folium* — leaf, alluding to the fern-like appearance of the leaves.

Common names. Fern-leaf wattle

Family. Mimosaceae.

Botanical features. *A. filicifolia* is usually a large shrub to an erect tree 2–14 m in height with smooth occasionally deeply fissured black or dark brown bark. The branchlets are ridged or flattened, glabrous or pubescent with short wide curved hairs. The compound leaf has a midrib 4–12 cm long, with 5–14 pairs of pinnae on a petiole 10–25 mm long. There are 1–3 glands on the petiole and 3–4 inter-jugary glands between each pair of pinnae. Each pinna is 15–75 mm long, densely packed with 30–50 pairs of linear to oblong leaflets, 5–6 mm long by 0.4–0.6 mm wide, hairy or glabrous and with obscure mid-nerve and slightly inrolled margins. The flowers are in globular heads, 20–35 flowered, golden yellow, on about 4 mm stalks, on an extended axillary inflorescence or in terminal panicles. The pod is almost straight, flat, 4–12 cm long by 7–18 mm wide, black to blue, almost glaucous. The seed is longitudinal in the pod, with a short funicle expanding adjacent to the seed to form an aril, 5 × 2–3 mm. The flowering time is July to October. Ripe seed is available for collection in summer some 5–6 months after flowering (Boland 1987).

The species is described by Stanley and Ross (1983) and Tame (1992).

Natural occurrence. *A. filicifolia* is found along the coastal fringe of New South Wales and extends inland to the northern and central tablelands and on to the northwestern and central western slopes. It is also found in southern Queensland on sandy soils derived from granite.

- Latitude. Range: 28–30°S and 31–35°S.
- Altitude. Main occurrence: 750–1200 m.
  Range: near sea level to 1350 m.

Climate. The southern coastal distribution is mainly in the warm humid zone. The northern distribution is included in both warm sub-humid and cool sub-humid zones. There is occasional winter snow on the northern tablelands. The mean maximum temperature of the warmest month is 25–27°C and the mean minimum of the coolest month is variable and ranges from 5°C to –2°C at high altitudes and 6–8°C in coastal regions. The average number of days where 32°C is exceeded is 1–10 for the northern tablelands and 7–10 for southern and lower altitude occurrences. At high altitudes 37°C is exceeded on fewer than 1–2 days and for southern ranges from 1–10 days annually. The coastal distribution is frost-free, inland there is an average of 1–5 annually and there are 45–65 frosts a year at high altitudes.

The 50 percentile rainfall is 750–1000 mm, the 10 percentile 500–700 mm and the lowest on record 350–500 mm. There are 90–120 raindays per year on average. The seasonal rainfall incidence shows a maximum in summer to early autumn for most of the distribution. The wettest months are November to March.

Physiography and soils. This acacia is most commonly found on undulating to moderately hilly topography, but also occurs on steep hillsides and in valley bottoms and along watercourses. In general the sites are well drained. In Queensland this species occurs only on sandy soil derived from granite in the Stanthorpe–Wallangarra area (Pedley 1987a). The parent rocks include basalt, porphry, sandstone, shales and slates.

Soils are generally acidic and vary from sands, sandy alluvia, loams, reddish clay, and gravelly clays.

Vegetation type. A component of the low tree layer beneath tall-open forest dominated by *E. dalrympleana* and *E. caliginosa* on the northern tablelands of New South Wales (Beadle 1981). It is also present in open-forest and to a limited extend in open-woodland and low woodland. The dominant associated tree genus is *Eucalyptus* with common species, in addition to those above, including *E. amplifolia*, *E. blakelyi*, *E. gummifera*, *E. laevopinea*, *E. macrorhyncha*, *E. pauciflora*, *E. radiata*, *E. saligna*, *E. stellulata* and *E. viminalis*. Other trees of the tall open-forest include *Syncarpia glomulifera* and *Tristaniopsis laurina*. In drier locations it occurs with cypress pines, *Callitris* spp., and in many areas with *Angophora* spp. Only a few acacias have been recorded in association with *A. filicifolia* and they include *A. falciformis*, *A. longifolia*, *A. parramattensis* and, at the southern limits, *A. trachyphloia*.

Utilisation.

Fodder: Not known to have fodder value.

Fuelwood: Listed as a useful fuel by Anderson (1968).

Wood: No information available. The small size of the tree will restrict the uses to small round timber such as posts and poles.

Other uses: A. filicifolia is a slender, erect and elegant tree and makes a very attractive ornamental for use in parks and home gardens. Unlike many other bipinnate acacias it is a poor producer of tannin.

Silvicultural features. This acacia has been rarely tested for plantation forestry mainly because it is not well known and seed for this purpose has not been generally available. It appears to be relatively fast-growing and has been found to form nodules with many strains of rhizobia (Roughley 1987).

Establishment: Propagation is by seed that has been treated by immersion in boiling water for 1 minute to break seedcoat dormancy. Treated seed gives a germination rate of 80% and averages 64 300 viable seeds/kg.

Yield: In the humid, subtropical climate of northern Guangdong, China (24°57'N; 480 m above sea level) on steep slopes of deep, infertile, acid yellow earths, a provenance of *A. filicifolia* from Singleton in New South Wales ranked best for height growth and seventh for dbh at 18 months from planting, out of the wide range of acacias tested. Average height was 5.6 m (Yang et al. 1991). These authors recommended this species and three other lesser-known bipinnate acacias (*A. fulva*, *A. pruinosa* and *A. glaucocarpa*) for systematic sampling and provenance testing on this site with proven performers like *A. dealbata* and *A. mearnsii*.

Pests and diseases. None recorded.

Limitations. Lack of reliable information on performance as an exotic and silvicultural characteristics. Probably relatively short-lived. The small size will limit the use of its wood to fuel, posts and poles.

Related species. The species has been mistaken as a form of *A. decurrens* and confused with *A. mearnsii* and *A. dealbata* (Cheel and Welch 1931). *A. decurrens* is distinguished by its prominently angled branches and mostly winged and glabrous branchlets. The leaflets are smaller in *A. mearnsii* which also has a narrower pod. *A. filicifolia* has close affinities with *A. dealbata* which bears more numerous and shorter leaflets, more glaucous foliage, and only one gland at the base of each pinnae pair.

Acacia flavescens

Main attributes. A small, fast-growing species adapted to infertile, sandy soils in the humid or sub-humid, lowland tropics and subtropics. A nitrogen-fixer and a potential fuelwood species.

Botanical name. *Acacia flavescens* A. Cunn. ex Benth was first described in *London J. Bot*. 1: 381 (1842). The specific name is from the Latin meaning pale yellow or yellowish, and presumably refers to the yellowish hairs on young branchlets.

Common names. Red wattle, yellow wattle.

Family. Mimosaceae.

Botanical features. This acacia varies from a moderately bushy shrub 4–6 m in height to a small tree with a reasonably straight main stem often about 10 m in height but occasionally taller. The bark is dark and longitudinally furrowed.

The young branchlets have relatively dense yellowish stellate hairs. The phyllodes are more or less ovate-falcate, usually with some stellate hairs persisting near the base, with three prominent longitudinal nerves, the upper two ending at the phyllode edge at an indentation, usually associated with a gland. The phyllodes are 9–24 cm long and 1–6 cm wide with conspicuous glands in indentations along the upper margin.

The inflorescence consists of heads of small pale yellow flowers in terminal panicles. The pod is flat, slightly winged, shining, with transverse veins and scattered hairs when young, 6–12 cm long by 1–2 cm wide. The seeds are black, 6 mm by 4 mm, with a small, pale aril. The flowering period is January–June and the seeds are mature August–December (Searle 1989).

Pedley (1978) and Stanley and Ross (1983) give botanical descriptions, while Anderson (1993) provides an illustration of flowers and phyllodes.

Natural occurrence. *A. flavescens* has an extensive distribution in the coastal lowlands of Queensland. It extends from about 100 km north of Brisbane to near the tip of Cape York. It is also found as far as 250 km from the coast on the Atherton and Blackdown Tablelands and Isla Gorge at altitudes up to about 650 m.

- Latitude. Range: 11–27°S.
- Altitude. Main occurrence: near sea level to 150 m. Range: near sea level to 1000 m.

Climate. This is a species of the warm sub-humid, hot sub-humid and humid zones with a limited area of the hot wet climatic zone. The mean maximum temperature of the hottest month is 31–33°C and a mean minimum of the coolest month is mainly 11–16°C. The number of days over 32°C is usually 15–60 but can be 100. Temperatures rarely exceed 38°C. Most of the area is frost-free but light frosts occur at higher altitude, inland localities.

The 50 percentile rainfall is mainly 1000–2150 mm but with extremes over 3000 mm, the 10 percentile is about 500–1000 mm and the lowest on record about 300–800 mm. The climate is tropical to subtropical with a strongly developed summer monsoon in the north and a moderate summer maximum rainfall in the south.

Physiography and soils. Much of the occurrence of *A. flavescens* is on the gently undulating coastal plain. It extends to the slopes of the coastal ranges and on to the lower parts of the tablelands in central and northern Queensland.

A. flavescens occurs on a range of soil types, usually sandy, well-drained and acidic. On the sandy or loamy alluvium of the coastal plain the soils may be acid to neutral grey-brown podzolics, red and yellow friable earths, and loams of moderate to low fertility. On the slopes and ranges the soils are frequently red and yellow earths of variable depth, often shallow or skeletal, derived from sandstone, metamorphics or granite. It is found locally on lateritic gravelly ridges. On the drier uplands and highlands in northern Queensland, *A. flavescens* also occurs on red basaltic krasnozems and deep granitic soils, and in the foothills, on red earths derived from basic volcanics (Isbell and Murtha 1972; Tracey 1982).

Vegetation type. *A. flavescens* is found commonly as a small tree 8–10 m tall in closed-forest with eucalypt and acacia emergents. The eucalypts include *E. intermedia*, *E. pellita*, *E. tereticornis* and *E. tessellaris*; and the acacias *A. cincinnata*, *A. crassicarpa* and *A. mangium* (Tracey 1982). Elsewhere it is found as a shrub or small tree 3–8 m tall in the understorey of open-forest associated with *E. tessellaris*, *E. tereticornis*, *E. alba* and *Lophostemon suaveolens*; in the drier woodlands with *E. drepanophylla*, *E. citriodora*, *E. acmenoides*, and *Syncarpia glomulifera*; and in the low woodland of the coastal alluvial plains with *Melaleuca viridiflora* and *E. alba* (Isbell and Murtha 1972; Tracey 1982). On Cape York it is common in open-forest communities of *E. tetrodonta* (Pedley and Isbell 1970).

Utilisation.

Fodder: Usually unpalatable to cattle but can be lightly grazed when under heavy stocking densities (Bailey 1972). Vercoe (1987, 1989) found that nutrient levels and in vivo dry matter digestibilities of *A. flavescens* foliage were low and below maintenance requirements for sheep and cattle.

Fuelwood: Has a dense wood, which should make an acceptable fuel.

Wood: Close-grained, hard, brown in colour and attractively marked. The air dry density is about 900 kg/m^3 (M. Cause, pers. comm.). The wood is not utilised in Australia.

Other uses: It appears suitable for erosion control in fire-prone areas in the tropics. The bark has a tannin yield of 10–26%.

Silvicultural features. A fast-growing small tree adapted to a wide range of soil types. *A. flavescens* coppices abundantly (Ryan and Bell 1989) and shoots vigorously from root suckers if the above-ground parts of the tree are damaged by fire or other agencies (Kleinschmidt and Johnson 1977).

Establishment: Propagation is from seed that has been immersed in boiling water for 1 minute to break seedcoat dormancy. Planted trees bear their first flowers at 24 months. Treated seed gives a germination rate of 60% and there are about 25 500 viable seeds/kg.

Yield: Natural regeneration of *A. flavescens* has reached 3.2 m tall after 22 months. In field trials in south-eastern Queensland, the species grew well, averaging more than 8 m in height and 17 cm in diameter (at ground level) in 4.5 years (Ryan and Bell 1991).

However, other reports are less encouraging. In Nepal, trees from a lowland coastal site in northern Queensland reached 1.4 m tall 21 months after planting on a site at 730 m above sea level, but only 1.6 m tall at nearly 5 years on a severely eroded lateritic site at 600 m. It grew very slowly at 2000 m (Anon. 1980b). The species gave very poor survival and growth when planted in the high country of Sri Lanka (Weerawardane and Vivekanandan 1991). In Thailand, *A. flavescens* gave variable performance in height and diameter growth and survival over five sites. At 3 years the species averaged 2.3–8.4 m tall, 1.5–7.6 cm dbh and 44–86% in survival depending on the site. The best growth, 8.4 m in height and 7.6 cm dbh, was on a high rainfall (1500 mm) lowland site with a pH of 4.9 (Chittachumnonk and Sirilak 1991). Two provenances gave below-average growth performance in a species trial at Kadoma, Zimbabwe (Mitchell 1989).

Pests and diseases. None recorded.

Limitations. The small dimensions of *A. flavescens* will restrict its use as wood for fuel, posts, and small poles, or for non-wood uses such as shelter, erosion control and fodder. It is unlikely to tolerate other than very light frosts. It has the potential to be a weed species in some situations (Anderson 1993).

Related species. The presence of yellow stellate hairs indicate a relationship with *A. leptoloba* (Pedley 1978).

Acacia glaucocarpa

Main attributes. A relatively fast-growing small bipinnate acacia with potential to produce fuelwood, posts and poles and provide light shade in subtropical and sub-humid areas.

Botanical name. *Acacia glaucocarpa* Maiden and Blakely was raised to species rank in *Proc. Soc. Qld* 38: 120 (1927) and was based on *A. polybotrya* Benth. var. *foliolosa* Benth., *Fl. Aust*. 2: 414 (1864). The specific name is derived from the Greek *glauco* — glaucous, bluish bloom and *carpos* — fruit, and refers to the bluish appearance of the young pods.

Common names. None known.

Family. Mimosaceae.

Botanical features. *A. glaucocarpa* is typically an erect, slender, single-stemmed small tree 6–10 m tall. The bark is dark and rough near the base of large trees but soon becomes smooth and greenish above. The branchlets have a rather dense covering of short, white hairs.

The leaves are bipinnate, with a petiole of 1–3 cm and an axis to 7 cm long. There are usually 3–7 pairs of pinnae of 5–7.5 cm long, each with 15–25 pairs of leaflets, 10 mm long by 3 mm wide. Glands occur between each pair of pinnae but may be absent from the central part of the leaf. The flowers are lemon to pale golden-yellow in globular heads in large panicles, usually terminal. The pods vary in length but are up to about 13 cm with a width about 1 cm; straight or curved and prominently contracted between the longitudinally positioned seeds. Flowering is from mid-February to July but in most years it is concentrated in April–May. The seed is black, 5–6 mm long by 3 mm wide, with a dark cream or brown aril. Ripe seed has been collected in November (Searle 1989).

A. glaucocarpa is described by Pedley (1979, 1987a) and Stanley and Ross (1983) and is illustrated by Lebler (1981).

Natural occurrence. *A. glaucocarpa* is restricted to Queensland and occurs in an area about 600 km long by 150 km wide from near Brisbane to the Tropic of Capricorn. It is particularly common in the south of this distribution (Pedley 1979).

Latitude. Range: 23–29°S.
Altitude. Main occurrence: 30–300 m.
Range: 30–450 m.

Climate. The distribution is confined to the warm sub-humid climatic zone. Mean maximum temperature of the hottest month is 31–34°C and mean minimum of the coolest month is 6–7°C. At inland occurrences there may be 60–120 days over 32°C and 5–20 days over 38°C, but temperatures are lower in more coastal localities where 38°C is rarely recorded. For most of the inland area there are 1–5 days of heavy frost, while coastal areas are mainly frost-free.

The 50 percentile rainfall is 650–850 mm, the 10 percentile 450–700 mm, and the lowest on record 300–450 mm. There is a moderate summer maximum and 80–110 raindays per year. The dry season (less than 30 mm rain per month) is short, averaging 1–3 months.

Physiography and soils. *A. glaucocarpa* occurs only in the Eastern Uplands physiographic division in undulating to hilly topography. It is found on narrow flats alongside small streams and extends to the crests of stony ridges usually occurring on rather deep soils derived from sandstone or schist. The soils are acidic or neutral, brown silty loams, alluvials, or fine sands.

Vegetation type. This species occurs mainly in low open-forest and open-forest with some populations in woodland associated with a mixture of rainforest shrubs in the understorey. The dominant trees are eucalypts with *E. crebra*, *E. tereticornis*, and *E. tessellaris* prominent. On lower slopes *A. glaucocarpa* may be associated with *E. maculata* while on the upper slopes and ridges it occurs with *E. melanophloia*. In these forest types there is a moderately rich shrub layer with acacias, such as *A. aulacocarpa*, being common. On the edge of streams, *Callistemon viminalis* and *Melaleuca* spp. may be associates.

Utilisation.

Fodder: Not known to have fodder value in the wild. Vercoe (1987, 1989) suggested digestibility (in vivo DMD of 40%) and protein content (12.6%) of the foliage may be suitable for fodder at below maintenance requirements with addition of some protein supplements.

Fuelwood: Should be satisfactory fuelwood.

Wood: Wood density is in the medium range with a basic density of 780 kg/m^3 (Davis 1994). The small size of the tree will restrict the uses to small round timber such as posts and poles.

Other uses: A. glaucocarpa is reported to be one of the best tannin producers of the Queensland acacias with a yield of 16–26% (Swain 1928a). It has potential to provide light shade, and it could make an attractive ornamental species.

Silvicultural features. A fast-growing, nitrogen-fixing tree of the subtropics. *A. glaucocarpa* regenerates well by coppice (Ryan and Bell 1989). Achieving optimum growth with this species may depend on the selection of the correct provenance for the particular planting site.

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seed-coat dormancy. Germination rate of treated seeds averages 73% and there are about 38 000 viable seeds/kg.

Yield: The species survived well and grew quickly in several field trials in southeastern Queensland, Australia (Ryan and Bell 1991). In trials planted at Wongi and Tuan in 1986, trees of the Blackdown Tableland provenance gave an average height of 8.6 m and 12.4 m and basal diameters of 12.7 cm and 18.2 cm, respectively, at 4.5 years. A Gayndah provenance planted in 1987 and assessed at 2 years was 7.7 m and 6.9 m in height and 14.0 and 13.0 cm basal diameter on the same two sites. The Gayndah provenance also grew well in northern Queensland at Mareeba and Charters Towers but could only survive well on acid red earths at Longreach in central Queensland with continuing irrigation (Bell et al. 1991).

Growth as an exotic has been encouraging at some sites. In a trial at 1100 m elevation and 1500 mm rainfall in Sri Lanka, a provenance from Blackdown Tableland had reached 10 m in height at 5 years (Weerawardane and Vivekanandan 1991). A provenance of *A. glaucocarpa* from southeastern Qld attained 5 m in height at 18 months in the subtropics of southern China (Yang et al. 1989). It has survived poorly in the semi-arid zone of Kenya (Chege and Stewart 1991; Kimondo 1991).

Pests and diseases. In field trials in southeastern Queensland, Australia, it was found to be occasionally seriously attacked by a stem borer, *Xyleutes liturata*. Larval tunnelling weakens the stem and branches of young trees and may result in breakage (Ryan and Bell 1989).

Limitations. It appears to be intolerant of severe droughts. The small size will limit the use of its wood to fuel, posts and poles.

Related species. *A. glaucocarpa* is a bipinnate acacia in the *A. decurrens–A. mearnsii* group.

Acacia harpophylla

Main attributes. A nitrogen-fixing shrub or tree tolerant of heavy clay soils, often highly alkaline or saline, in subtropical and warm temperate areas. It reproduces from suckers. The hard, heavy and strong wood makes a good fuel, a high quality charcoal, and can be used for posts, poles, and some forms of joinery. This acacia is excellent for shade, shelter and ornamental purposes.

Botanical name. *Acacia harpophylla* F. Muell. ex Benth was first published in *Fl. Austral*. 2: 389 (1864). The name *harpophylla* is derived from the Greek *(h)arpe* — scimitar and *phyllon* — a leaf in allusion to the curved sickle-shaped phyllodes.

Common names. Brigalow, brigalow spearwood (rare).

Family. Mimosaceae.

Botanical features. *A. harpohylla* is a medium-sized tree, usually 12–20 m and up to 24 m on the most favourable sites. The moderately straight trunk can reach a diameter of 60 cm. The bark is dark grey, hard, and longitudinally furrowed.

Phyllodes are curved, tapering to each end, 10–23 cm long by about 7–20 mm wide, grey to silver-grey in colour, smooth or covered with short scale-like hairs. The longitudinal venation is inconspicuous. Golden-yellow flower heads are clustered on a common stalk in leaf axils. The pod is reddish-brown, mainly 7–12 cm long, 5–8 mm wide, usually slightly curved, with longitudinal thickened margins and contracted between the longitudinally orientated seeds. The seeds are brown, ovoid, flattened and 1–2 cm long. Flower production is irregular, influenced by rainfall and soil moisture, and seed is not set every year. The flowering period is mainly July–September and seeds mature in November–December.

The botanical features are described by Pedley (1978) and Stanley and Ross (1983). The species is illustrated by Simmons (1981) and Cunningham et al. (1981).

Natural occurrence. *A. harpophylla* is moderately to very common over an area about 850 km long and up to 400 km wide from central Queensland to the northern border area of New South Wales, then extends south for a further 350 km. It mainly occupies a belt 150–500 km from the Queensland coast and extends up to 800 km inland in New South Wales.

- Latitude. Main occurrence: 21–30°S.
  Range: 19–33°S.
- Altitude. Main occurrence: 120–330 m.
  Range: near sea level to 450 m.

Climate. The principal distribution is in the warm sub-humid climatic zone, especially in Queensland, but in the south of its range it is found in the higher rainfall parts of the semi-arid zone. The main distribution has a hot to very hot summer, some winter frosts, and a moderate rainfall subject to high variability. The mean temperature of the hottest month is 32–34°C and the mean minimum of the coolest 4–7°C with 2–18 frosts a year. The temperature exceeds 38°C on up to 40 days each year at some inland sites.

The 50 percentile rainfall for the main area of occurrence is 500–750 mm, the 10 percentile 350–450 mm, and the lowest on record 150–300 mm. The Queensland distribution has a well-developed summer maximum with a dry season of 1–4 months and 50–75 raindays annually; in New South Wales the rainfall is more uniform, often with no months having less than 30 mm, and 50–60 raindays. For the drier, more inland areas the 50 percentile rainfall is 300–400 mm, the lowest on record down to about 100 mm, and a dry season of 5–7 months.

Physiography and soils. *A. harpophylla* is found both east and west of the Great Dividing Range, mainly in the Central Lowlands and Fitzroy Uplands. It grows in wide flats, plains and gentle, undulating lowlands; it rarely extends to hill slopes and ridges.

The soils are commonly deep and fine-textured derived from siltstone, shales, basic volcanic rocks or fine-textured alluvials. The soil types are grey, brown, and red clays, heavy, often alkaline or with saline B horizon, and usually moderately deep to deep. Many of the clays on which *A. harpophylla* grows are acid throughout and strongly so in the deeper subsoil (Stace et al. 1968). It also grows on texture-contrast red-brown earths, which are usually deep soils with an acidic sandy or loamy surface over a strongly alkaline clay subsoil. The soils, particularly the clays, are relatively fertile though available phosphorus is low except in the alluvial clays and basalt-derived soils (Isbell 1962; Johnson and Burrows 1981).

Vegetation type. In areas receiving over 500 mm annual rainfall *A. harpophylla* dominates open-forest communities 10–20 m tall; in drier areas woodlands and low open-woodlands are the most common structural form. The disturbance of open-forest communities by fire or past clearing has resulted in dense shrublands of *A. harpophylla* (Johnson and Burrows 1981).

In the north of its range it often forms dense pure stands but *Casuarina cristata* is a common associate that tends to predominate where soils become more waterlogged. *Eucalyptus cambageana* and *E. populnea* occur as canopy trees and emergents, especially on red-brown texture contrast soils, and *E. coolabah* is an associate on alluvial soils along watercourses or in flooded areas. In drier areas *A. harpophylla* may be co-dominant with *A. cambagei*, *A. excelsa* and *A. pendula*. More detailed descriptions of species associations are given by Johnson (1964) and Beadle (1981).

Utilisation.

Fodder: Sheep will eat young tender shoots from root suckers and windfall leaves but refuse more mature leaves. Mature leaves may be eaten by cattle when other forage is unavailable. It is not regarded as a good fodder tree (Anderson 1993; Everist 1969).

Fuelwood: It is a good fuel and source of charcoal (Hall et al. 1972).

Wood: The timber is very heavy (basic density about 900 kg/m^3), very hard, strong and elastic and can be used in the round for rails and building poles. It splits easily, can be planed to a fine, smooth finish and takes a high polish. It has been used in Australia for turnery and cabinet work. The heartwood resists decay and termites so that untreated fence posts will give reasonably long life (Da Costa and Gay 1966).

Other uses: An excellent species for shade and shelter as well as an attractive ornamental tree.

Silvicultural features. *A. harpophylla* exhibits variation in morphology and growth form. It appears to have a very wide physiological tolerance and colonises habitats that vary widely in terms of water relations and soil fertility (Coaldrake 1971).

Establishment: Seed is produced irregularly and often at intervals of several years. The seed has a thin, permeable seedcoat not requiring any form of pretreatment before germination. Fresh seed gives a germination rate of 97% providing about 18 900 viable seeds/kg. Seed viability is lost within 0.5–2 years unless the seeds are stored at subfreezing temperatures.

Seedlings develop a tap root initially and later form an extensive lateral root system concentrated in the upper 25 cm of the soil. The horizontal roots store large quantities of starch and produce numerous sucker shoots if the plant is damaged. This characteristic could be utilised to regenerate fuelwood plantings.

Yield: This species has rarely been planted. Published data from trials suggests it is slow-growing (0.3–0.5 m/year) (Ryan and Bell 1991) and intolerant of acidic site conditions (Pinyopusarerk 1989). A natural stand of seedlings grew to 8 m tall in 22 years. Growth of sucker shoots is somewhat faster and under good conditions they have reached 2 m in three years (Johnson 1964).

Pests and diseases. None recorded. Appears to be relatively resistant to termites.

Limitations. Lack of seed and slow growth rate may limit its use. Once established it is not easily eradicated (Johnson 1964). The tree is reported to cause 'brigalow itch', a form of dermatitis, in man.

Related species. Its close relatives are *A. cambagei* and *A. argyrodendron* (Thomson et al. 1994).

Acacia holosericea

Main attributes. A fast-growing nitrogen-fixing shrub or small tree adapted to a wide range of sites in the seasonally-dry and sub-humid tropics. It is promising for fuelwood, charcoal, windbreaks and soil conservation.

Botanical name. *Acacia holosericea* A. Cunn. ex G. Don in *Gen. Syst.* 2: 407 (1832). The species name is derived from the Greek *holo* — entire or whole, and the Latin *sericeus* — silky, with long straight close-pressed glossy hairs, in reference to the indumentum of the plant.

Common names. Candelabra wattle, 'wah-roon'.

Family. Mimosaceae.

Botanical features. A multi-stemmed large shrub or small tree up to 9 m tall. The branchlets have three acutely angled ribs, either smooth or with dense short hairs. The phyllodes are broadly elliptical, slightly to strongly asymmetrical, 10–25 cm long and mostly 2–5 cm broad. There are 3, rarely 2 or 4, prominent longitudinal nerves running into the dorsal margin. Secondary venation is net-like: the irregularly shaped nerve islands are typically less than 3 times as long as wide. Plants from Cooper Creek and Jabiru (Northern Territory) have glabrous phyllodes, but more typically the phyllodes are sparsely to densely hairy. The hairs are typically longer than in the related *A. colei*, and may be either appressed or erect. Some phyllodes have a small gland at the base of a distinct apical point.

The bright yellow flowers are on spikes 3–6 cm long in pairs in the upper axils. The pods are in densely intertwined clusters. They are coiled (at least twice), 2–8 cm long by 2–3 mm wide, thin-textured and sometimes constricted and raised over the seeds. The seeds are 2.5–3.5 mm long by 1.5–2 mm wide, rectangular, black, shiny with a small yellow aril at the base. The main flowering period is June–August but can be April–October. Fruits mature August–October.

The species is described and illustrated by Maslin and Thomson (1992).

Natural occurrence. This is an acacia of northern Australia. It extends from northern Western Australia through the Northern Territory to Cape York and northeastern Queensland.

- Latitude. Range: 12–25°S.
- Altitude. Main occurrence: near sea level to 400 m.
  Range: near sea level to 780 m.

Climate. The species occurs mainly in the warm to hot sub-humid zone with extension to the semi-arid zone. The mean maximum temperature of the hottest month (November or December) is 31–37°C. Winters are mild with mean minimum temperatures for the coolest month usually in the range 12–17°C. Most of the distribution is frost-free but up to about 10 frosts each year occur at some inland sites.

The 50 percentile rainfall is 300–1100 mm, the 10 percentile is 200–650 mm, and the driest on record about 125 mm. There is a well-developed monsoonal rainfall pattern with maximum falls in December–March. The dry season usually lasts for 5–7 months.

Physiography and soils. It occurs on inland plains, hilly uplands and coastal lowlands. The plains are flat or undulating, typically alluvial. The uplands are hilly or undulating often in the form of dissected plateaux and ranges of granite, quartzites, sandstones, and basalts. Lowlands are undulating or flat plains on limestone or easily eroded sedimentary rocks. *A. holosericea* commonly grows along permanent and seasonally-dry watercourses with sandy or gravelly banks. Occasionally it is found on stony hills or ridges.

Soils vary both in drainage, from freely drained to seasonally wet, and fertility, from infertile sandy loams to more fertile red volcanics. The major soil types are shallow acidic sandy lithosols and shallow loamy soils; others are earthy sand, yellow earths, and hard alkaline yellow and dark bleached duplex soils. It grows on both fine-textured alluvials (pH 6–9) and neutral red sandy loams in Western Australia.

Vegetation type. In Northern Territory *A. holosericea* is a common pioneering plant in disturbed situations especially favouring permanent and seasonal freshwater creeks and streams (Brock 1988). Riparian associates include *Melaleuca leucadendra*, *M. argentea*, *Casuarina cunninghamiana*, *E. camaldulensis*, *Acacia leptocarpa*, *Pandanus* spp. and *Terminalia* spp.. *E. grandiflora*, *E. polycarpa* and *A. aulacocarpa* are associates in woodland habitats.

In the more humid parts of its range in north Queensland *A. holosericea* occurs as an understorey in tall eucalypt woodland together with *E. cullenii*, *E. leptophleba*, *E. papuana*, *E. confertiflora*, *E. polycarpa*, *Erythrophloem chlorostachys* and *A. crassicarpa*. It also occurs as an understorey of low eucalypt woodlands (Tracey 1982).

In Western Australia it is a component of 'pindan' scrub, where associates include *Lysiphyllum cunninghamii*, *Ficus opposita*, *A. eriopoda*, *A. tumida* and *A. colei*.

Utilisation.

Fodder: A. holosericea is not grazed to any extent by stock in Australia. Analyses of fodder value have not been especially promising: phyllode digestibility (36–38%) and protein content (13–14%) were found to be lower than for the related *A. colei* and *A. cowleana* (Vercoe 1989).

Fuelwood: The wood is an excellent fuel: it has a moderately high density (550 kg/m^3), splits easily, dries rapidly and has acceptable burning properties (Gough et al. 1989).

Wood: The hard, dark brown heartwood may be turned into small decorative articles.

Other uses: A. holosericea was utilised for many purposes by northern Australian Aboriginal people. Different parts of the plant were used to make bush soap, medicine, fish poison and spear shafts (Brock 1988). It has been used to revegetate land after surface mining in northern Australia (Langkamp et al. 1982). *A. holosericea* has limited potential for production of human food in tropical dry zones (Thomson 1992).

Silvicultural features. A fast-growing, short-lived large shrub or small tree suitable for higher rainfall (> 700 mm) parts of the seasonally dry tropics. The species has poor coppicing ability.

Establishment: The mean number of viable seeds/kg is 92 900, with a germination rate of 86%. Pretreatment of seed with boiling water for 1 minute is necessary to break dormancy and enhance germination. Seedling

growth is rapid and a short nursery phase of 12–15 weeks is recommended.

Yield: In trials near Gympie (southeastern Queensland), *A. holosericea* grew to 4.3–6.4 m, with a basal stem diameter of 8–10 cm in 3.5 years (Ryan and Bell 1989). Similar growth rates were recorded from Tamil Nadu, India (R. Jambulingam, pers. comm.). In both trials Mt Molloy (Queensland) plants exhibited 35–40% faster height growth than plants from Jabiru (Northern Territory). At trial sites where mean annual precipitation exceeds 1000 mm *A. holosericea* has exhibited superior growth and survival to *A. colei*; however, the converse applies at sites receiving less than 800 mm.

Pests and diseases. Recorded minor insect pests include *Ancita marginicollis* (stem-boring beetle), *Dicranosterna picea* and *Myllocerus* sp. (beetle defoliators) and *Sextius* sp. (sap-sucker) (Ryan and Bell 1989). Recorded diseases include: the rusts *Aecidium* spp. and *Uromyces digitatus*; and the wilts *Fusarium* spp. and *Meloidogyne* spp.; and the powdery mildew *Oidium* spp. (Boa and Lenné 1994).

Limitations. The form and size of this species will restrict its use to fuelwood and charcoal. *A. holosericea* has many features of a colonising species, such as early (6–12 months) and heavy seeding habit, rapid growth and short life span (10–12 years), which suggests that it has the potential to become a weed in some situations.

Related species. Chromosome examination has shown *A. holosericea* to be tetraploid (4n = 52); a closely related diploid taxon has been named *A. neurocarpa* and a hexaploid taxon is *A. colei* (Maslin and Thomson 1992). Other close relatives of *A. holosericea* include *A. grandifolia*, *A. nesophila* and *A. pellita* (Pedley 1978).

Acacia hylonoma

Main attributes. An adaptable medium to tall tree of the wet to very wet tropical lowlands. It tolerates poorly drained soils of high clay content. Growth rate is moderate but the species usually has high survival. Little is known of its wood properties but it should provide good fuel. *A. hylonoma* has ornamental value on suitable sites.

Botanical name. *Acacia hylonoma* Pedley was first described by L. Pedley in *Austrobaileya* 1: 214 (1978). The specific name is based on the Greek *hyle* — forest, woodland and *nomos* — abode. This is in reference to the species' habitat.

Common names. None known.

Family. Mimosaceae.

Botanical features. *Acacia hylonoma* can be a large tree up to 25 m tall with a diameter at breast height of 40 cm. The bark is usually somewhat yellowish-brown. The branchlets are acutely angular, reddish, lenticular, glabrous; stipules deltoid about 0.5 mm long. The phyllodes are straight or curved, glabrous, mainly 8–13.5 cm long by 7–16 mm, widest at or below the middle, on a stalk 1–2 mm long. They display 4–10 longitudinal veins 1.5–2 mm apart with less prominent loosely anastomosing secondary veins between them. There is a small gland present on the upper edge of the phyllode, 5–15 mm from the base.

The flowers are in axillary twin globular heads, with approximately 25 flowers in each head, on 5–8 mm stalks. The pods are 9 × 1.2 cm and papery. The seeds are longitudinal in the pod, 5 mm long × 3.5 – 4 mm wide with slightly thickened funicle folded, not expanded, beneath the seed.

Flowering time is from August to November with ripe seed available in December.

The species is described by Pedley (1978) and Hyland and Whiffin (1993). It is illustrated in NAS (1983).

Natural occurrence. *A. hylonoma* is endemic to north-eastern Queensland where it is restricted to a few localities. The type specimen was collected in a State forest reserve, southeast of Cairns.

- Latitude: Main occurrence: 17°S.
- Altitude. Range: near sea level to 400 m.

Climate. The species is found between the hot wet and hot sub-humid climatic zones. The mean maximum temperature of the hottest month (December) is 32°C and the mean minimum of the coolest month 17°C. The area is frost free.

The 50 percentile rainfall is 2150 mm, the 10 percentile 1350 mm and the lowest on record 1100 mm. There is a well-developed summer maximum with the wettest month receiving 10 times the rainfall for the driest month (July to September). The average number of raindays a year is 146.

Physiography and soils. *A. hylonoma* occupies a very small area within the Peninsular Uplands of the Eastern Uplands physiographic division. It has been found growing on red earth, yellow-brown loams over granite and sometimes amongst granite boulders.

Vegetation type. *A. hylonoma* is one of the few acacias that is found in lowland rainforest. This species is favoured by disturbance and is a component of rain-forest regrowth. Species growing in association with *A. hylonoma* include *Flindersia pimenteliana*, *F. bourjotiana*, *Acacia aulacocarpa*, *Alstonia muellerana*, *Carnarvonia araliifolia*, *Commersonia bartramia* and *Elaeocarpus bancroftii*.

Utilisation.

Fodder: In a dry matter digestibility and nutrient analysis of *A. hylonoma*, Vercoe (1989) found that it had a predicted dry matter determination of 47.8% and a crude protein value of 14.3%. Although not considered to be a good fodder species, Vercoe concludes that this species warrants further investigation, as it comes close to the minimum requirements for certain nutrients.

Fuelwood: It should be a satisfactory fuel.
Wood: No data available, but is a potential provider of posts and poles.
Other uses: It is considered to be a useful ornamental for the wet to very wet lowland tropics on poorly drained soils with a high clay content (A. Irvine, pers. comm.).
Silvicultural features. *A. hylonoma* is a pioneering species of the rainforest and has the ability to produce viable seed from self-pollination (A. Irvine, pers. comm.). It is reported to coppice well, and root suckering has been observed.
Establishment: The species produces about 40 800 viable seeds/kg at an average germination rate of 76% after regular dormancy-breaking treatment (1 minute immersion in boiling water).
Yield: A. hylonoma appears to be adaptable, giving high survival on a range of sites in the tropics, but is relatively slow-growing compared to some other species. For example, near Gympie in southeastern Queensland two provenances averaged 6.5 m tall and 12.3 cm diameter ground level at 4.5 years (Ryan and Bell 1989, 1991). On a site in Thailand with 1300 mm/year rainfall and elevation of 450 m above sea level, *A. hylonoma* averaged 1.3 m in height at 12 months (Pinyopusarerk 1989). On an *Imperata cylindrica* grassland site in South Kalimantan, Indonesia it reached 3.9 m in 24 months (Otsamo et al. 1993).

Pests and diseases. None are recorded.
Limitations. Being a species of the wet sub-humid tropics it is unlikely to tolerate severe droughts and frosts. Its ability to root-sucker and self-pollinate suggest potential weediness problems on sites where conditions favour it.
Related species. *A. hylonoma* is closely related to *A. simsii* and *A. ramiflora*, by characteristics of the leaf venation and the structure of the inflorescence (Pedley 1978).

Acacia irrorata

Main attributes. A small fast-growing tree adapted to cool, moist sites in the subtropics and the warm temperate zones. It has potential for shade, shelter, erosion control, and ornamental purposes. It is a good fuelwood.

Botanical name. *Acacia irrorata* Sieb. ex Spreng., *Syst.* 3: 141 (182). There are two subspecies recognised, i.e. subsp. *irrorata* and subsp. *velutinella*. The specific name is from the Latin *irroratus* — moistened with dew, and the subspecific name is from *velutinus* — velvety, referring to the velvety foliage and branchlets which readily distinguish it from subsp. *irrorata*.

Common names. Green wattle (standard trade name), black wattle, blue skin, ferny wattle.

Family. Mimosaceae.

Botanical features. This bipinnate acacia is mainly found as a large shrub or small tree of 5–10 m but in favourable conditions has been recorded to over 20 m. Open-grown specimens branch freely and the trunk is often only well-defined for less than half tree height. At its best, the trunk is moderately straight to three-quarters of the tree height. *A. irrorata* closely resembles *A. mearnsii* in habit and general appearance (Sherry 1971). The bark is dark grey or black, firm and not as thick as that of many acacia species of similar size.

Mature leaves are dark green, leaf axis is ribbed, with close hair tufts along rough ridges, 4–6 cm long with 9–12 pairs of pinnae; secondary axes 2.5–4 cm long, each bearing 40–50 pairs of leaflets each 2–4 mm by 0.4–0.6 mm and darker green above; glands only at the base of few pinnae and never in between. The flowers are lemon to pale golden yellow, in globular heads on axillary racemes, sometimes forming terminal panicles. The pods are flat, linear or slightly constricted between the seeds, 6–10 cm long by 5–10 mm broad with sparse appressed hairs. The seeds are longitudinal in the pod, black, glossy or dull, 3–4 mm long by 2–3 mm wide, with a small yellow-brown terminal aril. The main flowering period for subsp. *irrorata* is November–January in New South Wales and December–March in Queensland; subsp. *velutinella* flowers in January–February; the pods are mature 7–9 months after flowering.

The species is described by Pedley (1979) and Tame (1992) and subsp. *velutinella* by Tindale (1966a). It is illustrated by Costermans (1981) and Lebler (1981).

Natural occurrence. An acacia of eastern Australia where it occurs in a coastal belt for over 1000 km from southeastern Queensland to southern New South Wales. It extends inland to the higher parts of the tablelands of New South Wales. The subsp. *velutinella* is common in the coastal areas of northern New South Wales.

- Latitude. Main occurrence: 26–36°S.
  Range: 25–37°S.
- Altitude. Main occurrence: near sea level to 1000 m.
  Range: near sea level to 1300 m.

Climate. The distribution is mainly in the warm humid climatic zone, with some extension into the warm sub-humid and cool humid zones. The mean maximum temperature of the hottest month is mainly 29–31°C, and the mean minimum of the coolest month 1–7°C. The average number of days over 32°C is 10–26 and there are up to 4 days over 38°C. Limited areas of the coast are frost-free, but elsewhere there may be up to 40 frosts recorded annually.

The 50 percentile rainfall is mainly 750–1100 mm, the 10 percentile 600–750 mm, and the lowest on record 400–600 mm. There is a weak summer-rainfall maximum in the south and a moderate summer maximum in the north. Raindays are in the range 105–125 per year and dry periods are not prolonged.

Physiography and soils. This species is confined to the Eastern Uplands physiographic division on undulating coastal lowlands, rarely on small flats close to the sea; the foothills, mountain slopes and valleys of the coastal escarpment and, to a limited extent, on the undulating high tablelands. It is frequent on the narrow flats along streams but also grows on steep slopes if the soil is moist and relatively fertile. Subspecies *velutinella* has been recorded also from *Melaleuca*-dominated swamps and hard gravelly ridges.

A. irrorata generally occurs on the heavier soil types derived from shales or other sedimentary rock formations, and basalt. It grows well on red volcanics, well-drained clays and gravelly soils, and is satisfactory on deep forest podzols, especially if soil moisture is adequate. Poorer specimens are found on shallow lithosols.

Vegetation type. This species is principally a component of tall open-forest, often on rainforest margins, but also occurs in open-forest. Where conditions are favourable it may be an important understorey species or it may dominate regrowth in small clearings. The associations are mainly dominated by *E. saligna* and *E. microcorys* on soils of relatively high fertility, by *E. resinifera* and *E. propinqua* on upper slopes, and *E. pilularis* on more siliceous parent materials.

Utilisation.

Fodder: Not recorded as a fodder species.

Fuelwood: It makes a good fuel when dry.

Wood: The heartwood is pale brown and hard. The wood is moderately dense. Green density is 1150 kg/m^3 and air dry density is 830 kg/m^3 (Bootle 1983). It can be used for posts and poles but may not be as durable as many other acacias.

Other uses: The bark is a very good source of tannin although the yield is inferior to that of *A. mearnsii*. This species appears to have a role for shade and tall shelter and also for soil conservation on steep slopes where there is moderately fertile soil and adequate rainfall. The soft green foliage is a feature that makes it an attractive ornamental tree.

Silvicultural features. A fast-growing species that regenerates rapidly after fire. These characteristics have made it a weed species in areas where eucalypts are being naturally regenerated (Floyd 1966). Its coppicing ability is not recorded but its close relationship to *A. dealbata*, which both coppices and produces root suckers, has been noted.

The potential of this species has not been adequately assessed because of the lack of a range-wide provenance collection. The few seedlots tested have given variable performance.

Establishment: This species produces about 101 100 viable seeds/kg at a germination rate of over 80%. The seeds require one of the routine treatments to break seedcoat dormancy. Nursery and establishment techniques devised for *A. mearnsii* can be applied to *A. irrorata*.

Yield: Near Gympie in southeastern Queensland, where the species is endemic, it survived and grew well averaging 12 m in height and 16.6 cm in basal diameter at 4.5 years (Ryan and Bell 1991). Elsewhere its performance has been less encouraging. For example, in China *A. irrorata* grew to 3 m in 18 months (Yang et al. 1991) but was much slower than the best-performing acacias (e.g. *A. filicifolia*, *A. fulva* and *A. dealbata*) which averaged more than 5 m. These plots were later severely damaged by snow, causing death to *A. irrorata*. Similarly in Nepal, in the middle mountains (1000–1400 m) its performance was unimpressive (Karki and Karki 1993).

Pests and diseases. *A. irrorata* is likely to be subject to a similar range of pests and diseases as is *A. mearnsii*. Defoliating moths and beetles and termites have been serious pests of *A. mearnii* (Sherry 1971) and this species is subject to a range of fungal diseases (Boa and Lenné 1994).

Limitations. This acacia requires moist, relatively fertile sites to achieve fast growth, and this will restrict the choice of sites. A variable, often crooked stem form will limit the utilisation to poles, although closely-planted trees should have better form. Its ability to regenerate rapidly makes it a potential weed species.

Related species. It is closely related to other bipinnate species including *A. dealbata*, *A. decurrens*, and *A. mearnsii*. Natural hybrids with *A. mearnsii* have been recorded (Moffett 1965).

Acacia julifera

Main attributes. A nitrogen-fixing shrub or small tree adapted to subtropical warm sub-humid or semi-arid areas and infertile, often shallow, sandy sites. Has potential for low shelter, especially in coastal areas, for fuelwood, and as an attractive ornamental species.

Botanical name. *Acacia julifera* Benth. in Hook., *London J. Bot*. 1: 374 (1842). The specific name is derived from the Latin *julus* — a catkin, and *fera* — bearing; the combination of the two alludes to the dense inflorescences in catkin-like spikes. There are two subspecies, subsp. *julifera* and subsp. *gilbertensis*.

Common names. None known.

Family. Mimosaceae.

Botanical features. This acacia is a small shrub or multi-stemmed bush 2–5 m tall, or a small tree with a single stem usually under 8 m in height but recorded up to 10 m. The bark is dark, furrowed, shedding in fibrous strips and reddish underneath .

The phyllodes are usually glossy, bright green but occasionally grey-green, sickle-shaped, 7–25 cm long by 5–25 mm wide with many non-reticulate longitudinal nerves, 3–5 nerves more prominent. Phyllodes and new growth of young plants are usually densely hairy; this persists on mature plants of subsp. *gilbertensis*. The inflorescence consists of vivid golden-yellow spikes of perfumed flowers up to 5 cm long and 1 cm in diameter. The spikes are mainly in pairs, rarely in threes, on a short axillary axis, which sometimes grows out into a leafy shoot. The pods are pale brown, straight, mostly round in subsp. *julifera*, slightly flattened in subsp. *gilbertensis*, 5–10 cm long by 2–5 mm wide, not constricted between the seeds. The seeds are longitudinal in the pod, black, oval, 3–4 mm long by 1.5–3 mm wide, with an oblique cup-shaped aril. Flowering is in winter, mainly May–June or later, and ripe seed has been collected during September to December.

The species is described by Pedley (1978) and Stanley and Ross (1983), and illustrated by Simmons (1981).

Natural occurrence. *A. julifera* subsp. *julifera* occurs mainly in the coastal and subcoastal districts from central Queensland to the New South Wales border area. It is uncommon in New South Wales where it occurs in the Clarence Valley. It is mainly within 150 km of the sea but there is an isolated occurrence in the Carnarvon Ranges some 400 km inland. The subsp. *gilbertensis* is more or less disjunct and is located in inland areas of northeastern Queensland.

- Latitude. Range: 20–28°S. (subsp. *julifera*); 17–21°S. (subsp. *gilbertensis*).
- Altitude. Range: subsp. *julifera*, near sea level to 250 m; subsp. *gilbertensis*, near sea level to 425 m.

Climate. For subsp. *julifera* the distribution is mainly in the warm sub-humid climatic zone but it occurs in the warm humid zone in some coastal locations. The subsp. *gilbertensis* is principally in the warm semi-arid zone with some extension into warm sub-humid areas. For subsp. *julifera* the mean maximum temperature of the hottest month is 30–33°C and the mean minimum of the coolest is 6–12°C. There are 10–75 days over 32°C but less than 5 days over 38°C each year. Areas very close to the sea are free of heavy frost but inland there is a greater incidence with up to 20 frosts a year in the coldest localities. The 50 percentile rainfall is about 800–1100 mm, the 10 percentile 450–700 mm, and the lowest on record 325–425 mm. There is a moderate summer maximum. The number of raindays is 60–90 and the dry season is very short.

For subsp. *gilbertensis* the mean maximum temperature of the hottest month is 34–36°C and the mean minimum of the coolest is 11–15°C. There are 100–130 days over 32°C and 15–30 days over 38°C each year. Heavy frosts are absent from most of the area but a few localities experience 1–2 frosts each year. The 50 percentile rainfall is about 800–1000 mm, the 10 percentile 375–525 mm, and the lowest on record 200–350 mm. There is a marked summer maximum becoming summer monsoonal in the north. The number of raindays is 45–65 per year and the dry season (less than 30 mm rainfall per month) extends for 6–7 months.

Physiography and Soils. The distribution of *A. julifera* is confined to the Eastern Uplands physiographic division in topography ranging from plains to low, somewhat hilly country. It grows on plateau escarpments, and is common on rocky slopes and ridges in some localities. It also is found on the small islands off the east coast of Queensland.

The soils are often shallow lithosols, sometimes very sandy, and including solodised solonetz types. Subsp. *gilbertensis* usually grows on seasonally waterlogged sandy soils, and subsp. *julifera* is common on well-drained sandy soils behind coastal dunes. The soils are derived from sandstone, granite and lateritic formations, and are generally acidic and of low fertility.

Vegetation type. *A. julifera* frequently forms dense pure stands in low woodland or shrubland but also occurs in low open-forest and woodland. The principal dominants are eucalypts including *E. citriodora*, *E. dichromophloia*, *E. maculata*, *E. melanophloia*, *E. normantonensis* and *E. tessellaris*. Other associates are *Alphitonia excelsa*, *Melaleuca nervosa*, *M. viridiflora* and *Petalostigma triloculare*. It frequently grows with other acacias and has been recorded with *A. blakei*, *A. shirleyi* and *A. uncifera*.

Utilisation.

Fodder: Not known to have any value as fodder.

Fuelwood: No data are available but the wood should be suitable for firewood or charcoal.

Wood: A potential producer of small, round timber for use as posts, poles or rails.

Other uses: The subsp. *julifera* should be suitable for low shelter in coastal areas. It is well-suited to ornamental use and is considered by Lebler (1979) to be as attractive as any acacia now in cultivation.

Silvicultural features. Both subspecies give rapid early growth. They coppice and have been noted to produce root suckers. Subsp. *gilbertensis* may be a more reliable coppicer than subsp. *julifera* (Ryan and Bell 1989).

Establishment: A. julifera regenerates mainly from seed. Planted specimens of both subspecies flowered at 13 months (Ryan and Bell 1989). There are about 60 900 viable seeds/kg in subsp. *julifera* and 21 300 viable seeds/kg in subsp. *gilbertensis*. The seeds require one of the routine treatments to break seedcoat dormancy.

Yield: Field trials including both subspecies have been planted near Gympie in Australia (Ryan and Bell 1989, 1991) and on several sites in Thailand (Pinyopusarerk 1989). Plots near Gympie averaged 7.5 m in height and 12.4 cm in basal diameter with 82% survival at 4.5 years. The two subspecies were highly ranked for height growth on dry sites in Thailand with the best growth 3.4 m in 12 months; however, survival averaged less than 70%. In Africa, *Acacia julifera* often showed good growth but generally had low survival and coppiced poorly after cutting (Chege and Stewart 1991; Kimondo 1991; Maghembe and Prins 1994).

Pests and diseases. None are recorded.

Limitations. The small size of this species will limit its use for wood production to fuelwood and small roundwood products. It has been unreliable in its ability to coppice after cutting and may require selection if this trait is required.

Related species. *A. julifera*, especially subsp. *julifera*, is closely related to and resembles in general appearance *A. blakei*, which is distinguished from *A. julifera* by its slightly glaucous phyllodes and flat pods (Lebler 1979). Subsp. *gilbertensis* has been confused with *A. difficilis*. In one area of central Queensland *A. curvinervia* intergrades with *A. julifera* subsp. *julifera* and intermediates occur. The area of intergrade is small in relation to their individual ranges and the species are regarded as distinct (Pedley 1978).

Acacia leptocarpa

Main attributes. A shrub or small tree that fixes nitrogen and grows fast on infertile, poorly-drained sites in the tropical and subtropical lowlands. Has potential for fuelwood, small posts and poles, shade, and ornamental purposes.

Botanical name. *Acacia leptocarpa* A. Cunn. ex Benth. in *London J. Bot.* 1: 376 (1842). The specific name is from the Greek *leptos* — slender, thin, and *carpos* — fruit and alludes to the slender pods.

Common names. None known.

Family. Mimosaceae.

Botanical features. This acacia varies from a shrub 3–5 m tall, usually with a short main stem, to a small tree of 12 m. On larger specimens the main trunk may be 25 cm diameter. It is well branched and has a light to moderately dense crown. On large trees the bark is deeply furrowed but on smaller stems is relatively thin and more or less tessellated.

The phyllodes are sickle-shaped, attenuate at the base, mainly 12–21 cm long by 10–25 mm wide. There are 3 prominent yellowish longitudinal veins with secondary veins parallel and widely spaced. The pale yellow to bright yellow inflorescence consists of moderately dense spikes 5–7 cm long in pairs. The pods are linear, curved, twisted or somewhat coiled, up to 15 cm long by 3–5 mm wide, flat but raised over the seeds. The seeds are longitudinal in the pod, 3–5 mm long, 2–3 mm wide, and the yellow-orange funicle is folded many times forming an aril that can be longer than the seed. Flowering occurs May–September and the seed is mature in October–December. A botanical description is given by Pedley (1978) and the species is illustrated in Brock (1988).

Natural occurrence. *A. leptocarpa* occurs in a coastal belt, mainly less than 100 km wide, from central Queensland to Cape York. It has a discontinuous distribution across northern Australia. It also is found in the Western Province of Papua New Guinea and in Irian Jaya.

- Latitude. Range: 8–26°S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 550 m.

Climate. This acacia occurs in the hot humid to sub-humid climatic zones, with some extension into the warm humid to sub-humid zones in southeast Queensland. The mean maximum temperature of the hottest month, mainly November to December, is 32–33°C with a few localities attaining 39°C. Many localities have 30–100 days each year over 32°C. The mean minimum temperature of the coolest month is 13–21°C, except in southeast Queensland where it may be as low as 10°C. The area of distribution is virtually frost-free.

The northern part of Australia and Papua New Guinea has a marked summer monsoonal incidence of rainfall (December–March); in southeast Queensland it is more uniform, although still with a well-defined summer maximum. The 50 percentile rainfall falls within the range 750–1750 mm, the 10 percentile 500–1250 mm, and the lowest on record 350–950 mm. In the drier areas *A. leptocarpa* is usually found in relatively low-lying situations where the soil moisture regime is favourable. Rain is recorded on 80–145 days each year.

Physiography and soils. In Australia, *A. leptocarpa* usually occurs on the flats and gentle slopes of the coastal lowlands, including stabilised dunes, but it extends to the slopes and ridges further inland. It is found on a variety of soil types, mostly colluvial and alluvial, derived from metamorphics. In northeastern Queensland it occurs often on loamy yellow podzolics, yellow earths, and yellow and grey solodics but elsewhere it can be on shallow lateritic and heavy clay soils. The soils are usually acidic and of low fertility.

Papua New Guinea occurrences are on the relict alluvial plain known as the Oriomo Plateau. It is found on infertile, well-drained or poorly drained strongly acid soils with a shallow sandy loam overlying a heavy clay, and on soils which are subject to prolonged flooding in the wet season.

Vegetation type. *A. leptocarpa* is a component of open-forest, low open-forest, and low open-woodland in northern Australia. On better-drained sites it is found with *A. flavescens* in the lower tree layer of eucalypt open-forest, including *E. alba*, *E. leptophleba*, *E. polycarpa*, and *E. tessellaris*. On heavier soils, which may be periodically flooded, it occurs in open-woodland and low open-woodland with *E. alba*, *E. leptophleba*, *Melaleuca nervosa*, *M. viridiflora*, *Allocasuarina littoralis*, and *A. luehmannii* (Pedley and Isbell 1970; Isbell and Murtha 1972; Tracey 1982).

In the woodland and open-forest in Western Province, Papua New Guinea *A. leptocarpa* occurs frequently with *A. aulacocarpa*, *A. auriculiformis*, *A. crassicarpa*, *A. mangium*, *Melaleuca* spp., and *Lophostemon suaveolens*. On seasonally-dry impeded-drainage areas, it is often associated with *Asteromyrtus symphyocarpa*, *M. viridiflora*, *Lophostemon suaveolens* and *Grevillea glauca* (Paijmans et al. 1971).

Utilisation.

Fodder: Not known. The favourable reports of Vercoe (1987, 1989) were later found to refer to another species.

Fuelwood: The wood from 4-year-old trees burnt fast and gave a charcoal of high heating efficiency (Yantasath et al. 1993).

Wood: White sapwood, dark brown heartwood, close-grained, hard, decorative and useful in turnery and cabinet work. The range of uses is limited by the small dimensions of the tree. It could provide small posts and poles for village use.

Other uses: A. leptocarpa is used in mine site rehabilitation in northern Australia. It is a well-shaped small tree, casting a light to moderate shade, which could be useful in amenity areas or for planting in association with crops. In full flower, it is a very ornamental species (Williams 1980).

Silvicultural features. *A. leptocarpa* is a fast-growing small tree to 12 m. It produces a single stem with a light crown. It fixes nitrogen and appears to be readily inoculated with a range of rhizobia strains (Dart et al. 1991). Reports of coppicing ability have been contradictory varying from failure (Ngulube 1991) to good (Ryan and Bell 1989). Root suckering has been recorded. It was reported to be highly resistant to termite attack in Zimbabwe (Mitchell 1989). Although occurring in

humid–sub-humid areas, it was one of the best adapted species in salt-affected land in northeastern Thailand with a dry season of 6–8 months (Pinyopusarerk 1992).

Spontaneous interspecific hybrids with *A. auriculiformis* have been noted and a manipulated hybrid with *A. mangium* would be worthy of study (Nikles and Griffin 1992).

Establishment: Flower buds appear as early as 14 months after planting. There are about 83 800 viable seeds/kg at an average germination rate of 73% after regular dormancy breaking treatment (1 minute immersion in boiling water).

Yield: It has shown rapid early growth and, on favourable sites, may reach its full potential size within three years. The best-performing provenances gave MAI's for height and diameter of 2.3 m and 1.8 cm respectively over 3 years and on several sites in Thailand (Chittachumnonk and Sirilak 1991). *A. leptocarpa* was amongst the most promising acacias for agroforestry in the dry-zone of Malawi; 88% survival, 3.8 m tall and 3.9 cm dbh at 3 years (Ngulube 1990a). Similar good performance has been reported in trials near Gympie (Ryan and Bell 1989, 1991) and in southern China (Yang and Zeng 1991). Provenance variation in this species has not been fully explored. Papua New Guinea provenances generally outperform those from Queensland.

Pests and diseases. None recorded.

Limitations. Provenance testing will be necessary to select optimum seed sources. The small stature of *A. leptocarpa* will restrict its wood and amenity use.

Related species. *A. leptocarpa* is allied to *A.* '*elachantha*' (MS), *A. cowleana*, and *A. longispicata* (B. Maslin, pers. comm.).

Acacia leucoclada

Main attributes. A fast-growing, adaptable bipinnate acacia of subtropical–temperate zones. It is nitrogen-fixing and has potential for utilisation for firewood, small round timbers and pulpwood. It is excellent for ornamental purposes.

Botanical name. *Acacia leucoclada* Tindale was described in the *Proceedings of the Linnaean Society* 91: 149–151 (Tindale 1966*a*). There are two subspecies; subsp. *leucoclada* and subsp. *argentifolia*. Subsp. *leucoclada* based on the Greek, *leucos* — white, and *clados* — a young branch or shoot, alluding to a tendency for the branchlets to be whitish. Subsp. *argentifolia* is after the Latin *argentum* — silver, and *folium* — a leaf, alluding to the glaucous, often quite silvery, leaves and twigs.

Common names. Northern silver wattle.

Family. Mimosaceae.

Botanical features. The type subspecies, *leucoclada*, is a shrub or very small tree 4–9 m tall, with bark of mature trees dark brown or black, rough and corrugated. The subspecies *argentifolia* is a larger tree to 20 m tall. The young branches are smooth, olive green and often glaucous, the bark on small trees smooth and light brown. Branchlets slightly angled, sometimes glaucous, glabrous or with short grey hairs and in subsp. *argentifolia* densely hairy with short hairs. The leaves are fern-like, green or bluish, made up of 6–16 pairs of pinnae 5–12 cm long, with 17–36 pairs of leaflets, 2–5 mm by 0.4–1.2 mm. The petioles are 1.5–3 cm long, sometimes glaucous, either without glands or with a gland just below the lowest pair of pinnae or mid-way between the latter and the base of the petiole. There is usually one gland at the base of each pair of pinnae and 2–4 glands between several pairs of pinnae. In the subsp. *argentifolia* there is often one gland near the base of the uppermost pair of pinnae and one sometimes two glands between all pairs of pinnae.

The inflorescence is a yellow, globular head with 22–26 flowers in each head, axillary or in panicles. The pods are stalked, reddish-brown or brownish grey, faintly or markedly glaucous, slightly constricted between the seeds or occasionally straight-sided, 3.5–11.5 cm long by 6–12 mm wide. Seeds are black, dull or glossy, oblong-elliptical, longitudinal in the pod with a prominent, terminal cream-coloured aril. Flowering is from late July to late September and fruits mature approximately 5 months later.

The species is described by Pedley (1979), Harden (1991) and Tame (1992).

Natural occurrence. *A leucoclada* subsp. *leucoclada* occurs mainly on the north, central and southwestern slopes of New South Wales. Subsp. *argentifolia* is restricted to southeastern Queensland and the far north coast of New South Wales.

- Latitude. Main occurrence: 26–29°S (subsp. *argentifolia*).
  Main occurrence: 29–34°S (subsp. *leucoclada*).
  Range: 26–35°S.
- Altitude. Main occurrence: 200 – 500 m.
  Range: near sea level to 1000 m.

Climate. Both subspecies are found in the warm sub-humid climatic zone. Populations of subspecies *argentifolia* grow in the cool to warm humid zone. The mean maximum temperature of the hottest month is 30–33°C for subsp. *leucoclada* and 26–32°C for subsp. *argentifolia*. The mean minimum of the coolest month is 0–4°C for both subspecies. The average number of days over 32°C is 37–88 for subsp. *leucoclada* and 10–60 for subsp. *argentifolia*. Heavy frosts can occur on average from 9–61 days annually, except in coastal areas.

The 50 percentile rainfall is in the range 575–990 mm, the 10 percentile 360–700 mm, and the lowest on record 185–430 mm. In the northern part of the range there is a moderate summer maximum. Over the southern part of the distribution the rainfall incidence is nearly uniform throughout the year.

Physiography and soils. This species is restricted to the New England–Morton Uplands and the Kosciusko Uplands within the Eastern Uplands physiographic division. It has been found growing on undulating to moderately hilly topography, sometimes along creek banks. The subsp. *argentifolia* frequently invades cleared farmland within its distribution. The species grows in a wide range of soils, including black and red soils, clay and sandy soils, lateritic kraznozems and gravelly loams.

Vegetation type. *A. leucoclada* is found in open-forest, woodland communities and on land that has been cleared for farming. Associate species include *Acacia deanei*, *A. decora*, *A. glaucocarpa*, *Eucalyptus albens*, *E. bancroftii* and *E. paniculata*.

Utilisation.

Fodder: Not known.

Fuelwood: No data available but wood density is medium to high (basic density of 626 kg/m^3, Clark et al. 1994), and the wood should be suitable for firewood or charcoal.

Wood: A potential producer of small, round timber for use as posts, poles or rails. *A. leucoclada* may be a useful source of pulpwood. Clark et al. (1994) reported that the species had a good pulp yield, excellent pulpwood productivity, moderate tear index and good tensile index when tested on a laboratory scale using a simulated Kraft process. However, the level of brightness achieved in the test conditions was below standard. Further tests are required to see whether different wood samples give different properties and whether different bleaching sequences and higher chemical charges can overcome the brightness problem.

Other uses: The subsp. *argentifolia* has been described as an outstanding foliage plant when cultivated as an ornamental (Wrigley and Fagg 1988).

Silvicultural features. This species is a small to medium tree with a distribution overlapping subtropical and temperate regions. It is adaptable and fast-growing, but lack of seed has meant that it has not been planted as an exotic until very recently. It should be possible to select seed sources for both drought and frost tolerance. It is reported to sucker freely (Wrigley and Fagg 1988).

Establishment: There are 51 600 viable seeds/kg and immersion in boiling water for 1 minute is required to break seedcoat dormancy. Nursery and silvicultural techniques used for *A. dealbata* are likely to be applicable.

Pests and diseases. No data available.

Limitations. Its size will limit utilisation to small round timbers. Ability to regenerate in agricultural lands suggests that this species is a potential weed species.

Related species. Subsp. *leucoclada* may be confused with *A. dealbata* and *A. deanei*. It can be distinguished from *A. dealbata* by the presence of a single, prominent, orbicular gland at the base of each pair of pinnae and the absence of interjugary glands on the midrib. Both species have glaucous pods. However, in *A. dealbata* they are glabrous, while in *A. leucoclada* minute hairs are present. The habit of subsp. *leucoclada* is more open than that of *A. dealbata*. *A. deanei* is distinguished by whitish-yellow hairs on the peduncles and golden pubescent petals. Subsp. *argentifolia* may be confused with *A. mollifolia* which has fewer pinnae and only jugary glands (i.e. glands that occur between the bases of a pair of pinnae) (Tame 1992).

Acacia longispicata

Main attributes. A small, fast-growing phyllodinous acacia adapted to the semi-arid tropics and subtropics. It requires more thorough testing but should have potential for firewood, posts, poles, shelter and ornament on seasonally-dry sites subject to some frost.

Botanical name. *Acacia longispicata* Benth. was described in T.L. Mitchell's Journal of an expedition into the *Interior of Tropical Australia* (1848) 298. There is one subspecies, subsp. *velutina*, described by Pedley in *Austrobaileya* 1: 176 (1978). The species name comes from the Latin *longus* — long and *spica* — point, in allusion to the long flower-spike. Subsp. *velutina* is from the Latin *velutinus* — velvety, and refers to the dense hairs on the branchlets and stalks that distinguish it from the type subspecies.

Common names. None known.

Family. Mimosaceae.

Botanical features. *A. longispicata* varies from a bushy shrub 3–5 m to a tree to 10 m tall. The shrub may be multi-stemmed. Branchlets are angular with dense, appressed or spreading hairs. The hairs extend to the leaf stalks, leaves and flower stalks. The phyllodes are 9–18 cm long by 1.3–4 cm wide, or 4–8 (–12) times as long as wide, on a stalk 6–10 mm. There is a large basal gland. Venation consists of 3 prominent, longitudinal veins basally confluent but distant from the lower phyllode margin and a network of sparse secondary veins. In subsp. *velutina* the hairs are dense and long on the branchlets and stalks, but the phyllodes are usually glabrous. Subsp. *velutina* has been recorded from one locality only, at Kingaroy, 300 km east of the nearest known stand of subsp. *longispicata*.

The flowers are in dense or sparse spikes, depending on the length, 5–12 cm long, on stalks usually 6–8 mm long, in pairs in the upper axils. The pods are to about 12 cm long × 2.5–3.5 mm wide, straight, flat but convex over the seed on each side. Seeds longitudinal in the pod 3.5–4.5 × 2–2.5 mm, with a yellow fleshy funicle folded beneath the seed.

Flowering time is from July to September and a month earlier for populations in the northern part of the distribution. Pods mature about November (Pedley 1978).

The species is described by Pedley (1978), and subsp. *velutina* in Stanley and Ross (1983).

Natural occurrence. There are two distinct areas of distribution in Queensland, that are separated by about 300 km. Both are situated on gentle and moderate topography of central Queensland.

- Latitude. Northern area: 17–21°S.
  Southern area: 23–27°S.
- Altitude. Main occurrence: 275–375 m.
  Range:125–380 m.

Climate. Both northern and southern areas are located within the warm semi-arid climatic zone, with some of the southern distribution extending into the warm subhumid zone. In the northern area the mean maximum temperature of the hottest month is 35–36°C and the mean minimum for the coolest month 8–11°C. There are 100–130 days a year when 32°C is exceeded and 15–30 days for over 37°C. Most of the area is free of heavy frosts, though a few of the highest localities have registered 1–2 frosts a year.

In the southern area the mean maximum temperature of the hottest month is 34–35°C and the mean minimum of the coolest 3–7°C. There are 90–120 days a year when the temperature exceeds 32°C and 16–24 for over 37°C. There are 2–23 frosts annually.

The 50 percentile rainfall is 475–800 mm, the 10 percentile 200–450 mm and the lowest on record 100–175 mm. There is a moderate summer maximum for rainfall and the number of raindays per year is 40–63.

Physiography and soils. Most of the distribution of this species is in the Eastern Uplands physiographic division, but the far southeastern area is in the Central

Lowlands. The topography varies from plains, often with small ridges 25–50 m high, to gentle hills. Rock outcrops associated with *A. longispicata* are basalts, sandstones and shales. It is widely distributed on sandy soils (Pedley 1978). Other soil types include sandy loams to friable clays in areas of basalt outcrops.

Vegetation type. The major types are low open forest and woodland, where *A. longispicata* occurs as scattered plants, or in dense pure stands on roadsides (Pedley 1978). The following are some of the dominant associated species: *Eucalyptus cloeziana*, *E. decorticans*, *E. dichromophloia*, *E. exserta*, *E. melanophloia*, *E. populnea*, *E. papuana*, *E. tessellaris*, *Callitris* spp. and *Acacia* spp. It also occurs in tall shrubland with various other *Acacia* species.

Utilisation.

Fodder: Not recorded as a fodder species.

Fuelwood: No data are available but the wood should be suitable for firewood or charcoal.

Wood: A potential source of small, round timber for use as post, poles or rails.

Other uses: A. longispicata should be suitable for low shelter in suitable climatic zones. The large silvery phyllodes and long flower spikes make it an attractive ornamental.

Silvicultural features. This species has not been widely planted because of the lack of seed collections. Consequently little is known of its potential under cultivation and appropriate establishment techniques.

Establishment: The species produces about 87 600 viable seeds/kg. The seeds require one of the routine treatments to break seedcoat dormancy.

Yield: Excellent performance on ferralitic soils near Bai Bang, Vietnam has been reported (L. Thomson, pers. comm.). In field trials near Gympie, Australia early growth was rapid with plots averaging 5.4 m in height in only 2 years (Ryan and Bell 1991).

Pests and diseases. None are recorded.

Limitations. The small size of *A. longispicata* will limit its use for wood production to fuelwood and small roundwood products. The ability in its native habitat to regenerate vigorously along disturbed road verges suggests that it has potential to become a weed species under certain conditions.

Related species. *A. longispicata* is usually easily identified because of its large silvery leaves and long flower spikes, but there is wide variation. It is closely related to and sometimes confused with *A. cowleana* but differs in phyllode venation and shape, longer flower spikes and in the constrictions between seeds of the pods. It is also related to *A. crassa* and remotely to *A. grandifolia* (Pedley 1978). It is distinguished from *A. crassa* by its pubescent branchlets and phyllodes.

Acacia maconochieana

Main attributes. A small erect tree with a high potential for production of firewood, small round timber and possibly fodder on heavy, alkaline soils in the hot semi-arid and sub-humid tropics. This species is highly tolerant of salinity and waterlogging.

Botanical name. *A. maconochieana* Pedley in *Austrobaileya* 2: 235–237 (1986). The species name honours the Australian botanist John Maconochie (1941–84).

Common name. Mullan wattle.

Family. Mimosaceae.

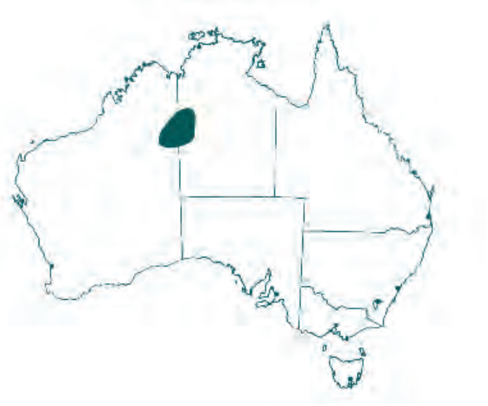
Botanical features. Typically an erect, single-stemmed tree to 12 m tall. Branch habit is ascending and the canopy somewhat rounded to 7 m across. Damage by flooding and cattle browsing at the sapling stage may promote a multi-stemmed habit. The bark is dark grey, longitudinally furrowed and persistent to the small branches.

The phyllodes are olive to grey-green, somewhat shiny, densely appressed pubescent, straight or slightly falcate, linear, 8–18 cm long by 1.5–6 mm wide, with up to 30 fine parallel longitudinal nerves; one centrally located nerve may be more prominent.

The yellow globular flower heads are arranged in densely pubescent, axillary racemes: the racemes are 2–4 branched with a short axis of 2–3 mm. Pods are straight, linear, 13 × 5 mm, flat and densely appressed pubescent. Seeds are longitudinally positioned in the pod, dark brown, shiny, mostly oval-elliptical, 4–6 × 2–4 mm and flattened. The cream-coloured funicle is twice-folded to form a basal aril. Pods mature from early November.

The species is described by Pedley (1986) and illustrated by Thomson and Hall (1989a).

Natural occurrence. *A. maconochieana* has a restricted distribution on low-lying areas in the central-western part of the Northern Territory and adjacent part of Western Australia. In the Northern Territory it has been collected from Nongra Lake (south of Inverway), Sanctuary Swamp, a saltpan near Tanami, and depressions on Tanami Downs station. In Western Australia it is common around Lake Gregory and associated playas. Further botanical exploration is likely to expand the known distribution of this species.



- Latitude. Range: 18–21°S.
- Altitude. Range: 250–400 m.

Climate. This species occurs in the hot arid zone. The mean daily maximum temperature of the warmest months (November to January) is 38–40°C and the mean daily minimum temperature of the coldest month (July) is 8–9°C. Frost conditions (<2°C) occur infrequently, possibly 1–2 days per year.

The 50 percentile rainfall is 225–350 mm, the 10 percentile 60–150 mm and the lowest on record 20–60 mm. There are 22–40 raindays a year. The rainfall pattern has a distinct summer maximum and about 75% of total rainfall falls between the months of December and March.

Physiography and soils. *A. maconochieana* is distributed only in the Western Plateau physiographic division. It occurs on low-lying areas surrounding ephemeral lakes and clay pans which may be periodically flooded to a depth of 2.5 m. Larger trees are able to tolerate prolonged inundation, but will eventually die if the roots are submerged for too long.

The soils are typically fine-textured alluviums of neutral to alkaline reaction. Recorded soil types include loams, clays with a thin covering of sand, and stony heavy clays. In some sites salts have accumulated to moderately high levels in surface layers, for example, soil saturation extract electrical conductivity (EC_e) of 8–11 dS/m at Tanami Downs and Lake Nongra (Vercoe and McDonald 1987).

Vegetation type. *A. maconochieana* typically occurs in monospecific stands of low open-forest and woodland. It may also occur in association with *Acacia stenophylla* and *Melaleuca uncinata*. The understorey is sparse, consisting of short-lived shrubs (e.g. *Senna notabilis*), herbs and grasses. Young trees may form thickets about 3–4 m tall.

Utilisation.

Fodder: The species appears to have a high palatability to cattle. Around Lake Gregory, young trees have been observed to be broken down and grazed by cattle. The phyllodes of the related *A. cana* have a high palatability and a similar digestibility (in vitro digestibility of 41%) and protein level (12%) to other Australian forage acacias, but are considered to be only low-maintenance fodder (Wilson and Harrington 1980).

Fuelwood: The heavy wood (800–850 kg/m^3) makes an excellent firewood, having a good upper calorific value (19.4 MJ/kg) but leaving a large quantity of ash. Investigations by the Division of Chemistry and Energy of the CIRAD Forêt (France) have indicated that the wood is not especially suitable for charcoal production. The charcoal had relatively high levels of ash (9.0%), residues (5.1%) and volatile substances (14.2%), and a below-average calorific value (30.8 MJ/kg).

Wood: The timber has a narrow to broad band of pale yellowish sapwood which contrasts sharply with the dark brown heartwood. It would be well suited for conversion into smaller decorative items. The trunk is typically straight and reaches suitable dimensions for use in the round as posts and small poles.

Other uses: It is useful for amenity plantings and larger specimens make excellent shade trees.

The soft-coated flat seeds are easily ground and the species may have some limited potential as a source of human food (Thomson 1992).

Silvicultural features. Little is known of the species' growth habits. It appears to be moderately fast-growing and long-lived. Its coppicing ability is unknown, but it has been observed to root sucker (T. Vercoe, pers. comm.). Glasshouse trials have indicated that seedlings have a very high tolerance to salinity (Aswathappa et al. 1987). Plants may tolerate frosts to about –5°C.

Establishment: A. maconochieana is readily propagated from seed of which there are about 41 000 viable seeds/kg. The only seedlot tested, from Bulbi Plain in Western Australia, had a high proportion (60%) of seeds with a soft seedcoat, which suggests the seeds may be killed by boiling water treatment. Nicking of the seedcoat may enhance the germination percentage.

Alternatively, untreated seeds may be soaked in cold water for 24 hours: those seeds which have imbibed are ready for sowing, while the remaining unswollen seeds could be given a short boiling water treatment (e.g. immersion in boiling water for 30–60 seconds) to remove seedcoat dormancy. Seedlings exhibit a moderate growth rate (about 15 cm in 2 months), and a nursery phase of 3–4 months is recommended.

Yield: It has exhibited promising early growth and survival in small-scale trials in low rainfall (350–500 mm) zones in Somalia and Rajasthan (India). However, near Niamey, Niger (550 mm rainfall) young plants were showing signs of severe moisture stress at the end of the six-month dry season (L. Thomson, pers. comm.). Early performance has been good on salt-affected soils in Pakistan (Sind Province) and northeast Thailand (N. Marcar, pers. comm.). At Tandojam in Pakistan it was 1.2 m tall and had a dbh of 2.65 cm at 15 months on a highly saline soil. This growth rate was inferior to that of *A. ampliceps*, *A. stenophylla* and *A. nilotica* on the same site (Ansari et al. 1993).

Pests and diseases. None recorded.

Limitations. It is likely to require supplementary natural or artificial inputs of water for satisfactory performance when planted in arid and semi-arid areas. It appears to be intolerant of acid soils (Aswathappa et al. 1990). Difficulties in obtaining seed of this remotely distributed, shy-seeding species is an impediment to its wider planting.

Related species. *A. maconochieana* is a member of the Microneurae group (within section Plurinerves), with its closest relative being *A. tephrina*. It is also closely related to *A. cana* and *A. latzii* (Thomson et al. 1994).

Acacia maidenii

Main attributes. A fast-growing, nitrogen-fixing tree suitable for fuelwood production in warm humid areas of subtropical and warm temperate regions.

Botanical name. *Acacia maidenii* F. Muell. in *Bot. Centralb*. 51: 398 (1892). The specific name honours J.H. Maiden (1859–1925), former Government Botanist of New South Wales and Director of the Royal Botanic Gardens, Sydney.

Common names. Maidens wattle, sally.

Family. Mimosaceae.

Botanical features. This acacia is usually a large shrub or small tree 4–8 m tall, typically with a well-defined main stem that is freely branched at a low level and forming a rounded crown in open-grown specimens. Under favourable conditions it also occurs as a tree 10–16 m tall, with a main stem 30–40 cm in diameter. The bark is grey to dark grey, hard, fibrous and moderately furrowed.

The bright green crown is conspicuous. Phyllodes are long, narrow, straight or gently curved and tapering at each end, with many fine longitudinal veins, 5–20 cm long by 5–20 mm wide. The branchlets are covered by conspicuous, cream-coloured lenticels or corky spots. The inconspicuous pale yellow flowers are in loose axillary spikes 2–5 cm long. They are found November–July with predominantly summer flowering in the north of the range and autumn–winter flowering in the south. The pod is turgid and fleshy when green but becomes woody and highly twisted, often in irregular loose spirals, when mature. The pods are 5–15 cm long and only 3–6 mm wide; longitudinally wrinkled with the surface sparsely covered in itchy, minute grey hairs. They are mature from about September–December. The seeds are longitudinal in the pod, shining black with a small terminal aril.

A botanical description is given by Pedley (1978) and Stanley and Ross (1983). The species is illustrated by Lebler (1979) and Fuller (1980).

Natural occurrence. *A. maidenii* is distributed in a coastal belt in eastern Australia from central Queensland to Victoria. It is common in the coastal forests of New South Wales and southern Queensland, but is rare and localised in Victoria, and north of the Tropic of Capricorn in Queensland.

- Latitude. Main occurrence: 26–34°S.
  Range: 21–38°S.
- Altitude. Main occurrence: 25–300 m.
  Range: near sea level to about 900 m.

Climate. The distribution is mainly in the warm humid climatic zone with some extension into warm sub-humid areas and marginally into the cool humid zone. The mean maximum temperature of the hottest month is 28–32°C and the mean minimum of the coolest mainly 6–7°C. The average number of days over 32°C is 20–60 and there are less than 5 days a year over 38°C. Areas close to the coast are frost-free but most other areas have 1–10 heavy frosts each year.

The 50 percentile rainfall is 900–1300 mm, the 10 percentile 600–900 mm, and the lowest on record 400–700 mm. There is a summer to early autumn rainfall maximum which is well-marked in the north but which shows a gradual transition to a more or less uniform distribution in the south. The average number of raindays is 100–120, and prolonged dry periods are rare.

Physiography and soils. This acacia occurs entirely in the Eastern Uplands physiographic division and is mainly found in the undulating lowlands and the foothills of the coastal escarpment. It grows commonly along stream banks and lower slopes in hilly topography and is found close to the sea on stabilised sand dunes, on sand ridges around coastal lakes, and adjacent to mangrove areas.

It grows best on moderately deep soils, with a high organic matter, often derived from basalt or shales. It occurs on deep sands, but not on the shallow lithosols common in areas of outcropping sandstone. The soils are usually moist, of moderate fertility and well drained.

Vegetation type. *A. maidenii* has its best development in tall open-forest or open-forest dominated by eucalypts. In wetter areas it occurs on the margins of closed-forest (rainforest) and is very common as regrowth in forest clearings. It is a common understorey associate in the *Eucalyptus grandis* alliance with species such as *Lophostemon confertus* and *Syncarpia glomulifera* (Beadle 1981). It is also recorded with *E. crebra*, *E. drepanophylla*, *E. tereticornis*, *Araucaria cunninghamii* and *Casuarina cunninghamiana*. *Acacia* associates include *A. glaucocarpa*, *A. loroloba*, and *A. obtusifolia*. It grows as a shrub on sand dunes and other beachfront sites but is not common in areas dominated by shrubs.

Utilisation.

Fodder: Probably not eaten by stock in its area of natural occurrence, but no information on palatability is available.

Fuelwood: A good fuel, formerly used in bakers' ovens (Maiden 1917).

Wood: The wood is fairly hard and light in weight with prominent annual rings. An average basic density of 620 kg/m^3 was determined for wood from young planted trees (Davis 1994). The wood is suitable for small joinery items or any purpose where medium strength is required (Baker 1913). The timber has, however, been regarded as 'inferior and of little importance' in New South Wales (Anderson 1968).

Other uses: The good shape and relatively dense foliage make *A. maidenii* suitable for amenity use, shade, and shelterbelt planting. It is an inferior source of tannin (Maiden 1917; Swain 1928a).

Silvicultural features. A fast-growing tree that may be relatively short-lived on some sites. Regenerates from seed, coppice and root suckers.

Establishment: A. maidenii produces 58 200 viable seeds/kg at an average germination rate of 82% after one of the routine pretreatments to break seedcoat

dormancy (e.g. 1 minute immersion in boiling water).

Yield: Few trials of the species on appropriate sites have been established. One constraint has been the lack of a rangewide seed collection. One provenance of *A. maidenii* when planted in trials near Gympie, Queensland gave excellent survival (99%) and reasonable growth performance (mean height of 4.4 m and mean diameter at ground level of 9.7 cm) when assessed at two years (Ryan and Bell 1991).

Pests and diseases. In its natural habitat it is often covered in galls caused by a small wasp, *Trichilogaster maidenii* (Maiden 1917).

Limitations. The adaption of this species to relatively moist, moderately fertile sites will limit the range of conditions under which it can be planted. The inferior wood quality makes it unsuitable for construction timber.

Related species. When not in flower *A. maidenii* may be confused with *A. melanoxylon* and *A. implexa*. It is more closely related, however, to *A. floribunda*, *A. longifolia* and *A. longissima* (Pedley 1978) and may be distinguished from these by the golden pubescence on the peduncles.

Acacia mangium

Main attributes. *Acacia mangium* has become a major plantation species in the humid tropical lowlands of Asia. Its success is due to its: extremely vigorous growth (wood volumes of over 30 m^3/ha/year on favourable sites); tolerance of very acid, low nutrient soils; ability to grow reasonably well where competition is severe, such as on *Imperata* grasslands; relative freedom from diseases; wood properties which potentially make it acceptable for a wide range of end uses; and ease of establishment. Plantations in Indonesia and Malaysia are the resource base for a large pulp and paper industry. Other uses include fuelwood, building and furniture timber and particle board.

Botanical name. *Acacia mangium* Willd. This acacia was originally described as *Mangium montanum* Rumph. in *Herbarium Amboinense* (1750) but changed to an *Acacia* in 1806. The specific name is an allusion to Rumphius' observation that this tree resembled 'mangge' or mangroves in Indonesia.

Common names. Brown salwood (Australian standard trade name), mangium, Sabah salwood, black wattle or hickory wattle, and tongke hutan or mangge hutan (Indonesia) and biar (PNG).

Family. Mimosaceae.

Botanical features. *Acacia mangium* is a large tree, to 30 m tall, with a straight bole, which may be over half the total tree height. Trees with a diameter over 50 cm are rare. It may be reduced to a small tree or large shrub of 7–10 m on adverse sites. The bark surface is rough, furrowed longitudinally, and varies in colour from pale grey-brown to brown. The lower bole is sometimes fluted.

Mature phyllodes are very large, up to 25 cm long and 5–10 cm broad. They are dark green, glabrous on a glabrous pulvinus 6–10 mm long. The phyllodes are characterised by four (rarely three) main longitudinal nerves, basally confluent but distinct from lower margin. Secondary nerves are inconspicuous. The whitish (or cream) flowers are in rather loose spikes up to 10 cm long, singly or in pairs in the upper axils. Flowers are present in May in Australia and the seed matures in October–December. Farther north the fruits mature earlier with seed available in July in Indonesia, and late September in Papua New Guinea. The seed pods are linear, tightly coiled when ripe, slightly woody,

7–8 cm long and 3–5 mm wide. The seeds are black and shiny, longitudinal, elliptical, ovate to oblong 3–5 × 2–3 mm with a yellow or orange (rarely red) funicle folded to form an oily, fleshy aril beneath the seed. A full botanical description is provided by Pedley (1975) and the species is illustrated in NAS (1983). Awang and Taylor (1993) provide a comprehensive monograph on the growing and utilisation of *A. mangium*.

Natural occurrence. In Australia, this species is found only in northern Queensland where it has a very limited distribution in the coastal tropical lowlands. It extends through the Western Province of Papua New Guinea into the Indonesian provinces of Irian Jaya and Maluku.

- Latitude. Main occurrence: 8–18°S.
  Range: 1–18°30′S.
- Altitude. Main occurrence: sea level to 300 m.
  Range: near sea level to 800 m.

Climate. The natural occurrence overlaps the tropical warm and hot climatic zones, either humid or wet. The temperatures are high and equable throughout the year. The mean maximum of the hottest month is 31–34°C and the mean minimum of the coolest 15–22°C. Despite the high mean minimum, the daily maximum temperature rarely exceeds 38°C. The area is frost-free.

The mean annual rainfall is 1500–3000 mm. In a typical location the 50 percentile rainfall is 2150 mm, the 10 percentile 1300 mm and the lowest on record 1000 mm. The seasonal distribution is monsoonal or shows a strongly developed summer maximum with January–March very wet. The driest months are July–October, each averaging over 40 mm. Booth and Yan (1991) summarised the climatic requirements of the species under cultivation.

Physiography and soils. In Queensland, *A. mangium* grows on the metamorphic, granitic, and acid volcanic formations of the foothills of the coastal ranges and on the sandy or loamy alluvium of the coastal plain. The soils are acid grey-brown podzolics, red and yellow friable earths, and loams of moderate to low fertility.

In Papua New Guinea and adjacent areas of Irian Jaya, Indonesia, *A. mangium* occurs on the relict alluvial plain known as the Oriomo Plateau. It is also abundant on the flood plains of the Aramia and Fly Rivers. *A. mangium* is found mainly on well-drained, strongly acid soils with a shallow clay loam overlying a heavy clay, and sometimes on imperfectly drained soils subject to brief flooding in the wet season and rapid drying out in the dry season. It is usually replaced by *A. auriculiformis* and *Melaleuca* spp. on sites that have prolonged flooding. The soils are gleyed red and yellow earths or red and yellow latosols (Bleeker 1983). They are generally of low fertility and are especially poor in available phosphorus.

Vegetation type. *A. mangium* grows on the margins of closed-forest (rainforest), in open-forest and woodland, especially where there is disturbance by fire. In northern Queensland it occurs in tall forests on well-drained sites in the foothills and lowlands associated with various eucalypts and acacias. As a component of fringing vegetation on river banks it is frequently associated with rainforest species such as *Flindersia brayleyana* and *Cardwellia sublimis*. Elsewhere it occurs on the slightly better-drained sites within the swampy coastal plains where melaleucas are locally dominant. Tracey (1982) describes the vegetation types in humid, tropical Queensland.

Papua New Guinea occurrences are in tall woodland and open-forest frequently in mixed associations with *Acacia*, *Melaleuca* and *Lophostemon* spp. These vegetation types are described by Paijmans et al. (1971), Paijmans (1976) and Skelton (1987). At the western extremity of its range in Indonesia, *A. mangium* is dominant in small stands on disturbed sites in, or on the fringes of, closed-forest and *Melaleuca* woodland.

Utilisation. The species has become a major reforestation species in tropical Asia and has potential in parts of Africa and South America, although little used in its area of natural occurrence.

Fodder: The leaves can serve as forage for livestock (NAS 1983). Preliminary study of fodder values has shown that *A. mangium* meets the minimal requirements for certain nutrients and warrants further investigation (Vercoe 1989).

Fuelwood: Mature wood is dense and is a good fuel (NAS 1983) but young trees (2.5 years) make poor firewood (Gough et al. 1989). The physical properties, calorific values and burning properties are described by Yantasath et al. (1993). In Sabah, *A. mangium* produces charcoal of reasonable quality and is suitable for the manufacture of wood pellets and activated carbon (Udarbe and Hepburn 1987). It has shown promise as a fuelwood species in Fiji (Bell and Tevita Evo 1983).

Wood: It has hard, pale yellow-brown heart wood with a narrow band of light coloured sapwood and close grain. Basic density is 420–483 kg/m^3 and air-dry density is 500–600 kg/m^3 (Razali and Hamami 1992). It is classed as a light hardwood with low to moderate strength properties.

The timber can be sawn easily, polished, drilled and turned. The wood is fairly stable, with green to air-dry shrinkage of 6.4% tangentially and 2.7% radially. It kiln-dries well without serious defects (Razali and Hamami 1992). It is very durable when exposed to weather but not in contact with the ground. Heartwood is moderately resistant to preservative treatment (Keating and Bolza 1982). It makes excellent particle board, and is suitable for furniture and cabinet-making (Anon. 1979; Tham 1979), light structural works, agricultural tools, boxes and crates. It has been sliced for veneer (Razali and Hamami 1992) and was used locally for house construction at one time in Australia.

Plantation-grown trees are very promising for the production of unbleached kraft pulp (for bags, wrapping paper, linerboard) and high quality neutral sulfite semi-chemical pulp (for corrugating, medium and higher-grade packaging-type products)(Logan 1987). The sulfate process with 12–15% alkali yields 47–57% of screened pulp (Clark et al. 1991). Acceptable pulp yields were also obtained from high-yield mechanical type pulps (Logan 1987). Large-scale plantations have already been established in Malaysia and Indonesia for the production of paper pulp.

Other uses: With its dense evergreen foliage, *A. mangium* makes a useful shade, screening, and soil-cover crop. It has been used experimentally as shade for cocoa in Sabah. Its flowers are a source of bee forage and contribute to honey production (Moncur et al. 1991a). *A. mangium* is sometimes planted in mixture with tree species which do not fix nitrogen to maintain or improve soil fertility. Leaves (phyllodes) are very good for soil mulching.

Silvicultural features. Mangium is a fast-growing, relatively short-lived (30–50 years) species adapted to a wide range of acidic soils (pH < 4.0) in moist tropical lowlands. In China, *A. mangium* grows slowly when mean monthly temperatures fall below 17°C, and the species is sensitive to frost. While it prefers fertile sites that have good drainage (but not excessively well drained), it will tolerate soils of low fertility and impeded drainage. It is killed by fire only if the stem diameter is less than about 10 cm. The root system is shallow and vigorous. Branches are persistent as the species does not naturally self-prune. Stem heart rot sometimes develops from dead branch stubs. Fluting of the bole is often a problem. In some locations, *A. mangium* has a tendency to form multiple stems. The cause of these is not fully understood although it does appear partly related to soil fertility, competition, and use of oversized spindly seedlings. Higher phosphate levels in the trees and less competition appear to encourage it. Stem straightness also varies with site, being poorer on sites with higher fertility where growth is fast (Mead and Miller 1991).

There are large provenance differences in growth rate, stem straightness and frequency of multiple leaders. International provenance trials were established during the 1980s (Doran and Skelton 1982). Results of these trials were reported by Harwood and Williams (1992). There were highly significant differences in performance between experimental sites (19), between provenance regions (5) and among the local provenances within provenance regions. Growth was generally fast at near-equatorial trial sites, with mean annual height increment around 3–4 m, and slower for sites further from the equator. Papua New Guinea provenances were consistently the best performers, closely followed by the Claudie River provenance from north Queensland. Since establishment of these trials, further comprehensive seed collections have been undertaken and seedling seed orchards established to produce better quality seed for future planting programs. In contrast to large differences in growth performance of families and provenances, isozyme studies indicate low levels of genetic variability within and between populations in this species (Moran et al. 1989b). Harwood and Williams (1992) suggested that isozyme studies only examine a small sub-set of the genome, and therefore do not provide an absolute measure of overall genetic variation.

A. mangium can fix nitrogen after nodulating with a range of *Rhizobium* and *Bradyrhizobium* strains in many tropical soils. It is, however, much more specific in its rhizobia affinities than *A. auriculiformis* (Dart et al. 1991). Galiana et al. (1994) reported a highly significant *Bradyrhizobium* strain × provenance interaction in field trials on the Ivory Coast. This nitrogen-fixing potential may only be realised in many soils if adequate fertiliser is applied. Dart et al. (1991) reported large responses to P fertiliser and sometimes K fertiliser while dela Cruz and Umali-Garcia (1992) reviewed several papers where responses to N fertiliser applied at the rate of 30–300 kg N/ha were reported. Nodule development was suppressed or reduced at higher levels of N. *A. mangium* has associations with both ecto- and endomycorrhizal fungi. The ecto-mycorrhizal fungus *Thelephora* spp. forms a beneficial association and *Glomus fasciculatus* and *Gigaspora margarita* have been shown to be effective vesicular arbuscular mycorrhizas (dela Cruz and Umali-Garcia 1992).

Establishment: Flowering and seeding commence at about 2–3 years of age under plantation conditions. In Thailand, *A. mangium* has two flowering seasons, one in March–April and another during August–December (Yantasath et al. 1992). In Sabah, flowering peaks are in December–March and May–September (Sedgley et al. 1992). Pollination is by insects, especially bees, and mature pods can be harvested about 6–7 months after flowering. There are typically 63 600 viable seeds/kg. Mature seeds require a pregermination treatment, such as mechanical scarification of the seedcoat or immersion in boiling water to break dormancy; immersion for 30 seconds with the heat source removed followed by a 24-hour soak in tap water is recommended (Bowen and

Eusebio 1981; Liang 1987). After suitable treatment germination is rapid and typically exceeds 75%. Seedlings can attain the plantable height of 25 cm in 12 weeks. Inoculation with appropriate rhizobia may be beneficial.

Research into vegetative propagation of *A. mangium* is continuing and progress to date is encouraging. Grafting and marcotting are possible but they are not suitable for large-scale production of clonal material. Stem cuttings of young *A. mangium* seedlings are easily rooted when they are treated with hormones and planted in suitable rooting medium. However, the rooting percentage of stem cuttings decreases significantly with older stock plants (Wong and Haines 1992; Poupard et al. 1994).

Plantations are generally established using containerised seedlings. Direct seeding has been tried but results are variable. While *A. mangium* stumps coppice profusely, the coppice shoots lack vigour and are an unsuitable base for the second rotation. The second rotation may utilise the abundant natural regeneration that appears after logging debris is burnt. Site preparation for planting may involve slashing or complete ploughing of *Imperata* grass followed by chemical control (Otsamo et al. 1995) or burning logging debris. Weed control is applied during the first year, and occasionally in the second year. The method and frequency will vary with site and weed problem.

Initial spacing is governed by the need for rapid canopy closure and the end products required. For high quality logs, sufficient numbers need to be planted to enable the selection of crop trees with excellent form. Practices vary: in Peninsular Malaysia trees are planted at 900 stems/ha (3 × 3.7 m), in Sabah, spacings of 1075, 1250 and 1680 stems/ha are used. Use of fertiliser at establishment varies. In Peninsular Malaysia, Mead and Miller (1991) recommend the application of 100 g of triple superphosphate (TSP)/ tree at planting followed by a second application 150 g TSP at 5–6 months on fertile sites and, on less fertile *Imperata* sites, N and trace elements in addition to TSP. On sites where *A. mangium* develops multiple stems from its base the trees need to be singled before they are 1.5 m tall. Later singling is more time-consuming and runs the risk of encouraging butt rot.

Plantations for chipwood, pulpwood or firewood are not usually thinned or pruned and are harvested at 6–7 years, or about the point of maximum MAI. When growing *A. mangium* for sawn timber, pruning is required to overcome the degradation caused by branches and associated heart rot, and regular heavy thinning is needed to maintain large deep crowns and fast diameter growth. At conventional stockings competition starts to influence diameter growth at 1–3 years. Sawlog rotations of 15–20 years are envisaged in Malaysia (Mead and Miller 1991).

Yield: Under optimal conditions *A. mangium* grows very fast and reaches 20–25 m tall and 20–30 cm diameter at 10–13 years in Sabah (Jones 1983). At Sabah Softwoods Sdn. Bhd. unthinned stands planted at 1075–1680 stems/ha reach their maximum MAI in volume (to a 10 cm top) at 6 years after planting on high quality sites (>21 m^3/ha at 8 years) and at age 7 years on poorer sites. Soil depth and topographic position can influence yield in *A. mangium*. Volume production on deep alluvium may be almost double that on the skeletal soils.

Pests and diseases. Lenné (1992) and Lee (1993b) have reviewed the literature on *A. mangium* diseases, and Hutacharern (1992, 1993) lists a wide range of insect pests affecting the tree. Despite the substantial number of diseases and pests associated with it, this acacia appears to be less vulnerable to damage than many other tree species. Insect damage to the wood by carpenter ants *(Camporatus* sp.), termites *(Coptotermes* sp.) and a Cerambycid wood borer *(Xystocera* sp.) has been recorded in localised areas in Sabah (NAS 1983).

Rootrot of *A. mangium*, caused by *Ganoderma* sp. and *Phellinus* spp. affects young stands in Malaysia, Philippines and Fiji. A yellow, mottled, soft, light heart rot (causal agent unknown) is a potentially serious disease in Malaysia with 50% of trees affected in some stands. This disease has also been observed in Thailand. Cankers associated with decayed branch stubs and pruning wounds were good indicators of heart rot. Infected trees can continue to grow vigorously to maturity.

Limitations. *A. mangium* is unlikely to grow well on sites where there is a severe period of drought, incidence of frost or high soil pH. The species is susceptible to wind damage and could become a weed under certain conditions.

Related species. It hybridises with *A. auriculiformis* (Turnbull et al. 1983). *A. mangium* resembles *A. holosericea* and the two species have been confused. *A. holosericea* is usually a shrub or small tree which occurs on drier sites.

Acacia mearnsii

Main attributes. A fast-growing, nitrogen-fixing tree adapted to a wide range of sites from the temperate and subtropical lowlands to tropical highlands. It yields high quality condensed tannin, paper pulp, rayon, charcoal and fuelwood. The use of *A. mearnsii* tannin in waterproof wood adhesives for the production of reconstituted wood is expanding. A useful species for erosion control, windbreaks and soil improvement.

Botanical name. *Acacia mearnsii* De Wild. Formerly known as *A. mollissima* Willd. or *A. decurrens* (Wendl.). Willd. var. *mollis* Lindl. The specific name is after A.R. Mearns (1856–1916), an American army surgeon who collected the type specimen from a cultivated tree near Thika in Kenya. It was first published in *Pl. Bequaert* 1925.

Common names. Black wattle (standard trade name), late black wattle, acacia negra (Brazil).

Family. Mimosaceae.

Botanical features. A large shrub or small tree, typically in the height range 6–10 m but at times reaching 20 m. Open-grown specimens are freely-branched from near ground level and with 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 old trees is brownish-black, hard and fissured but on younger stems and the upper parts of old trees it is grey-brown and smooth. The branchlets are hairy and only slightly ribbed. The fern-like, bipinnate dark-green foliage is made up of 8–21 pairs of pinnae each with 15–70 pairs of leaflets; leaflets are crowded, 1.5–4 mm by 0.5–0.75 mm, olive green; glands numerous irregularly spaced between each pair of pinnae along the upper surface of the minutely hairy rachis; overall length of the compound leaf typically 8–12 cm.

The inflorescence consists of globular heads with 20–30 pale creamy yellow flowers in axillary or terminal racemes or panicles. The pods are more or less straight but often constricted between the seeds, finely hairy, 5–15 cm long by 4–8 mm wide. There are 7 (1–14) seeds, longitudinal in the pod, black, smooth, ovoid, 3–5 mm long by 2–3.5 mm wide with a short, creamy, terminal aril. Flowering takes place between October and December and fruits mature in 12–14 months.

The species is described and illustrated by Boland et al. (1984) and Tame (1992).

Natural occurrence. *A. mearnsii* occurs in south-eastern Australia. It extends through southern New South Wales, from a northern limit west of Sydney, and southern Victoria to southeastern South Australia and Tasmania.

- Latitude. Main occurrence: 35–43°S. Range: 33–43°S.
- Altitude. Main occurrence: sea level to 200 m. Range: near sea level to 1070 m.

Climate. Most of the distribution is in the warm sub-humid zone, extending in places to the warm humid zone. At the highest altitudes *A. mearnsii* occurs in the cool sub-humid and humid zones. The mean maximum temperature of the hottest month is mainly in the range 21–27°C and the minimum of the coolest month –3–7°C. The average number of days over 32°C is 1–15 and it is rarely found in areas where the temperature exceeds 38°C. Coastal localities have no heavy frosts, inland there are from 1–20 per year and at some higher altitudes up to 80 are recorded, with a record of low –12°C.

The 50 percentile rainfall is mainly in the range 440–1600 mm, and the lowest on record 360–450 mm. Seasonal incidence varies from a well-defined winter maximum in the south but becomes more uniform and tends to a weak summer maximum in the most northern parts of the occurrence. Booth and Jovanovic (1988a) provide a profile of climatic variation in this species.

Physiography and soils. *A. mearnsii* occurs in the Eastern Uplands physiographic division mainly on easterly and southerly aspects of low hills in coastal lowlands and adjacent lower slopes of the tablelands and ranges. It 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 podzols of moderate to low fertility. The best soils for black wattle 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 5–6.5. It is not common on poorly-drained or very infertile sites.

Vegetation type. Black 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 thickets especially where it has recolonised cleared land. In low altitude coastal areas it grows with *E. saligna*, *E. bosistoana*, *E. muellerana*, *E. ovata*, *E. globulus*, *E. tereticornis* and *E. viminalis*. Higher altitude associates include *E. cypellocarpa*, *E. radiata*, *E. smithii*, and *E. viminalis*.

Utilisation. *A. mearnsii* is cultivated in Brazil, China, India, Indonesia, South Africa and eastern Africa. South African plantations cover 160 000 ha (Boucher 1980), Brazil has over 200 000 ha of plantation (Higa and Resende 1994), and there are some 30 000 ha in China.

Fodder: The leaves 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 considered that digestibility was probably affected by the high tannin content in the leaves and twigs (5.7% DW). Considered to be inferior stock feed in Japan but has been fed to cattle in Hawaii during drought periods.

Fuelwood: The moderately dense wood, which splits easily and burns well, makes excellent fuelwood and charcoal. The charcoal is extensively used for cooking in Kenya and southern Brazil. A Brazilian company, Tanac, has developed special kilns for the production of activated carbon (for use in pollution control) from *A. mearnsii* (Boland 1987). The wood is used in Indonesia for domestic fuel and curing tobacco leaves (Berenchot et al. 1988).

Wood: Sapwood is very pale brown and the heartwood light brown with reddish markings. It is fine-textured and has indistinct growth rings. The basic density is about 630 kg/m^3 and the air-dry density 550–750 kg/m^3 (Bootle 1983). Physical and mechanical properties of plantation-grown wood are described by Gupta and Kukreti (1983). The timber must be seasoned slowly to avoid checking. The wood is hard but is moderately easy to work and takes a good polish. Preboring is necessary before nailing. Susceptible to termite and *Lyctus* attack.

The sapwood absorbs preservatives readily but the heartwood is moderately resistant.

The wood is used for house poles, mine timbers, tool handles, cabinetwork, joinery, flooring, construction timber, matchwood, and hardboard. It is suitable for a wide range of paper and paperboard products (Logan 1987; Nicholson 1991; Guigan et al. 1991). Kraft pulps using 13% active alkali yielded about 53% of screened pulp of Kappa number 20. A cubic metre of *A. mearnsii* wood produces about 320 kg of pulp. 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 the manufacture of kraft pulps (Logan 1987). In both South Africa (Sherry 1971) and India (Nilgiris area) it is used in the production of rayon.

Other uses: A. mearnsii produces the world's most important vegetable tannin. The bark is very rich in condensed tannin (35–51% DW) but yields are influenced by several factors including genetic variability, age and environment. Tannin industries based on this species have been developed in Brazil (Oliviera 1968), China (Hillis 1989), Kenya (Kenya Forest Service 1971), India (Samraj and Chinnamani 1978; Gupta et al. 1981), South Africa (Sherry 1971), Tanzania (Kessy 1987) and Zimbabwe (Luyt et al. 1987). In addition to its use for leather tanning, the bark extract is used to prepare tannin formaldehyde adhesives for exterior grade plywood, particleboard and laminated timber (Coppens et al. 1980).

A. mearnsii has been effective in controlling soil erosion on steep slopes and improving soil fertility (NAS 1980; Waki 1984). In central Java and in Kenya, foliage is used as a green manure to improve agricultural yield.

Plantations can produce more than 20 t/ha of fresh foliage annually (Cheboiwo and Ongugo 1989). *A. mearnsii* has also been used in Java as a fallow crop in a rotational system with agricultural crops such as tobacco, maize, cassava and various vegetables. *A. mearnsii* has been used for shelterbelts, green firebreaks and ornamental purposes. Poles with bark intact are used to support oyster racks (S. Searle, pers. comm.).

Silvicultural features. A fast-growing pioneer species which reaches its maximum growth rate 3–5 years after planting. Deaths in plantations due to over-maturity are frequent after 10 years in South Africa. The root system develops mainly in the soil surface layer and tap roots are short so that it is not very windfirm. It is a light-demanding species, which is sensitive to fire when young (< 3 years) and to temperatures below about −5°C to −6°C. Being a nitrogen fixer, it will tolerate relatively infertile sites but requires a good supply of phosphorus for rapid growth. Its coppicing ability is generally weak although small stumps coppice readily.

Optimal areas for commercial plantations of *A. mearnsii* in subtropical parts of South Africa are above 400 m altitude where the rainfall is in the range 850–1200 mm and the mean annual temperature above 16°C (Schonau and Schulze 1984). In more tropical areas *A. mearnsii* is best grown in the highlands at 1500–2500 m with a mean annual rainfall of 900–1600 mm and mean annual temperature 12–18°C (Webb et al. 1980). In a climatic analysis of successful plantation and trial sites, Booth (1992) suggested the range of suitable conditions for *A. mearnsii* plantations was: mean annual temperature 14–22°C, min. temperature of coldest month 0–1°C, max. temperature of hottest month 21–35°C, mean annual precipitation 700–2300 mm. Absolute minimum temperature should be above –5°C to avoid frost damage (Booth and Hong 1991).

A. mearnsii shows variation in growth rate, adaptation to drought and low temperatures and in wood and bark characteristics. Although it has been an important plantation species outside Australia for more than 100 years and selection and breeding programs based on local land-races have been established (e.g. in South Africa and Brazil), it is only in recent years that systematic range-wide seed collections have been made to exploit provenance variation for such commercial characteristics as volume and tannin yield. The results to date are summarised in the following.

A comparison of tannin contents of bark samples from 18 uneven-aged natural populations of black wattle in Australia showed Tasmania–Victoria provenances (46.9% and 46.6%) had more tannin in their bark than the South Australia–New South Wales group (39.4% and 38.8%)(Guangcheng et al. 1991). Similar results were reported for polyflavanoid contents and yields of bark extractives (Yazaki et al. 1990). Patterns of morphological variation in seedlings of *A. mearnsii* were studied by Bleakley and Matheson (1992). Tasmanian and mainland provenances diverged and, in turn, were subdivided into low elevation and higher elevation groups based on morphological features of young seedlings. It is still to be determined if these groupings extend to such economic traits as bark thickness and tannin yield. Trials in southern China have shown significant within and between provenance variation in growth performance, form and tannin production and significant provenance × site interaction. At 2–4.5 years from planting, Australian mainland provenances, especially those from New South Wales and Victoria, were superior to Tasmanian sources and the best of the Australian material was far better than the local land-races (Gao and Li 1991; Gao et al. 1991). In Brazil, provenances from coastal New South Wales are performing best among a limited number of natural provenances under trial (Higa and Resende 1994). Searle et al. (1994) reported on provenance variation in frost tolerance of *A. mearnsii* in laboratory trials. High altitude New South Wales provenances (Bungendore, Bombala–Dalgety and Cooma) and two low elevation provenances, Apsley (Tas.) and Minhamite (Vic.), were the most tolerant. 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. The highly significant between- family variation for frost tolerance within provenances indicates the potential for selection and breeding to increase the cold-hardiness of the species (Searle et al. 1991).

Establishment: Flowering in plantations is as early as 20 months after sowing. Pollen is aggregated into a polyad containing 16 pollen grains. The species is insect-pollinated especially by honeybees and appears to be self-incompatible (Grant et al. 1994). Estimates of outcrossing rates range from 69–100%. Many factors combine to result in a low pod set (0.03–0.1%) from the vast numbers of flowers formed (Moncur et al. 1991b). There are about

71 900 viable seeds/kg. To ensure rapid and complete germination, seedcoat dormancy must be broken before sowing. Mechanical scarification can be very effective but the seed is more commonly treated by immersion in very hot water (90°C) for 30–60 seconds (Poggenpoel 1978) or in boiling water for 1 minute (Doran and Gunn 1987). The seed is then washed in cold water, floating seed and impurities skimmed off, and dried. Treated seed may be stored safely for at least one year.

The seeds may be sown in prepared sites in the field or raised in containers in a nursery. Nursery establishment is generally by sowing the pre-treated seeds directly into the containers. Usually two seeds are sown and surplus seedlings are transplanted to containers where seeds fail to germinate. Seedlings can reach plantable size (20 cm in height) in 4 months. Inoculation with an appropriate strain of rhizobia may be beneficial. When sowing directly in the field, the seed is sown in rows 1.8–2.7 m apart in well-cultivated and weed-free ground. Seeding rate is 1.2–2.4 kg/ha. Seedlings are thinned at regular intervals until routine spacings are achieved. Vegetative propagation by rooted cuttings is difficult but a technique is described by Zeijlemaker (1976).

The species is intolerant of weed competition when young and plantations must be kept clean until canopy closes (Luyt et al. 1987). The importance of site preparation by ploughing or ripping and weed control in promoting rapid establishment and growth has been demonstrated by Boden (1984). Very significant increases in wood volume and tannin yield after fertilising with phosphorus have been shown by Schonau (1983), Herbert (1984) and Waki (1984). A spacing of 2.75 m × 1.2 m (3000 trees/ha) is often used in South Africa to permit selection and removal of trees with gummosis. Thinning practice varies. In Zimbabwe, the initial stocking of 2469 stems/ha is reduced to 2000/ha when tree height averages 4 m and is further reduced to 1500–1700/ha when trees average 7 m tall. Intercropping is sometimes practiced in Kenya and, in Brazil, a crop of maize or manioc is often grown between the rows of trees in the first year.

A rotation length of 8–10 years with a range of 5–12 years is standard practice for tannin production. Establishment of subsequent rotations may involved replanting, or the logging debris may be stacked in rows, burnt, and the resultant natural regeneration thinned to regular spacings.

Bark stripping is best done when the sap is flowing and this occurs during the warm, wet summer months. If the bark must be stored, it should be carefully dried in well-aerated strips to minimise formation of mould.

Yield: Typical yields for well-managed South African plantations 10–11 years old in Natal, are 21 t/ha of bark (dry) and 112 t/ha of wood (airdry) and in the colder southeastern Transvaal 16.6 t/ha and 74.8 t/ha, respectively. At this age, the trees are 17 m tall and 14 cm diameter in Natal, and 14 m tall and 13 cm diameter in Transvaal (Stubbings and Schonau 1982). On appropriate sites and where the trees are fertilised a mean annual increment over 7–10 years of 15–25 m^3/ha of wood is feasible.

Pests and diseases. In Australia, the leaf-eating fireblight beetle, *Pyrgoides orphana*, is a serious pest of *A. mearnsii* (Elliott and de Little 1984) and was one of the early disincentives for planting the species in Victoria (Searle 1991). Luyt et al. (1987) list white grub (*Lepidioto mashona*), grasshoppers, cutworms and damping-off as problems in the nursery and a sap sucker, wattle mirid (*Lygidolin laevigatum*), amongst the most serious of pests in young plantations in Zimbabwe. *Loranthus* termites and a number of other insects cause problems in Tanzania (Kessy 1987). In southern Brazil heavy damage is caused by a beetle which girdles twigs and branches (Vulcano and Pereira 1978), and various stem borers can cause severe damage. A number of pests and diseases of *A. mearnsii* are listed by Sherry (1971). *A. mearnsii* is included in Lenné's review (1992) of diseases of multipurpose woody legumes in the tropics and in an overview of diseases of *Acacia* by Lee (1993a). An apparent physiological disorder known as 'gummosis', in which gum is exuded in the absence of any obvious injury, causes losses and is common where the species has been cultivated outside its natural climatic range.

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 −4°C or lower. Poor stem form often limits utilisation of timber from plantations.

Related species. *A. mearnsii* belongs to a group of 49 closely related taxa in the Section Botrycephalae. This group includes *A. dealbata*, *A. decurrens*, *A. irrorata*, *A. parramattensis* and *A. silvestris* (Boland 1987).

Acacia melanoxylon

Main attributes. *A. melanoxylon* is a long-lived, nitrogen-fixing species that may attain up to 1.5 m in diameter and 40 m in height. It is suitable for planting in moist conditions in cool climates. It is prized for its decorative wood which is used in furniture and veneer. It is also useful for shade and shelter and ornamental plantings. To produce good timber, the correct provenance must be used and the trees grown on sheltered sites in the presence of a nurse species or in carefully managed, closely spaced plantations. Palatability of the juvenile foliage to wild and domestic animals can be a major constraint to successful establishment.

Botanical name. *Acacia melanoxylon* R.Br. The name was published in *Ait. Hort. Kew.* 2nd edn, 5: 462 (1813). The specific name is derived from the Greek *melanos* — black and *xylon* — wood.

Common names. Australian standard trade name is blackwood. The species is sometimes referred to as Tasmanian blackwood or swamp blackwood.

Family. Mimosaceae.

Botanical features. Blackwood is often 10–20 m tall and 0.5 m diameter, but varies from a small shrub to one of the largest acacias in Australia, attaining heights up to 40 m and diameters of 1–1.5 m on lowlands in northwestern Tasmania, and in southern Victoria. In open situations the smaller and medium-sized blackwood trees are freely branched from near ground level, but the largest plants have a well-developed trunk which is usually fairly cylindrical but may be shortly buttressed or flanged at the base. The hard rough bark is brownish-grey to very dark grey and is longitudinally furrowed and scaly, shedding in narrow vertical strips. The branchlets are angular with conspicuous ribs; young branchlets are pubescent to hoary, becoming glabrous. The deep or dull-green phyllodes are alternate, simple, narrow-ovate, somewhat falcate or almost straight, 8–13 × 0.7–2 cm and rounded or rarely acute at the tip. There are 3–5 prominent longitudinal veins; pulvinus 2–4 mm long; gland small 1–10 mm above the base; bipinnate foliage often persists to about the 20th node on young plants.

The inflorescence consists of 3–5 relatively large globular heads carried on short axillary racemes, 2.5–5 cm long. Each head consists of 30–50 flowers which are whitish to very pale yellow. The legumes are flat, rather thin, 6–10 × 0.4–0.6 cm, mid-brown and when ripe either irregularly twisted or openly coiled. Seeds are black, oval and flat and 6–10 are carried longitudinally in the pod; funicle is pink or red, half-encircling the seed in a double fold on each side, aril is small. Flowering is variable throughout the species range. In the northern part of the range flowering tends to be in late winter–spring while in the southern part of the range flowering is spring–summer. Ripe seed is available during summer–autumn with a mid-February peak and little seed is retained on branches beyond April (Jennings 1991).

The relatively wide phyllodes, longitudinal venation, pale flowers and twisted or coiled legume with red funicle are the key distinguishing features of this species. It is described and illustrated in many texts including Boland et al. (1984), Floyd (1989) and Tame (1992).

Natural occurrence. The natural range of *A. melanoxylon* extends from Mt Lewis and the Atherton Tableland in northern Queensland through the tablelands and coastal escarpments of southeast Queensland, New South Wales and Victoria to the Mount Lofty Ranges in South Australia and to southern Tasmania. It is found only at higher altitudes in the tropical part of its range.

- Latitude. Range: 16–43°S.
- Altitude. Range: near sea level to 1500 m.

Climate. The principal occurrence is in the cool and warm humid climatic zones, but it is common in the warm sub-humid zone. Summers are mild to warm, with the mean maximum temperature of the hottest month 23–26°C and the mean minimum of the coldest month 1–10°C, with 1–40 heavy frosts a year. Some of the area experiences a few light snowfalls in a year.

The mean annual rainfall is 750–1500 mm, with a low to moderate variability; precipitation is mainly on 100–120 days per year, rising to 150–180 where the largest trees grow. Rainfall has a winter maximum in the southern part of the species range, an even distribution in the central part, and a summer maximum in the north.

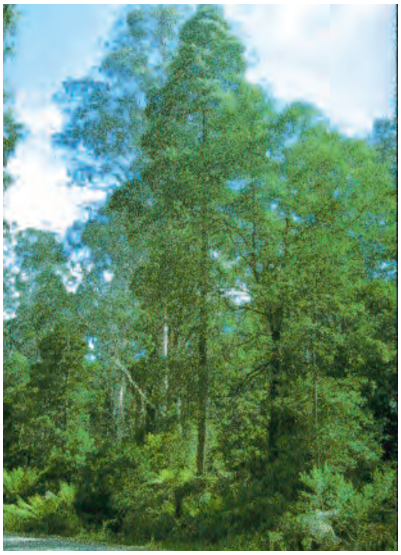
A summary of the climatic requirements of the species under natural and cultivation conditions is given by Marcar et al. (1995); mean annual temp. 9–25°C, min. temp. of coldest month –3–16°C, max. temp. of hottest month 19–33°C, mean annual precipitation 480–2940 mm, dry season 0–6 months.

Physiography and soils. The topography varies from lowland swampy areas and the lower valley slopes of hilly and mountainous areas to higher hill slopes and tablelands and even exposed mountain tops.

Best growth is on slightly acidic, forest podsols and alluvia of high nutrient status, but as a smaller tree, the species grows on a wide range of podsols, sandy loams, kraznozems and even the residue from tin sluicing operations.

Vegetation type. Blackwood is predominantly an understorey species. In northern New South Wales and southern Queensland it is often the major early secondary tree species in disturbed temperate (cool and warm) rainforests (Floyd 1990). The main vegetation types are cool temperate rainforests (nanophyll moss forests) and tall open-forest. Only as a smaller tree is it common in open-forest and, as a small shrub, in mountain heath. It also occurs in teatree swamps in Tasmania. Blackwood has a higher tolerance of saturated soil conditions than most eucalypt or rainforest overstorey species and therefore tends to become a more significant component of stands in swampy or seasonally flooded sites. However, the best growth occurs on well-drained soils with blackwood often occupying mounds and dry banks in swamp conditions.

Under optimum conditions its associates are *Eucalyptus regnans*, *E. obliqua*, *E. delegatensis and E. viminalis*. At higher altitudes there may be *Nothofagus cunninghamii* (myrtle beech) and *N. moorei* (negrohead beech), with one of the larger ferns (*Dicksonia antarctica*) in cool, wet areas. In the drier and warmer areas there are many species of eucalypt, especially stringybarks, and amongst the shrub vegetation several other acacias



and, in places, species of *Xanthorrhoea*. Associates in the teatree swamps of Tasmania include *Melaleuca ericifolia*, *M. squarrosa*, *Leptospermum lanigerum* and *L. scoparium* with *N. cunninghamii*, *Atherosperma moschatum*, *Eucryphia lucida*, *Anodopetalum biglandulosum* and other rainforest species in the understorey (Allen 1992).

Utilisation. Blackwood is recognised as an outstanding cabinet timber in Australia. Formerly exported, supplies have dwindled and the annual production of about 10 000 m^3 is now used within Australia. Most timber comes from the natural forests of Tasmania where the resource is actively managed. Supplies from main land Australia of which Victoria contributes most (500–1000 m^3), are now modest. As an exotic it has been most extensively grown in India and South Africa and shows promise in New Zealand (Gleason 1986). It is also common in the hill country (1400–2000 m) of Sri Lanka (Midgley and Vivekanandan 1986) and in the high country (>1200 m) of East Africa (e.g. in Kenya and Tanzania).

Fodder: The foliage is harvested for cattle fodder in the Nilgiri Hills region of India, although tests in Australia show predicted in vivo digestibility at 45% or below animal maintenance levels (Vercoe 1987).

Fuelwood: Air dry wood of *A. melanoxylon* has relatively low density. It ignites easily and burns quickly and quietly with large flame and little smoke but does not form hot embers (Groves and Chivuya 1989). The wood is used for fuelwood in India and Sri Lanka, although it would be considered of poor quality for certain cooking requirements and for room heating.

Wood: Sapwood is white, up to 10 cm wide and susceptible to attack by *Lyctus* borer. The heartwood is golden-brown to darker brown, sometimes with reddish tints and streaks. The grain is usually straight but is sometimes attractively figured with stripes, mottled, raindrop, birdseye and fiddleback patterns together with a beautiful surface lustre. It is of moderately low basic density 465–670 kg/m^3 for 72-year-old trees and 390–576 kg/m^3 for 46-year-old trees in New Zealand (Harris and Young 1988) and only moderately hard, but takes a high polish. Blackwood is prized for cabinet work, panelling, inlays, bent work and staves. Availability of sound large logs is limited and today the timber is mainly used for sliced veneer, especially on particle board for cabinet work and furniture, with 'scrap' sizes for small fancy articles. The wood has good acoustic qualities and is suitable for violin backs. Small diameter, fast-grown logs do not develop the growth stresses of some eucalypt species and good sawn conversion can be expected from trees grown on 40–50-year rotations.

Other uses: Open-grown specimens retain their lower branches for many years and form excellent single-row shelterbelts. It grows well on some exposed sites, without attaining saw log sizes. It also has a useful role in plantings for shade and beautification in cool to mild climates with an adequate rainfall.

Silvicultural Features. Blackwood is a long-lived, hardy tree and is considered both moderately drought and frost resistant (Anon. 1980a) and tolerant of periodic waterlogging and slightly saline soils where reduced growth can be expected at EC_e less than 5 dS/m (Marcar et al. 1995).

The oldest known blackwood was 210 years old when harvested near Smithton, Tasmania (Mesibov 1980 in Jennings 1991). Blackwood plantings in New Zealand withstand severe frosts down to about −7°C. Below this temperature trees may be killed back to ground level but many recover by coppicing. In trials in southeastern Queensland, a tropical and subtropical provenance coppiced best when cut at 1 m and both displayed abundant root suckering (Ryan and Bell 1989).

As might be expected in a species with such a wide geographic range, there is considerable genetic variation between trees from different localities: in growth traits (Jennings 1991); in phyllode and fruit shape and size and in the age of change from bipinnate to phyllodineous leaves (Farrell and Ashton 1978); in frost resistance (Franklin 1987); and in certain anatomical features of the wood (Wilkins and Papassotiriou 1989). Isozyme analysis of 27 provenances covering the distribution of *A. melanoxylon* showed a distinct genetic separation between the northern and southern populations near the Hunter River in New South Wales (Playford et al. 1991, 1993). Populations to the north of the Hunter River were much less heterozygous than the southern populations, although mean heterozygosity levels were high. This separation coincided with a disjunction in the distribution of the species indicating that the species has evolved separately in the two regions for a considerable time. Southern populations were further divided in northern Victoria. Most of the genetic diversity as assessed by allozyme variation was found within populations but there was an unusually high level of variation between populations (37.7%). Provenance trials on three sites in South Africa at 8–10 years from planting showed that provenances from Mt Sabine (Vic.) and Smithton (Tas.) and a seedlot of select trees from Natal were the most consistent for volume growth of the eight provenances tested (de Zwaan and van der Sijde 1990). In view of these findings, careful selection of provenance to match the conditions of the planting site is well justified. In addition, Harris and Young (1988) reported substantial between-tree variation in wood density in a 46-year-old stand of blackwood in New Zealand, suggesting that selection and breeding to eliminate the lowest density trees might be warranted. In this study a positive association was found between faster-grown trees and darker heartwood, but no association was found between growth rate and density.

In South Africa, topsoil properties have proved important in the selection of suitable sites for blackwood. The preferred soils have a texture range from a sand to silt loam, high humus content, at least 0.7 m deep and of good drainage (Grey and Taylor 1983).

Establishment: Blackwood may flower from as early as 2 years (Ryan and Bell 1989). There are 64 000 viable seeds/kg with an average germination rate of 75%. Immersion in water at 90°C for 1 minute will break seedcoat dormancy. Treated seed is usually sown directly into polythene containers and seedlings reach plantable size in under six months. Seedling development is poor without rhizobia, so young seedlings may need to be innoculated if propagated in sterilised or new soil (de Zwaan 1982). Studies in progress in Australia are showing some strains of rhizobia to be much more effective in stimulating growth of *A. melanoxylon* than others (A. Gibson, pers. comm.). Thus, the most effective strain × provenance combinations could be proposed. Phosphate fertilizers have been found to be beneficial in the nursery and in the field.

Although blackwood is tolerant of very moist conditions and survives waterlogging for several months of the year in the swamps of Tasmania, it is important that the water is moving, however slowly, as blackwood will not grow in stagnant, waterlogged areas. Blackwood is shallow-rooted and is susceptible to windthrow, particularly in wet soils.

Care must be taken in site selection and silviculture in order to grow good timber trees of *A. melanoxylon*. While tolerant of a wide range of environmental conditions including soils of low fertility, it produces good timber only where it is sheltered from wind by topography, nurse-vegetation or mutual protection. Best results are achieved where trees grow in light-wells or gaps in an established canopy of other trees. In Tasmania, blackwood is planted with *Pinus radiata* or eucalypts, especially *E. nitens*, at stockings of 62.5 blackwood seedlings/ha and 1250 nurse crop trees/ha (Hickey 1988). The tree can be grown in single-species plantations but, because it will develop forks and heavy branches at wide spacing, close initial spacing (e.g. 2.5 × 2.5 m) followed by intensive pruning and thinning is necessary to produce timber trees. Final crop numbers should be about 100 stems/ha (Anon. 1978). In Tasmania blackwood is managed as a 70-year rotation aiming at logs with a minimum diameter of 50 cm and a stocking of 200 stems/ha. Enrichment planting with potted nursery stock is used when natural regeneration is inadequate (Hickey 1988).

Yield: Over a wide range of sites in New Zealand, diameter growth of blackwood averages 10–15 mm per year and rotations of 40 years are expected to produce trees of 50–60 cm dbh with an acceptable amount of heartwood and about 25 m tall. Similar growth rates are reported in South Africa where mean annual increment averages about 16 m^3/ha (Esterhuyse 1985; de Zwaan and van der Sijde 1990).

In Australia, a MAI of 15 m^3/ha is obtained on good quality sites in Tasmania. At this growth rate it is uneconomic to grow blackwood unless combined with a nurse crop of clear wood *Pinus radiata* or eucalypt pulpwood (Allen 1992).

Tropical provenances have been little tested. In species trials on subtropical and tropical sites in Queensland, tropical provenances grew more vigorously than a Victorian provenance and had annual height growth exceeding 2 m (Ryan and Bell 1991). The species showed poor early development on seasonally dry lowland sites in Thailand (Pinyopusarerk and Puriyakorn 1987).

Pests and diseases. Allen (1992) provides a summary of pests and diseases of blackwood. In natural stands, blackwood is attacked by a wide range of insects but none is seen as being of economic consequence (Jennings 1991). Seedlings may be defoliated by moths or grasshoppers, and larger trees attacked by wood borers, leaf eaters, psyllids and scale insects. Susceptibility to fungal diseases such as *Armillaria* and *Phytophthora* appears to be minimal. Significant pests in New Zealand are the ghost moth (*Aenetus virescens*) and pinhole borers *(Platypus* spp.). Various fungal diseases have been reported on young plants of *A. melanoxylon* in southern India including *Fusarium semitectum* which causes shoot dieback in two-year-old plants (Mohanan and Sharma 1988).

Whilst relatively free of significant insect attack and pathogens, blackwood is subject to a substantial number of vertebrate pests (see Allen 1992).

Limitations. Blackwood seedlings are extremely palatable to native marsupials, mammals, deer, domestic livestock and rabbits. As a result, tree protection or animal control measures may be needed for the first three years to ensure successful establishment. Survival is poor if planted on clay soils subject to waterlogging. The species will produce quality timber only under certain environmental conditions and from certain provenances. A shallow root system predisposes it to windthrow. It has become a weed species in South Africa where it regenerates in gaps in indigenous forests.

Related Species. *A. frigescens* and *A. implexa* are closely related to *A. melanoxylon*.

Acacia murrayana

Main attributes. A fast-growing, nitrogen-fixing shrub or small tree which tolerates drought, fire, and infertile soils. It has potential for fuelwood and low shelter in sandy, warm to hot, arid zones.

Botanical name. *Acacia murrayana* F. Muell. ex Benth. in *Fl. Austral.* 2: 370 (1864). Named in honour of Dr J.P. Murray (ca 1835–fl.1873), surgeon and plant collector who on Howitt's expedition of 1862 collected specimens of *A. murrayana* at Coopers Creek. *A. frumentacea* is now included in *A. murrayana*.

Common names. Sandplain wattle, colony wattle, Murray's wattle, powder bark wattle.

Family. Mimosaceae.

Botanical features. This wattle is a shrub 2–5 m or small tree up to 8 m, single or multi-stemmed from the base, with a spreading canopy 3–8 m wide; bark smooth, white, grey or brown with a distinctive powdery white bloom (pruinose). Phyllodes variable, linear to narrow-elliptic, straight or curved, pale green sometimes pruinose, leathery, 5–18 cm long by 1.5–10 mm, wide thickened margins and mid-nerve prominent. The bright yellow globular flower heads are in axillary racemes. Pods light brown, papery, 5–8 cm long, 8–12 mm broad, with broad nerve-like margins, flat but raised over the seeds, straight or slightly constricted between the seeds. Seeds black, almost orbicular, transverse in the pod, 4–5 mm long by 3–3.5 mm wide, attached to a short funicle with up to 3 folds. There is no aril. Flowering occurs in spring, from August to November, and seeds are mature in November and December.

The species is described and illustrated by Pedley (1979) and Whibley and Symon (1992).

Natural occurrence. *A. murrayana* has an extensive distribution in arid areas from southwestern Western Australia through Central Australia to inland southwestern Queensland and northwestern New South Wales.

- Latitude. Main occurrence: 24–31°S.
  Range: 21–32°S.
- Altitude. Main occurrence: 50–550 m.
  Range: near sea level to 750 m.

Climate. Most populations occur in the warm arid climatic zone but some extend into the warm semi-arid zone. The mean maximum temperature of the hottest

month is 34–38°C, and the mean minimum of the coolest 4–6°C. Except for a few places on or near the coast of Western Australia, all the regions experience some heavy frosts, mainly 1–8 per year.

The higher rainfall areas are in Queensland and New South Wales. Most of the distribution has a 50 percentile of 200–300 mm, a 10 percentile of 100–250 mm, and a lowest on record of 50–125 mm. The seasonal distribution of rainfall varies widely from a summer maximum in the north to a weak summer maximum in the south. Rainfall incidence is erratic in Western Australia, with the wettest month being in winter.

Physiography and soils. Most of the topography where *A. murrayana* occurs is very gentle, frequently as plains, but with some low ridges and mesas. The occurrences are mainly on extensive sandy plains or inland sand dunes. It is found on dune crests and slopes, in the flats between dunes, in the sandy beds of ephemeral rivers, on alluvial plains, and less commonly on small rocky rises.

The most common soil type is red or yellow deep sands, but it is also found on loamy or clay soils, including crusty alkaline and neutral duplex soils and neutral red earths. The soils are usually well drained, and on the sand plains are usually deep enough to absorb all but exceptionally heavy rains. Levels of nitrogen and phosphorus in the soils are invariably low. Data for typical sites in Central Australia are given by Winkworth (1967).

Vegetation type. *A. murrayana* is a component of woodland and low woodland in the higher rainfall areas but is more commonly in tall open-shrubland and hummock grassland in more arid regions. In the east it is found growing in woodland communities dominated by *Callitris* spp. and *Eucalyptus populnea*; throughout most of its range it is associated with *A. aneura* and *A. victoriae*. On the extended flanks of dunes it grows with *A. ligulata*, and in western areas it occurs with *A. linophylla* and *A. ramulosa* on sandy rises or sand dunes. In Central Australia it is found in arid spinifex (*Triodia* and *Plectrachne* spp.) grasslands with low eucalypts such as *E. papuana* and *E. terminalis*, or with the mallee, *E. gamophylla*. More detailed regional accounts of the vegetation types including *A. murrayana* are given by Beard (1976), Boomsma and Lewis (1980), and Winkworth (1967).

Utilisation.
Fodder: Dry matter digestibility of foliage was assessed by Vercoe (1989) as being below maintenance levels. The phyllodes have moderate nutritive value but are only lightly grazed by cattle in the Northern Territory (Chippendale and Jephcott 1963). They are rarely grazed by sheep and have been suspected of causing poisoning (Webb 1948). The pods, however, are readily eaten by sheep (Allen 1949).
Fuelwood: Highly suitable for fuelwood and charcoal (Thomson et al. 1994). The suckering habit will assist the management of this species for fuel.
Wood: No data available on wood properties. The small size of the stems will restrict the use of the wood to turnery articles and small round wood uses.
Other uses: A. murrayana can form thickets from root suckers, so having the potential for low shelter. It flowers profusely and may prove useful for ornamental purposes and as a pollen source for bees. In the past, seed of *A. murrayana* was a food source for Central Australian Aborigines (House and Harwood 1992). It bears uniformly heavy seed crops and the seeds are nutritious, containing 20% protein, 5% fat and 64% carbohydrate.

Silvicultural features. This acacia forms colonies from subsurface adventitious sprouts often a considerable distance from the parent plant. Established plants are fire-tolerant and resprout readily after wildfires from epicormic buds in the relatively thick bark at the stem base, or from stem and major roots (Hodgkinson 1982). It reaches reproductive maturity early, flowers regularly and produces abundant seed. The growth pattern is distinctly seasonal with the main vegetative growth during spring (Maconochie 1973) and it loses many of its phyllodes in winter (Cunningham et al.

1981). It has a relatively short life-span, about 15–25 years, during which time in its natural habitat it rarely produces a trunk with a diameter over 10 cm (Maconochie 1982). It is relatively salt-sensitive (Aswathappa et al. 1987).
Establishment: A. murrayana has 19 900 viable seeds/kg, which have a thick testa and require one of the routine treatments to break seedcoat dormancy (e.g. 1 minute immersion in boiling water). Germination rate averages 70%.
Yield: Reports of performance are variable and this is most likely due to some planting on inappropriate sites. In the Northern Territory at Alice Springs, *A. murrayana* grew reasonably quickly while rainfall was above average (390 mm/year) but health was significantly affected during a dry period (< 150 mm/year). At 10 years *A. murrayana* had grown into a multi-stemmed tree, 6 m tall with 3–4 stems of approximately 10 cm dbh (Kube 1987). In Queensland *A. murrayana* failed near Gympie (Ryan and Bell 1989) but showed early promise on coarse-textured soils near Longreach (Ryan and Bell 1991). It gave poor survival and growth to two years of age in southern Africa (Gwaze 1989; Maghembe and Prins 1994).

Pests and diseases. No data available.

Limitations. The small size of *A. murrayana* limits the use of its wood to fuel. Its capacity to regenerate vigorously both from seed and by vegetative structures suggests that it has the potential to be a weed species under appropriate conditions.

Related species. The narrow phyllode form of *A. murrayana* is closely related to *A. pachyacra* (Maslin 1981); the broad phyllode form has some affinity with *A. jennerae* (Whibley and Symon 1992). It is also related to *A. praelongata* (Thomson et al. 1994).

Acacia neriifolia

Main attributes. An attractive, relatively fast-growing nitrogen-fixing shrub or small tree adapted to a range of well-drained soils in warm sub-humid areas. It will tolerate snow, heavy frosts and moderate droughts. Has potential for planting in tropical and subtropical highlands for fuelwood, small round timbers, windbreaks and as emergency fodder.

Botanical name. *Acacia neriifolia* Cunn. ex Benth. in Hooker's, *London J. Bot.* 1: 357 (1842). The species name is derived from the generic name of the oleander (*Nerium*) and the Latin *folium* — leaf, in allusion to the resemblance of the phyllodes to the true leaves of oleander.

Common names. Oleander wattle, less commonly bastard yarran, white wattle or silver wattle.

Family. Mimosaceae.

Botanical features. Often observed as a single-stemmed but freely-branched shrub of 2–5 m in open situations. It commonly grows to a small slender tree 6–8 m tall and occasionally as a taller tree of 10–15 m. The tall specimens have been reported from Queensland. The bark is pale grey or dark grey and somewhat compact, the branches are slender and slightly angular covered with silvery appressed hairs or a whitish bloom when young.

The phyllodes are straight or slightly curved, thick, 5–15 cm long by 4–12 mm wide, densely downy, with a prominent mid-rib and usually 1–3 glands on the upper margin. The flowers are bright yellow, in small globular heads on slender racemes 3–9 cm long in the phyllode axils. The pods are smooth, flat, straight, or slightly curved, 7–16 cm long and 6–10 mm wide, with paler thickened margins, often slightly constricted between the longitudinally arranged seeds. The seeds are black, oval-oblong, 5–12 mm long by 4–9 mm wide with a prominent pale terminal aril. Flowering occurs June–October with the main period in July–August in the north and west of its range and about a month later in the south and east. Mature pods have been collected in November–December.

The species is described in more detail by Pedley (1979), Stanley and Ross (1983) and Tame (1992). It is illustrated by Simmons (1981).

Natural occurrence. *A. neriifolia* is found in an area about 1000 km long and less than 200 km wide from central New South Wales to central Queensland along the Great Dividing Range.

- Latitude. Main occurrence: 25–31°S.
  Range: 23–32°S.
- Altitude. Main occurrence: 200–500 m.
  Range: 100–1100 m.

Climate. Most of the distribution is in the warm sub-humid climatic zone. The mean maximum temperature of the hottest month is 30–33°C and the mean minimum of the coolest 3–5°C. There are 30–60 days when the temperature exceeds 32°C and 1–6 days when it is over 38°C. Most of the lower altitude localities have 13–30 heavy frosts annually but at the highest altitudes there are 50–60 frosts a year.

The 50 percentile rainfall is mainly 600–800 mm, the 10 percentile 450–525 mm and the lowest on record 250–425 mm. The rainfall has a moderate summer maximum with January the wettest month and July or August the driest. There are about 70–90 raindays per year and extended periods of drought are rare.

Physiography and soils. Most of the distribution is in the New England–Moreton Uplands physiographic province of the Eastern Uplands division. The topography in which *A. neriifolia* is found varies from gently undulating to hilly and sometimes mountainous country. It has been recorded growing on sandstone, andesite, basalt, granite, conglomerates and shale. The soils vary from infertile shallow rocky lithosols and podzolics of the mountain sides to deep strongly structured red-brown, fertile volcanic krasnozems. The soils are acidic and well drained. Some of the tallest specimens have been found on the deep red-brown basaltic clays, but *A. neriifolia* can reach 8 m on shallow sandy soils.

Vegetation type. The dominating structural vegetation types are low open-forest and woodland. The principal tree species in the associations are *Eucalyptus* or *Callitris*. In Queensland it has been recorded growing with *E. cloeziana*, *E. crebra*, *E. fibrosa*, *E. maculata*, *E. tenuipes*, *E. trachyphloia* and *E. watsoniana*. In northern New South Wales it occurs with other acacias such as *A. doratoxylon* and *A. penninervis* in the tall shrub layer of forest and woodland associations dominated by *E. macrorhyncha*, *E. youmanii* and *E. andrewsii* (Beadle 1981).

Utilisation.

Fodder: It has some value as forage for animals, especially sheep, during times of drought (Anderson 1968). Vercoe (1989) estimated the crude protein levels of phyllodes to be in the range 14–16% (DM) with a predicted in vivo dry matter digestibility of 33–35%. As the species came close to the minimum requirement for certain nutrients, it was recommended for further study of its fodder potential.

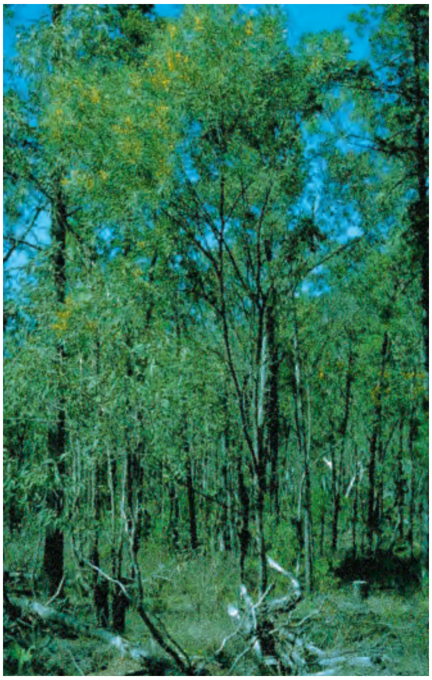
Fuelwood: No specific information available but probably is a good fuel.

Wood: The timber is attractively marked, close-grained and tough but of no local importance in Australia. It has potential for post and pole production.

Other uses: The bark has a tannin content of 11–14% (Swain 1928a) and was formerly used locally for tanning in southern Queensland (Maiden 1922). *A. neriifolia* makes an attractive ornamental tree and it is cultivated for gardens in eastern Australia (Forestry Commission of New South Wales 1980). It is sometimes grown for windbreaks in Australia (Simmons 1981).

Silvicultural features. A fast-growing species that will withstand snow and heavy frosts. It has grown best on relatively light, often stony, well drained sites. *A. neriifolia* coppiced poorly when cut below 1 m, and coppicing performance was rated as only fair at 1 m (Ryan and Bell 1989).

Establishment: Propagation is from seed that has been immersed in boiling water for 1 minute to break seedcoat dormancy. A light seed crop was observed on planted specimens in Queensland as early as 16 months (Ryan and Bell 1989). Treated seed gives a germination rate of 70% and there are about 22 300 viable seeds/kg.



Yield: In field trials in southeast Queensland, one provenance (Toowoomba) grew very rapidly, averaging nearly 14 m tall and 19 cm in basal diameter in 4.5 years (Ryan and Bell 1991). The other provenance tested (Blackdown Tableland) grew at only half this rate and was of poorer form, indicating the need to trial a range of seed sources when assessing the potential of this species.

Pests and diseases. None recorded.

Limitations. Vigorous growth can be expected only on well drained sites where there is a short dry season. The small size of *A. neriifolia* will limit its use to fuelwood, posts, poles and non-wood purposes such as shelter and amenity.

Related species. This acacia exhibits considerable variation in its natural habitat and Pedley (1979) recognises two well-defined variants which may deserve formal recognition. One variant is from the Granite Belt and near Inglewood in Queensland and comprises rather large trees with larger coriaceous phyllodes, while the other is intermediate in characteristics of juvenile leaves, phyllodes and flowers with *A. pustula*. This variant occurs in the Toowoomba–Crows Nest–Yarraman area. *A. neriifolia* is also very closely related to *A. pustula*, and distinctions between the two species are slight and arbitrary.

Acacia oraria

Main attributes. A small, nitrogen-fixing tropical tree or shrub that can grow in exposed coastal situations on infertile, possibly saline, sites. *A. oraria* also tolerates highly alkaline sites. It can be used for ornament, shelter, fuelwood, and the production of small posts. Its dense foliage and heavy litter fall can suppress *Imperata* grass within 1–2 years.

Botanical name. *Acacia oraria* F. Muell. in *Fragm*. 11: 66 (1879). The specific name is based on the Latin *orarius* — belonging to the coast, and refers to the habitat of the species.

Common names. Suli (Timor); not known in Australia.

Family. Mimosaceae.

Botanical features. Usually a small tree with a well-defined main stem and in the height range 6–10 m. It may also be a freely-branched shrub, 3–5 m tall, in open, unfavourable growing conditions. In Indonesia it can be a widely-branched tree of 10–15 m. The bark is fibrous and fissured.

The phyllodes are rather thick, obovate-falcate, the lower margin more or less straight and the upper curved, broadest about or above the middle; 5–10 cm long by 1–4 cm wide and covered with white resin when young. There are three prominent and about six secondary longitudinal nerves reticulately nerved between. The branchlets are angular and covered with a whitish resin.

The flower heads are globular, axillary or sometimes terminal which may grow out into leafy shoots. The pod is flat with nerved margins, twisted or coiled when fully mature, covered in a white resin and up to 12 cm long by 1–2 cm broad. The seeds are longitudinal in the pod, black, about 4 mm long and 3 mm wide. A red translucent funicle encircles or almost encircles the seed. Flowering has been observed from January to June with mature seed harvested in September and October in northern Queensland (Searle 1989).

A botanical description is provided by Pedley (1978).

Natural occurrence. *A. oraria* is found in north-eastern Australia and on the Indonesian islands of Flores and Timor. The main Australian distribution is

from Princess Charlotte Bay to Bowen in Queensland. Most occurrences are along rivers or very close to the sea. It occurs on Timor up to at least 300 m and is recorded up to 700 m on Flores Island.

- Latitude. Main occurrence: 14–20°S.
  Range: 8–22°S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 700 m.

Climate. Occurs in the warm and hot humid climatic zones, but with a few locations in the hot wet and the hot sub-humid zones.

The mean maximum temperature of the hottest month is 32–34°C. The mean minimum of the coolest month is about 14–17°C but reaches 22°C at northern coastal sites. The number of days over 32°C is mainly 30–60 and the temperature rarely exceeds 38°C. Frosts are absent.

The 50 percentile rainfall in typical locations is 1750–2150 mm, the 10 percentile 1250 mm and the lowest on record 900–1000 mm. Comparable figures for the sub-humid areas are less than half those stated. In the north there is a strong monsoonal rainfall pattern with January–March very wet and August–October very dry. To the south, the incidence changes to a strong summer maximum.

Physiography and soils. The Australian occurrences are in the Eastern Uplands physiographic division and are usually confined to the ridges and spurs of the wet foothills or on sandy beach ridges. It is common on the edge of sandy beaches, sometimes on the frontal dune within a few metres of the high tide level. In the drier parts of its distribution it occupies the channels of seasonally dry watercourses where it may be inundated by floods during the wet season. The soils are often deep, calcareous beach sands with shell grit or yellow earths. The soils are usually sandy, infertile, range from acidic to alkaline, and may be saline or subsaline. In Indonesia it is common on shallow soils over limestone.

Vegetation type. *A. oraria* is found in woodland and shrubland, especially near beaches, to layered woodland and the edges of rainforest. In the saline littoral zone it is found on beach ridges within the mangrove complex. On these sites it is associated with such species as *Canarium australianum*, *Casuarina equisetifolia*, *Cassine melanocarpa* and *Mimusops elengi*.

In the foothills it occurs in open forest or forest dominated by *A. aulacocarpa*, *A. cincinnata* and other tall acacias, but as the sites become drier, *A. oraria* increases in frequency and *A. leptocarpa* is a more common associate. *A. oraria* is one of the woody species that invades fire-degraded grasslands of *Imperata cylindrica* and *Themeda triandra* on spurs in the coastal foothills when they are protected from frequent fires (Tracey 1982). In woodland it may be associated with eucalypts such as *E. intermedia* and *E. tessellaris*.

Utilisation.

Fodder: Not known to have fodder value.

Fuelwood: Has been planted experimentally for fuelwood in Java.

Wood: Little is known of the wood properties. It has pale sapwood and dark brown heartwood, which may be attractively marked. Posts cut from *A. oraria* have been favoured by local people for house construction on Flores Island.

Other uses: It has been used as an ornamental for street planting in parts of Indonesia near the coast. It could find a use in coastal and foreshore planting for shade and low shelter. In Thailand *A. oraria* has shown potential for reclaiming *Imperata* grassland which is suppressed within 1–2 years by the dense foliage and heavy litter fall (Pinyopusarerk 1993).

Silvicultural features. A small tree, adapted to sandy soils in the lowland tropics and subtropics. It tolerates a range of pH conditions including some salinity and alkalinity. *A. oraria* was ranked amongst the most highly salt-tolerant species of a range of acacias screened in a glasshouse trial (Aswathappa et al. 1987).

The species has been observed to coppice in nature and was rated as fair but variable in this attribute in trials in southeastern Queensland (Ryan and Bell 1989).

Establishment: Propagation is by seed that has been treated by immersion in boiling water for 1 minute to break seedcoat dormancy. Flowering has been observed as early as 24 months on planted trees in southeastern Queensland. Germination rate averages about 50% and there are 42 700 viable seeds/kg.

Yield: The species has been trialed in several countries (Australia — Ryan and Bell 1989, 1991; China — Yang and Zeng 1991; Indonesia — Otsamo et al. 1993; Sri Lanka — Vivekanandan 1993; and Thailand — Pinyopusarerk 1989, 1993). In general growth rate is modest with MAI for height growth about 1 m, but survival is mostly excellent (± 90%). High survival and dense foliage make this a potentially useful species for fuelwood production on *Imperata* grassland. A wider range of seedlots need to be screened to gauge the species' full potential, as significant provenance variation has been indicated in trials (Pinyopusarerk 1993).

Pests and diseases. In southeastern Queensland a defoliator, *Myllocerus* sp. Family Curculionidae, was identified on this species but damage was not serious (Ryan and Bell 1991).

Limitations. It is unlikely to tolerate heavy frosts. Its capacity to invade grassland suggests that it has the potential to become a weed species in certain circumstances.

The small size of the tree will limit the use of the wood to fuel, posts and poles, and small joinery items.

Related species. A rather distinct species. Has some affinities with *A. melanoxylon* and, more distantly, *A. frigescens* (B. Maslin, pers. comm.).

Acacia orites

Main attributes. A tall, straight, fast-growing nitrogen-fixing tree adapted to warm temperate and subtropical climates. It is well suited to inclusion in agroforestry systems or as a nurse crop for other trees, due to its light shade and rapid growth. Its wood is suitable for fuel, and larger specimens can supply a high quality furniture timber.

Botanical name. *Acacia orites* Pedley in *Proc. Roy. Soc. Queensland* 75: 32 (1964). The specific name is after the Greek *oreites* — a mountaineer, in reference to its occurrence on high ranges.

Common names. Mountain sallow wattle, mountain wattle.

Family. Mimosaceae.

Botanical features. Under optimal conditions *A. orites* may develop into an impressive tree to 30 m tall, but on less favourable sites it is reduced to 8–10 m. It has a straight cylindrical bole up to half the total tree height with a maximum diameter of 75 cm at breast height. The bark on smaller trees and branches is pale pink-brown becoming dark brown and fissured with age on lower parts of the bole (Floyd 1989). Branchlets are glabrous or with sparse appressed hairs and are held in a semi-erect or horizontal position.

Mature phyllodes are bright green, smooth, thin-textured, linear-lanceolate, straight or somewhat falcate, 8–20 cm long and 3–8 mm wide. They typically taper to a recurved, non-pungent point. Venation consists of 6–9 widely spaced anastomising secondary nerves, with 1–3 more prominent. There is a small gland on the upper edge about 3–5 mm above the base of the phyllode.

The inflorescence consists of creamy to pale lemon-yellow fragrant flowers arranged loosely in a cylindrical spike of 2–7 cm length. Flower parts (sepals and petals) are usually in fours. One, or more commonly, two spikes are produced in the upper axils. The seed pod is straight, 6–11 cm long and 3–4 mm wide, thin and raised over the longitudinally aligned seeds. The seeds are dark brown, 3–4 mm long by 1.7–2 mm wide, and attached to the pod by a cream aril which is folded once or twice. Flowering time is August–September (Tindale and Herscovitch 1990).

Seeds mature between November and January about 3–4 months after flowering.

A botanical description is given by Pedley (1964) and the species is illustrated by Lebler (1979) and Floyd (1989).

Natural occurrence. *A. orites* has a very restricted distribution along the New South Wales–Queensland border from Whian Whian State Forest, near Rosebank (NSW) to Upper Tallebudgera (Qld) in the north.

- Latitude. Range: 28°13'S–28°18'S.
- Altitude. Main occurrence: 400–900m.
  Range: 250–1200m.

Climate. The occurrence is in the warm (annual mean temperature 13–17°C), humid (1380–3320 mm) zone. The mean maximum of the hottest month is 23–26°C. The mean minimum of the coolest month is 2–6°C. Frosts are absent near the coast, but light frosts are a common occurrence during winter at elevated (900–1200 m) inland locations.

The 50 percentile rainfall is about 1500–2500 mm, the 10 percentile 1000–1660 mm and the lowest on record 750–1250 mm. There is a well-developed summer rainfall pattern. Nevertheless rain occurs throughout the year, and the mean precipitation for the driest quarter is quite high (190–335 mm). The wettest site is near Springbrook (3320 mm) and the driest sites are inland elevated occurrences on Wilsons Peak and Mount Nothofagus (1380–1530 mm). Rainfall is supplemented by condensation of mist.

Physiography and soils. This species is associated with the Mount Warning and Focal Peak Shield volcanoes. The volcanic-derived soils are acidic (pH 5–6) yellow earths. They are relatively infertile soils derived from rhyolite and trachyte, well-structured and freely draining, and may be shallow on steep slopes and ridge top locations. It has also been recorded from brown clays of sedimentary origin.

Vegetation type. *A. orites* is a component of tall open-forest, where it favours the margins of warm temperate rainforest and secondary regrowth stands arising from a major disturbance. Dominant associate species include *Eucalyptus campanulata*, *E. saligna*, *E. microcorys*, *E. pilularis*, *Syncarpia glomulifera* and *Lophostemon confertus*. Associate rainforest and understorey species include *Acacia melanoxylon*, *A. obtusifolia*, *Alphitonia excelsa*, *Duboisia myoporoides*, *Ceratopetalum apetalum* and *Zieria arborescens*.

Utilisation.

Fodder: Not known.

Fuelwood: The moderately dense wood is easily split and should prove a useful fuel.

Wood: The heartwood is brown and medium hard. It is easily worked and an excellent cabinet timber (Floyd 1989).

Other uses: Its light canopy and erect habit suggest it would be suitable as a tree component in agroforestry systems and it has been described as a good fast-growing nurse tree (Floyd 1989). The mass display of fragrant flowers contributes to the ornamental appeal of this species (Jones 1986).

Silvicultural features. A fast-growing species adapted to infertile acidic soils in warm temperate and tropical highland regions. Its coppicing ability is not recorded, but it can be reproduced by root cuttings (Floyd 1989).

Establishment: There are about 85 000 viable seeds/kg, and these require a routine treatment to break seedcoat dormancy.

Yield: Specific information on growth rates is lacking but seedlings grew over 2 m in the first year in a garden planting in Canberra (southeastern Australia).

Pests and diseases. In southeastern Queensland the seed pods are often heavily insect galled (Lebler 1979) and in southeastern Australia the phyllodes may be attacked by the Acacia-spotting bug (*Eucerocoris tumidiceps*) (L. Thomson, pers. comm. 1984).

Limitations. *A. orites* is probably only moderately frost-resistant and planting will be restricted to moister (> 1200 mm) sites with a short dry season. It is not well adapted to tropical lowland sites and has exhibited poor survival and grown slowly on an acidic infertile clay in Fiji.

Related species. *A. orites* is a member of the Tetramerae group within the section Juliflorae, with flower parts in fours. It has two close relatives, *A. floribunda* and *A. courtii*. *A. floribunda* has longer phyllodes, greater than 10 cm or 15–35 times as long as broad (Pedley 1964). *A. courtii* has very similar morphology to *A. orites*. It is distinguished by having a dense network of veins on the phyllodia which are glaucous yellow-green, pendulous branchlets, thick woody pods and earlier flowering (February–April).

Acacia pachycarpa

Main attributes. A nitrogen-fixing small tree or shrub that grows on clay sites in hot, arid areas. Has potential to provide fodder, low shelter, and fuelwood. Seed is edible.

Botanical name. *Acacia pachycarpa* F. Muell. ex Benth. in *Fl. Aust.* 2: 408 (1864). The specific name is from the Greek *pachys* — thick or stout, and *carpus* — fruit, referring to the appearance of the pod. It is synonymous with *A. crassifrugis* Tindale and Maconochie.

Common names. None known.

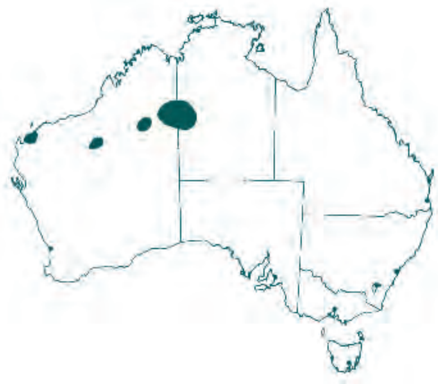
Family. Mimosaceae.

Botanical features. A small single-stemmed tree or shrub with several stems, commonly 3–4 m tall but recorded to 6 m. It has pendulous branches and on more favourable sites may have a large crown. The bark on the trunk is furrowed, hard and dark grey, becoming smooth and light grey on upper branches.

The phyllodes are highly variable in shape among trees within populations. They are elliptical to linear, long and narrow, 15–23 cm in length by 6–20 mm wide, more or less curved with 1–5 longitudinal nerves more prominent and numerous minor nerves. The creamy-yellow flowers are in spikes, 3–3.5 cm long on a short peduncle, 4–20 mm long. The pods are swollen when fresh, narrow-oblong, 7–15 cm long by 1–2 cm wide, woody, yellowish-brown, more or less shiny, straight or twisted, convex over the seeds but not strongly constricted between them, often breaking between the seeds. The seeds are transverse in the pod, smooth, shiny, somewhat variable in colour from pale brown to black, 6–9 mm long by 5–7 mm wide and 3–4 mm thick, with a terminal small white aril. Flowering is variable and mature pods have been observed from March to October.

The species is described by Maslin (1981) and illustrated under the name *A. crassifrugis* by Tindale and Maconochie (1972).

Natural occurrence. This species has a relatively restricted natural range with a main distribution that straddles the Northern Territory–Western Australia border near latitude 20°S. In Western Australia there are isolated occurrences in the Great Sandy Desert and near Onslow on the coast (Maslin and Pedley 1982).



- Latitude. Range: 19–22°S.
- Altitude. Range: About 100–300 m.

Climate. Meteorological records for the inland areas where *A. pachycarpa* occurs are sparse and much of the data in the following climatic summary have been inferred from peripheral stations.

The distribution is in the hot arid climatic zone. The mean maximum temperature of the hottest month is 37–41°C, and the mean minimum is up to about 12°C. The average number of days when the temperature exceeds 32°C is 200–280 (Onslow 162 days) and there are 80–150 days over 38°C (Onslow 46 days). Minimum temperatures are slightly higher in inland districts than near the coast during the hot months but in winter (July) they are about the same throughout. Ground frosts may occur on winter nights.

The 50 percentile rainfall is 225–350 mm, the 10 percentile 60–150 mm, and the lowest on record 20–60 mm. The seasonal distribution is a summer maximum, tending to be monsoonal. There are 22–40 raindays each year. The rainfall is erratic, any month can be completely rainless, and in some wetter months more rain has been recorded than the average for the year.

A more detailed description of the climate in the Great Sandy Desert region is given by Beard (1974).

Physiography and soils. *A. pachycarpa* is confined to the Western Plateau physiographic division where it is generally found in the plains along drainage lines, in clay depressions, or on clayey flats. The soils include alluvial sands and loams and heavier black and red cracking clays. It is recorded growing on red, cracking clay soils often with lateritic pebbles (Tindale and Maconochie 1972). It appears to tolerate a degree of salt in the soil.

Vegetation type. *A. pachycarpa* is usually found as a single species shrub community on heavier soils and along drainage lines on the Mitchell Grass–Woolybutt (*Astrebla pectinata–Eragrostis xerophila*) plains. It has been recorded growing with *Acacia stenophylla*, *A. victoriae*, *Atalaya hemiglauca*, *Senna oligophylla*, *Eremophila bignoniiflora* and *Eucalyptus victrix*. Accounts of communities including *A. pachycarpa* are given by Beard (1974) and Beadle (1981) but these refer to the more widespread *A. ancistrocarpa*, which occurs in mixed shrub communities on red sands and stony plains.

Utilisation.

Fodder: In its natural habitat *A. pachycarpa* is heavily grazed by animals (Tindale and Maconochie 1972) and it appears to be a good fodder species.

Fuelwood: It has not been used as fuel but it has the potential to produce small-sized firewood.

Wood: The wood is heavy with an air-dry density of 1010 kg/m^3 (Davis 1994).

Other uses: This acacia has potential to provide low shelter. Its pendulous habit suggests it is a potential ornamental plant for arid areas but its green pods produce an unpleasant odour, similar to *A. cambagei* and *A. georginae*, so that planting close to habitation is undesirable. Ripe seeds of *A. pachycarpa* were reportedly used as a staple food by Aborigines (Brand and Cherikoff 1985). The seeds are nutritious containing 22% crude protein, 8% fat and 57% carbohydrate (Orr and Hiddins 1987).

Silvicultural features. This small tree or shrub grows relatively fast in its natural habitat. It produces large seed crops and regenerates readily from seed. It will produce basal shoots and possibly root suckers after fire. Although reportedly tolerant of a degree of salt in the soil in its natural habitat, it ranked amongst the less tolerant species of a range of acacias screened for salt tolerance in a glasshouse trial (Aswathappa et al. 1987).

Establishment: Propagation is by seed which requires immersion in boiling water for 1 minute to break seed-coat dormancy. Germination rate averages 74% and there are 4900 viable seeds/kg.

Yield: Growth in trial plots in Australia and Kenya has generally been modest (± 1 m per year) and survival often disappointing (± 50%) (Ryan and Bell 1991; Chege and Stewart 1991; Kimondo 1991). As few provenances have been available for trial it is possible that the best material has not yet been tested.

Pests and diseases. None recorded.

Limitations. The small size of this species will limit its use to firewood and non-wood purposes such as forage and low shelter. Its lack of frost-tolerance would be a disadvantage in colder arid areas. *A. pachycarpa* emits an offensive odour.

Related species. *A. pachycarpa* is related to *A. cuthbertsonii* which differs in having hairy branchlets, smaller phyllodes and flower heads and a gland on the phyllode margin up to 3 mm from the base (B. Maslin, pers. comm.). It has been confused with *A. ancistrocarpa* but is not seemingly related (B. Maslin, pers. comm.).

Acacia platycarpa

Main attributes. A moderately fast-growing, nitrogen-fixing small tree. It is suitable for fuelwood production and sand stabilisation on well drained, infertile sandy soils in the semi-arid and sub-humid tropics.

Botanical name. *Acacia platycarpa* F. Muell. in *Linn. Soc. Bot*. 3: 145 (1859). The specific name is derived from the Greek *platys* — broad and *carpos* — fruit, in allusion to the broad, woody pods.

Common name. Ghost wattle, pindan wattle, mandjoh.

Family. Mimosaceae.

Botanical features. *A. platycarpa* grows into a small tree to 6–10 m tall. In more arid or regularly burnt habitats it is frequently reduced to a spindly or multi-stemmed shrub. The bark is rough, tessellated to sub-fibrous, dark grey-brown or reddish-brown on the lower trunk, and the branches are covered in a whitish bloom. The phyllodes are variable, dull grey-green or light bluish-green, sometimes glaucous, broadly and obliquely falcate, 5–15 cm long × 1.5–4.5 cm wide, with 3–4 major longitudinal veins and prominently reticulated between. There is a basal gland, and usually 1–3 smaller glands associated with nerve endings on the upper lobed margin.

Masses of cream-coloured, globular flower heads are produced during a short period between November and July. These are prominently displayed above the foliage and arranged in simple axillary or terminal racemes, or panicles. Broad flattened woody pods, 5–16 cm long × 2–3.5 cm wide, mature during August and September. The seeds are brown, oval, 7–10 mm long × 5–8 mm wide and transversely arranged in the pod.

The species is illustrated in Maslin (1981), Petheram and Kok (1983) and Brock (1988), and a complete botanical description is given in Pedley (1978).

Natural occurrence. *A. platycarpa* has a wide distribution in northern Australia, from central and northern Queensland and the Northern Territory into the Kimberley region of Western Australia, with an extension to the western edge of the Great Sandy Desert. There are disjunctions in its distribution in north-western Queensland and the Victoria River region of the Northern Territory.

- Latitude. Main occurrence: 12–20°S
  Range: 10–25°S.
- Altitude. Main occurrence: near sea level to 450 m.
  Range: near sea level to 700 m.

Climate. This species occurs in warm to hot (annual mean temperature 21–29°C) tropical climates. Summers are hot with a mean maximum temperature of the hottest month (November to February) between 30 and 40°C. The mean temperature of the coldest month is between 5.5°C and 21°C. The main distribution is frost-free, but locations in central Queensland may occasionally experience temperatures down to –1°C.

The 50 percentile rainfall is 450–950 mm, the 10 percentile 275–600 mm and the lowest on record 150–425 mm. For most of the distribution the number of raindays per year is 40–60 mm. The mean annual rainfall varies from 1800 mm on northeastern Cape York Peninsula (Queensland) down to 270 mm on the western edge of the Great Sandy Desert in Western Australia. This is a remarkable range considering that the species is not receiving additional run-on water in the arid parts of its occurrence. Rainfall is distributed monsoonally or with a strong summer maximum in the southernmost locations. More than 50% of rainfall is recorded during the wettest three months between December and March. In the most arid locations in the Great Sandy Desert rainfall is erratic both within and between years (Beard 1974).

Physiography and soils. Much of the topography consists of gently sloping terrain, sandplains and undulating low hills, but it also grows in deeply dissected rocky tablelands in the Kimberley region. On the Dampier Peninsula and La Grange Plateau in Western Australia it grows on a very gently undulating sandplain, with some exposed sandstone. The soils are acidic to neutral (pH 5.5–7) earthy sands. Further east on the South Fitzroy Plains it grows on neutral to alkaline yellow and red leached earths and skeletal gravelly sands. In Western Australia it also grows in deep sand in the swales of aeolian dunes both near the coast and inland on the edge of the Great Sandy Desert. It occurs on a wide range of neutral (pH 6–7) infertile sandy soils in the Northern Territory and Queensland, including grey loamy sands.

Vegetation type. *A. platycarpa* is mostly an under- or mid-storey component in eucalypt-dominated woodlands and open-forest. Common associates include *E. argillacea*, *E. ferruginea*, *E. miniata*, *E. papuana*, *E. tectifica*, *E. tetrodonta* and *E. zygophylla*. Other associates include *Acacia difficilis*, *A. shirleyi*, *Brachychiton diversifolius*, *Persoonia falcata* and *Terminalia platyptera*.

Near the northern tip of Cape York Peninsula it grows as a mid-storey component in a tall open-woodland of *Eucalyptus polycarpa* and *E. tetrodonta*. Small tree associates in this area include *Acacia crassicarpa*, *A. rothii*, *Grevillea glauca*, *Parinari nonda* and *Syzygium suborbiculare*. It also grows in *Acacia*-dominated scrub communities in Western Australia, where associates include *A. colei*, *A. eriopoda*, *A. tumida*, and *Lysiphyllum cunninghammii*. It grows in an open scrub of *A. ancistrocarpa*, *A. stipuligera*, *Eucalyptus gamophylla*, *Grevillea wickhamii* with *Triodia* spp. comprising the dominant groundcover. At Mission Cove in northwestern Australia it co-occurs with *A. tumida*, *Crotalaria* sp., *Tephrosia* sp. and *Terminalia petiolaris* on coastal sand dunes.

Utilisation.

Fodder: It does not appear to be grazed in its native habitat, and is unlikely to have any importance for fodder production.

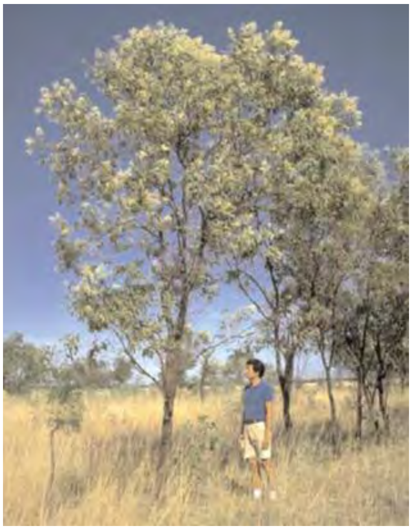
Fuelwood: It has good potential as a source of firewood.

Wood: No data available.

Other uses: More shrubby forms are well suited to provision of low shelter and sand stabilisation, while in higher rainfall zones it would develop into a useful shade tree. It has good ornamental potential (Brock 1988).

Silvicultural features. *A. platycarpa* has the capacity to regrow from basal shoots following mild fires and has a moderate coppicing ability (Ryan and Bell 1989).

Establishment: The species is readily propagated from seed, and there are 4300 viable seeds/kg. Seedcoat



dormancy is removed by immersing the seed in a large volume of boiling water (100°C) for 30–60 seconds. A nursery phase of about 4 months is recommended.

Yield: A. platycarpa has displayed moderately fast early height growth rate in the sub-humid tropics. Plants from near Chillagoe, north Queensland grew far more rapidly than those from Katherine, Northern Territory in trials in southeast Queensland. After 4.5 years Chillagoe plants were 4.8–6.8 m tall compared with 1.7–3.0 m for Katherine plants (Ryan and Bell 1991). In Thailand after 24 months the Chillagoe provenance reached 4.4 m and the Katherine provenance 4.5 m tall at Ratchaburi (964 mm rainfall), but at Si Sa Ket (1586 mm) the Chillagoe provenance was 4.8 m, significantly taller than the Katherine provenance which was 3.0 m (Pinyopusarerk 1989). It failed completely when planted on cracking-clay soils in the arid environment of central Queensland (Ryan and Bell 1991).

Pests and diseases. Recorded pests include a minor defoliator (*Jalmenus daemeii*), a sap sucker (*Sextius* sp.) and an unidentified stem borer (in the family Xyloryctidae) which may ringbark branches and small stems (Ryan and Bell 1991).

Limitations. The small size of *A. platycarpa* will normally restrict its use to fuelwood and non-wood uses such as shelter and sand stabilisation. Little is known of its genetic variability.

Related species. *A. platycarpa* is an extremely variable species and may consist of several taxa (Pedley 1978). Its closest relatives are *A. dunnii*, *A. sericata* and *A. tolmerensis* (Thomson et al. 1994).

Acacia plectocarpa

Main attributes. A nitrogen-fixing small tree or shrub adapted to infertile, often skeletal, sandy soils or laterites in the tropical hot humid to hot semi-arid climatic zones. It has potential for fuel, posts and poles, fodder, low shelter and reclamation of degraded lands.
Botanical name. *Acacia plectocarpa* subsp. *plectocarpa* A. Cunn. ex Benth in *London J. Bot*. 1: 375 (1842). The specific name is based on the Greek *plectos* — plaited, twisted, and *carpos* — fruit, in reference to the form of the pod. Pedley (1990a) reduced *A. tanumbirinensis* Maiden (1917) to become a new subspecies of *A. plectocarpa*, hence subsp. *tanumbirinensis* (Maiden) Pedley.
Common names. Black wattle is a rarely-applied common name.
Family. Mimosaceae.
Botanical features. Usually a small tree 3–6 m tall but may reach 10 m. The bark is dark grey and deeply fissured. The phyllodes are straight or curved, linear to narrowly elliptic, mainly 9–20 cm long by 2–16 mm wide, longitudinal nerves numerous, 1–3 more prominent. The inflorescences are spikes 2.0–5.5 cm long by 3–5 mm wide, pale to bright yellow, densely flowered, on short stalks, 1–5 in the axils. The pod is brown, linear to oblong, straight, undulate, 3.5–10 cm long by 5–12 mm wide, resinous, papery or leathery, raised over seeds alternately on each side. The seeds are black or brown, discoid to ellipsoid, oblique or transverse in the pod, 3–5 mm long by 2–3 mm wide with a white terminal aril folded 2–4 times and a small, depressed areole. Flowers May to August. Mature seed has been collected in August–October.

Subsp. *tanumbirinensis* is distinguished from the type by characteristics of the phyllode (straight), corolla (very hairy) and seeds (oblique in the pod with funicle folded twice).

An updated botanical description is given by Leach (1994) and the species is illustrated by Brock (1988).
Natural occurrence. Subsp. *plectocarpa* occurs in the Kimberley region of Western Australia and the northern part of the Northern Territory. Subsp. *tanumbirinensis* occurs adjacent to the south coast of the Gulf of Carpentaria, predominantly in the Northern Territory but also recorded in the far northwestern corner of Queensland.

- Latitude. Range: 11–18°S.
- Altitude. Main occurrence: near sea level to 150 m.
  Range: near sea level to 300 m.

Climate. The main occurrence is in the hot sub-humid climatic zone with extension into the hot semi-arid zone in Western Australia. It is found near the boundary of the hot humid zone in coastal areas of the Northern Territory. The mean maximum temperature of the hottest month, November or December, varies from about 33°C on the coast to as high as 38–40°C for some places in the semi-arid zone. The temperature exceeds 32°C on 220–280 days and is over 38°C from about 1–5 days near the coast to up to 150 days for inland occurrences. The mean minimum temperature of the coolest month is within the range 8–19°C and all the area is frost-free.

There are considerable differences in the amount of rainfall received in different parts of the natural distribution. The 50 percentile is 600–1600 mm, the 10 percentile 400–1100 mm, and the lowest on record 300–900 mm.

There is a strongly developed monsoonal rainfall pattern with a dry season (less than 30 mm/month) for about 7 months in semi-arid areas and 5–6 months in sub-humid–humid areas. The number of raindays each year is mainly 50–70.
Physiography and soils. Most of the topography is gentle to moderate, with some steep slopes of plateau escarpments and relatively small ridges. *A. plectocarpa* has been recorded mainly on sandstone-derived soils; it also occurs at the base of quartzite hills, on lateritic areas, and on siltstone. It is commonly found on alluvial gravelly sands close to or in watercourses. The soils are mainly lithosols, earthy sands, and ironstone gravels, which are acidic and of low fertility.

Vegetation type. This acacia occurs in open-forest, woodland, low woodland, open-woodland, and tall shrubland. Generally the cover is sparse with a ground layer of grasses, but in some coastal areas *A. plectocarpa* forms dense thickets. Eucalypts frequently form an upper canopy and commonly include *E. alba*, *E. clavigera*, *E. miniata*, and *E. tetrodonta*. Species of *Melaleuca* and *Pandanus* are also recorded as associates. Kabay and Burbidge (1977) describe several vegetation associations that include *A. plectocarpa*.

Utilisation.

Fodder: The phyllodes are palatable to both cattle and sheep (Hamel 1980). Vercoe (1989) estimated the crude protein levels of phyllodes to be 9% with predicted in vivo dry matter digestibility of 43%. As the species came close to the minimum requirements for certain nutrients it was recommended for further study of its fodder potential.

Fuelwood: The dense wood is suitable for fuelwood and charcoal production (Gough et al. 1989; Yantasath et al. 1993).

Wood: The heartwood is brown and the sapwood is pale yellow but wood properties have not been studied in detail. The basic density of 2.5-year-old wood was 604 kg/m^3 with an average green density of 1040 kg/m^3 (Gough et al. 1989). It is probable that the wood is suitable for posts and small poles.

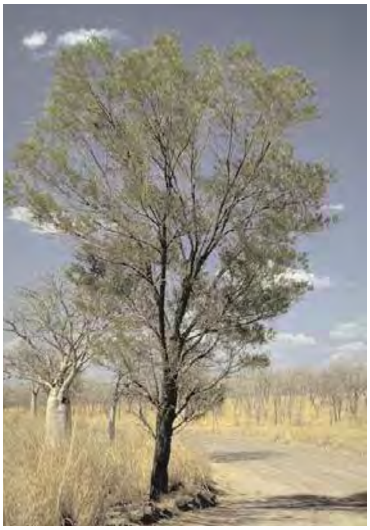
Other uses: Suitable for light shade and low shelter. Could be used to form the lower component of windbreaks (Hamel 1980). It is used for mine-site rehabilitation in northern Australia (Langkamp 1987).

Silvicultural features. A small tropical tree or shrub that grows fast when young. It is moderately drought and salt tolerant (Aswathappa et al. 1987; Marcar et al. 1991b), although provenances can be expected to vary in their levels of tolerance.

The species coppiced well when cut at 1 m but performed less well when cut closer to the ground (Ryan and Bell 1989).

Establishment: Propagation is by seed treated by immersion in boiling water for 1 minute to break seedcoat dormancy. The species flowers 12–24 months from planting. Germination rate is 80% and there is an average of 59 800 viable seeds/kg.

A. plectocarpa appears to nodulate with only a restricted range of rhizobia strains (Dart et al. 1991). Innoculation of nursery soils with effective rhizobia may enhance survival and growth.



Yield: On tropical and subtropical sites with a dry season extending to six months (e.g. Mareeba, Qld), *A. plectocarpa* survives and grows well with MAIs for height growth usually in the range 1–2 m (Bell et. al. 1991; Chege and Stewart 1991; Gwaze 1989; Kimondo 1991; Mitchell 1989; Ryan and Bell 1991). It has shown better adaptability than *A. auriculiformis* to infertile sandy soils and prolonged dry season in a field trial in northeastern Thailand (Boland and Pinyopusarerk 1987). As conditions become harsher with dry seasons extending to 8 months, growth and survival tend to decline sharply (Bell et al. 1991). Variation between provenances in growth rate and survival has been indicated in a number of reports (e.g. Chege and Stewart 1991) and further exploration of its genetic variability is warranted.

Pests and diseases. The seeds may be severely damaged by insects and this can result in low germination percentages.

Limitations. The small size of *A. plectocarpa* will restrict its use to fuel, posts, poles and non-wood uses such as fodder or shelter. Its ability to tolerate a dry season of over 6–8 months is doubtful but provenance tests are required for confirmation.

Related species. *A. plectocarpa* shows considerable variation over its geographical range. Pedley (1978, 1990a) and Leach (1994) have defined the relationships of this species. *A. plectocarpa* is closely related to *A. helmsleyi*, *A. armitii* and *A. echinuliflora*. *A. plectocarpa* is very difficult to distinguish from *A. torulosa* if pods are absent (M. McDonald, pers. comm.).

Acacia polystachya

Main attributes. A nitrogen-fixing tree that is adaptable to a range of infertile soils, including some tolerance to salinity and alkalinity, in the humid and sub-humid tropics. It has the potential to produce fuelwood, posts and poles, and to provide shade, shelter, and erosion control.

Botanical name. *Acacia polystachya* A. Cunn. ex Benth. in Hooker's *London J. Bot*. 1: 376 (1842). The species name is derived from the Greek *poly* — many, numerous, and *stachya* — an ear of maize, synonymous with a spike in modern botany, and referring to the inflorescence (many spikes).

Common names. None known.

Family. Mimosaceae.

Botanical features. Varies from a bushy shrub 3–4 m in height in open situations near the coast to a tall, relatively small-crowned tree up to 25 m in rainforest. The dark grey bark has been variously described as 'smooth' in rainforest to 'fissured' or 'coarsely-plaited', and is rather hard and tough to cut (Hyland 1971).

The phyllodes are curved and somewhat sickle-shaped, mainly 9–17 cm long by 15–25 mm wide, glabrous, with generally 3, sometimes 2 or 4, prominent longitudinal veins, which arise from a single vein at the base of the phyllode.

The flowers are in rather sparse spikes 4–8 cm long located in pairs at the base of rudimentary axillary shoots. The seed pods are flat, glabrous, more or less glaucous, up to 10 cm long and 6–8 mm wide. The seeds are black, shiny about 4 mm long, 3 mm wide, with an yellow or reddish funicle partially encircling the seed and folded into an aril. They are held longitudinally in the pod. Flowering is May–July and the fruits mature October–December.

Botanical descriptions are provided by Pedley (1978) and Hyland and Whiffin (1993).

Natural occurrence. *A. polystachya* occurs in northern Queensland where it extends from Cape York to near Cairns, mainly on lowlands near the sea. It occurs on offshore islands from the Palm Islands near Ingham to Moa Island in Torres Strait. It has not been recorded in Papua New Guinea.

- Latitude. Range: 10–19°S.
- Altitude. Main occurrence: near sea level to 250 m.
  Range: near sea level to 500 m.

Climate. The distribution is mainly in the hot humid climatic zone, but at the higher altitudes away from the coast it borders on the hot sub-humid zone. The mean maximum temperature of the hottest month is usually 31–33°C and the mean minimum of the coolest 16–21°C. The number of days over 32°C is 30–100 and only occasionally does the temperature exceed 38°C. The area is frost-free.

The 50 percentile rainfall is 1150–2150 mm, the 10 percentile 650–1350 mm, and the lowest on record 500–1150 mm. There is a monsoonal rainfall pattern with a dry season for 4–7 months. The average number of raindays each year is in the range 75–150.

Physiography and soils. All of the occurrence is within the Eastern Uplands physiographic division. It is found in the lowlands, often immediately behind beaches on the sandy soils of old beach ridges; and in the foothills of the coastal ranges, on steep, rocky slopes or on alluvia adjacent to watercourses. The soil parent material is often granite, quartzite, sandstone or schist, and the soil types are yellow earths or yellow podzolics. The soils vary from skeletal to deep alluvials derived from acid and basic rocks, and deep, often calcareous, beach sands.

Vegetation type. *A. polystachya* is one of the few species of acacia associated with rainforest. In the moist foothills, tall *Eucalyptus torelliana*, *E. intermedia* and *E. tereticornis* occur over a mixed acacia-rainforest understorey. The acacias associated with *A. polystachya* include *A. mangium*, *A. cincinnata* and *A. aulacocarpa*. In drier situations *A. mangium* is often replaced by *A. polystachya* (Tracey 1982).

On the lowland beach ridges *A. polystachya*, *E. pellita* and *E. tessellaris* are emergents 15–20 m tall over a lower canopy, including *A. crassicarpa*, *Alphitonia* *excelsa*, *Canarium australianum*, and *Terminalia sericocarpa*. The canopy is wind-sheared along the foredunes and may be reduced to a thicket 1–2 m tall. Between the beach ridges in the swales are tall *Melaleuca* species.

Utilisation.

Fodder: Not known to have fodder value.

Fuelwood: Has a hard, heavy wood that makes good fuelwood and charcoal (Yantasath et al. 1993).

Wood: Wood of this species is similar to that of *A. auriculiformis*. Four-year-old trees had a basic density of 648 kg/m^3 (Yantasath et al. 1993). The heartwood is dark brown or red with attractive markings. It has not been utilised in Australia other than in the islands of Torres Strait where it has been used for making harpoon spears for dugong hunting.

Other uses: It has potential for planting in the lowland tropics on sandy calcareous sites on the coast to provide shade and shelter. It will tolerate a high level of salt spray.

Silvicultural features. A species of high biomass producing potential adapted to a wide range of freely draining infertile soils in the lowland humid tropics.

A. polystachya will coppice successfuly but only if cut well above the ground. Three-year-old trees of *A. polystachya* coppiced poorly near ground level but 92% of stumps coppiced at 30 cm and 73% at 50 cm in Malawi (Ngulube 1990a). Visaratana (1989) recorded the highest number of bud clusters at 80–90 cm above ground level. Poor coppice resulted from cutting heights of 10 cm and 50 cm and fair coppices from 100 cm in trials on two provenances in southeastern Queensland (Ryan and Bell 1989).

Considerable provenance variation may exist in this species, for example, in trials in Timor, Indonesia, the Lockerbie provenance from Queensland showed tolerance to a high level of soil alkalinity (pH 8–9) on a vertisol derived from Bobonaro clay, while another source from Bridle Logging Area, Queensland gave poor tolerance (McKinnell and Harisetijono 1991).

Establishment: Propagation is by seed that has been treated by immersion in boiling water for 1 minute to break seedcoat dormancy. Flower buds have been recorded on 3-year-old trees. Germination rate is about 80% and there is an average of 60 100 viable seeds/kg. A nursery phase of 2–3 months is recommended (Ngulube 1988).

Yield: The species tends to be multi-stemmed (often up to 10 stems) and heavily branched from ground level so, although height growth is generally ranked as modest

(0.7–1.2 m/year) (Chittachumnonk and Sirilak 1991; Gwaze 1989; Ngulube 1990a; Ryan and Bell 1991; Vivekanandan 1993), total biomass production may be substantial. Pinyopusarerk (1993) noted the good performance of *A. polystachya* at Ratchaburi, Thailand, where the dry season lasts at least 6 months with very high temperatures. There *A. polystachya* showed no signs of water stress and retained a full crown, in contrast to many other acacias that shed foliage and showed other signs of stress. A feature of the species is its high rate of survival in varying conditions. Provenance variation is indicated and the species warrants further exploration and testing.

Pests and diseases. A sap-sucker of the family Cercopoidea was reported on planted specimens in southeastern Queensland (Ryan and Bell 1991) but appeared to be causing little damage.

Limitations. It is unlikely to tolerate other than very light frosts. All provenances tested up to now have resulted in multi-stemmed shrubs or small trees.

Related species. Natural hybrids of *A. polystachya* and *A. auriculiformis* have been recorded (NAS 1983), and also hybrids with *A. mangium* (Nikles and Griffin 1992). The pod width (6–8 mm in *A. polystachya* and 8–18 mm in *A. auriculiformis*), shape and texture are good discriminative features from *A. auriculiformis*. Also the seeds lie longitudinally in the pod in *A. polystachya* and transversely in *A. auriculiformis*. However, the two species are difficult to separate botanically if pods are unavailable.

Acacia rothii

Main attributes. A nitrogen-fixing small tree with potential for revegetating eroded and mined areas, or as a fuelwood species on sandy, infertile sites in the humid tropical lowlands.

Botanical name. *Acacia rothii* Bailey in *Qld Agric. J.* 6: 39. *t.* 161 (1900). The specific name honours Dr W.E. Roth, who obtained the type specimen.

Common names. None in common usage. Known as 'tooroo' by the Aborigines, in part of its range.

Family. Mimosaceae.

Botanical features. This is a small tree, usually 6–10 m tall, but up to 12 m. It has a moderately straight single stem with dark, rough, furrowed bark. The branchlets are coarse, angular and glabrous.

The phyllodes are slightly to strongly curved, about 15–25 cm long by 15–25 mm wide, 9–13 times as long as wide, with a prominently wrinkled stalk. There are 2–3 conspicuous longitudinal nerves. A prominent gland occurs at the base of the phyllode with one or two smaller ones often present above the middle.

The flowers are in globular heads on axillary racemes. The pod is rather unusual, being flat, woody, glaucous and rather large, about 9–17 cm long by 3–5 cm wide. The seeds are transverse in the pod, 8–12 mm long and 5–7 mm broad, with a long funicle thickened to form a small cup-shaped aril enclosing less than one-third of the seed. Flowering takes place about June and the pods, which mature in late August–September, remain on the tree for a long period and can be collected until December or later.

A botanical description is given by Pedley (1978) and the species is illustrated by Bailey (1900a).

Natural occurrence. *A. rothii* is restricted to the northern part of Cape York Peninsula, Queensland, where it is relatively common, and to a few isolated occurrences in the Northern Territory.

- Latitude. Range: 11–15°30'S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 800 m.

Climate. *A. rothii* is mainly in the hot humid climatic zone, but with extension into the hot sub-humid zone. The mean maximum temperature of the hottest month is 31–35°C in Queensland, but can be up to 37°C in the Northern Territory. The mean minimum temperature of the coolest month is 17–22°C and the area of natural occurrence is frost-free.

There is a well-developed summer monsoon with rains December–April and a very dry period in July–September. For most localities the 50 percentile rainfall is within the range 1400–1700 mm, the 10 percentile 950–1300 mm, and the lowest on record 700–850 mm. There is a dry season of 6 months and rain is recorded in about 100–120 days each year.

Physiography and soils. On Cape York Peninsula, *A. rothii* occurs on low hills and gently undulating to almost level plains. It has been found on, and at the base of, sandstone escarpments in Arnhem Land, Northern Territory. The soils are mainly deep, sandy or loamy, red and yellow earths or lateritic red earths, and shallow gravelly soils. They are acidic to neutral in reaction, well-drained and generally have a low nutrient status.

Vegetation type. *A. rothii* is the most common acacia found in the understorey of open-forest of *Eucalyptus tetrodonta–E. nesophila* in the northern parts of Cape York Peninsula. Common associates include *Erythrophleum chlorostachys*, *Acacia flavescens*, *A. crassicarpa*, *Grevillea glauca*, *G. parallela*, *Planchonia careya*, *Neofabricia myrtifolia*, and *Melaleuca viridiflora*. It is a component of closed heath on undulating land in the northeastern part of Cape York Peninsula where most of its associates of the open-forest also occur, but are much reduced in size (Pedley and Isbell 1970).

Utilisation.

Fodder: The phyllodes have a low in vivo dry matter digestibility and are below the minimum requirements for certain nutrients (Vercoe 1989). The large seeds and pods may have some value for fodder.

Fuelwood: The dense wood should be suitable for fuel.
Wood: The heartwood is dark red-brown and is surrounded by a narrow band of pale sapwood. Other properties not known. It has been used by the Australian Aborigines for spear heads and woomeras.
Other uses: A. rothii has been very successful for revegetating open-cut bauxite mining sites in northern Queensland.

Silvicultural features. A small tree or shrub that grows rapidly on infertile, sandy sites in the tropics. *A. rothii* forms both ecto- and endo-mycorrhizal associations (Reddell and Warren 1987) and appears to nodulate with only a restricted range of rhizobia strains (Dart et al. 1991). Innoculation of nursery soils with effective symbionts may enhance survival and growth.
It regenerates from root suckers and coppices very freely (Ryan and Bell 1989), factors which ensure its recovery after fire and will assist in its management as a fuelwood crop.
Establishment: There are about 3300 viable seeds/kg and they require the routine treatment of immersion in boiling water for 1 minute to break seedcoat dormancy. Based on a very small sample, the germination rate was 52%. The large size of the seed facilitates direct sowing.
Yield: It is a slower-growing and longer-lived species than many other acacias. Growth rates up to 3 m in 2 years on less compacted soils and up to 2.6 m in 3 years on more compacted soils have been recorded in north Queensland (A. Gunness, pers. comm.). In trials in southeastern Queensland, *A. rothii* attained a mean height of 5.7 m and basal diameter of 11.7 cm in

4.5 years (Ryan and Bell 1991). On a site in Thailand it attained 2.4 m in 12 months (Pinyopusarerk 1989), but gave very poor survival and growth in the up-country of Sri Lanka (Weerawardane and Vivekanandan 1991).

Pests and diseases. None recorded. Parrots feed on the seeds.

Limitations. The small size of *A. rothii* will restrict its use as a wood to fuel, small posts and poles, and small joinery items. It is unlikely to tolerate frosts. A persistent species with the potential to become a weed under some conditions.

Related species. The large woody pods and large seeds held transversely in the pods are similar to *A. platycarpa* but in other characters, *A. rothii* resembles *A. mimula*.

Acacia salicina

Main attributes. A vigorous tall shrub or tree. Nitrogen-fixing and relatively drought resistant, it grows on a wide range of soils and is tolerant of saline and alkaline conditions. Provides good shade and shelter, has some fodder value, and is useful for some soil conservation purposes.

Botanical name. *Acacia salicina* Lindl. in T.L. Mitchell's *Three Exped. E. Australia* 2: 20 (1838). The species name is from the Latin, *salix* — a willow, in reference to the weeping habit of the tree.

Common names. Cooba (standard trade name), willow wattle, doolan, Broughton willow wattle, and native willow.

Family. Mimosaceae.

Botanical features. A tall shrub or tree, usually 7–13 m, though it may grow to 20 m. The tree usually has a well-defined main stem, with drooping branches and pendulous blue-green or deep-green foliage. The bark at the base is hard, rough, grey-brown and fissured, and is smooth and grey on upper branches. Phyllodes are extremely variable both in shape and size, broad-linear to narrow-lanceolate, elliptic, 4–17 cm long and 4–25 mm broad with a prominent mid-nerve. They are thick, sometimes glaucous, and with two glands, one at the tip, one near the base. The globular, pale yellow flowerheads are in axillary branched racemes, sometimes clustered, or in pairs on long stalks. Pods glaucous, thick, woody, oblong, almost straight, 4–12 cm long and 1 cm wide, constricted only where the seed is aborted. Seeds longitudinal in the pod, shiny, dark brown to black, oval to oblong-oval, 4–6 mm long and 3–4 mm broad; with a thick, red aril. It flowers irregularly throughout the year, but mainly April–June. Pods mature in the second half of the year in Queensland (Pedley 1979), while February to April is the usual seed-collecting period in South Australia (Bonney 1994).

It is described and illustrated by Holliday (1989b), Tame (1992) and Whibley and Symon (1992).

Natural occurrence. This species grows in eastern Australia, with its major distribution in central Queensland and New South Wales. It also occurs over much of central South Australia and has a limited occurrence in southern areas of the Northern Territory and in northwestern Victoria.

- Latitude. Main occurrence: 20–30°S.
  Range: 19–37°S.
- Altitude. Main occurrence: 50–300 m.
  Range: near sea level to *ca* 600 m.

Climate. *A. salicina* occurs in the warm sub-humid and the wetter parts of the semi-arid climatic zones, but extends into the arid zone along watercourses and other situations where supplementary water is available. The mean maximum temperature of the hottest month is 32–36°C in most areas, but can exceed 38°C in the arid parts of South Australia and the Northern Territory. With the exception of a few coastal areas in Queensland, the mean minimum of the coolest month is 4–8°C. There are 1–12 frosts a year in non-coastal areas.

The 50 percentile rainfall is 375–550 mm, the 10 percentile 225–250 mm and the lowest on record 125–250 mm. Seasonal distribution varies with a well-developed summer maximum in northeastern Queensland, through a more or less uniform distribution, to a well-defined winter-spring maximum in the far south. The dry season in most of the occurrences is 4–8 months, but in the drier parts it extends to 12 months. Climatic indicators for predicting areas suitable for growing *A. salicina* are provided by Marcar et al. (1995).

Physiography and soils. *A. salicina* is mostly found on flat alluvial plains and floodplains. It also grows on minor drainage areas and sandy tracts on hills and footslopes of volcanic and mixed sedimentary rocks, stony plains, partly dissected sandstone plateaux, and sand dunes. Major soil types are the dark cracking clays (black earths) of the floodplains, and acid and neutral red earths. Other soils include brown and red cracking clays, solonized brown soils (calcareous and sandy earths), shallow loamy and sandy soils, and desert loamy soils (crusty red duplex). The soils are of moderate to low fertility and can be alkaline or saline.

Vegetation type. The eastern part of the distribution is mainly in woodland and open-woodland dominated by *Eucalyptus drepanophylla*, *E. crebra*, *E. melanophloia*, and *Acacia harpophylla*. Along flood plains and watercourses *E. camaldulensis* is a major associate. In central Queensland it occurs in the better-watered sites of the *Astrebla* (Mitchell grass) herblands and in woodlands with *A. cambagei*. In the northeast and coastal areas *A. salicina* may be found in open-forest with *E. tereticornis* and *E. moluccana* or with *A. cambagei* and *A. harpophylla*. The western and some southern areas of occurrence are shrublands.

Utilisation.

Fodder: The leaves and pods are eaten readily but not frequently by sheep (Everist 1969; Cunningham et al. 1981). The high level of tannin in the leaves has been suspected of poisoning hungry cattle (McCosker and Hunt 1966). Protein, nutrient and digestibility levels were found to be close to maintenance requirements by Vercoe (1989). It has been planted as a fodder species in the arid zone of Libya and showed promise in semi-arid areas of Iran (Webb 1973) and Kuwait (Firmin 1971).

Fuelwood: It should make a satisfactory fuel.

Wood: The heartwood is dark brown and attractively marked, close-grained, tough and moderately heavy with an air-dry density of 675 kg/m^3 (Cause et al. 1974). It takes a high polish and has been used for quality furniture for which purpose it rivals the well-known furniture timber *Acacia melanoxylon*.

Other uses: The drooping habit and attractive foliage makes this a desirable species for amenity planting. *A. salicina* is used for shade, shelter, and ornamental purposes in North Africa and the Middle East (Heth and Dan 1978; Kaplan 1979; Weinstein and Schiller 1979). It suckers freely and can be used to stabilise sandy areas and to control erosion along stream banks. *A. salicina* is planted as a soil stabiliser on steep slopes of Cape Verde (Sandys-Winsch and Harris 1992). It is used for mine-site rehabilitation in parts of its natural range (Langkamp 1987).

Silvicultural features. A relatively fast-growing tree, which reproduces vegetatively from root suckers but seeds irregularly in the wild. It coppices well when young

(Ryan and Bell 1989). *A. salicina* is moderately to highly salt-tolerant; expect reduced growth at EC_e 10 dS/m and reduced survival at EC_e 15 dS/m (Marcar et al. 1995).

Establishment: Propagation is by seed treated by immersion in boiling water for 1 minute to break seedcoat dormancy. It flowers within 2 years of planting. There are 15 200 viable seeds/kg and germination rate averages 69%. A procedure for rapid micropropagation of *A. salicina* was described by Jones et al. (1990).

Yield: Growth rates usually fall in the range of 1–2 m/year (Bell et al. 1991; Kimondo 1991; Mitchell 1989; Ryan and Bell 1991; Webb 1973). In a rain-fed runoff farming system in the arid zone of Israel, the mean total fresh biomass was about 25 kg/tree/year for the 2-year rotation and 30 kg/tree/year for the 4-year rotation (Zohar et al. 1988).

Pests and diseases. *A. salicina* suffers a moderate level of damage to leafblister sawfly (*Phylacteophaga* sp.) and lerp (*Cardia* sp.) (Marcar et al. 1995). It is damaged in Australia by acacia rust (*Uromyces fusisporus*) (Lee 1993a).

Limitations. The vigorous suckering habit and tendency to form thickets could cause problems in certain situations.

Related species. *A. salicina* is related to *A. ampliceps*, *A. bivenosa*, *A. ligulata* and *A. sclerosperma*.

Acacia saligna

Main attributes. A small nitrogen-fixing tree native to the southwest of Western Australia. It is fast-growing, will coppice readily and is tolerant of a wide range of soils, including calcareous and slightly saline types in temperate climates. *Acacia saligna* is planted in North Africa, the Middle East and South America for fodder, fuelwood, sand stabilisation and as a windbreak. In Australia it is most commonly used as an ornamental, but is being increasingly planted in agroforestry systems for fodder production and soil conservation.

Botanical name. *Acacia saligna* (Labill.) H. Wendl. was published in *Comment. Acac.* 4: 26 (1820) based on *Mimosa saligna* Labill. The name *A. cyanophylla* Lindl. is regarded as a synonym. The name *saligna* is derived from the Latin *salignus* — willowy or willow-like, presumably because the branches of this species are often drooping, as in some species of willows (*Salix*). The synonym —*cyanophylla* is derived from the two Greek words, *kyanos* — blue, and *phyllon* — a leaf, in allusion to the phyllodes which are sometimes sub-glaucous or glaucous.

Common names. Golden-wreath wattle, coojong, orange wattle and blue-leafed wattle.

Family. Mimosaceae.

Botanical features. The form of this acacia is commonly that of a bushy shrub dividing near the base into several stems which in turn carry many branchlets, and the result is a dense bush which may be wider than the plant is high. The shrub form is usually in the height range of 2–5 m but the species may also grow into a small tree 5–9 m high, with a short but well-defined main stem. The young plant has dense, sometimes pruinose, foliage. The older stages are openly branched and may be susceptible to attack by gall rust, *Uromycladium tepperianum*.

The phyllodes are variable, mainly linear to lanceolate, 8–25 cm long × 0.4–2 cm broad (phyllodes may be broader in the seedling/intermediate phase), straight or falcate, green or glaucous, tapering gradually toward the base and apex; midrib conspicuous with fine but distinct lateral veins; glands basal. The inflorescence is an axillary raceme shorter than the phyllodes (rarely reduced to a solitary head), flower heads globular, deep yellow to almost orange, 25–75 flowered; peduncles slender, glabrous, 5–20 mm long. Legumes linear, 5–14 cm long, 5–6 mm broad, straight or slightly curved, surface slightly undulate, glabrous, brown, margins thickened, slightly constricted between the seeds. Seeds longitudinal in the legume, 5–6 mm long × 3–3.5 mm wide, dark brown to black and shiny, funicle short, thickening into a cream-coloured aril. Flowering period in Western Australia is August to October resulting in ripe seed in November to January.

The species is described by Maslin (1974b) and illustrated by Whibley and Symon (1992).

Natural occurrence. This is a species of south-western Western Australia, where it is very common on the poor sandy soils of the Swan Coastal Plain from Gingin southwards to Busselton and on the heavier clay soils as far north as the Murchison River. Its eastern limits are about 200 km east of Esperance.

- Latitude. Range: 27–35°S.
- Altitude. Range: sea level to 300 m.

Climate. This species has its main occurrence in the warm, sub-humid and humid climatic zones, but it extends into the higher rainfall parts of the semi-arid zone. The mean maximum temperatures of the hottest month show a considerable range from about 23°C on parts of the south coast to nearly 30°C at Perth, to 32–36°C for northern and inland locations. The mean minimum of the coolest month shows a smaller range, being mainly within the limits of 4.5–9°C. Most situations on the coast are frost-free, especially from Perth northwards, but inland there is an average of 1–6 frosts per year.

The mean annual rainfall for the humid zone is 750–1000 mm, with an abrupt drop for the sub-humid zone to 450–500 mm, and as low as 300 mm in the semi-arid zone. The variability is moderately high for most inland and northern locations. There is a well-developed winter maximum, with most of the precipitation from May to September; the driest months have averages of 12–15 mm. The number of raindays is 65–90 for most of the area, but on parts of the south coast it is as high as 130–180.

Marcar et al. (1995) summarise the climatic requirements of the species under natural and cultivated conditions: mean annual temp. 13–21°C, min. temp. of coldest month 2–10°C, max. temp. of the hottest month 26–36°C, mean annual precipitation 280–1210 mm, length of dry season 0–12 months.

Physiography and soils. This acacia mainly grows on gentle undulating topography and coastal sand plains, but extends to a wide variety of situations from swampy sites and river banks to small, rocky hills (often granitic) and the slopes of the coastal ranges. It occurs on many soil types, especially poor and calcareous sands, but also moderately heavy clays and on a range of podzolics.

Vegetation type. *A. saligna* has its principal occurrence in the more open parts of the dry sclerophyll forest or in the temperate woodlands which comprised the original community over much of what is now wheat–sheep country. In the drier parts of its range it also occurs in semi-arid low woodlands and mallee communities, only rarely extending to heath communities. It often occurs in eucalypt woodland dominated by *Eucalyptus gomphocephala*, *E. loxophleba* and *E. wandoo*. Shrub and small tree genera with which it is associated include *Allocasuarina*, *Casuarina*, *Calothamnus*, *Dryandra*, *Hibbertia* and other species of *Acacia*.

It has become naturalised in parts of southern and eastern Australia, from South Australia and Victoria to southeast Queensland.

Utilisation. A versatile hardy plant widely cultivated in North Africa, the Middle East and South America for agroforestry, wasteland utilisation and soil conservation purposes (Crompton 1992). Over 200 000 ha have been planted in North Africa as a fodder source for sheep and goats.

Fodder: The phyllodes, young shoots, pods and seeds, whether fresh or dry, are protein-rich and non-toxic and palatable to both sheep and goats (Anon. 1955;

Michaelides 1979). The phyllodes should not be used as a sole diet for small ruminants (sheep and goats) because of low intake and negative nitrogen balance, caused mainly by high tannin content (Woodward and Reed 1989; Degen et al. 1995). However, Degen et al. (1995) concluded that the tree might have potential as a supplementary fodder due to its high crude protein content.

The fodder value of *A. saligna* for Barki sheep was evaluated and compared to alfalfa in Egypt (El-Lakany 1988). Replacing 50% of daily dry matter intake of alfalfa by acacia foliage increased the total digestible nutrients and decreased digestible protein of feed intake. Feeding alfalfa alone constitutes a waste of protein, while mixing it with acacia, which has a relatively high energy content, improves feeding efficiency.

This feed is especially valuable during the dry season when other forage is scarce. Regrowth on established bushes of *A. saligna* can be completely grazed-off in autumn without harming the plants. The chemical composition shows the following ranges: dry matter (50–55%), crude protein (12–16%), crude fibre (20–24%), crude fat (6–9%), and ash (10–12%) (El-Lakany 1987). Analysis of phyllodes from trial plantings in southeast Queensland indicate a moderately low digestibility (36.5% predicted in vivo) but high levels of crude protein (18.3%) (Vercoe 1989). The low Ca to P ratio of 4:1 should enable efficient use of phosphorus supplements.

Fuelwood: The wood is used as fuel and charcoal. *A. saligna* was amongst a group of acacias assessed as being reasonably satisfactory for this purpose by Hall (1939). The group gave a charcoal yield of 24% and had medium specific gravity and low tar yield (13.5–17%).

Wood: A. saligna wood has been successfully processed into particle board in Tunisia (El-Lakany 1987). In the Mediterranean region it is used for vine stakes and small agricultural implements (Michaelides 1979).

Other uses: In southwest Western Australia, *A. saligna* is a successful farm tree for reduction of water tables and mitigation of salinity, provision of shade and shelter and reduction in farm nutrient run-off. It is well-suited to heavy saline and waterlogged clay soils where it gives fast growth, excellent survival and large crown growth (Bennett and George 1993). *A. saligna* has been successfully established in Western Australia by direct sowing in regions with annual rainfall as low as 350–500 mm (Scheltema 1992).

The tree is used extensively for coastal and inland sand dune fixation in North Africa, the Middle East, and South Africa and for gully erosion control in Uruguay. It is also used in Australia for rehabilitation of areas mined for coal and mineral sands (Langkamp 1987).

Trees were planted in the past for tannin production from the bark which contains 30% tannin (Hall and Turnbull 1976). Damaged bark exudes copious amounts of very acidic gum. Such acid-stable gum has promise for use for pickles and other acidic foodstuffs (Michaelides 1979). The leaves of *A. saligna* can be used to dye wool a lemon-yellow colour using an alum mordant (Martin 1974). *A. saligna* is also widely planted as a valuable hardy ornamental.

Silvicultural features. This small, fast-growing acacia is used extensively in winter rainfall zones for coastal sand stabilisation, windbreaks, fuel and fodder. It is tolerant of drought, waterlogging, light frost, alkalinity and salt (Simmons 1981). Marcar et al. (1995) advise to expect reduced growth at EC_e about 5 dS/m when growing *A. saligna* on saline soils.

A. saligna is relatively shortlived in cultivation (10–20 years) and suckers to form small colonies (Whibley and Symon 1992). It coppices well and fodder biomass production is optimised by regular annual harvesting. The species has responded well to irrigation (6 L/tree every second day) in Egypt (El-Lakany 1987). The tree nodulates with certain strains of *Rhizobium* (Roughley 1987). In common with many other acacias, it forms associations with VA mycorrhizal fungi (Reddell and Warren 1987). Its efficiency in fixing atmospheric nitrogen as well as mycorrhizal associations are under investigation in Tunisia (Nasr 1986 cited in El-Lakany 1987). Nakos (1977) found that the ability of *A. saligna* to fix nitrogen was greatly reduced by drought, water-logging, shading or defoliation.

A. saligna occupies a diversity of habitats over a substantial geographic range. It would be prudent, therefore, to test a range of provenances when introducing the species to a new area.

Establishment: There are 45 700 viable seeds/kg of an average germination rate of 74%. Prior to sowing, seed should be immersed in boiling water for 1 minute to remove seedcoat dormancy. Seedcoats can also be manually scarified. Treated seed should be planted to a depth of 0.5 cm. Optimum temperature for germination is in the range of 15–20°C. Seedlings can be produced either by direct sowing or in a nursery. A nursery phase of 10–12 weeks is recommended. Young plants require protection from grazing animals.

A. saligna has been successfully micropropagated using a tissue culture technique (Jones et al. 1990).

Yield: A. saligna grows quickly in favourable conditions, often reaching 8 m tall with a spread as great as its height in 4–5 years. Annual wood yields vary from 1.5–10 m^3/ha (NAS 1980). In the arid zone of Tunisia and Libya, *A. saligna* produces fuelwood at a rate of up to 3500 kg dry-wood/ha/year on deep sandy loam alluvia receiving an average of 150 mm annual precipitation and some runoff (El-Lakany 1987). Annual harvesting for biomass production was found to be optimal in drip-irrigated trials near Cairo where production of foliage was 12–13 t/ha in the first year and increased with age (El-Lakany 1988). The wide variability between trees suggested that useful gains might be obtained through breeding. In trials in a subtropical area in southeast Queensland, *A. saligna* attained an average height of 6.2 m after only 41 months but slowed down substantially in the following year to average 6.7 m at 4.5 years (Ryan and Bell 1989, 1991).

Pests and diseases. Older plants are susceptible to gall rust, *Uromycladium tepperianum*, and various gall-exploiting insects. In parts of Western Australia more than 90% of *A. saligna* trees bear conspicuous woody galls (Van den Berg 1978). This gall rust has been used as a biological control agent for *A. saligna* in South Africa (Selincourt 1992). The natural insect enemies of *A. saligna* in Western Australia have been studied by Van den Berg (1980) cited in Whibley and Symon (1992). Larvae of 36 species of *Lepidoptera* (moths and butterflies) were found on *A. saligna*. Those damaging the phyllodes were the most common. Adults or larvae of 55 species of *Coleoptera* (beetles and weevils) and adults and/or nymphs of 40 species of *Hemiptera* (cicadas, plant hoppers, plant lice, scale insects, and bugs) were also recorded. Those feeding on sap and twigs were most abundant. The study was done to establish the importance of natural enemies with a view to biological control of these wattles in South Africa. The plant has extrafloral nectaries at the bases of the phyllodes. These attract ants which are believed to reduce the numbers of leaf-eating insects. Rodents sometimes attack the roots. Termites may cause serious problems in tropical countries (Michaelides 1979).

Limitations. Caution is advised when using *A. saligna*. The tree has become a major weed in South Africa by invading and displacing the native vegetation (Roux and Middlemiss 1963). The species was introduced to South Africa in the first half of the nineteenth century. It has spread to waterways and irrigation channels. The seed has also spread in river sand transported for road and dam construction. Its hardiness and ability to coppice rapidly after fires or from trunks has also led to widespread establishment (Stirton 1980). The species has become naturalised in northern New South Wales and at a few localities in southern Queensland from escapes from plantings for sand mine reclamation work in northern New South Wales (Stanley and Ross 1983).

Acacia saligna used for shade and soil stabilisation in the coastal dry zone of Chile. *Photograph courtesy of Oliver Strewe.*

It is highly palatable to stock and may need to be protected during establishment. *A. saligna* is short-lived (10–15 years) and becomes untidy with age.

A. saligna grows poorly in tropical areas, except at high altitudes. In the tropics a similar species, *A. ampliceps*, which tolerates alkaline and saline soil conditions and has potential as a fodder tree, may prove more suitable.

Related species. *A. saligna* has no known close relatives but it resembles, superficially, a number of species including *A. pycnantha* (B. Maslin, pers. comm.).

Acacia sclerosperma

Main attributes. A multi-stemmed, large shrub suitable for well-drained alkaline, skeletal and saline soils, in hot arid zones. It has good potential for fuelwood production, soil stabilisation and amenity plantings.

Botanical name. *Acacia sclerosperma* F. Muell. in *Southern Science Record* 2: 150 (1882). The specific name is from the Greek *scleros* — hard, and *sperma* — seed, an apt reference to the very hard seeds. A new subspecies *glaucescens* Chapman and Maslin has been described in *Nuytsia* 8(2): 272–275 (1992).

Common names. Large-seeded cooba, limestone wattle, silver bark wattle.

Family. Mimosaceae.

Botanical features. *A. sclerosperma* is typically a multi-stemmed, spreading, large shrub 4 m tall and 4 m across. The canopy is more or less rounded and dense. Bark is light grey to brownish-grey with longitudinal fissures. Branchlets are whitish to light grey, ascending, glabrous in subsp. *sclerosperma* and usually minutely pubescent with very short soft hairs in subsp. *glaucescens*. Phyllodes are thick with one longitudinal nerve on each face. Phyllode shape in subsp. *sclerosperma* is narrow, linear, 4.5–14 cm × 1–4 mm, green to subglaucous, but for subsp. *glaucescens* narrowly elliptic to narrowly oblong-elliptic, 3–6 cm × 6–17 mm, glaucous.

Flower heads are large, 10–13 mm diameter, globular and bright golden yellow. There are 15–20 flowers in the head for subsp. *sclerosperma* and 20–25 for subsp. *glaucescens*. They are borne on long peduncles 10–18 mm either singly or in very short axillary racemes of 2–4 heads. The pods are large and woody, 6–12 × 1–2 cm, strongly constricted between the seeds (like a string of beads with up to 8 articles), smooth and often pruinose when young. The seeds are 7–10 mm long, 5–9 mm wide and 4–7 mm thick with a hard, very thick seedcoat, dark brown, shiny, round to oval and longitudinally positioned in the pod (Chapman and Maslin 1992). The aril is dark red.

In subsp. *sclerosperma*, flowering specimens have been collected April–October and mature seed in October and December. In subsp. *glaucescens* flowering occurs July–August and mature seed is available November to January (Chapman and Maslin 1992).

The species is described by Chapman and Maslin (1992) and illustrated by Mitchell and Wilcox (1994), Simmons (1981) and Thomson and Hall (1989b).

Natural occurrence. *A. sclerosperma* is a common species in central-western and northwestern Western Australia. It is found in an area from north of Geraldton to near Port Hedland and inland for 500–600 km.

- Latitude. Range: 20–29°S.
- Altitude. Range: near sea level to 750 m.

Climate. This is mainly a species of the hot arid climate zone, but it also occurs in the hot semi-arid zone. The inland summers are extremely hot, with a mean maximum temperature of the hottest month of 37–39°C, moderating near the coast to 31–35°C. The mean temperature of the coldest month varies from 7°C for higher inland locations to 13°C for northern, coastal sites. Inland locations may experience 2–6 light frosts per year.

The 50 percentile is 175–325 mm, the 10 percentile 50–125 mm and the lowest on record 30–75 mm. Rainfall is markedly variable between years, and seasonality varies from a distinct winter maximum in the south to a summer monsoonal pattern in the north. In the transition zone from winter to summer rainfall there may be a bimodal pattern with a late summer peak (January–March) and a lesser peak in winter (May–June).

Physiography and soils. *A. sclerosperma* grows in a wide variety of habitats. The species commonly grows in shallow alkaline (pH 9–10) sands, sandy loams and sandy clays over limestone. It may also be present on kopi rises (wind-blown gypseous deposits) surrounding salt lakes. It occurs on sandplains (red earthy sands) and coastal sand dunes. *A. sclerosperma* also grows on a variety of hard and/or stony soils. These include compacted alkaline (pH 7.5–9) red sandy to clay loams, very stony alkaline (pH 7.5–9) red clay loams and stony acidic (pH 5.5–6) red loamy clays with a quartz or ironstone hardpan. It has been observed on neutral (pH 6.5–7) sands and sandy loams at the base of granite outcrops.

Vegetation type. *A. sclerosperma* is widespread in tall open-shrubland communities. *Acacia victoriae* and *A. tetragonophylla* are very common associates. Subsp. *sclerosperma* has been found growing in coastal dunes, while subsp. *glaucescens* is sometimes in open scrub associated with saltbushes and hummock grassland (Chapman and Maslin 1992). It also frequently occurs as a scattered shrub in low woodlands along drainage lines. Associated tree species include *Eucalyptus camaldulensis*, *E. victrix*, *E. striaticalyx* and *Casuarina obesa*. On the more saline sites associates include *A. cuspidifolia*, *A. sibilans*, *Hakea preissii*, *Melaleuca* spp., *Myoporum* spp. and chenopods (*Atriplex*, *Halosarcia*, *Rhagodia* and *Maireana*). Beard (1975, 1976) provides detailed information on vegetation associations which include *A. sclerosperma*.

Utilisation.

Fodder: The phyllodes are not palatable. They are not very nutritious having a crude protein content of 8% and in vitro digestibility of 45% (Mitchell and Wilcox 1988).

Fuelwood: The numerous small trunks and branches are likely to prove suitable as firewood.

Wood: Its wood consists of a broad band of pale sapwood with a brown heartwood. Basic wood density is 860 kg/m^3 (Davis 1994).

Other uses: Excellent potential for soil stabilisation and low windbreak plantings. The naturally bushy multistemmed habit may be further enhanced by coppicing. It is planted as an ornamental and amenity species in Israel (P. Sandell, pers. comm.) and tolerates coastal salt spray (Simmons 1981). It is used for revegetating mining sites and for amenity planting in Australia (Langkamp 1987).

Silvicultural features. *A. sclerosperma* is a moderate to slow-growing long-lived acacia. While it is very drought-tolerant, growth will be enhanced by supplementary

watering with brackish water where drainage is good. It has excellent coppicing ability.

Establishment: Propagation is from seed. Germination rate is 95% providing an average of 3300 viable seeds/kg. Pretreatment is required to break seedcoat dormancy by immersion of the seed in boiling water for 5 minutes. It is suggested the nursery phase be about 3 months.

Yield: Early height growth has been 2 m in 3 years under semi-arid conditions in India and Senegal. It is one of the best-adapted Australian acacias for near coastal regions of Senegal where biomass and coppicing studies are in progress (Cossalter 1987). Growth in Kenya has been modest with MAI for height of 0.9 to 1.4 m (Chege and Stewart 1991; Kimondo 1991). Survival has been poor (32%) on a sodic site with seasonal waterlogging in Pakistan (Marcar et al. 1991b).

Pests and diseases. None recorded.

Limitations. Its small size will restrict its use to fuelwood, soil stabilisation and amenity plantings. It is not recommended for heavy waterlogged soils, for which more suitable alternatives, e.g. *Acacia ampliceps* and *A. stenophylla*, are available. Selection of appropriate seed sources will be particularly important for this variable species.

Related species. *A. sclerosperma* is in a taxonomically complex species group, including *A. ampliceps*, *A. bivenosa*, *A. ligulata*, *A. rostellifera*, *A. salicina*, *A. tysonii* and *A. xanthina* (Maslin 1982; Chapman and Maslin 1992). Hybrids have been found between the subspecies of *A. sclerosperma* and *A. ampliceps*, *A. bivenosa*, *A. ligulata* and also between the two subspecies (Chapman and Maslin 1992).

Acacia shirleyi

Main attributes. A nitrogen-fixing tree of moderate size adapted to infertile, acid to very acid lateritic soils in the semi-arid and sub-humid tropics. It can provide fuelwood, poles and rails, shade and shelter on relatively harsh sites.

Botanical name. *Acacia shirleyi* Maiden in *Proc. Roy. Soc. Qd* 53: 218 (1920). The specific name honours Dr J.F. Shirley (1849–1922), an inspector of schools in Queensland and a keen plant collector.

Common names. Usually referred to as lancewood. This name is also applied to a group of species each of which occurs as dense, pure stands of slender trees on lateritic and sandstone tablelands or scarps (Johnson and Burrows 1981). It is preferable to distinguish *A. shirleyi* by the common name 'Shirley's lancewood'.

Family. Mimosaceae.

Botanical features. A tree to 18 m tall and 30–40 cm diameter, with rough, longitudinally fissured, dark grey bark. In close-spaced stands the crown is relatively narrow and the branches commonly ascend at an acute angle. The branchlets are angular, glabrous, and yellowish.

Phyllodes are linear, straight or curved, greyish green, normally 10–15 cm by 2–7 mm. There are many fine parallel veins with the central one usually more prominent. The flowers are in single or paired cylindrical spikes 2–4 cm long. The pods are narrow-oblong to 12 cm by 4–6 mm, somewhat woody, raised over and constricted between seeds, glabrous and finely wrinkled. The seeds are longitudinal in the pod 4 mm long by 2–3 mm wide with a basal aril. Flowers appear in February–April and seed matures September–December.

The species is illustrated by Brock (1988) and Jessop (1981), and a botanical description is given by Pedley (1978) and Stanley and Ross (1983).

Natural occurrence. *A. shirleyi* has an extensive distribution that stretches in an arc from southern Queensland to the base of Cape York Peninsula, across the Barkly Tableland into the central north of the Northern Territory. It is rare in coastal areas.

- Latitude. Range: 14–28°S.
- Altitude. Main occurrence: 100–300 m.
  Range: 50–350 m.

Climate. Most of the distribution in the Northern Territory and northwestern Queensland is in the hot semi-arid zone. Further south in Queensland the climate is warm semi-arid in inland areas and warm sub-humid nearer the coast.

The mean maximum of the hottest month is mainly 34–38°C with 75–265 days over 32°C and 5–100 days over 38°C each year. The mean minimum temperature of the coolest month is usually within the range 6–11°C. The coolest sites are in the south of the distribution where 1–2 frosts annually are recorded, elsewhere its area is frost-free.

The 50 percentile rainfall is 500–750 mm, the 10 percentile 325–475 mm, and the lowest on record 100–275 mm. The northern part of the distribution has a summer monsoon and in the south, there is a well-developed summer maximum.

Physiography and soils. The distribution extends across the northern parts of the three main physiographic divisions in Australia, the Eastern Uplands, Interior Lowlands, and Western Plateau. *A. shirleyi* is found mainly on rocky outcrops and steep slopes of low sandstone hills and on dissected lateritic mesas, less than 75 m above the base level.

A. shirleyi typically occurs on stony or gravelly lithosols (Beadle 1981) but more specifically, according to Johnson and Burrows (1981), it is found on three major soil types: shallow lateritic red and yellow earths over massive laterite, sandy or sandy loams developed on laterized sandstone, and shallow lateritic podzolics developed on quartzose sandstones capped by laterite. The soils are usually acid to very acid, occasionally neutral, with low levels of nitrogen, phosphorus, and organic matter. It also grows on shallow soils over limestone in the Northern Territory.

Vegetation type. *A. shirleyi* forms low open-forest or open-forest up to 18 m tall in the moister parts of its range, and low woodlands or open-woodlands in drier areas. The communities are usually dense pure stands of *A. shirleyi*, occasionally with emergent eucalypts. The eucalypts include: bloodwoods such as *E. trachyphloia*, *E. dichromophloia*, and *E. citriodora*; ironbarks including *E. drepanophylla*, *E. melanophloia* and *E. shirleyi*; and boxes such as *E. thozetiana* and *E. brownii*. Most communities lack a woody understorey but in the tropics *Erythrophleum chlorostachys* may be present and in the subtropics *Alphitonia excelsa*, *Petalostigma pubescens* and *Erythroxylum australe* (Isbell and Murtha 1972; Beadle 1981; Johnson and Burrows 1981). On slightly deeper and more loamy soils *A. shirleyi* is replaced by *A. catenulata*.

Utilisation.

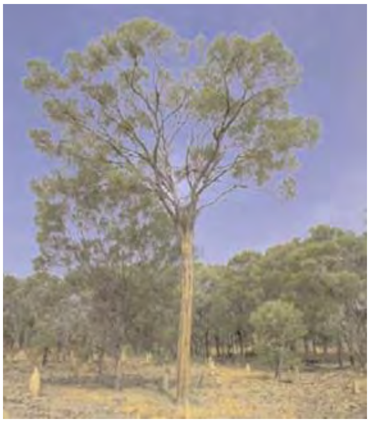
Fodder: The leaves are eaten fairly readily by stock although local differences in palatability are reported (Everist 1969). Vercoe (1987, 1989) recommended this species for further study after finding good phyllode dry matter digestibility (average of 53%) and crude protein levels (average 13%).

Fuelwood: An excellent firewood.

Wood: A hard, strong, heavy wood with an air-dry density of about 1025 kg/m^3 (Davis 1994). A dark brown heartwood with a narrow pale sapwood. The wood is brittle, relatively straight-grained, and splits readily. It is often used for fencing rails and poles but there are conflicting reports of the durability of posts in contact with the ground. There is a potential export market in the Northern Territory for wood from the natural stands for wood turning, parquetry flooring and high quality veneer, and for specialised industrial purposes such as shuttles and spindles (Fitzgerald 1991).

Other uses: Merits consideration for shelter, shade, and soil protection in appropriate climatic and soil conditions. Its narrow crown, greyish-green glaucous phyllodes and attractive flowers make it an excellent candidate for amenity plantings.

Silvicultural features. A tree of moderate size adapted to shallow, infertile sandy or gravelly soils. Under natural conditions it usually regenerates from seed (Gillison 1983) but it may have the capacity to reproduce from root suckers. It showed poor coppicing potential in trials in southeastern Queensland (Ryan and Bell 1989). Its occurrence in dense, pure stands suggests that it will be suitable for planting at close



spacing. It was found to have poor tolerance of soils of pH 8 and above (McKinnell and Harisetijono 1991) and was ranked amongst the less tolerant acacia species for salt tolerance in a glasshouse screening trial (Aswathappa et al. 1987).

Establishment: Propagation is by seed treated by immersion in boiling water for 1 minute to break seedcoat dormancy. Flowering has been noted as early as 14 months on planted specimens in southeastern Queensland (Ryan and Bell 1989). Average germination rate of seed is 56% with 59 200 viable seeds/kg. A nursery life span of greater than 3 months may be required because of slow initial growth (Ngulube 1988).

Yield: The major concern about this species in trials undertaken to date is its poor survival when planted as an exotic. Survival is often as little as 30–40% (Chege and Stewart 1991; Chittachumnonk and Sirilak 1991; Kimondo 1991). This may be related to the fact that *A. shirleyi* appears somewhat selective in its choice of rhizobia strains (Roughley 1987; Dart et al. 1991), and innoculation of nursery soils with effective strains of the symbiont is to be recommended. On sites where reasonable survival (± 80%) has been recorded, MAIs for height growth average 1.8 m (Chittachumnonk and Sirilak 1991; Ryan and Bell 1991).

Pests and diseases. It appears to be susceptible to termite attack with 16% mortality reported in plots in Zimbabwe (Mitchell 1989).

Limitations. Unlikely to tolerate heavy frosts. The wide geographic range suggests provenance testing will be desirable to select the best seed sources.

Related species. *A. shirleyi* is related to *A. petraea* and *A. ammobia* (Thomson et al. 1994).

Acacia silvestris

Main attributes. A fast-growing, nitrogen-fixing tree adapted to cool–warm sub-humid conditions. Has potential to produce fuelwood, poles, and timber in the tropical highlands or warm temperate lowlands. A useful tree for windbreaks and ornamental purposes.

Botanical name. *Acacia silvestris* Tindale in *Vict. Nat.* 73: 162–163 (1957). The species name is derived from the Latin *silvestris* — living in woods, and was probably applied because the species often grows in forests. Before it was recognised as a separate species in 1957 it was referred to as *A. dealbata*.

Common names. Bodalla wattle, Bodalla silver wattle, red wattle.

Family. Mimosaceae.

Botanical features. Commonly a tree 8–20 m, but occasionally up to 30 m tall and 1 m diameter. In dry areas on shallow soils it may be reduced to a sprawling shrub less than 2 m high. Open-grown specimens have a short trunk and are very branchy, but trees grown in forest conditions can have a long clean stem of up to 20 m. The bark on smaller trees and the branches of larger specimens is relatively smooth, grey or blotchy grey. Young branches are covered with a dense mat of silvery hairs.

The leaves are bipinnate with 6–18 pairs of pinnae, each with up to 40 pairs of leaflets 4–9 mm by 0.8–2.0 mm and broadest towards the base; a gland at the base of each pair of pinnae and 1–3 between. The flowers are in bright yellow globular heads in racemes. The pods are linear-oblong, 5–15 cm long by 6–10 mm wide, slightly hairy, glaucous, and constricted between the seeds. Seeds are longitudinal in the pod, black, 4–5 mm long by 3–4 mm wide, with a small pale yellow terminal aril. Flowering is in late winter-spring, mainly July–September, and seed fall is in summer, December–January.

The species is described by Tindale (1957) and Tame (1992) and the botanical features illustrated by Costermans (1981).

Natural occurrence. This acacia has a limited distribution in eastern Victoria and in the south coastal region of New South Wales. The largest trees occur in the northern part of the occurrence.

- Latitude. Range: 35–38°S.
- Altitude. Main occurrence: 30–300 m.
  Range: near sea level to 1000 m.

Climate. The main distribution is in the warm sub-humid climatic zone but there is some extension into the cool sub-humid zone. The mean maximum temperature of the warmest month is 24–27°C and the mean minimum of the coolest 0–4°C. It is estimated that there are 5–15 days over 32°C each year and less than 2 days over 38°C. Most of the distribution experiences some heavy frosts, mainly 5–30 per year but up to 60. The lowest temperature on record is in the range –3°C to –8°C.

The 50 percentile rainfall is mainly in the range 800–1100 mm, the 10 percentile 520–650 mm, and the lowest on record 400–500 mm. For most localities the incidence of rainfall is more or less uniform throughout the year. There are 90–130 raindays per year, and prolonged periods of drought are rare.

Physiography and soils. *A. silvestris* is confined to the Kosciuskan Uplands physiographic province of the Eastern Uplands division. It grows on a wide range of topography that includes river valleys in hilly to mountainous country, steep rocky hillsides, and stony ridges. It has been recorded from slates and sandstones but it is found on the latter only to a limited extent.

The soils vary from skeletal lithosols to deep red-brown podzolics and alluvials. *A. silvestris* reaches its largest dimensions on the moist, deep soils of moderate fertility in the bottom of gullies.

Vegetation type. *A. silvestris* occurs in tall open-forest, open-forest, woodland and tall shrubland. It commonly forms patches of closed-forest, occurring as pure stands or thickets without an understorey, possibly the result of mass regeneration following fire (Forestry Commission of New South Wales 1983). In southern New South Wales it is found in association with eucalypts including *E. bosistoana*, *E. longifolia*, *E. muellerana*, *E. smithii*, and *E. viminalis*. In eastern Victoria it occurs on the drier slopes and rocky escarpments in woodland with *E. polyanthemos* and *E. sideroxylon* or in tall shrubland with shrubby forms of *E. glaucescens*, *E. saxatilis*, *E. smithii*, and *E. viminalis* (Forbes et al. 1982).

Utilisation.

Fodder: The value for forage is unknown.

Fuelwood: Produces a relatively dense wood and is recommended as fuel (Forestry Commission of New South Wales 1980).

Wood: The wood is hard, strong and tough. It is pale brown but may have reddish streaks. The air-dry density is about 600–650 kg/m^3. The wood has been used for tool handles and is locally regarded as having good potential for furniture and general joinery. It could also provide building poles, mine timbers, and fence posts. Tests by Fang et al. (1991) on the kraft (sulfate) pulping properties of Australian-grown *A. silvestris* showed an oven-dry pulp yield of 53% and pulp properties suitable for a wide range of paper and paper board products.

Other uses: The bark has a high tannin content, but is inferior to *A. mearnsii*, which has a higher yield and a more readily processed bark.

It has been planted as an ornamental species in Australia and it is also recommended for windbreaks, avenue plantings (Forestry Commission of New South Wales 1980) and as a source of winter pollen for bees (Clemson 1985).

Silvicultural features. This species is fast-growing but is probably only moderately drought and frost tolerant (to –6°C). It regenerates from seed in the soil following light–moderate fires (Floyd 1966). Unlike *A. dealbata*, it is not reported to reproduce from root suckers.

Establishment: Propagation is from seed following immersion in boiling water for 1 minute to break seed-coat dormancy. There is an average of 37 400 viable seeds/kg at a germination rate of 73%. Nursery and establishment techniques developed for *A. mearnsii* should be appropriate for *A. silvestris*. The trees should

be planted at close spacing to reduce heavy branch development if straight clean boles are required.

Yield: The species is poorly adapted to the subtropical lowland conditions in southeastern Queensland, with only 13% of trees surviving at 4.5 years. They were 6.4 m tall at this age (Ryan and Bell 1991). *A. silvestris* has grown well in New Zealand on a range of sites: in Canterbury, height growth was 2 m/year (Sheppard 1987). On a subtropical site at 480 m altitude in northern Guangdong Province, China, *A. silvestris* at 4.7 m tall in 18 months ranked amongst the better-growing acacias under trial (Yang et al. 1991). This species grew poorly on a degraded highland area in Sri Lanka, reaching only 2 m in 2.5 years (Weerawardane and Vivekanandan 1991).

Pests and diseases. None recorded.

Limitations. Appears somewhat site-specific and may only grow well on moist, moderately fertile sites. Its tendency to form thickets without an understorey suggests that it has the potential to become a weed species under some conditions.

Related species. *A. silvestris* is closely related to *A. dealbata*, but the latter is distinguished by its hairless pods and the single gland at the base of each pair of pinnae. The large markedly acute leaflets (pinnules) of *A. silvestris* are characteristic and separate it from the *A. decurrens–A. mearnsii* group of acacias in eastern Australia (Tindale 1957).

Acacia simsii

Main attributes. A woody multi-stemmed nitrogen-fixing tropical shrub that grows rapidly. Suitable for small-sized firewood, erosion control, low windbreaks, and ornamental purposes.

Botanical name. *Acacia simsii* A. Cunn. ex Benth. in *London J. Bot*. 1: 368 (1842). The species was named after an English medico, Dr J. Sims (1749–1831), who edited several British botanical journals and gave his plant collection to Kew Herbarium.

Common names. Heathlands wattle, Sim's wattle.

Family. Mimosaceae.

Botanical features. A shrub, usually 2–4 m tall, rarely 6–7 m, with 2–4 stems of small diameter from near ground level. The bark tends to be smooth and thin, brown on the mature trunk but mottled grey on the smaller branches.

The phyllodes are narrow, straight or slightly curved, tapering into a fine upturned hook, rather thin, mainly 5–12 cm long by 2–7 mm wide. The flowers form an axillary group consisting of two pairs of bright yellow globular heads. The pod is somewhat glaucous, more or less flat but prominently raised alternately over the seeds and constricted between them, 5–8 cm long by 4–7 mm wide. The seeds are longitudinal in the pod, dark brown, more or less round and slightly compressed, 2–4 mm long by 2–3 mm wide, with a small, pale aril. *A. simsii* can flower from one-year-old. Flowering may occur at most times of the year but in Australia it peaks January–March (Simmons 1981; Searle 1989). In Papua New Guinea there is a heavy flowering in August and in Irian Jaya, in September. The time of seed maturation depends on flowering time. On Cape York Peninsula, Queensland, mature seed has been harvested April to October (Searle 1989) and from Western Province, Papua New Guinea in September–October.

A botanical description is given by Pedley (1978) and the species is illustrated by Simmons (1981) and Brock (1988).

Natural occurrence. *A. simsii* has its main occurrence in northern Queensland and southern New Guinea. In Queensland it extends from Cape York to near Mackay, usually in coastal or subcoastal areas within 100 km of the sea. In the Northern Territory it has a more restricted distribution in the Gove area and on the edge of the Barkly Tableland. The distribution in New Guinea is unusual in that it occurs on the north coast as well as both east and west of the Gulf of Papua in southern New Guinea (Pedley 1975). It also occurs in southern Irian Jaya.

- Latitude. Range: 3–21°S.
- Altitude. Main occurrence: near sea level to 300 m.
  Range: near sea level to 800 m.

Climate. This species is found in a wide range of climatic zones. It occurs commonly in the hot to warm humid and sub-humid zones, and to a lesser extent in the hot wet and warm semi-arid areas. The mean temperature of the hottest month is mainly in the range 32–35°C but attains 37°C in the drier inland areas. There are usually 30–130 days over 32°C and 1–15 days over 38°C. The mean temperature of the coolest month is mainly 13–17°C, but the range is 10–22°C. Most of the area is frost-free but occasional frosts are recorded on inland sites at higher altitudes.

The 50 percentile rainfall is mainly 1000–1800 mm, the 10 percentile 600–1100 mm, and the lowest on record 500–900 mm. For most of the area there is a well-developed summer monsoon with most rain December–March and the months of July–October dry to very dry. The number of raindays varies widely, 50–150 depending on the climatic zone.

Physiography and soils. In Australia the greater part of the natural distribution is in the Peninsular and Burdekin Uplands but there are minor occurrences on the Lander–Barkly Plains and Northern Australian Plateaux physiographic provinces. It is found mainly on the gentle slopes and plains of coastal areas and on tablelands and gently undulating terrain along the Great Dividing Range. In Papua New Guinea and adjacent areas of Irian Jaya it occurs on the relict alluvial plain known as the Oriomo Plateau and in low foothills elsewhere.

It occurs on a range of acidic rocks including granite, sandstone, conglomerates, and to a lesser extent, basalt. The soils range from light brown volcanic clays to skeletal types, including coarse gravelly granitic podzolics, laterites, shallow clay duplex loams and alluvial soils of variable depth. The majority of soils are acidic, sandy or gravelly and well drained.

Vegetation type. *A. simsii* commonly occurs in open-forest and medium to low woodland dominated by eucalypts or acacias. Dominant eucalypts in the forest and woodland formations include *E. acmenoides*, *E. citriodora*, *E. crebra*, *E. intermedia*, *E. leptophleba*, *E. microtheca* and *E. polycarpa*. *Acacia holosericea*, *Grevillea glauca*, *G. parallela*, *Melaleuca viridiflora* and *Persoonia falcata* are associated with *A. simsii* in the understorey. In New Guinea it is often associated with the taller acacias *A. mangium*, *A. aulacocarpa*, and *A. crassicarpa*, and with *Melaleuca* spp. *A. simsii* is also a component of closed heath in the northern parts of Cape York Peninsula (Pedley and Isbell 1970). It may form dense thickets on disturbed sites.

Utilisation.

Fodder: Vercoe (1989) tested the fodder characteristics of both the seeds and phyllodes of *A. simsii*. While the phyllodes were of variable fodder potential, the seeds which are produced in abundance by this species from a young age appeared to provide the potential of a high-protein supplement. Once the hard seedcoat had been cracked, the seeds were easily digested and were of high protein and phosphorus.

Fuelwood: The large amount of relatively fine stem and branch wood is likely to be more suitable for direct use as firewood than conversion into charcoal.

Wood: Very small dimensions and not used in Australia.

Other uses: Is used in the revegetation of bauxite mining sites on Cape York Peninsula and as a garden ornamental in coastal towns in northern Queensland. It could be planted for erosion control, low windbreaks and rapid soil improvement.

Silvicultural features. This small multi-stemmed shrub grows rapidly and produces seed within two years. It is short-lived and may not survive more than about 6 years. It will tolerate a wide range of soil types but appears better adapted to well drained sites.

A. simsii does not appear to coppice either after cutting or fire damage. It forms both endo- and ecto-mycorrhizal associations.

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seed-coat dormancy. Average germination rate is 60% giving 81 700 viable seeds/kg. Its tendency to grow in dense thickets suggests that it could be planted at close spacing to provide small-sized firewood.

Yield: In trials in southeastern Queensland, average height growth of several plots was 3.8 m with a mean diameter at ground level of 9.1 cm at 4.5 years (Ryan and Bell 1991). It was amongst only a few acacias giving greater than 50% survival under irrigation on coarse-textured red earths (mildly acid) near Longreach, Queensland (Bell et al. 1991). Good survival was reported over a range of sites in Thailand with two provenances averaging 1.8 m in height at 12 months (Pinyopusarerk 1989). The species was subject to significant termite mortality (9 and 16%) in trials in Zimbabwe (Mitchell 1989).

Pests and diseases. None recorded.

Limitations. A short-lived, fire-sensitive, non-coppicing species. The small size of *A. simsii* will restrict its use to small fuelwood or non-wood uses such as low windbreaks. Its ability to produce seed rapidly and to form thickets suggests that it has high potential for weediness.

Related species. The flower structure and phyllode venation suggest that *A. simsii* is related to *A. ramiflora*, *A. excelsa*, *A. complanata*, *A. legnota*, *A. fleckeri*, and *A. multisiliqua* (Pedley 1978). It is also closely related to *A. confusa* of Taiwan and the Philippines, and Pedley (1975) speculates that *A. confusa* may have evolved from *A. simsii*.

Acacia stenophylla

Main attributes. A nitrogen-fixing small tree adapted to saline, heavy clay soils in arid and semi-arid areas where supplementary groundwater is available. Suitable for fuelwood, small round timbers, shelterbelt planting and amenity purposes.

Botanical name. *Acacia stenophylla*, A. Cunn. ex Benth. in Hooker's *London J. Bot*. 1: 366 (1842). The species name is derived from the Greek, *stenos* — narrow, and *phyllon* — leaf, alluding to the characteristic very narrow phyllodes.

Common names. River cooba (standard trade name), also river myall, belalie, dunthy, black wattle, dalby wattle, ironwood, native willow, eumung, eumong, gurley.

Family. Mimosaceae.

Botanical features. *A. stenophylla* is typically a small tree 4–10 m tall. It may be erect and single-stemmed or divided into several stems about 1 m above the ground. The spreading pendulous branches form a rounded crown. The bark is dark grey-brown, rough, and fibrous. Phyllodes long and narrow, 15–40 cm by 3–8 mm, straight or sometimes curved, usually smooth, with many prominent fine longitudinal nerves, the central nerve slightly more prominent than the rest, apex acute and often hooked.

The flowers are pale yellow, in globular heads on short stalks in clusters or short racemes of 1–6 heads. Pods are grey, bluish-grey or brown, strongly constricted between the seeds, 10–20 cm long by 1 cm broad, straight or curved, slightly wrinkled over the seeds. Seeds longitudinal in the pod, brown, oval-shaped, 7 mm long, 5–6 mm wide, with a small white aril. The seed is not easily separated from the pod, which breaks up into single-seed units. Flowers irregularly throughout the year, or in April to July with pods mature from September to December in Queensland (Pedley 1978; Searle 1989). February to May are given as seed-collecting months in South Australia (Bonney 1994).

The species is described by Pedley (1978) and illustrated by Whibley and Symon (1992) and Tame (1992).

Natural occurrence. This acacia has an extensive distribution in central and eastern Australia. It is found

from the River Murray in South Australia and Victoria to western New South Wales, Queensland, Northern Territory, with a small extension into Western Australia.

- Latitude. Main occurrence: 23–33°S.
  Range: 17–36°S.
- Altitude. Main occurrence: 50–325 m.
  Range: near sea level to 625 m.

Climate. The majority of the distribution is in the warm arid climatic zone, but some of the large trees and more extensive stands grow in the semi-arid zone of New South Wales and Queensland. The species extends into the sub-humid zone in southeastern Queensland. Except at its southern limits, the mean maximum temperature of the hottest month is 35–38°C and the mean minimum of the coolest month 4–7°C. On average there are 110–130 days per year over 32°C and 15–50 days over 38°C. The average number of heavy frosts per year is 1–20.

There is a wide range in rainfall together with high variability. The 50 percentile is 125–600 mm, the 10 percentile 60–350 mm, and lowest on record 40–200 mm. Over most of the region there is a well-developed to moderate summer maximum. In the most northern districts, rainfall is monsoonal with most falling in summer, but at the southern extremity of the distribution there is a winter maximum. In many areas the mean monthly rainfall is very variable from year to year and from season to season. The incident rainfall is often supplemented by groundwater or periodic flooding.

Climatic indicators for predicting areas suitable for growing *A. stenophylla* are given by Marcar et al. (1995).

Physiography and soils. *A. stenophylla* is widely distributed throughout the Interior Lowlands physiographic division. It occurs on plains and gentle slopes and is common on the margins of watercourses, river flood plains, and depressions. The soils are mainly fine-textured alluvials, grey cracking clays, and red sandy clay. They may have a high pH and may be saline in the lower horizons.

Vegetation type. *A. stenophylla* occurs in ribbon-like stands along watercourses as a component of open-forest, woodland or low woodland dominated by eucalypts. Close to the rivers *E. camaldulensis* is the principal species and is flanked by communities of *E. coolabah* (in the north) and *E. largiflorens* (in the south). *A. stenophylla* is present in the understorey, often with *A. salicina* and *A. pendula*. It also occurs in association with *E. populnea* and *Casuarina cristata*, but frequently forms pure stands along watercourses in semi-arid areas (Pedley 1978).

Utilisation.

Fodder: It is rarely utilised by cattle (Cunningham et al. 1981) but it is palatable to sheep (Everist 1969) and could be a useful fodder reserve in droughts. Vercoe (1987) estimated an in vivo dry matter digestibility of 43% and crude protein level of 11% for phyllodes in one trial. However, a second study on different material was less promising, suggesting variation between provenances (Vercoe 1989).

Fuelwood: It is an excellent fuel (Hall et al. 1972).

Wood: The timber is very hard, heavy, close-grained, dark, reddish-brown to almost black and beautifully marked, and is suitable for furniture (Maiden 1922). Air-dry density is 900 kg/m^3 (Davis 1994). It is used for fence posts.

Other uses: It makes a good windbreak and is quite ornamental. It also has potential for rehabilitating mine dumps (Lamont 1978).

Seeds and pods were roasted and used by Australian Aboriginal people as a food source (Cribb and Cribb 1976).

Silvicultural features. *A. stenophylla* is highly salt-tolerant (expect significant growth reduction at EC_e about 10–15 dS/m with reduced survival above 15 dS/m), tolerant of alkalinity and periodic flooding, and is adapted to a wide climatic range (Marcar et al. 1995). It is only moderately drought and frost tolerant in cultivation (Forestry Commission of New South Wales 1980).

Coppicing and root suckering have been noted in natural stands (Searle 1989; Bonney 1994).

Establishment: Propagation is by seed that has been immersed in near-boiling water (90°C) for 1 minute. Manual and acid scarification are also effective seed pretreatments, but the standard boiling water treatment at 100°C is too severe (Doran and Gunn 1987). Germination rate averages 73% and there are 10 600 viable seeds/kg. The species may be amenable to micropropagation (Crawford and Hartney 1987).

Yield: A. stenophylla has given variable performance in trials, often surviving only poorly when planted on acid, freely draining sites to which it is poorly adapted (e.g. Chege and Stewart 1991; Kimondo 1991; Ryan and Bell 1991). Where survival has been good (± 80%), mean annual increments for height growth are in the range 0.8–1.7 m. The best growth reported was on a sodic site in Pakistan where trees averaged 2.3 m tall and individual trees were as high as 4.2 m at 16 months (Marcar et al. 1991b). Marked variation in form of provenances has been noted (Marcar et al. 1995), indicating the need to test a range of provenances in introductory trials.

Pests and diseases. The seeds are sometimes heavily attacked by insects.

Limitations. This species is only moderately drought-tolerant and its planting in arid areas should be limited to sites where supplementary water is available.

Related species. *A. stenophylla* is frequently confused with and bears a superficial resemblance to *A. coriacea*, although they are probably not closely related (Cowan and Maslin 1993). *A. stenophylla* differs from *A. coriacea* in having wider-spaced phyllode nervation and seeds with a white aril. The pods of *A. stenophylla* are not dehiscent as in *A. coriacea*.

Acacia stipuligera

Main attributes. A moderately fast-growing shrub or small tree with potential for fuelwood production and sand stabilisation in hot, semi-arid, subtropical and tropical zones. The seeds have potential as a famine or subsistence food for humans.

Botanical name. *Acacia stipuligera* F. Muell. in *J. Proc. Linn. Soc. Bot.* 3: 144 (1859) and a subspecies *glabrifolia* Maiden and Blakely in *Proc. Roy. Soc. Queensland* 38: 120 (1927). The derivation of the species name is from the Latin *stipula* — stalk, blade, stipule, and *gero* — to bear, in allusion to the persistent stipules.

Common names. Tjilpirinpa, Kulaiaan.

Family. Mimosaceae.

Botanical features. *Acacia stipuligera* is a spreading, multi-stemmed shrub or small tree 2–5 m tall by 3–7 m across. The trunk is typically divided into 3 or more stems near ground level. The bark is smooth, sometimes slightly fissured and light grey with a purplish hue. The branchlets are round, slightly ribbed, and vary from slightly pubescent (in Queensland) to densely covered in white short soft hairs (Northern Territory and Western Australia). Stipules are persistent, dark brown and broadly triangular, 1.5–2 mm long, sparsely hairy. The phyllodes are alternate, almost stalkless, elliptical, 3–6 by 1–1.7 cm, slightly asymmetric (Maslin 1981), bluish to yellowish green, with 2 or 3 longitudinal nerves and a prominent gland up to 1 cm from the base. Two subspecies are distinguished mainly on the characteristics of the phyllodes and young tips: subsp. *glabrifolia* from Queensland with resinous young tips and glabrous phyllodes (Pedley 1987b, 1990a), and subsp. *stipuligera*, which is pubescent.

The inflorescence is a cylindrical spike 2–3 cm long, on a hairy stalk 1–5 mm long. Bright yellow flowers are produced in profusion. The pod is narrowly cylindrical, glabrous, straight, woody, 4–10 cm long and 2.5–4 mm wide, the margins sometimes sticky. There are distinct longitudinal ridges or lines on the pod in individuals found in Queensland, but indistinctly so in those from Western Australia (Wheeler et al. 1992; Pedley 1978). The seeds are longitudinal, narrow rectangular, 4–5 mm × 2 mm, brown with a pale area surrounding the areole and a large, white, cap-like aril. Flowering occurs between May and July (Pedley 1978). Seed matures in September–October.

The species is described by Maslin (1981) and illustrated by Thomson and Hall (1989c) and Wheeler et al. (1992).

Natural occurrence. *A. stipuligera* has a wide distribution in northern Australia. Its main occurrence is in a broad belt which extends from coastal northwestern Australia through the central part of the Northern Territory to near the Queensland border. There is a major disjunction of 900 km to the most eastern populations in central-eastern Queensland. An outlier population at Carlia Creek in the Kimberleys is the most northern record.

- Latitude. Range: 15–24°S
- Altitude. Range: near sea level to 525 m.

Climate. *A. stipuligera* is predominantly a species of the hot semi-arid and arid zones, with a small extension into the sub-humid zone. The summers are very hot and the area is largely frost-free. The mean maximum temperature of the hottest month is 34–41°C. The temperature exceeds 38°C between 28–52 days per year. The mean minimum temperature of the coolest month is 9–12°C and the lowest recorded –4°C. Temperatures rarely drop below zero and only the more elevated, southern localities would experience more than one frost per year.

The 50 percentile rainfall is 300–700 mm, the 10 percentile 124–420 mm and the lowest on record 70–382 mm. Rainfall follows a strong monsoonal pattern in the north, grading into a well-defined summer maximum in the south and east.

Physiography and soils. The greater part of the distribution is in the Western Plateau physiographic division, but it is also found in the northern part of the

Eastern Uplands division. *A. stipuligera* flourishes on sandy sites receiving run-on water. It is not, however, confined to low-lying areas, and commonly occurs on sandplains and the lower parts and base of sand dunes. It has also been recorded from the base of quartzite hills, sandstone cliffs and lateritic outcrops.

The soils are well-drained, predominately deep red sands and sandy loams. Other soil types include brown sandy loams, red earths, gravelly sands and stony alluvials. The soils are mainly acid to neutral, but it has also been recorded growing on sand over limestone.

Vegetation type. *A. stipuligera* forms thickets in low-lying sandy areas. It also occurs in the acacia-dominated 'pindan' scrubs of northwestern Australia and in tall open-shrublands and open scrubs. Associated shrub species include *A. adsurgens*, *A. ancistrocarpa*, *A. coriacea*, *A. cowleana*, *A. drepanocarpa*, *A. lysiphloia*, *A. monticola* and *A. tenuissima* and species in the genera *Capparis*, *Senna*, *Dodonaea*, *Eremophila*, *Grevillea*, *Hibiscus*, *Melaleuca* and *Petalostylis*. On many sites spinifex grasses (species of *Triodia* and *Plectrachne*) are abundant.

It also occurs in open-woodland communities with scattered, often stunted trees including *Allocasuarina decaisneana*, *Eucalyptus argillacea*, *E. brachyandra*, *E. brevifolia*, *E. melanophloia*, *E. papuana*, *E. pruinosa*, *E. similis*, various bloodwoods including *E. cliftoniana* and *E. erythrophloia*, and several *Hakea* species.

Utilisation.

Fodder: Its fodder value is unknown. *A. stipuligera* gave a negative response when tested for the presence of cyanide (HCN) (Conn et al. 1985).

Fuelwood: It should be suitable for use as fuelwood.

Wood: It has a broad pale yellowish sapwood and dark brown heartwood, and a basic density of 810 kg/m^3 (Davis 1994). The wood is available only in small diameters.

Other uses: The species has potential for sand stabilisation and should make an outstanding ornamental under cultivation (although rather short-lived). The relatively soft-coated seeds are produced in profusion in good seasons, easily harvested, and have been used traditionally for food by Australian Aboriginal people (O'Connell et al. 1983; Thomson 1992). The nutritional composition of *A. stipuligera* seeds is given by Brand and Maggiore (1992). Its seed has potential as a famine or subsistence food for humans.

The gum of *A. stipuligera* has similar features to the gums from *A. torulosa*, *A. tumida* and *A. difficilis*. It has a low rhamnose content, negative rotations and high values for nitrogen, methoxyl and uronic acid groups. It is unique for an *Acacia* in the formation of a loose gel during dialysis (Anderson et al. 1983).

Silvicultural features. The species has only recently been included in field trials, and hence little growth data is available. Field observations suggest it is moderately fast-growing, short-lived (< 10 years) and a poor coppicer. Fully-grown plants are killed by fire, but young plants may resprout following partial crown damage.

Establishment: The species is readily propagated from seed, of which there are about 80 800 viable seeds/kg at a germination rate of 85%. It is necessary to carry out pretreatment of the seed by immersion in boiling water for 30–60 seconds to remove seedcoat dormancy prior to sowing. Plants flower at a young age, e.g. flower heads were observed at 11 months in trials in southeastern Queensland (Ryan and Bell 1989). A nursery phase of 10–12 weeks is recommended.

Yield: In a trial in southeastern Queensland, *A. stipuligera* attained 4.1 m in height at 4.5 years; however, survival was poor at this site (38%) (Ryan and Bell 1991).

Pests and diseases. None are recorded.

Limitations. Its small size will limit its use to fuelwood production and soil stabilisation, but its short life span and poor coppicing ability are limitations for these purposes.

Related species. *A. stipuligera* is a member of section Juliflorae and is most closely related to *A. conspersa* (Thomson et al. 1994).

Acacia tephrina

Main attributes. A tree to 20 m tall growing on heavy clay soils in tropical warm to hot, semi-arid environments. It fixes nitrogen and has potential for fuelwood, posts, poles, shelter, and fodder.

Botanical name. *Acacia tephrina* Pedley in *Austrobaileya* 1(4): 342 (1981). The specific name appears to be based on the Greek *tephro* — grey, ash-grey, alluding to the dense hairs on the branchlets and phyllodes. Before 1981, occurrences of *A. tephrina* were included under *A. cana*.

Common names. Boree is widely used but the name is also given to *Acacia pendula* in New South Wales.

Family. Mimosaceae.

Botanical features. This acacia is an erect tree 10–20 m tall with a narrow, high crown when in dense stands on favourable sites. Elsewhere it is a small tree, 4–9 m high, with a wider and deeper crown. The bark is thick, dark grey and more or less tessellated.

The phyllodes are straight or slightly curved, long and narrow, 7–17 cm by 2–6 mm wide. The phyllodes and branchlets are covered with a dense mat of short, white hairs. The flowers are in globular heads on a branched raceme. The pod is long and narrow, up to 6.5 cm by 5 mm, flat, and slightly contracted between the longitudinally arranged seeds. The seeds are 5.5 mm long by 3.5 mm wide with a small basal aril. The species is reported to be winter-flowering (May–June) (Latz 1992) and mature seed has been collected in November (Searle 1989).

The botanical features are described by Pedley (1981) and Maslin (1981).

Natural occurrence. The principal distribution of *A. tephrina* is in a relatively compact area of north-central Queensland, mainly west of the Great Dividing Range but extending to the coast near Bowen.

- Latitude. Range: 18–27°S.
- Altitude. Main occurrence: 200–400 m.
  Range: near sea level to 450 m.

Climate. The most common occurrence is in the warm semi-arid climatic zone, with some extension into the hot semi-arid zone in the west of the distribution and into the warm sub-humid zone in the east. In the main area the mean maximum temperature of the hottest month is 35–38°C, the mean minimum of the coolest 5–10°C. The number of days over 32°C is

mainly 125–140. There are 28–42 days over 38°C. Most localities have 1–5 heavy frosts each year, with a few places up to 15.

The 50 percentile rainfall is 400–550 mm, the 10 percentile 200–300 mm, and the lowest on record 100–200 mm. There is a summer maximum rainfall throughout the area and a dry season (less than 30 mm a month) of 4–8 months. The average number of raindays is 40–54.

Physiography and soils. The main occurrence of *A. tephrina* is in the Central Lowlands province of the Interior Lowlands physiographic division on very gently undulating topography. The eastern stands are in the Fitzroy Uplands on relatively gentle slopes or shallow open valleys in hilly country. This acacia occurs frequently on cracking clay soils, often over calcareous shales. It is recorded from red, brown, and grey clays, black earths, red earths and from red and yellow earth sands. The clay soils have a moderate to low nutrient status, and are frequently alkaline (to pH 9) or neutral at the surface and saline.

Vegetation type. *A. tephrina* occurs as tall woodland in the moister parts of its range and as low woodland or open-shrublands in more arid areas. In the tall woodland this acacia often occurs in almost pure stands, with a canopy level of 15–20 m and only a grassy understorey. Communities of *A. tephrina* or *A. tephrina*–*A. cambagei* often occur on the fringes of and form mosaics with grasslands of *Astrebla* species. Species such as *Lysiphyllum carronii*, *Alectryon oleifolius*, *Atalaya hemiglauca* and *Flindersia maculosa* may be found in the canopy layer, especially in more mesic areas, with *Eremophila* spp. forming an often very sparse low shrub layer (Johnson and Burrows 1981). In some localities

A. tephrina replaces *A. cambagei* on higher ground (Davidson 1954). In the drier areas on fine-textured soils, *A. tephrina* is a component of sparse low woodland or tall open-shrubland, with *Atalaya hemiglauca* and *Grevillea striata* common associates (Perry and Lazarides 1964).

Utilisation.

Fodder: Eaten by both sheep and cattle in times of drought but should not be fed as the sole diet to sheep as impaction will develop (Everist 1969).

Fuelwood: The wood has been compared with that of *A. cambagei*, which makes an excellent fuel, burns green or dry and with intense heat (NAS 1980). It makes large quantities of ash and it is difficult to keep fire bars clean.

Wood: The wood is hard, heavy, and dark red-brown in colour. It is suitable for posts, rails, and poles.

Other uses: It has potential to provide light, shade and shelter.

Silvicultural features. *A. tephrina* is a moderate to slow-growing, long-lived (i.e. > 50 years) tree that can tolerate a long dry season and alkaline, heavy clay soils. Seedlings proved moderately tolerant of salt in a glasshouse screening trial (Aswathappa et. al. 1987).

The species appears to regenerate readily in nature from coppice and root suckers.

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seed-coat dormancy. Only one seedlot has been available for seed testing. It gave a germination rate of 40% and 23 300 viable seeds/kg.

Yield: A. tephrina was unsuccessful when planted in trials in southeastern Queensland, failing completely on one site and giving 13% survival on another.

Surviving individuals grew very slowly, reaching only 0.6 m at 4.5 years (Ryan and Bell 1991). These sites have soils quite different from the alkaline–neutral clays to which this species is adapted. Performance of the species outside Australia is unknown.

Pests and diseases. None recorded.

Limitations. The wood has a high ash content. Its growth rate is relatively slow.

Related species. It is closely related to *A. cana* of New South Wales. *A. cana* has sharply pointed, often narrower phyllodes and differences in the inflorescence (Pedley 1981). Other related species are *A. calcicola*, *A. maconochieana* and *A. microcephala* (Thomson et al. 1994).

Acacia torulosa

Main attributes. A small, fast-growing shrub or small tree adapted to a wide range of sites in tropical hot sub-humid and hot semi-arid climatic zones. It is nitrogen-fixing and potentially useful for fuelwood, low shelter, ornamental purposes and human food.

Botanical name. *Acacia torulosa* Benth. in *J. Proc. Linn. Soc. Bot*. 3: 139 (1859). The specific name is derived from the Latin *torulus* — a little bulge, and *osus* — abounding in, and refers to the pods, which are strongly constricted between the seeds.

Common names. Torulosa wattle, deep-gold wattle, thancoupie.

Family. Mimosaceae.

Botanical features. A shrub or small tree, often 5–8 m tall but may reach 12 m, with a wide crown. Branchlets angular and yellowish. Phyllodes hairless, straight or curved, very narrow, broadest about the middle, 9–17 cm long by 5–12 mm wide, 1–3 nerves more prominent than the rest. The dull gold flowers are on spikes usually 1–3 cm long (Pedley 1978) but may be 6–10 cm (Hearne 1975) in axillary pairs. The pod is contracted between the seeds and raised above them, up to 10–16 cm long by 3–6 mm wide, longitudinally wrinkled and yellow-brown. The seeds are longitudinal in the pod, 4–7 mm long by 3–5 mm wide, shiny brown-dark brown, with a very small pale terminal aril. Flowering is from May to July and the fruits mature August–December.

It is described by Pedley (1978) and illustrated by Brock (1988).

Natural occurrence. This is a species of northern Australia where the main distribution is in the lowlands of the north of the Northern Territory and Cape York Peninsula, Queensland. There are isolated occurrences in Western Australia.

- Latitude. Main occurrence: 12–18°S.
  Range: 11–22°S.
- Altitude. Main occurrence: near sea level to 250 m.
  Range: near sea level to 350 m.

Climate. Most of the distribution is in the hot sub-humid climatic zone but there is also an appreciable area that is hot semi-arid. It rarely occurs in the hot humid zone. The mean maximum temperature of the hottest month is 34–38°C and the mean maximum of the coolest is about 11–17°C. There is great variation in the number of very hot days, inland localities may have about 280 days over 32°C and 70 days above 38°C, whereas coastal locations in eastern Australia may have 80 days and 2 days, respectively. Heavy frosts are absent from most of the area but at a few of the more inland locations frost may be recorded once or twice annually.

There is considerable variation in rainfall but for most of the distribution the 50 percentile is 700–1150 mm, 10 percentile 275–800 mm, and the lowest on record 225–475 mm. In northern areas there is a strong monsoonal pattern of rainfall with a long dry season May–October. In southern localities of Queensland there is a well-developed summer maximum with less summer rain but with a similar long dry season. The number of raindays each year is about 40–80.

Physiography and soils. *A. torulosa* grows in the three main physiographic divisions, i.e. Western Plateau, Interior Lowlands, and Eastern Uplands. Much of the topography consists of gentle to moderate slopes but there are areas of more rugged country, especially in the Western Plateau. *A. torulosa* is present on the plains and gentle topography of the Interior Lowlands and on the more variable slopes of the Eastern Uplands. It is recorded from extensive plains, stony hills, ridges of steep slopes, beach dunes, and stream banks.

The soils are often alluvial or colluvial derived from a variety of parent materials, but are commonly sandy red and yellow earths of sandstone origin. They are usually well-drained and include deep sands, rocky skeletals, silts, and loams. Some of the largest trees grow on alluvial sandy loams. The soils are generally acidic and of low fertility but may be alkaline or slightly saline in some localities.

Vegetation type. *A. torulosa* sometimes forms dense stands of slender unbranched trees similar to *A. shirleyi*

(Pedley 1978). It is also found in a wide range of vegetation types with the majority of occurrences being in low woodland or low open-forest. The formations may be layered with eucalypts forming the upper canopy and *A. torulosa* being present in the shrub layer. Associated species include *Acacia crassicarpa*, *Adenanthera abrosperma*, *Alphitonia excelsa*, *E. brevifolia*, *E. dichromophloia E. miniata*, *E. leptophleba*, *E. papuana*, *E. phoenicia*, *E. setosa*, *E. shirleyi*, *E. similis*, *E. tetrodonta*, *Erythrophleum chlorostachys*, *Grevillea glauca*, *Melaleuca nervosa*, *Parinari nonda* and *Syzygium suborbiculare*.

In semi-arid localities of the Northern Territory it occurs on sand-dunes and stony rises with spinifex, *Triodia* spp. In Western Australia it is found as a minor component of 'pindan', a grassland wooded by a sparse upper layer of trees and a dense, thicket-forming middle layer of *Acacia* spp. (Beard 1979). It occurs in woodland or shrubland on coastal sand-dunes and woodland dominated by melaleucas.

Utilisation.

Fodder: Of little value for forage (Vercoe 1989).

Fuelwood: It should produce good quality fuelwood.

Wood: Dark brown, tough and strong. Air-dry density about 720 kg/m^3.

Other uses: Recommended for planting in gardens or amenity areas (Hearne 1975). Its broad crown gives good shade and it has been used as a low windbreak in Niger. Used for mine-site rehabilitation in northern Australia (Langkamp 1987).

The easily harvested seed has potential as a human food. However, a noxious dust is given off during processing (House and Harwood 1992).

Silvicultural features. A large shrub to small spreading tree, moderately long-lived (i.e. 10–50 years) with rapid growth when young. It was the least salt-tolerant of a range of acacias screened in a glasshouse trial (Aswathappa et al. 1987). Its intolerance to high soil alkalinity (pH 8 and above) has been demonstrated by its failure on such sites in Indonesia (McKinnell and Harisetijono 1991). *A. torulosa* has been reported to form endomycorrhizal associations (Reddell and Warren 1987). Coppicing ability is variable but most reports suggest it to be poor (Ryan and Bell 1989).

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seedcoat dormancy. Flowering has been noted as early as 23 months in trials in southeastern Queensland (Ryan and Bell 1989). Germination rate averages 80% and there are 26 700 viable seeds/kg. A minimum nursery phase of 3–4 months is recommended (Ngulube 1988).

Yield: In trials of several provenances in south eastern Queensland, overall growth (MAI for height: 1.6 m) and survival (84%) to age 4.5 years were good. It was one of only a few acacias to give better than 50% survival under irrigation on coarse textured soils near Longreach. It survived poorly on the same site when not irrigated (Ryan and Bell 1991). It grew well on raised coral terrace soils (ultisols) of pH 7.5 in Indonesia, averaging 2.7 m in 2 years (McKinnell and Harisetijono 1991), and was listed as a species warranting further study in Zimbabwe where it had attained up to 2.1 m in 1.5 years (Gwaze 1989). Growth in Kenya was variable and was marred by generally poor survival (Chege and Stewart 1991; Kimondo 1991). Provenance variation in growth and survival indicate that a range of provenances should be screened when testing this species.

Pests and diseases. *A. torulosa* is damaged by termites and suffers minor borer damage under natural conditions. Minor damage by the sap sucker *Eriococcus coriaceus* was recorded on plants in southeastern Queensland (Ryan and Bell 1991).

Limitations. The small size will restrict its use to fuelwood or small roundwood. It is not adapted to poorly drained sites or severe frosts.

Related species. It is a close relative of *A. tumida* and *A. eriopoda*. Fruiting specimens are rarely misidentified. However, in their absence it is often confused with *A. plectocarpa*.

Acacia trachycarpa

Main attributes. A moderately fast growing, multi-stemmed shrub or small tree adapted to a range of soils in the hot arid and semi-arid tropics. Has good potential for fuelwood, forage, and for soil protection.

Botanical name. *Acacia trachycarpa* E. Pritzel in *Bot. Jahrb*. 35: 308 (1904). The specific name is from the Greek *trachys* — rough, and *carpos* — fruit, referring to the surface texture of the pod.

Common names. Minni Ritchi (also applied to other acacia species with a similar type of bark).

Family. Mimosaceae.

Botanical features. A multi-stemmed, spreading shrub to small tree, 1–8 m tall, with dark reddish bark peeling in narrow curled strips to form the typical 'minni ritchi' bark type. The phyllodes are flat, narrowly linear, 3–8 cm long by 1–2 mm wide, non-shiny, slightly resinous, with 1 or 2 prominent longitudinal nerves and a thickened upper marginal nerve. The foliage is dense, soft and delicate. The stipules are persistent on the branchlets. Flower heads are yellow, distinctly cylindrical, 1–2 cm long. Pods are strongly curved, 8–10 mm wide, resinous and sticky, frequently with sparse golden hairs, and with net-like venation. Seeds obliquely orientated in the pod, shiny, brown, oblong to round, flattened, 5–8 mm long, 4–7 mm wide, with a small continuous areole surrounded by a narrow band of pale tissue, and a creamy yellow terminal aril. Flowers from April to August (Craig 1983; Simmons 1981) and seeds are mature in October–November.

It is described and illustrated in Wheeler et al. (1992) and Simmons (1981).

Natural occurrence. *A. trachycarpa* is mainly confined to the Pilbara area in the northwest of Western Australia.

- Latitude. Range: 20–24°S.
- Altitude. Range: near sea level to 400 m.

Climate. The distribution lies in the warm to hot, arid and semi-arid climatic zones. The mean maximum of the hottest month is in the range 37–42°C, the mean minimum of the coolest month 8–12°C. On the coast there are 170 days over 32°C and 30 over 38°C each year, but inland there are about 250 days over 32°C and 160 days over 35°C. Coastal areas are frost-free but inland there are 2–5 frosts annually, with the lowest temperature on record near –3°C.

The 50 percentile rainfall is 230–400 mm, the 10 percentile 120–180 mm, and the lowest on record 20–70 mm. The rainfall has a summer maximum with a dry season of 7–8 months. There are 20–40 raindays each year.

Physiography and soils. *A. trachycarpa* is confined to the Pilbara Province of the Western Plateau physiographic division on sand plains and rolling, stony topography. It is found commonly along creeks and rivers (Maslin 1982). The soils are chiefly shallow earthy or stony sands with some cracking clays and calcareous earths. They are derived from sandstones, shales, and limestone. The coastal plains are mainly red earthy sands derived from sandstones. The soils are infertile and neutral to alkaline in reaction. The topography, geology, and soils of the region are described in detail by Beard (1975).

Vegetation type. *A. trachycarpa* is a component of tall shrubland or is present in the understorey of open-forest or woodland communities fringing watercourses. In the 'pindan' shrubland of the sand plains it may form pure thickets or be associated with other acacias including *A. coriacea*, *A. holosericea*, *A. monticola*, *A. stipuligera*, and *A. tumida*. On minor drainage lines it occurs with *Eucalyptus aspera*, *A. coriacea*, and *A. sclerosperma*; and on the fringes of major creeks it is found with *A. coriacea* and *Hibiscus panduriformis* under tall trees of *E. camaldulensis* and *Melaleuca leucadendra* (Burbidge 1959). On the rolling stony country it occurs with *E. gamophylla*, *E. leucophloia*, *A. ancistrocarpa*, *A. bivenosa*, *A. grasbyi*, *A. pyrifolia*, *Grevillea wickhamii*, and *Hakea suberosa* (Beard 1975).

Utilisation.

Fodder: This species was unknown as a fodder species in Australia but in West Africa it retains its foliage during the dry season and is palatable to sheep, cattle and goats (Cossalter 1987). A trial in Senegal planted at 3 m × 3m spacing produced 2.03 t/ha of foliage at 1.5 years (Hamel 1980), while 3.3 t/ha of foliage was produced after 2.2 years at 2 m × 1.5 m spacing in Malawi (Maghembe and Prins 1994). Maslin et al. (1987) found hydrogen cyanide in the leaves but at levels well below those considered dangerous.

Fuelwood: The many fine branches produced by this shrub are more useful for fuelwood than for charcoal. The air-dry density is 770 kg/m^3 and the calorific value 4740 kcal/kg. A trial in Senegal produced 11.7 t/ha/year of green wood, slightly less than *A. holosericea* at 13.2 t/ha/year on the same site (CTFT 1984).

Wood: Not tested in Australia. The small size of the stems will limit use to fuelwood.

Other uses: Has potential for erosion control and the fixation of sand dunes (Hamel 1980). Used successfully in Niger as a low windbreak.

Silvicultural features. A small, moderately fast-growing shrub or tree. It is sensitive to frost and does not appear to be very fire-tolerant. In West Africa, *A. trachycarpa* appears best adapted to coastal areas where annual rainfall is greater than 500 mm or areas that receive run-on water (Cossalter 1987). It regenerates readily from seed and has been reported to root sucker. Coppicing ability is variable, ranging from poor to good (Thomson et al. 1994).

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seed-coat dormancy (Gunn 1990). Germination rate is 68% and there are 12 100 viable seeds/kg.

Yield: Trials of this species in West Africa have been made with a single provenance from a coastal area of Western Australia. Initial growth rate was fast. On an alluvial soil at Keur Mactar, Senegal, with a mean annual rainfall of 587 mm and a dry season of 7 months, a trial plot of *A. trachycarpa* at 1.5 years of age had a mean height of 2.68 m and a survival rate of 95% (Hamel 1980). At several other sites in Senegal, growth averaged 3.6 m ± 15% at 5.5 years (Thomson 1989a). Elsewhere in Africa performance has been poor, e.g. in Kenya (Chege and Stewart 1991; Kimondo 1991) and Malawi (Maghembe and Prins 1994).

Pests and diseases. None are recorded.

Limitations. The small size of this species will restrict the range of uses to which it can be applied. *A. trachycarpa* is regarded as a highly variable taxon encompassing at least two subspecies. Few provenances have been trialed because of lack of seed. Sampling and testing of a wider range of provenances is to be recommended.

Related species. *A. trachycarpa* is closely related to *A. lysiphloia*, *A. gracillima*, and *A. chisholmii* (Hopper and Maslin 1978) and to *A. monticola* and *A. effusa* (Thomson et al. 1994). It forms natural hybrids with *A. ancistrocarpa* (Maslin 1983) and *A. tumida* (Thomson et al. 1994).

Acacia trachyphloia

Main attributes. A fast-growing, nitrogen-fixing erect tree adapted to cool–warm sub-humid conditions. Has potential to produce fuelwood, poles and timber in the tropical highlands or subtropical and warm temperate lowlands. A useful tree for windbreaks and amenity purposes.

Botanical name. *Acacia trachyphloia* Tindale in the *Proc. Linn. Soc. NSW.* 85: 248 (1960). The name is derived from the Greek *trachys* — rough, shaggy, and *phloios* — bark of a tree, alluding to the species rough bark, especially on the lower part of the trunk.

Common names. Bodalla wattle, a name also applied to *A. silvestris*.

Family. Mimosaceae.

Botanical features. A shrub or small tree 3–18 m tall, bark smooth grey becoming rough and corrugated with age. Young shoots and branchlets with long, golden silky hairs. The bipinnate leaves are dark green above, slightly paler beneath on stalks 3–15 mm long, without glands, the rib of the leaves is 3.5–8 cm long with long, silky golden hairs, and globose, hairy glands between the upper 4–8 pairs of pinnae only. Each leaf has about 9–22 pairs of pinnae, 1–3.5 cm long with 16–28 pairs of narrow oblong leaflets (pinnules) 1–2.5 mm long and 3–4 mm wide, with golden or white appressed hairs below and often above.

The yellow flowers are in globose heads, in racemes of panicles each with 10–16 flowers. Pods are relatively straight and flat, margin sometimes thickened, brownish black or dark blue, somewhat leathery, glaucous, glabrous, not constricted between the seeds 4–7 cm long by 4–8 mm broad. Seeds are black, glossy, oblong-elliptical, longitudinal in the pod with a prominent aril over the apex of the seed. Flowering time is from August to October, with pods ripening around December (Tindale 1960).

The species is decribed by Tindale (1960) and Tame (1992). It is illustrated by Costermans (1981) and Harden (1991).

Natural occurrence. This species is restricted to a small area in coastal southeastern New South Wales from Lake Conjola to Bodalla State Forest. It extends to adjoining areas on the Southern Tablelands, around Braidwood.

- Latitude. Range: 35–36°S.
- Altitude. Main occurrence: 10–650 m.
  Range: near sea level to 900 m.

Climate. The coastal distribution lies in the warm humid climatic zone, with a belt of the warm sub-humid zone. The populations on the tablelands are in the cool sub-humid zone. The mean maximum temperature of the hottest month is 23–26°C and the mean minimum of the coolest month 0–6°C. There are 4–20 days over 32°C, on average. The coastal areas are frost-free, but elsewhere heavy frosts occur on average from 1–66 days annually.

The 50 percentile rainfall is 700–950 mm, the 10 percentile 465–700 mm, and the lowest on record 390–500 mm. Rain is recorded on an average of 110 days per year. Seasonal distribution is mainly a summer maximum, that extends to about mid-winter (June). The driest months are August to September.

Physiography and soils. *A. trachyphloia* is restricted to a small Kosciuskan Uplands province of the area within the Eastern Uplands physiographic division. It is found along creek flats on heavy alluvial soils in undulating country, moist gullies and flood banks. It is also found on rocky hillsides. *A. trachyphloia* has been recorded growing in gravelly clays, red-brown volcanics and stony colluvial soils.

Vegetation type. Most frequently a co-dominant or understorey species in open-forest dominated by various eucalypts including *Eucalyptus fastigata*, *E. maculata*, *E. radiata* subsp. *radiata*, *E. saligna* and *E. viminalis*. Other associates include *Acacia longifolia*, *A. filicifolia*, *A. irrorata*, *A. mearnsii*, *A. mabellae* and *Syncarpia glomulifera*.

Utilisation.

Fodder: The value for forage is unknown.

Fuelwood: No specific information available but probably is a good fuel.

Wood: The wood is reported to be very hard, but no other information on wood properties is readily available.

Other uses: The soft, dark-green ferny foliage and contrasting pendulous golden tips make it a useful tree for ornamental purposes. Also used for windbreaks.

Silvicultural features. A fast-growing species that will withstand moderate frosts. It appears to be a poor coppicer (Ryan and Bell 1989). The full potential of this species for multiple purpose uses has yet to be elucidated.

Establishment: Propagation is by seed that has been immersed in boiling water for 1 minute to break seed-coat dormancy. Flower buds were observed in south-eastern Queensland on planted specimens as early as 25 months (Ryan and Bell 1989). Germination rate averages 63% and there are 67 800 viable seeds/kg. Nursery methods such as those developed for *A. mearnsii* would be appropriate for this species.

Yield: One seedlot from temperate southern New South Wales when planted in subtropical south eastern Queensland grew well and averaged 10 m tall and 16.3 cm basal diameter at 4.5 years (Ryan and Bell 1991). Survival was variable with one site averaging 66% and the other 88%. On a subtropical site at an altitude of 480 m in northern Guangdong province in southern China, *A. trachyphloia* attained 3.7 m in height and 2.4 cm dbh in 18 months. It was, however, not one of the faster-growing species on this site where the best species/provenances (e.g. *A. dealbata*) attained 5 m at the same age (Yang et al. 1991).

Pests and diseases. Swarming leaf beetle, *Monolepta australis* and its relative *M. germari* (Chrysomelidae) caused occasional serious leaf defoliation of planted trees in southeastern Queensland (Ryan and Bell 1991). Minor damage was caused to the same plots by a leaf tier, *Epiphyas* sp. (Tortricidae) and another leaf defoliator, *Myllocerus* sp.

Limitations. It will probably grow well only on relatively fertile soils where frosts are not severe.

Related species. Most closely allied to *A. oshanesii*, but differs in the distinctly paler undersurface of the leaflets, and the hairs are pale brown in colour rather than golden (Tindale 1960). Both species have pendulous foliage and few glands restricted to the bases of the upper pairs of pinnae, and no glands between the pairs of pinnae or leaflets.

Acacia tumida

Main attributes. A nitrogen-fixing shrub or small tree with potential for use as fuelwood, erosion control, and low windbreaks in sandy areas with a tropical, hot semi-arid or sub-humid climate. The seeds have potential as a famine or subsistence food for human beings.

Botanical name. *Acacia tumida* F. Muell. ex Benth. in *Flora Aust*. 2: 409 (1864). The specific name is from the Latin *tumidus* — swollen, thickened, referring to the pod.

Common names. Pindan wattle, sickle-leaf wattle.

Family. Mimosaceae.

Botanical features. A multi-stemmed bushy shrub or single-stemmed tree 3–12 m with grey-brown, more or less smooth or fissured bark and a well-developed crown. The branchlets are glabrous and pruinose, and the phyllodes are grey-green or shiny green, strongly sickle-shaped, 8–16 cm long and 2–5 cm wide, thick, slightly leathery, with 3 prominent and 4 subprominent longitudinal nerves and numerous fine secondary parallel nerves. *A. tumida* shows great variability in phyllode shape. The golden-yellow flowers are in spikes 2–6 cm long, on stalks 5–15 mm long, usually in racemes up to 10 cm long, often as long as the phyllodes. The flowers may be strongly perfumed. Pods are up to 16 cm long by 5–10 mm wide, sub-woody, straight to slightly curved, more or less wrinkled longitudinally. Seeds are shiny, dark brown-black, 5–8 mm long and 3–4 mm wide, with a prominent pale yellow terminal aril. Flowers are present in May to August, with mature seed available September to November in northern Australia (Thomson 1992).

The species is illustrated and described by Maslin (1981), Petheram and Kok (1983) and Wheeler et al. (1992).

Natural occurrence. This is a relatively common species in northwestern Australia. It is found throughout much of the Kimberley region and extends inland to the northern parts of central Australia.

- Latitude. Range: 11–23°S.
- Altitude. Main occurrence: near sea level to 300 m.
  Range: near sea level to 500 m.

Climate. Grows mainly in the hot semi-arid and the hot sub-humid zones in the Northern Territory and Western Australia. There are small occurrences in the arid zone in the south of its distribution. The mean maximum temperature of the hottest month (usually November) is about 37–38°C and the range is 34–42°C. The mean minimum of the coolest month is 10–13°C, but coastal values increase to 20°C. The average number of days when the temperature exceeds 32°C is 250–280. All coastal and low altitude localities are frost-free, but at high altitudes inland there are on average 1–2 frosts annually.

The 50 percentile rainfall is mainly 450–1000 mm. The 10 percentile is 125–625 mm and the lowest on record 30–425 mm. There is a moderate to strongly developed monsoonal rainfall pattern with a wet summer and a dry season from 5 to 9 months.

Physiography and soils. Much of the topography where *A. tumida* occurs is gently undulating but it is found in some rugged ranges. The physiography and soils of the western area of the distribution are described by Beard (1979). Commonly found on quartzite and sandstone, it is recorded from granite, laterite, schist and basalt. It is found in a variety of situations including valley alluviums, shallow rocky soils on upper slopes and ridges, sand plains, and coastal sand dunes.

The soils include lithosols, red siliceous sands, red or yellow earthy sands, and red earths. They range from acidic to alkaline, are usually permeable and of low nutrition status.

Vegetation type. The main structural vegetation type is low woodland and sparse shrubland. Near the coast of Western Australia it occurs in 'pindan woodland' with a tree layer 12–15 m tall and a dense shrub layer of acacia up to 5 m over a relatively sparse grassy ground layer (Beard 1979). Eucalypts are common in the tree layer with *A. platycarpa* and *A. eriopoda* in the understorey. On high, rocky ground, *Eucalyptus confertiflora* is characteristic in the upper storey with *A. tumida* and *A. eriopoda* below. *A tumida* is also found as a shrub in low woodland to low open-forest along watercourses with *E. houseana*, and *Melaleuca* spp. in inland desert areas. *A. tumida* occurs with *E. brevifolia*, *Grevillea pyramidalis* and various *Acacia* spp. or forms a moderately dense shrub layer under scattered low trees of *E. dichromophloia* and *Grevillea striata*. In dissected laterite country, it is associated with *E. brevifolia*, *A. holosericea*, *A. monticola* and *A. lysiphloia* (Beard 1979).

Utilisation.

Fodder: The immature pods are readily eaten by cattle in Australia. Vercoe (1989) showed the phyllodes to be of poor digestibility and low nutritional status. However, the phyllodes are reported to be moderately palatable to cattle and sheep in West Africa (Hamel 1980), where the species yields 2.6 kg dry phyllodes/tree and 8.7 kg of wood/tree when planted at 3 m × 3 m and harvested after 18 to 23 months (Cossalter 1987).

Fuelwood: A good fuelwood. *A. tumida* is recommended for trial for short rotation firewood production (Fox 1987).

Wood: Little is known of the wood properties.

Other uses: Gave good results when used to fix sand dunes threatening fruit and vegetable gardens in Senegal (CTFT 1983), but *A. holosericea* and *A. trachycarpa* are more satisfactory for the same purpose (Hamel 1980). Selected forms of *A. tumida* would make attractive ornamentals.

Seeds of *A. tumida*, eaten green or mature, were traditional food of the Australian Aborigines. It is a precocious and prolific-seeding species and can yield in excess of 100 kg of seed/ha from degraded, infertile sites within 2–3 years of planting (Thomson 1992). The seeds are nutritious, containing 18% crude protein, 6% fat and 9% available carbohydrate (Harwood 1994). The species appears to possess nearly all the attributes to make it a most useful food source for people living in subtropical–tropical dry zones.

Silvicultural features. A moderate to long-lived small tree or shrub that grows rapidly when young. It is usually killed by hot fires. It has wide morphological variation as well as variation in economically important traits such as coppicing ability, and may constitute more than one taxa as currently circumscribed (Thomson 1989a). Successful

management of stands for ongoing seed production will probably require regular rejuvenation of the shoot by low cutting (e.g. at 1 m) (Thomson 1992).

Establishment: Propagation is from seed which requires immersion in boiling water for 1 minute to break seed-coat dormancy. Plants flower early (e.g. 2–8 months after planting in southeastern Queensland) (Ryan and Bell 1989), and set heavy seed crops within 2–3 years. Germination rate is 77% and there are 15 200 viable seeds/kg.

Yield: *A. tumida* has survived poorly on all sites in south-eastern Queensland (Bell et al. 1991; Ryan and Bell 1991). It gave variable performance in Kenya reaching 3.7 m in 18 months in the best trial (Chege and Stewart 1991; Kimondo 1991) and poor performance in Malawi (Maghembe and Prins 1994). In contrast, *A. tumida* is the fastest growing Australian *Acacia* in the Sahelian zone of West Africa (CTFT 1983; Cossalter 1987; Kjellstrom and Gamatie 1989), typically averaging more than 1 m/year height growth in early years. Survival has usually been satisfactory.

Pests and diseases. Can be killed by termites (Petheram and Kok 1983).

Limitations. The small size of this species will limit its use to fuelwood, posts and non-wood purposes. Results from trials in tropical West Africa have shown it is sensitive to drought (Cossalter 1986).

Related species. *A. tumida* is closely related to *A. difficilis*, *A. hamersleyensis A. mountfordiae*, *A. retinervis* and *A. torulosa*. It will hybridise with *A. eriopoda*, *A. trachycarpa* and *A. difficilis* (Thomson et al. 1994).

Albizia lebbeck

Main attributes. *A. lebbeck* is a medium to fast-growing drought-tolerant, deciduous, nitrogen-fixing tree suitable for dry to sub-humid regions. It has agroforestry potential in the semi-arid tropics. It is a valuable fuel, fodder, small timber and shelter tree suitable for saline, alkaline and marginal soils.

Botanical name. *Albizia lebbeck* (L.) Benth. in Hooker's *London J. of Botany* 3: 87 (1844). The genus was named after Filippo del Albizzi, a Florentine nobleman who in 1749 introduced *A. julibrissin* into cultivation. The species name is from the Arabic 'laebach', the name for this plant.

Common names. Indian siris, siris, woman's tongue, East Indian walnut, lebbeck.

Family. Mimosaceae.

Botanical features. A deciduous tree, *A. lebbeck* can attain a height of 30 m and a diameter of 1 m, but more commonly it is 15–20 m tall and 50 cm in diameter at maturity, with grey fissured corky bark, somewhat flaky. The compound leaves are bipinnate, glabrous or slightly hairy on the axis, pinnae in 2–4 pairs, each with 2–11 pairs of obliquely oblong leaflets 15–45 × 8–22 mm, shortly stalked (Nielsen 1985). The glabrous glands are raised, elliptic to circular, on the upper side of the stalk close to the base and between most pairs of leaflets (Hyland and Whiffin 1993).

The inflorescence consists of large clusters 5–7.5 cm wide of fragrant pedunculate globular heads on stalks 5–10 cm long. The corolla is 5.5–9 mm long, glabrous, cream, white or green, with numerous pale green stamens on filaments 15–20 mm long. Flowering occurs from September to October (Wheeler et al. 1992). The pods are pale straw to light brown at maturity, narrow-oblong 15–26 × 3–5 cm, papery-leathery, flat and not raised or constricted between the seeds. The seeds are brown, flat, orbicular or elliptic, 8–10 × 6–7 mm. They are transversely placed with 6–12 in each pod. Mature pods remain on the tree for long periods of time and are available May–July (Brock 1988).

It is described and illustrated by Verdcourt (1979) and Brock (1988).

Natural occurrence. *A. lebbeck* occurs extensively throughout the Indian subcontinent and in Thailand and Malaysia (Little 1983). It has been widely cultivated and is now pantropical. Natural populations in Australia occur in the Kimberley region of Western Australia, the extreme north of the Northern Territory and offshore islands, and on Cape York Peninsula in Queensland. Seed from Asia has been widely used throughout northern Australia, and differentiating between native and exotic forms will become increasingly difficult (Hyland and Whiffin 1993).

- Latitude. Range: 11–16°S (Australia).
- Altitude. Range: near sea level to 750 m.

Climate. The distribution is in the hot humid climatic zone. The mean maximum of the hottest month is 30–35°C and 19–31°C for the mean minimum of the coolest month. The area is frost-free.

The northern part of Australia has a marked monsoonal incidence of rainfall. The 50 percentile rainfall lies in the range 1030–1755 mm, the 10 percentile 720–1230 mm, while the lowest on record is 385–1050 mm. There are 75–125 raindays per year.

Physiography and soils. The species occurs on the Kimberley plateau on soils overlying basalts (Miles et al. 1975) and amongst sandstone boulders and basalt outcrops on breakaway slopes. It is also found on the banks of streams on riverine sites (Beard 1979), and on stabilised dunes or low lateritic ledges above the beach (Brock 1988). Examples of soils types include, shallow sandy soils, laterite and loam laterite.

Vegetation type. *A. lebbeck* is a dominant species in semi-evergreen vine forests (monsoon forest) in areas with a mean annual rainfall of 1300–1500 mm and a very dry winter (Beadle 1981). Associated dominants include *Adansonia gregorii*, *Alphitonia excelsa* and *Bombax ceiba*. It is also in semi-deciduous microphyll vine thicket on scree slopes of quartz sandstone mountains.

Associate species include *Paramygnia trimera*, *Celtis philippensis* and *Pouteria sericea* (Miles et al. 1975). The thicket has a closed canopy with emergent trees of 9–15 m. On lateritic plateaux *A. lebbeck* grows with *Hakea arborescens* and *Grevillea mimosoides* in the shrub layer beneath low woodland and low open-forest. Dominant species are *Eucalyptus tetrodonta*, *E. nesophila*, *Ficus* sp. and *Canarium australianum*.

Utilisation. Most references to utilisation of the species come from the Indian literature and from reviews by Hocking (1993) and MacDicken (1994).

Fodder: In Queensland, *A. lebbeck* is regarded as a highly promising forage species. Green leaves, fallen flowers and dry leaves are palatable. The pods contain saponin and are not eaten in large amounts by sheep although cattle eat them readily (Lowry 1991; Burrows and Prinsen 1992). Outside Australia, the species is often grown as fodder for cattle, camels and water buffalo (MacDicken 1994).

Fuelwood: It is an excellent fuelwood species with a specific gravity of 0.5–0.6 kg/m^3 and a calorific value of 5200 kcal/g (NAS 1980). Fuelwood plantations at 3 × 3 m clear felled on a 10-year rotation produce about 50 m^3/ha of stacked fuelwood (Hocking 1993).

Wood: The sapwood is pale and the heartwood brown streaked with darker bands. It is moderately heavy and hard, strong and fairly durable, seasons well and works and polishes easily, and the timber can be used for furniture, panelling, veneering, turnery and general construction.

Other uses: The species is commonly grown as a shade tree in coffee and tea gardens and along avenues (Everist 1969). It can be planted in exposed coastal situations and as quick-growing shelter for less hardy plants (Hearne 1975). Due to its extensive, fairly shallow root system, *A. lebbeck* is also recommended for eroded areas. It is a rich source of honey. The bark is used locally in India for tanning and when dried and pounded can be used for soap. The reddish gum is a substitute for gum arabic. The nitrogen-rich leaves are valuable as mulch and green manure (Hocking 1993).

Silvicultural features. *A. lebbeck* is a nitrogen-fixing tree which can tolerate droughts and some frost after the first year (Gupta 1993). It grows well on fertile, well-drained loamy soils but poorly on heavy clays. It tolerates moderately alkaline or seasonally waterlogged

soils (MacDicken 1994; Tomar and Yadav 1982). It root suckers, coppices well and responds to pruning and lopping. Trees are vulnerable to strong winds and are killed by even light fires (Gupta 1993).

Establishment: Best established through the use of potted seedlings, although bare-rooted seedlings, stump cuttings and direct seeding have all been successful (MacDicken 1994). There are about 7000–12 000 seeds/kg (Hocking 1993). Freshly collected seed has about 70% germination capacity after scarification and immersion in boiling water or acid treatment to break seedcoat dormancy. Typical espacements are 3 × 3m for fuelwood and 5 × 5m for timber (Hocking 1993).

Yield: Timber plantations in India clear felled after 25–30 years yield about 10–12 m^3/ha/year of timber, but under semi-arid conditions and on shallow soils, a mean annual increment of 2–3 m^3/ha is obtained (Hocking 1993). In Queensland *A. lebbeck* reaches about 11 m in height and 0.5 m dbh in 30 years (Cameron and Jermyn 1991).

Pests and diseases. Root rots, cankers, heart rots, spot fungi and rusts can cause damage (Gupta 1993). There is also a wide range of insect pests including sap suckers, wood and seed borers and defoliators such as psyllids (Hegde and Relwani 1988). In Nigeria, damage has been caused by the striped mealy bug, *Ferrisia virgata* (Kadiata et al. 1992).

Limitations. Seedlings can be destroyed or severely damaged by browsing animals (NAS 1980). Its shallow, wide lateral rooting system makes it less suitable for some agroforestry uses. There is little information on its genetic variability.

Related species. Allied to *A. canescens* and *A. procera*.

Albizia procera

Main attributes. A moderately fast-growing tree adapted to the humid and sub-humid tropics. It is nitrogen-fixing and will grow on degraded soils. A useful wood for house construction, furniture, farm implements, fencing and charcoal.

Botanical name. *Albizia procera* (Roxb.) Benth. was based on *Mimosa procera* Roxburgh and published under *Albizia* by G. Bentham in Hooker's *London. J. Bot*. 3: 89 (1844). The species name is derived from the Latin, *procerus* — very tall or high, possibly alluding to the height the species can attain.

Common names. Forest siris (standard trade name), white siris, safed siris (India), weru (Indonesia), brown albizia (Papua New Guinea).

Family. Mimosaceae.

Botanical features. *A. procera* is typically a small tree 7–15 m tall, but can reach 30 m. The bark is smooth, pale grey-green, yellowish-green or brown with horizontal grooves, sometimes flaky. The compound leaves have 3–5 (–8) pairs of pinnae with a petiole 5.5–12 cm long with a large, brown, oblong gland near the base. Leaflets are in 6–12 pairs, elliptic-oblong, glaucous and paler beneath, 2–6 cm long and 7–33 mm wide, emarginate or rounded at the apex and oblique at the base, glabrous or finely pubescent on both sides.

The inflorescence is a large terminal panicle, with sessile, white or greenish-white flowers in small 15–30 flowered heads, 13 mm in diameter on stalks 8–30 mm long. The fruit is a pod, reddish to mid-brown, linear-oblong, 10–25 cm long by 2–3 cm broad with distinctive long points at both ends. It contains 6–12 brown seeds that are arranged more or less transversely in the pod. At maturity the pod splits open to release the seeds. In Australia, flowering occurs about March to May and the fruits mature from July to October.

It is described and illustrated by Brandis (1972) and Verdcourt (1979).

Natural occurrence. Widely distributed from India and Burma through Southeast Asia to Papua New Guinea and northern Australia. In Australia *A. procera* is most common in coastal areas of northeastern Queensland. There are also disjunct occurrences in the Kimberley region in northern Western Australia.

- Latitude. Main occurrence: 16–21°S.
  Range: 10–21°S.
- Altitude. Main occurrence: near sea level to 250 m.
  Range: near sea level to 650 m.

Climate. The Australian distribution lies in the hot humid and sub-humid zones, and rarely close to the hot semi-arid zone. The mean maximum temperature of the hottest month is mainly 31–34°C and the mean minimum of the coolest 11–19°C. There are 60–100 days over 32°C and from 0–4 days over 38°C. The area is frost-free.

The 50 percentile rainfall is mainly 1000–1750 mm but the extremes are from 650 to 2150 mm. The most northerly localities have a strong summer monsoon rainfall pattern. Elsewhere on the central east coast of Queensland there is a strong summer maximum. There are 60–125 raindays per year.

Physiography and soils. The distribution in Australia is in the Eastern Uplands and Western Plateau physiographic divisions. In the west it occurs on sandstone plateaux overlying basalt. Eastern occurrences are mainly in the foothills and coastal lowlands on shallow sandy or loamy soils of low to medium fertility derived from basalts, granite or shales. Other soil types include acid and neutral yellow earths, acid red friable earths and solodized solonetz and solodics.

Vegetation type. In Australia *A. procera* is found mainly in woodland, open-woodland and open-forest dominated by eucalypts. It occurs commonly in the understorey of woodland 10–20 m high dominated by *Eucalyptus intermedia*, *E. pellita*, *E. tereticornis*, *E. tessellaris*, *E. torelliana*, *Acacia aulacocarpa*, *A. mangium* and *Lophostemon suaveolens*. The woodlands are often burnt regularly and the ground layer is dominated by the grasses *Imperata cylindrica* and *Themeda triandra*

(Tracey 1982). It is co-dominant in low open-forest with *E. miniata* and *E. polycarpa* in northern Western Australia.

Utilisation.

Fodder: Not known to have been used as forage in Australia, where Vercoe (1989) found in vivo dry matter digestibility of foliage to be low (19.4%). However, in India the leaves are considered good cattle feed. A study on a 6–7-year-old plantation of *A. procera* in India showed that green fodder production was 28.7 kg/tree (range 24.6–34.4 kg/tree) and 8.04 t/ha (range 6.9–9.9 t/ha) (Gupta 1993).

Fuelwood: Makes excellent charcoal and fuelwood (Campbell 1980). The high rate of biomass production (124 t/ha oven-dry at 5.5 years), high proportion of biomass in stem and branches (91%) and observed vigorous coppicing after felling led Lugo et al. (1990) to recommend the species for fuelwood production in Puerto Rico.

Wood: Carries a large amount of non-durable, yellowish- white sapwood. The heartwood is hard and heavy, light or dark brown with light and dark bands resembling walnut. It is straight-grained, splits readily, seasons well, works easily and is durable (Brandis 1972). The air-dry density is 640–880 kg/m^3. Makes a good cabinet and furniture timber, and is also suitable for general construction, agricultural implements, poles, house posts and packing cases.

Other uses: A useful tree for farm and amenity planting, light shade, fire-breaks and for the rehabilitation of seasonally dry eroded and degraded soils. The bark is a good source of tannin (Japing 1936).

Silvicultural features. A fast-growing, semi-deciduous, light-demanding and fairly drought-tolerant tree. In the absence of regular burning it will colonise *Imperata* grassland (Tracey 1982). The seedlings are somewhat frost-tender. The tree can be heavily pruned or pollarded to give a bushy crown (Hearne 1975). May produce root suckers after damage (Troup 1921) and coppices readily (Ryan and Bell 1989).

Establishment: There are about 17 000 viable seeds/kg. The seeds germinate readily without treatment when fresh (Campbell 1980), but seedcoat dormancy soon develops requiring boiling water treatment. Can be direct sown or propagated by stumps, cuttings, and seedlings (NAS 1979). Germination is rapid and

seedlings can be planted out after two months (Campbell 1980).

Yield: In trials in southeastern Queensland, growth rate and survival varied substantially among provenances. The best-performing provenance (S14962, 12 km south of Port Douglas, Qld) averaged 2.3 m in height after 2 years (Ryan and Bell 1991). Annual wood production of about 10 m^3/ha has been recorded in Java (NAS 1979). Height growth was reported to be moderately fast with seedlings reaching 3.3 m in height in four years (Troup 1921). A 6–7-year-old plantation in India had a mean tree height of 7.8 m and a dbh of 26.1 cm. The corresponding mean fuelwood yield was 24.4 kg/tree and 6.8 t/ha (Gupta 1993). In Thailand, the species grew an average of 1.5 m in 12 months on 3 sites. Survival was excellent in two areas (90%) but poor on a third (49%) (Pinyopusarerk 1989).

Pests and diseases. In India the hemipterous insect *Oxyrachis tarandus* causes considerable damage (Troup 1921), and in Indonesia the tops of young trees may be damaged by *Rhynchites* beetles (Kalshoven 1934). Stem borer attacks are reported from Zimbabwe (Streets 1962). A serious outbreak of leaf-spot fungus, *Cercospora albiziae*, on *Albizia procera* in India was reported by Nath et al. (1988).

Limitations. Has the potential to become a weed in some environments.

Related species. Allied to *A. canescens* and *A. lebbeck*.

Allocasuarina luehmannii

Main attributes. Bull oak is a medium-sized tree which tolerates wind, drought, frost, waterlogging and moderate salinity. The timber makes good firewood, mine props and posts. It is suitable for amenity planting in parks and avenues and open shelterbelts in sub-humid and semi-arid climatic zones. The species is less palatable than most casuarinas.

Botanical name. *Allocasuarina luehmannii* (R.Baker) L. Johnson was named *Casuarina luehmannii* by R. Baker in *Proc. Linn. Soc. New South Wales* 24: 608 (1900). This species was subsequently placed in the genus *Allocasuarina* by Johnson (1982) and validly published in *J. Adel. Bot. Gard.* 7(3): 314 (1985). The generic name is from the Greek *allos* — other, and the Latin *casuarius* — a cassowary, in allusion to the resemblance of the foliage to the plumage of the Cassowary. It refers to its relationship with the genus *Casuarina*. The species name honours J.G. Luehmann (1843–1904), who became Victorian Government Botanist and Curator of the Melbourne Herbarium.

Common names. Bull oak (Buloke).

Family. Casuarinaceae.

Botanical features. A small to moderate-sized tree 9–15 m high, but 6–8 m on unfavourable sites. *A. luehmannii* has an erect trunk, dominant for most of the height, and is typically 30–70 cm in diameter. The bark is dark and furrowed. The branchlets are ascending to 40 cm long, divided up into articles 8–22 mm long, 1–2 mm diameter, finely pubescent in the furrows when immature, ridges (phyllichnia) flat to slightly rounded, leaf teeth in whorls of 10–14, erect, 0.5–1.0 mm long. Dioecious with male and female flowers on different plants. Male spikes 1.5–4.5 cm long, 5–8 whorls per cm. Flowers are yellow-brown, available in September–October. Cones very shortly cylindrical, broader than long, pubescent when young, sessile or shortly stalked to 5 mm long, cone body 5–12 mm long by 8–17 mm diameter, protuberance pyramidal or flattened, with 1–4 fertile whorls. The winged seed is 4.5–5.0 mm long, glabrous and red-brown in colour. Seed collection is undertaken in March to May in South Australia (Bonney 1994).

The species is described by Wilson and Johnson (1989) and illustrated by Anderson (1993) and Doran and Hall (1983).

Natural occurrence. The main distribution is in a belt 60–150 km wide which extends from southeastern South Australia, across central Victoria, along the western slopes of New South Wales into southeastern Queensland. Inland from the main occurrence, there is a wide belt where the species is rare. The distribution is sparse in central Queensland and there is a disjunct northern occurrence around Mareeba in north Queensland. It occurs rarely towards the coast, except in the Hunter Valley in New South Wales and from Maryborough to Bowen.

- Latitude. Main occurrence: 26–38°S.
  Range: 20–38; 16–18°S.
- Altitude: Range: near sea level to 800 m.

Climate. Throughout its range *A. luehmannii* is mainly in the warm sub-humid climatic zone and with only a limited extension into the warm semi-arid zone in New South Wales and Victoria. The mean maximum temperature of the hottest month is 29–35°C and that of the coldest month 2–4°C. The average number of days when 32°C is exceeded is 22–90 and 3–17 days for over 37°C. Heavy frosts occur and average 4–18 (range 0–50) per year.

The 50 percentile rainfall is 425–650 mm, the 10 percentile 325–450 mm and the lowest on record 150–300 mm. The seasonal incidence varies from a slight winter maximum in South Australia to a well-developed summer peak in most of Queensland. In this area the northern Queensland locality has a monsoonal pattern with the maximum rainfall in February. The driest on record is 100 mm and the maximum 1150 mm.

Physiography and soils. Most of the distribution is on gentle to moderate lower inland slopes of the Eastern Uplands physiographic division. To a limited extent the species extends into the Interior Lowlands in the southeast part of its distribution. Only locally does it occur on ridges and other steep topography. Whilst the species grows mainly on sandy soils and light loams, it has been reported from a wide range of soils including solodic soils, red brown earths, brown soils of heavy texture, stony and gravelly types, inland sand-hills and non-calcareous soils.

Vegetation type. The broad vegetation type is mainly woodland, sometimes low open-forest and, on marginal areas, sometimes tall shrubland. *A. luehmannii* is an important component of the low tree or tall shrub layer understorey beneath woodlands dominated by different eucalypts. The density varies from dense stands to scattered individuals. On solodic soils it often forms a distinctive understorey in the woodlands of the drier parts of New South Wales (Beadle 1981). Dominant eucalypts such as *E. crebra*, *E. melanophloia*, *E. normantonensis*, *E. populnea*, *E. moluccana* and *E. woollsiana* are characteristic of such woodlands. Other dominant tree species are *Callitris glaucophylla*, *Brachychiton populneus* and *Angophora floribunda*. Associate shrub species include *Acacia* spp., *Callitris endlicheri*, *Allocasuarina inophloia*, *Carissa lanceolata*, *Geijera parviflora*, *Atalaya hemiglauca*, *Capparis mitchellii* and *Eremocitrus glauca*.

Utilisation.

Fodder: The deciduous branchlets of this species are relatively coarse and wiry and are considered of inferior value for stock fodder (Anderson 1993).

Fuelwood: An excellent firewood.

Wood: The heartwood is red, with rather coarse grain and prominent medullary rays. It is very heavy, hard and of moderate durability. Air-dry density is about 1050 kg/m^3 (Bootle 1983). Sapwood is resistant to lyctid borer attack. It does not season readily and is susceptible to splitting. The wood has been used for roofing shingles, flooring, fancy turnery and fencing.

Other uses: Bull oak is suitable for amenity planting in parks or avenues. It will provide satisfactory but somewhat open shelterbelt protection, and on moderately good sites, early growth is relatively fast.

Silvicultural features. The species is reported to be easy to grow, yet to date not cultivated extensively partly due to unavailability of seed (Bonney 1994). Under some conditions the species develops a suckering habit, and there are reports that it will withstand

wind, light frost, drought, poorly aerated soils, seasonal inundation and moderate salinity (Marcar et al. 1995). Mycorrhizal associations have been reported on the roots of *A. luehmannii* (Dommergues et al. 1990), but nodulation with *Frankia* species has yet to be recorded (NAS 1984).

Establishment: Can be established successfully as container-grown seedlings and is amenable to direct seeding. No seed pregermination treatments are necessary and there is an average of 157 600 viable seeds/kg. The optimum temperature for germination of *A. luehmannii* is 25°C (Turnbull and Martensz 1982).

Yield: There have been reports of fast early growth of this species (Cremer 1990). However, the Mareeba provenance in trials in southeastern Queensland grew relatively slowly to reach 3.6 m tall in 4.5 years (Ryan and Bell 1991). Near Longreach in central Queensland it grew best under irrigation on acid red earths, recording 71 cm in height at 18 months. Survival was poor on alkaline cracking clays (Ryan and Bell 1991).

In the Negev region of Israel, *A. luehmannii* has been successful on loess and sandy loess soils in depressions and on terraces which receive 210–350 mm annually. Here it has recorded a MAI for height of 0.3 m over 29 years (Weinstein 1985).

Pests and diseases. None are recorded.

Limitations. Slow to moderate growth rate. Suckering habit indicates a potential to weediness in some conditions.

Related species. The species belongs to the genus *Allocasuarina*, which is endemic to Australia and comprises 59 species.

Alphitonia excelsa

Main attributes. A shrub or tree that tolerates a wide range of soil types and climatic conditions. It is both drought-resistant and moderately tolerant of frost. The wood is suitable for cabinet work, general building and flooring, and as a fuel. The tree can be used for ornamental, shade and shelter purposes.

Botanical name. *Alphitonia excelsa* (Fenzl) Reiss. ex Benth. in G. Bentham's *Flora Australiensis* 1: 414 (1863). *Alphitonia* from the Greek *alphiton* — baked barley meal, referring to the mealy red covering around the hard cells in the fruit. The species name is from the Latin *excelsa* — tall, lofty, and alludes to the tall stature of the species.

Common names. Standard trade name is red ash. Others are red almond, sarsaparilla, leather jacket, red tweedie, humbug, coopers wood, white leaf, white myrtle, soap tree.

Family. Rhamnaceae.

Botanical features. Ranges from a multi-branched shrub to a tall tree 25–35 m. It is usually a small to medium-sized tree, less than 15 m tall, with a trunk that divides at about half total height into an umbrageous grey-green crown. The bark is smooth, steely-grey on young trees, but deeply fissured, very hard and rough on old specimens. Young branchlets are covered with grey or golden-brown hairs, becoming smooth and with prominent leaf scars on older branchlets. Stipules slender-pointed, conspicuous 2–10 mm long, are shed as the leaves expand. Leaves alternate, simple broad elliptical to lanceolate, 8–15 cm by 2–5 cm, upper surface dark glossy green, silvery-white beneath. The inflorescence consists of cymose panicles with small, scented cream flowers. Flowers prolifically during November to March in the south and from April to May in the north. Fruit is a dryish drupe, globular, 6–10 mm diameter, usually containing two glossy dark brown seeds. The fruit walls split and are shed when mature, leaving the seed, enclosed in a bright red aril, persistent on the branchlets until removed by birds. Fruits ripen from October to January in the south (Floyd 1980) and June to September in the north (Brock 1988).

The species is described by Floyd (1980) and illustrated by Anderson (1993).

Natural occurrence. Has a wide geographic range on the coast and western slopes of southern New South

Wales to northern Queensland and Torres Strait, also the 'Top End' of the Northern Territory and the Kimberleys of Western Australia.

- Latitude. Main occurrence: 17–35°S.
  Range: 10–38°S.
- Altitude. Main occurrence: near sea level to 350 m.
  Range: sea level to 750 m.

Climate. *A. excelsa* tolerates a wide range of temperature and moisture conditions. Most of the distribution is in the warm sub-humid climatic zone but it extends into the hot and warm humid zones and into the higher rainfall regions of the warm and hot semi-arid zones. There is wide variability in the monthly mean temperature, the hottest being 29–38°C. The mean minimum of the coolest month is 3–8°C. The temperature exceeds 32°C on average 25–120 days per year, and 38°C on 1–25 days. Frosts are absent in coastal areas and the far north, but elsewhere average 1–18 per year.

The 50 percentile rainfall is 650–1250 mm and the 10 percentile 425–700 mm, with the lowest on record 250–600 mm. Rainfall incidence varies from a well-developed December to March monsoon with a distinct dry season, to a moderate summer maximum. The number of raindays per year averages 60–100 for most of the distribution but may reach 150 days in the wettest areas.

Physiography and soils. *A. excelsa* is found in rugged ranges and plateaux of basalt, granite and sandstone, on undulating to low hills on shale and broad valley floors. It also occurs in coastal lowlands sometimes immediately behind the frontal sand dunes. Soils are frequently infertile and include red and yellow earths, red podsolics, yellow bleached duplexes, shallow sand soils, grey and brown and red cracking clays, and skeletals.

Vegetation type. In the eastern New South Wales and Queensland rainforests, *A. excelsa* occurs locally in small mainly pure stands or in mixed forest dominated by such genera as *Ceratopetalum*, *Diploglottis*, *Schizomeria*, *Doryphora*, *Caldcluvia*, *Argyrodendron*, and *Drypetes* (Beadle 1981). It occurs as a shrub or small tree in scattered rainforest-derived communities in the semi-arid zones, dominated by such species as *Alstonia actinophylla*, *Cadellia pentastylis* and *Brachychiton rupestris*. Elsewhere it grows in woodland, open woodland and open forest where *Acacia shirleyi*, *Callitris glaucophylla*, *Eucalyptus tetrodonta*, *E. polycarpa*, *E. alba*, *E. tereticornis*, *E. maculata*, *E. cullenii*, *E. drepanophylla*, *E. microneura* or *E. orgadophila* may be dominant. *A. excelsa* is noted as being a colonising species in pure stands that occur early in a succession in regrowth after fire or in a clearing. It is rarely found in mature forests.

Utilisation.

Fodder: The leaves and young shoots are grazed by stock (Swain 1928a; Floyd 1980). However Vercoe (1989) found that in vivo dry matter digestibility was low (27.6%) and certain key nutrients in the foliage were below stock maintenance levels.

Fuelwood: It is a good firewood (Maiden 1904).

Wood: The heartwood is pale pink when freshly cut, darkening with age to bright orange-red. The wood is strong, moderately hard and heavy, air-dry density 550–850 kg/m^3 and not difficult to work. Suitable for ornamental panelling, cabinet work, general building work, flooring, tool handles, cases, plywood and joinery (Bootle 1971; Floyd 1980). According to Bootle (1971), the wood has low durability and should not be used in contact with the ground; however, Floyd (1980) refers to it as 'fairly durable' and Swain (1928a) as 'durable' and used for fencing in northern Queensland.

Other uses: An attractive tree for amenity use (Hearne 1975). Also suitable for use in hedges (Forestry Commission NSW 1980). It is used in mine-site rehabilitation in northern Australia (Langkamp 1987). The bark yields about 11% tannin (Swain 1928a). Australian Aboriginal people used the crushed leaves, bark, root and wood of this tree medicinally, both internally as a bitter stomachic and externally for relief of muscle pain, headache and toothache (Aboriginal Communities of the Northern Territory 1993; Lassak and McCarthy 1983). They also used crushed leaves and fruit as a fish poison.

Silvicultural features. A pioneer species that will tolerate dry, infertile sites and withstand coastal exposure. It coppiced poorly in trials in southeastern Queensland (Ryan and Bell 1989). When grown as a solitary feature tree it forms a dome-shape crown with widely-spaced branches. In colder areas the leaves tend to be shed in winter.

Establishment: The seed is not easy to extract from the fruit and gives off a fine irritating dust. The first flower buds appear 1–2 years after planting. There are about 4500 viable seeds/kg and germination is promoted by scarification or treatment with boiling water or a weak acid. Seven seedlots tested at CSIRO gave a low germination rate, averaging only 27% after pre-germination treatment.

Yield: In trials in southeastern Queensland, *A. excelsa* survived well and grew steadily to reach 4.8 m in height and 10.3 cm in basal diameter at 4.5 years (Ryan and Bell 1991). Rarely tested as an exotic, but grew to a mean height of 19 m and diameter of 25 cm in 55 years in deep sand in South Africa (Streets 1962). A single introduction into Zimbabwe failed in three localities (Barrett and Mullin 1968).

Pests and diseases. Young trees can be defoliated and severely set back by grasshopper attacks, and wild trees are usually heavily attacked by leaf-eating insects (Hearne 1975).

Limitations. A relatively slow-growing tree for which no information on provenance variation is available.

Related species. *A. excelsa* is a complex species which may comprise several related taxa (K. Thiele, pers. comm.). *A. petriei* is a close relative (Floyd 1980).

Alphitonia petriei

Main attributes. A fast-growing, hardy pioneer species that may attain heights of 40 m in suitable tropical locations. The wood is of low density and limited durability. The species is an attractive ornamental, useful for reclamation work.

Botanical name. *Alphitonia petriei* Braid and C. White was described in *Kew Bull. Misc. Inf.* 4: 178 (1925). The species name is after W.R. Petrie (1875–fl. 1930s), a forester with the Queensland Government who drew White's attention to the species.

Common names. Pink almond (standard trade name), pink ash, foambark, red ash, sarsaparilla, soap tree, white ash, white-leaf.

Family. Rhamnaceae.

Botanical features. *Alphitonia petriei* is a tree usually to 20 m in height and 35 cm diameter, but can attain 40 m and 60 cm diameter on suitable sites. It has a more layered crown of horizontally arranged leaves than *Alphitonia excelsa*. The trunk is cylindrical, not buttressed. It has attractive grey, smooth bark with grey-brown grooves that are dark and deeply fissured on larger trees in Queensland (Francis 1970). The blaze is rose pink on trees with 35 cm diameter, liniment-scented. The branchlets are covered with reddish-brown short hairs at the tips and a strong liniment or sarsaparilla-like smell when broken or bruised (Floyd 1989). Leaves alternate, egg-shaped to narrow elliptical, 7–15 cm, sometimes 2–5 times long as broad, with a fine point at the tip, dark green and glossy above, white below with dense, short white hairs. Petioles are 10–20 mm long. Venation is visible and sunken on top, more prominent below, yellow-brown. There are 8–12 lateral veins. The inflorescence is in terminal or axillary corymbs or panicles. Flowers are white, cream or pale green, fragrant, the stamens enveloped by the petals (Hyland and Whiffin 1993). The flowering period is from September to November (Floyd 1989). The fruit is a dryish drupe, dull black, 7–15 mm in diameter, with a raised scar of the calyx rim below the middle and globular to round in cross-section, but flattened horizontally. It contains three hard cells with a powdery red-brown covering. Each cell contains a single, glossy orange-red seed, about 3 mm long, flattened oval, that is exposed when the outer flesh falls away when ripe from February to July (Jones 1986).

The species is described and illustrated by Floyd (1989) and Francis (1970).

Natural occurrence. *A. petriei* occurs in the high rainfall areas of north Queensland from Cairns to Cape York Peninsula and southwards to Rockhampton and Brisbane. It is rare in New South Wales and occurs in the subtropical rainforest around the upper Orara River, north of Coffs Harbour and northwards to the Queensland border.

- Latitude. Main occurrence: 16–18°S
  Range: 10–28°S
- Altitude. Main occurrence: 100–900 m.
  Range: near sea level to 1600 m.

Climate. The distribution, except for a few isolated areas, is in the warm to hot humid climatic zone, but extends to the hot wet zone in places and, for a few southern locations, also extends to the warm sub-humid zone. The mean maximum temperature of the hottest month is 28–33°C and the mean minimum of the coolest 6–22°C. The average number of days when 32°C is exceeded is 20–50 and 0–4 for over 37°C in the eastern distribution. There are no frosts for most of the area, except for the tablelands near Atherton and lower altitudes in the south, where 1–4 frosts are recorded each year.

The 50 percentile rainfall is 1100–1650 mm (maximum of 2000 mm), the 10 percentile 650–1350 mm and the lowest on record 500–800 mm. In the north there is a strong monsoonal pattern of rainfall, with most of the rain falling from December through to March or April. The driest months are July to September. To the south there is a summer maximum where the rainfall is 3–5 times that for the driest month. For most of the distribution the annual number of raindays is 120–160.

Physiography and soils. Mostly in the Eastern Uplands physiographic division. It occurs in the lowlands, foothills and highlands of tropical northeast Queensland (Tracey 1982). *A. petriei* grows on steep slopes with residual quartzite outcrops or basaltic scoria, on alluvium beside permanent streams and in fire-degraded grassland with woody regrowth on coastal foothills. It has been recorded growing on basalt, granite and metamorphic rocks. Soils are alluvia derived from a mixture of acid and basic rocks, yellow earth on deeply weathered granite, basaltic red earths, brown and yellow earths, granitic yellow podzols and soils with impeded drainage.

Vegetation type. Found on the edges of coastal subtropical rainforest and in the ecotone with tall open-forest dominated by *Lophostemon confertus* and *Eucalyptus microcorys* (Floyd 1989). Other associated species are *E. grandis* and *E. saligna*. In northeast Queensland Tracey (1982) has recorded *A. petriei* in mesophyll vine forest types, notophyll vine forest types and vine forests dominated by eucalypt and acacia emergents. *A. petriei* is a component of the understorey formed beneath these forests, usually to about 10–25 m or lower. It is a pioneer species in areas that are subjected to disturbance.

Utilisation.

Fodder: The leaves and young shoots are eaten by stock (Francis 1970).

Fuelwood: Not known to have been used as a fuel.

Wood: Readily worked and is suitable for use where protected from the weather and where strength is not critical. The pinkish-red heartwood is light with an air-dry density of about 400 kg/m^3. The sapwood is white. Suitable for packing cases (Floyd 1989).

Other uses: An attractive tree for amenity planting in parks (Wrigley and Fagg 1988). It is a useful shelter plant, excellent for reclamation planting along streams (Jones 1986). The Australian Aboriginal people of northern Queensland inhaled the methyl salicylate vapours produced from a decoction of the bark, for the relief of muscular pains (Lassak and McCarthy 1983).

Silvicultural features. A fast-growing pioneer species that commonly colonises disturbed roadsides or rain-forest regrowth sites throughout Queensland and New South Wales (Nicholson and Nicholson 1985). *A. petriei* has a well-developed tap root that may allow seedlings to exploit nutrients and water stores beyond the reach of shallow-rooted rainforest species (Hopkins 1990). In a trial of rainforest regeneration at Lake Eacham, of

simple notophyll evergreen vine forest that had been cleared for grazing on soils over schist, *A. petriei* was one of the first trees to regenerate into the grass (Tracey 1985). *Acacia aulacocarpa*, *A. cincinnata* and *Alstonia muellerana* were other colonisers. Tracey (1985) comments that the *Acacia* and *Alphitonia* may have come from long-lived buried seeds on the site.

Establishment: It is not easy to germinate from seed and extraction requires mechanical aids. The seed has a hard shell that requires chipping or boiling to facilitate germination (Nicholson 1991). It can be raised from cuttings (Floyd 1989). There are 6000 fruits and 150 000 seeds/kg (Floyd 1989). One seedlot tested at CSIRO gave a germination rate of 60%, providing 68 400 viable seeds/kg.

Yield: A. petriei reached an average height of 4.4 m and 9.4 cm in basal diameter in 2 years in trials in south-eastern Queensland (Ryan and Bell 1991). It failed when planted off-site in more arid conditions at Longreach in central Queensland.

Pests and diseases. None are recorded.

Limitations. The wood is of low density and too weak for structural purposes.

Related species. *Alphitonia incana* (Roxb.) Kurz., is found in similar habitats to *A. petriei* in north Queensland, and replaces it in the northern part of the Northern Territory and in the Kimberley region of Western Australia. It differs from *A. petriei* in its longer stipules, larger fruits and flowering season (March–May) (K. Thiele, pers. comm.). *A. petriei* is distinguished from the related *A. excelsa* by its larger flowers and fruit, the latter being somewhat flattened.

Alstonia scholaris

Main attributes. *Alstonia scholaris* is a common, medium to large tropical hardwood tree with an extensive occurrence in the Asia–Pacific region. It has a moderate to fast growth rate. The timber is a general purpose indoor wood and can be used also for pulp and paper production. The bark contains alkaloids useful for medicinal purposes.

Botanical name. *Alstonia scholaris* (L.) R.Br. was based on *Echites scholaris* by Carl von Linné (Linnaeus) and later published under *Alstonia* by Robert Brown in *Mem. Wern. Nat. Hist. Soc.* 1: 76 (1811). *Alstonia* is named after Dr C. Alston, (1685–1760), Professor of Botany at Edinburgh University. The name *scholaris* is derived from the use of the wood as school boards in Burma (Boland et al. 1984).

Common names. White cheesewood (standard trade name), milky pine, milkwood, birrba, koorool.

Family. Apocynaceae.

Botanical features. *Alstonia scholaris* is a medium to large tree to about 40 m high with corky grey, grey-white bark, somewhat tessellated. The boles of larger trees are strongly fluted to 10 m. The outer blaze is cream to yellowish in colour with an abundant milky exudate (latex) that flows rapidly when cut. The leaves are in whorls of 4–8 in the upper axils. The leaf stalks are 1–1.5 cm long, the lamina obovate to elliptical or elliptical-lanceolate, glabrous or sparsely hairy, tapering towards the base, 11.5–23 cm long by 4–7.5 cm wide. The upper surface is dark green, the lower green-white with 25–40 pairs of lateral veins on each side of the midrib and 2–6 mm apart. The tip of the leaf is rounded or shortly pointed, tapering towards the base.

The inflorescence is a much-branched terminal panicle, up to 120 cm long. The flowers are 7–10 mm long, white, cream, or green, the tube hairy, lobes sparse or densely pubescent 1.5–4 mm long, the left margins overlapping, strongly perfumed (Hyland and Whiffin 1993). The fruit is a pendulous, two-lobed dry-dehiscent follicle, brown or green, dry or woody, spindle-shaped, 15–32 cm long, 4–6 mm diameter, each containing numerous flat, oblong brown seeds, 4–5 mm by 0.9–1.2 mm, with a tuft of hairs 7–13 mm long at each end. The seed does not taper to a point at either end (Hyland and Whiffin 1993). The flowering period is from October to December (Boland et al. 1984).

It is described by Hyland and Whiffin (1993) and illustrated by Francis (1970), Williams (1984) and Boland et al. (1984).

Natural occurrence. In Australia the species is widespread in coastal areas in northern Queensland including Cape York Peninsula, and extends southwards to central Queensland. Disjunct populations occur away from the coast in the Northern Territory. The species also occurs in Papua New Guinea, the Pacific Islands, South Asia, Indonesia and other parts of Southeast Asia and China.

- Latitude: Range: 10–21°S (Australia).
- Altitude: Range: near sea level to 900 m.

Climate. The distribution is in both hot humid and warm humid climatic zones. The mean maximum temperature of the hottest month is 30–32°C and the mean minimum of the coolest month 12–22°C. Frosts are absent over the whole area.

The 50 percentile rainfall is mainly in the range 1200–1600 mm, but in moist areas increases to 1600–2400 mm. The 10 percentile is mainly 600–800 mm, but increases to around 1200 mm in wetter areas. The rainfall has a strongly developed monsoonal pattern, falling mainly between December to March.

Physiography and soils. The distribution lies in the northern part of the Eastern Uplands physiographic division. The topography varies from lowlands and foothills to uplands. On steep slopes there may be much surface rock. Some lowlands consist of old beach ridges bordering mangroves (Tracey 1982).

Soils include alluvia, basaltic red earths, yellow earth with grey-brown topsoil, stony red earth on basic volcanic, sandy grey earth, brown earth from a volcanic mixture of rocks, and on soils derived from metamorphic rocks.

Vegetation type. *A. scholaris* is a dominant canopy species found in mesophyll vine forest with a canopy height of 35–42 m (Tracey 1982). On soils with impeded drainage derived from granite or basalt, *A. scholaris* occurs in mesophyll vine forest dominated by palms with a dense closed canopy to about 20 m. It is also a dominant species in notophyll vine forests, with a canopy of 25–45 m associated with *Argyrodendron peralatum*, *Castanosperum australe*, *Ceratopetalum sucirubrum*, *Darlingia ferruginea* and *Ficus* spp. *A. scholaris* is found with other typical rainforest species in forests dominated by eucalypts including *Eucalyptus tereticornis*, *E. tessellaris* and *E. intermedia*. *A. scholaris* occurs in a mosaic of vegetation types on swampy coastal plains. These are characterised by palm species such as *Archontophoenix alexandrae* and/or *Licuala ramsayi*.

Utilisation.

Fodder: Not known as a fodder tree.

Fuelwood: A. scholaris was recommended as a fuelwood species for the patana lands of Sri Lanka (Gorrie 1950), managed under a short coppice rotation (6–8 years).

Wood: Heartwood cream to pale yellow, sapwood wide and visually indistinct from the heartwood. Often has strong odour and bitter taste. Air-dry density is about 400 kg/m^3. The heartwood is not sufficiently durable for external use, but is readily impregnated with preservatives (Bootle 1983). It is used for pattern-making, corestock, plywood, carving and mouldings (Bootle 1983). It is not a structural timber. In Sri Lanka the wood is used for making coffins, because of its lightness (Bodkin 1991). It is regarded as suitable for pulp and paper production (Anon. 1976).

Other uses: Australian Aboriginal people used the bark for treatment of abdominal pains, dysentery and fevers (Webb 1960) and the latex for neuralgia and toothache (Webb 1948). In India the bark is used to treat bowel complaints and has proved a valuable remedy for chronic diarrhoea and the advanced stages of dysentery. The active constituents are alkaloids found in the bark and latex (Lassak and McCarthy 1983).

Silvicultural features. There is little published information on the germination and establishment of this species in cultivation in Australia. In Darwin, plantings of *A. scholaris* have shown fast early growth and exhibited

good form (Hearne 1975). It is adaptable to a wide range of soils including lateritic and skeletal soils, sandy beach areas and rainforest fringe sites. Regular dry season watering was essential for good growth, and deep mulch proved beneficial to young trees.

The species reached an average height of 3.6 m and diameter of 10 cm at 3.5 years in mixed species, social forestry plantings in West Bengal, India. This performance was considered poor amongst the various species tested (Nath et al. 1989).

In plantations in Taiwan, *A. scholaris* reached an average of 23.5 m in height and 51 cm dbh in 18 years. A maximum of 35 m in height and 109 cm dbh was attained at 41 years of age (Shen-Cheng 1983).

Pests and diseases. A leaf skeletoniser, *Parotis marginata*, causes significant damage to nursery stock and young plantations of *A. scholaris* in Bangladesh (Ahmed et al. 1974). The timber is liable to termite, pinhole borer and marine borer attack (Keating and Bolza 1982). The sapwood is highly susceptible to lyctid borer attack (Bootle 1983).

Limitations. Food becomes tainted when it is brought into direct contact with the wood (Bootle 1983). Both heartwood and sapwood are very susceptible to blue stain and are extremely non-durable; the sapwood is prone to borers.

Related species. There are about 40–45 *Alstonia* species in Africa, Asia, Malesia, Melanesia and Australia. Six species occur in Australia (Forster 1992). It can be distinguished from *A. actinophylla* by its broader leaves and larger number of secondary veins on either side of the leaf midrib.

Asteromyrtus brassii

Main attributes. A fast-growing small tree that tolerates wet acid soils, but is very adaptable to differing soil and topographic conditions in the hot humid tropics. It is a source of posts, poles and firewood and may be useful for soil stabilisation, shelter and amenity planting on difficult sites such as those close to the sea.
Botanical name. *Asteromyrtus brassii* (Byrnes) Craven in *Aust. Syst. Bot.* 1: 379–380 (1989, '1988') was first published as *Melaleuca brassii* by Byrnes (1985) from a specimen collected from the Oriomo River, Papua New Guinea. The genus is from the Greek *astero* — starry, and Latin *myrtus* — myrtle, referring to the radiating bundles of stamens. The species was first collected by and named after L.J. Brass (1900–1971), a botanist who worked in Papua New Guinea.
Common names. No common names listed.
Family. Myrtaceae
Botanical features. Usually a shrub or small tree 3–9 m but may reach 25 m in height in some locations. The hard bark is brown or dark grey, fibrous with longitudinal fissures. The upright branches form a dense rounded crown. The leaves are narrow elliptic to narrow obovate 4–9 cm long by 5–15 mm wide, the apex narrowly acute to obtuse, the very apex subapiculate to rounded, 5–11 major nerves. The stalk is very short. The inflorescence is globose, on branchlets or branches beneath the leaves, not terminal. Stamens 30–50 per bundle, the filaments deep pink to bright red, 10–14 mm long, the bundle claw 8–10 mm long and linear or tapering to a fine point. The globular, aggregate fruit 1–1.5 cm in diameter is covered with the persistent bracts and floral tubes of the spent flowers, eventually becoming smooth after several seasons (Wrigley and Fagg 1993). The seeds are 3–4.5 mm long, slightly larger at one end with a small, well-developed wing at the seed apex, sometimes nearly half the length of the seed, but absent or weakly developed at the sides. The flowering period can extend throughout the year, but is mainly from May to September. Ripe seed has been collected in northern Australia in November–December (Searle 1989).

The species is described in detail by Byrnes (1985) and Craven (1989).

Natural occurrence. In Australia this species is restricted to the northeastern part of Cape York Peninsula as far south as the McIlwraith Range. It is also found in the Western Province of Papua New Guinea, and probably extends into Irian Jaya, Indonesia.

- Latitude: Range: 8–14°S.
- Altitude: Range: sea level to 300 m.

Climate. *A. brassii* is found in the hot humid zone. The mean maximum temperature of the hottest month is 31–34°C. The mean minimum of the coldest month is 18–22°C. The average number of days when 32°C is exceeded is about 50–90. The area is frost-free.

The 50 percentile rainfall is 1400–1950 mm, the 10 percentile 1100–1400 mm and the lowest on record 700–900 mm per year. The rainfall has a strong summer monsoonal pattern, with the months of August and September almost without rain. The average number of raindays is 120–300 annually.
Physiography and soils. The distribution is confined to the Eastern Uplands physiographic zone. The species has been collected from a range of topographical sites, such as quartz or exposed granite ridges, to gentle hill slopes and on gently undulating terrain on the Oriomo Plateau of Papua New Guinea. Soil types include sands, fine silty clays, deep sandy bleached grey earths and shallow stony sands (Pedley and Isbell 1970). It is generally not found on soils with impeded drainage in Papua New Guinea (B. Gunn, pers. comm.).
Vegetation type. This species has been recorded in a variety of vegetation types, among which are low open-forest and woodland, monsoon forest and woodland,

scrub, heath on sand and in a gallery community on white bleached sand. Associate species are: *Acacia leptocarpa*, *A. crassicarpa*, *A mangium*, *Banksia dentata*, *Allocasuarina littoralis*, *Grevillea glauca*, *Callitris intratropica*, *Neofabricia myrtifolia* and *Melaleuca viridiflora*. In Papua New Guinea *A. brassii* is found in woodland, on permanently dry, either undulating to flat or hilly, terrain with a dense shrub layer and thin woody climbers (Paijmans 1975). Common associate species are *Lophostemon suaveolens*, *M. dealbata*, *A. mangium*, *A. crassicarpa*, *A. leptocarpa*, *Dillenia alata* and species belonging to the genera *Alphitonia*, *Alstonia* and *Xanthostemon*.

Utilisation.

Fodder: Not known to have forage value.

Fuelwood: There is no information on the burning properties of the wood; however, it is used locally as firewood in Papua New Guinea.

Wood: Quantitative descriptions of wood properties are unavailable. It is highly regarded locally in Papua New Guinea for posts and as a source of poles for house construction.

Other uses: It has potential for shelter and soil conservation planting in tropical areas and on sites which range from infertile rocky ridges to sub-saline conditions adjacent to mangroves. The species is used for minesite rehabilitation in northern Australia (Langkamp 1987). *A. brassii* foliage contains a reasonable concentration of essential oil (1–1.4% on dry weight) whose principal components are gamma-terpinene (15–34%) and 1,8-cineole (24–46%) (Brophy et al. 1994). Although not used presently, the composition of the oil suggests that it may be useful locally (e.g. in Papua New Guinea) as a general antiseptic.

Silvicultural features. *A. brassii* has the reputation of being a hardy plant, much more erect than *A. symphyocarpa* and with a preference for sandy soils (Wrigley and Fagg 1988). It is reasonably fire-tolerant and coppices readily in nature (B. Gunn, pers. comm.)

Establishment: Propagation is from seed or cuttings. There are approximately 171 000 viable seeds/kg.

Yield: A. brassii is reputedly fast-growing; however, there are few published reports of growth performance available. The species is under trial on the seasonally inundated, acid sulfate soils of the Mekong Delta of Vietnam. It appears not to be well adapted to these conditions. The best performance was from a Papua New Guinea provenance which gave 39.1 % survival and reached only 1.6 m in height in 2 years (H. Chuong, pers. comm.). In contrast, a provenance of *A. symphyocarpa* from northern Queensland had reached > 1 m (66% survival) in the same trials.

Pests and diseases. None are recorded.

Limitations. Based on its ecological preferences in Papua New Guinea, it may not tolerate impeded or waterlogged soil conditions. It is also likely to be frost tender.

Related species. *Asteromyrtus* is a recently reinstated genus (Craven 1989) of shrubs and trees in the family Myrtaceae. It comprises seven species, *A. angustifolia*, *A. arnhemica*, *A. brassii*, *A. lysicephala*, *A. magnifica*, *A. symphyocarpa* and *A. tranganensis*. Only *A. brassii* and *A. symphyocarpa* have orange to red flowers. *A. brassii* is distinguished by its erect branchlets.

Asteromyrtus symphyocarpa

Main attributes. A small tree adapted to acidic, infertile and periodically waterlogged soils in the lowland tropics. Potential for fuel, small round timbers, erosion control, and revegetation of mining areas. The essential oil has medicinal properties.

Botanical name. *Asteromyrtus symphyocarpa* (F. Muell.) Craven in *Aust. Syst. Bot.* 1: 393 (1989, '1988') was originally published as *Melaleuca symphyocarpa* by F. Mueller in *Trans. Phil. Inst. Vic.* 3: 44 (1859). The specific name is presumably from the Greek *symphyo* — to unite, and *carpos* — fruit, referring to the clustered fruits.

Common names. Liniment tree.

Family. Myrtaceae.

Botanical features. A multi-stemmed shrub or small tree usually in the height range 3–12 m in Australia. Reaches larger dimensions in Papua New Guinea. The crown may be pendulous and the stem is sometimes fluted. The bark is dark, hard, slightly flaky but not papery and layered. The branches are erect and the branchlets pendulous, hairless and sometimes glaucous. Leaves are alternate, narrowly elliptic to narrowly obovate, 3–9 cm long by 0.5–2 cm wide, blunt at the tip, with 5–10 major nerves, with a short stalk. The flowers are in dense, more or less, globular heads. The stamens are 10–25 per bundle, the filaments yellow to orange, sometimes turning red after or at anthesis, 10–15 mm long, the bundle claw 8–9.5 mm long. The inflorescences are on the branchlets or branches beneath the leaves, or occasionally in the upper axils or terminal (Craven 1989). This feature, together with the brightly coloured flowers, is an indication that *A. symphyocarpa* and *A. brassii* originated separately within the genus as a positive reaction to bird feeding preferences (Craven 1989). The flowering period is throughout the year, but usually February to July. The fruiting heads are about 8–15 mm in diameter and comprise a number of closely packed woody capsules. The seeds are widest above the middle, the wing well developed at the seed apex and usually extending to one side of the seed, 2.5–3 mm long, mature from July to December.

The species is described by Craven (1989). The flower is illustrated by Williams (1980), Brock (1988) and Wrigley and Fagg (1993), and the tree form by Gillison (1983).

Natural occurrence. *A. symphyocarpa* is found in the Northern Territory from around Darwin to Cape York Peninsula in northern Queensland. It extends to southern Papua New Guinea and Irian Jaya in Indonesia.

- Latitude. Range: 10–19°S. (Australia only).
- Altitude. Range: near sea level to 200 m.

Climate. The main distribution is in the hot subhumid climatic zone but it extends into the hot humid zone and marginally into the semi-arid zone. The mean maximum temperature of the hottest month is mainly in the range 33–37°C, and the mean minimum of the coolest month 17–22°C. There are 100–230 days over 32°C and 1–10 over 38°C. Most of the area is frost-free but a few southern inland localities occasionally record frosts.

The 50 percentile rainfall is 850–1300 mm, the 10 percentile is 550–1000 mm, and the lowest on record 350–850 mm. There is a well-developed summer monsoonal pattern, with January to March being the wettest months. Raindays average 50–90 per year.

Physiography and soils. Although *A. symphyocarpa* occurs in all three major physiographic divisions in Australia it is mainly confined to flat or undulating topography. Most occurrences are on low-lying flood plains near the coast, and fringing watercourses and lagoons. It is recorded as growing at the base of sandstone cliffs. The occurrences in Papua New Guinea and nearby Irian Jaya are on the relict alluvial plain known as the Oriomo Plateau.

In many localities the soils are clays and fine-textured alluvia in areas with impeded drainage, but it is common in north Queensland on sandy soils over a hard, cemented subsoil. Soil types include red and yellow earths, brown soils of light texture, and red and yellow podzolics, often in areas that are flooded with shallow water for short periods each year (Perry and Lazarides 1964).

Vegetation type. In Australia *A. symphyocarpa* is mainly a component of low woodland or low open-forest in which the trees are fairly closely spaced. In places it is a gregarious small tree, 2–3 m tall, forming rather dense small patches and strips of open-scrub. It is commonly associated with *Pandanus spiralis*, *M. acacioides*, *M. nervosa*, *M. viridiflora*, *Banksia* spp., *Eucalyptus polycarpa*, *Grevillea pteridifolia* and *Lophostemon suaveolens* (Perry and Lazarides 1964; Story 1969).

In Papua New Guinea it occurs on sandy plains with a strongly impeded drainage and forms open-scrub 2–8 m tall with *M. cajuputi*, *Banksia dentata* and *Grevillea glauca*. It also occurs in woodland on well to imperfectly drained sites with *M. cajuputi*, *M. leucadendra*, *Acacia mangium* and *Lophostemon suaveolens* (Paijmans 1971).

Utilisation.

Fodder: A. symphyocarpa is not a fodder species.

Fuelwood: There is no information on the burning qualities of the wood, but some closely related species are satisfactory fuels.

Wood: Dark-coloured, close-grained and prettily marked (Bailey 1900b). Could be used for posts, poles, and small stakes. Australian Aboriginal people use the wood to make spears and several implements (Brock 1988).

Other uses: A decorative small screening tree suited to gardens, streets, median strips and mixed parkland plantings (Brock 1988), and a possible source of honey. It may have a place in erosion control on suitable sites and is used in the revegetation of mining areas in northern Australia (Langkamp 1987). Crushed leaves in water have been used by Australian Aboriginal people for the treatment of colds and influenza (Aboriginal Communities of the Northern Territory 1993). The leaves contain essential oils rich in the therapeutic compound 1,8-cineole (40–70%) (Brophy et al. 1989; Brophy et al. 1994). This species is reputedly the source of Cajuput oil produced in Irian Jaya.

Silvicultural features. A small tree that grows on a range of infertile soils often with impeded drainage and

periodically waterlogged. *A. symphyocarpa* tolerates fire and will reshoot from epicormic shoots on the stem and from suckers on an extensive rhizomatous system (C. Lacey, pers. comm.). Coppicing ability was rated as good to fair by Ryan and Bell (1989), and there was evidence of provenance variation. Its ability to coppice is an advantage if it is used for fuelwood, small poles or essential oils.

Establishment: Propagation is from seed which require no pretreatment to germinate, and cuttings. Flowering occurs early with the first buds appearing in 13–23 months (Ryan and Bell 1989). The seed is very fine, with 311 800 viable seeds/kg.

Yield: Two provenances were trialed in southeastern Queensland (Ryan and Bell 1991). The best performing provenance (Weipa, Qld) survived well (92%) and had a moderate growth rate of 0.7 m/year. MAIs for height growth exceeded 1 m on several trial sites in Thailand (Pinyopusarerk 1989) and Zimbabwe (Gwaze 1989).

Pests and diseases. None recorded.

Limitations. The suckering habit of this species could be a problem under some circumstances.

Related species. *Asteromyrtus* is a recently reinstated genus (Craven 1989) of shrubs and trees in the family Myrtaceae. It comprises seven species, *A. angustifolia*, *A. arnhemica*, *A. brassii*, *A. lysicephala*, *A. magnifica*, *A. symphyocarpa* and *A. tranganensis*. Only *A. brassii* and *A. symphyocarpa* have orange to red flowers. The latter is distinguished by its pendulous branches.

Banksia integrifolia

Main attributes. A shrub or tree suitable for planting where tolerance of wind and salt exposure is important. Used in both temperate and tropical areas for windbreaks, avenue planting, and as an ornamental. It is a source of honey and fuelwood.

Botanical name. *Banksia integrifolia* L.f. in *Suppl. Pl.* 127 (1781). The generic name commemorates Sir Joseph Banks (1743–1820), one of the first botanists to visit Australia. The specific name is from the Latin *integer* — entire, and *folium* — leaf, alluding to the adult leaves which do not have serrated or lobed edges.

Common names. White honeysuckle, coast banksia, honeysuckle oak.

Family. Proteaceae.

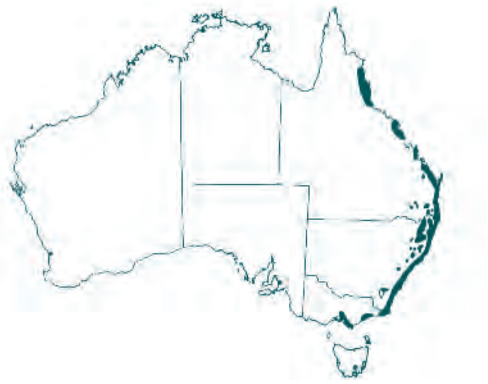
Botanical features. A large shrub or small tree, usually 10–16 m, it can reach 25 m, but sometimes does not exceed 5 m in exposed coastal situations. The trunk is often twisted and leaning. The bark is dark grey, hard, thick and roughly tessellated. Branches are smoother and young branchlets densely hairy. Seedling and coppice leaves are alternate with serrated margins. Mature leaves are entire or with a few short teeth, narrowly obovate or lanceolate. The upper surface is dark green and the underside is white. The inflorescence is a terminal, cylindrical spike, 7–15 cm long and 5–7 cm wide, with pale yellow flowers. Flowering occurs January to July. Only a small proportion of flowers set fruit, which mature 8–10 months after flowering (September to April). The fruiting body is a spike made up of follicles (individual fruits). Each follicle consists of two hard, woody, shallowly convex valves that open at maturity to release two seeds. The seed is 2–5 mm wide, dark brownish-black and glistening, and has a brown papery wing.

Four subspecies are recognised by Thiele and Ladiges (1994), viz:

Subsp. *integrifolia*: Tree to 25 m. Juvenile leaves wedge-shaped, 3–6 cm × 2–3 cm. Mature leaves whorled, narrow, 4–10 cm long, dull green above.

Subsp. *compar* (R.Br.) K.R. Thiele: Tree to 16 m. Juvenile leaves 10–18 cm × 1–2 cm. Mature leaves whorled, narrow, 10–20 cm long, wavy, usually shiny dark green above.

Subsp. *aquilonia* (A.S. George) K.R. Thiele: Tree to 15 m. Juvenile leaves very narrow and sharp-pointed 7–24 cm × 6–21 mm, often toothed. Mature leaves spirally arranged,



5–20 cm × 6–12 mm, shiny dark green above. Rusty brown hairs on the undersurface.

Subsp. *monticola* K.R. Thiele: Shrub or medium tree 2–25 m. Juvenile leaves 9–17 cm × 2–3 cm, spinescent marginal teeth. Mature leaves whorled, 9–19 cm × 1.5–2 cm, somewhat shiny dark green above, often drying with a dull bronze tint.

The species is described and illustrated by George (1981, 1984a), Boland et al. (1984) and Thiele and Ladiges (1994).

Natural occurrence. The most widespread species of *Banksia*, extending for more than 3000 km along the east coast of Australia, from Victoria to northern Queensland, usually within 50 km of the coast. Subsp. *integrifolia* is found in coastal areas from Victoria to Fraser Island, Queensland. Subsp. *compar* occurs generally on coastal dunes and plains from Rainbow Beach to Proserpine in Queensland (20–26°S). Subsp. *aquilonia* is a disjunct taxon restricted to coastal and montane areas of northern Queensland (16–18°S), and subsp. *monticola* occurs from the Blue Mountains in the south along the ranges of central New South Wales northwards to the Queensland-New South Wales border (28–33°S).

• Latitude. Range: 16–40°S.

• Altitude. Range: sea level to 1700 m.

Climate. The distribution is mainly in the warm humid and sub-humid climatic zones. Subsp. *aquilonia* is restricted to the hot humid climatic zone. Mean maximum temperature of the hottest month is 27–32°C, while the mean minimum of the coolest month is 3–13°C. Coastal areas are frost-free. At the high elevations in northern New South Wales there are more than 65 frosts per year and in Queensland, the average is 1–2 frosts annually.

The 50 percentile is 850–1200 mm a year and the 10 percentile 600–1000 mm. The lowest on record is 350–600 mm. Seasonal incidence varies from a strong summer maximum in northerly locations to a spring maximum in central Victoria.

Physiography and soils. *Banksia integrifolia* is confined to the Eastern Uplands physiographic division. Subsp. *integrifolia* and subsp. *compar* typically occur in littoral situations on coastal cliffs and headlands, river estuaries, and consolidated sand dunes. Subsp. *aquilonia* and subsp. *monticola* extend to uplands and dissected plateaux, the latter on fertile soils derived from igneous parent rocks. Best development is on well-drained sandy or loamy soils and alluvia derived from basalt or granite, but it may also be found on yellow and red earths and poorly drained, seasonal swamps with humic gley soils. The soils are usually acid to neutral.

Vegetation type. *B. integrifolia* may be found in eucalypt open-forest, woodland, low woodland, shrubland, and mixed closed-forest (rainforest). Subsp. *integrifolia* and subsp. *compar* are components of coastal woodland and low woodland often with *Eucalyptus botryoides* and *Leptospermum laevigatum*. Subsp. *monticola* occurs in montane situations in association with *E. pauciflora*, *E. viminalis*, *Nothofagus moorei* and *Orites excelsa*. In north Queensland, subsp. *aquilonia* is found as a shrub 3–5 m high under a scattered tree layer of *Syncarpia glomulifera*, *E. intermedia*, *Allocasuarina littoralis* and *Acacia flavescens* in medium and low woodland.

Utilisation.

Fodder: Not known to have been used as fodder.

Fuelwood: The wood naturally splits upon drying and makes a very useful fuelwood.

Wood: Pinkish, becoming dull brown on exposure, with an attractive oak-like figure when cut on the corner. The wood is light (air-dry density of about 530 kg/m^3), soft, has little strength and is somewhat difficult to season (Swain 1928a). It has been used for veneer, small cabinet work and fancy articles, and occasionally for ribs and knees in boat building.

Other uses: Used as an ornamental, in windbreaks, and as an avenue plant. Subsp. *integrifolia* may be used to stabilise sand dunes after initial fixing of the dunes by other species such as *Casuarina equisetifolia*. The flowers produce good quantities of pollen and nectar, and the honey has weak density and a strong flavour (Blake and Roff 1958). Subsp. *integrifolia* is used successfully as a rootstock for several ornamental banksias. A prostrate form shows excellent potential for ground cover.

Silvicultural features. The coastal subspecies are very resistant to salt spray and are moderately drought- and frost-tolerant. Tolerates a range of sites but freely drained, sandy acid soils are most suitable (Holliday and Watton 1971). It is long-lived and can develop a massive trunk. It may be pruned moderately hard (George 1984a). George (1981) reports that root suckers are sometimes produced if the roots are uncovered or disturbed. After a fire it regenerates from epicormic shoots in the trunk.

Establishment: The easiest method of propagation is by seed. There are about 52 300 viable seeds/kg. Recommendations for raising plants and establishing seedlings in the field are given by George (1984a). The seeds germinate readily in 1–2 weeks without pretreatment. As the seedlings are sensitive to damping-off fungi, the seeds should be sown in sterilised soil on sand. The seedlings can be transplanted to containers when they have 2 or 3 true leaves (Hockings 1977).

Yield: In a field trial in southeastern Queensland Subsp. *compar* grew moderately fast, reaching 4.5 m in height and 13.8 cm in basal diameter in 4.5 years (Ryan and Bell 1991).

Pests and diseases. It is susceptible to damage by the root rot fungus *Phytophthora cinnamoni* (George 1984a).

Limitations. It has a tendency to form a crooked stem. Northern forms may not be frost-tolerant.

Related species. The closest relatives to *B. integrifolia* are *B. dentata* L.f., and *B. saxicola* A.S. George. Natural hybrids occur with *B. marginata* (L. Thomson, pers. comm.).

Brachychiton diversifolius

Main attributes. A drought-tolerant, deciduous to semi-deciduous tropical tree adapted to a wide range of well-drained soils. Has potential as a stock fodder and amenity tree.

Botanical name. *Brachychiton diversifolius* R.Br. was named by Robert Brown in *Pl. Jav. Rar*. 234 (1844). There are two subspecies, subsp. *diversifolius* and subsp. *orientalis* described by G.P. Guymer in *Aust. Syst. Bot*. 1: 231 (1988). *Brachychiton*, from the Greek *brachys* — short, and *chiton* — outer covering, because of the loose outer covering of the seed (Baines 1981). The species name is from the Latin *diversus* — different, and *folium* — leaf, in allusion to the variation in size and shape of the juvenile leaves.

Common names. Northern kurrajong (standard trade), tropical kurrajong, airitja, nanunguwa.

Family. Sterculiaceae.

Botanical features. A small tree, 5–18 m tall, and up to 35 cm diameter, deciduous or semi-deciduous. The trunk is cylindrical. The bark is dark grey or brown, tessellated on the trunk and major branches. Branchlets are pale green or somewhat bluish-green, 2–4 mm in diameter. Leaf blades are shiny above, entire and rarely with short lateral-lobes, ovate or ovate-lanceolate or heart-shaped, 6–18 cm by 3–10 cm on stalks 3–8 cm long. The inflorescence is axillary with 15–60 flowers on 3–7 cm long pale green panicles. The male and female flowers are without petals, the calyx resembling the petals, green, stippled or blotched with red on the inside, on the outside covered with golden brown hairs, 6–8 mm long by 12–16 mm wide. Fruit are woody follicles that split open at maturity along an inner suture, dark grey to black. They are glabrous outside, ellipsoid or obovoid, on a short stalk that is frequently twisted and beaked at the apex, 6–10 cm long and 3–4.5 cm wide. The follicle is prickly-hairy inside with dense simple and star-shaped hairs. The seeds are yellow or cream, smooth, ovoid, 8–10 mm long × 4.5–5 mm, 10–22 per follicle. Flowering is from May to December (Wilson 1992) or June to September–October (Brock 1988; Guymer 1988). Fruits are available August to January (Wilson 1992) or October to December (Brock 1988).

The differences between the two subspecies as described by Guymer (1988) are:

Subsp. *diversifolius*: star-shaped hairs on the outside of the flower (perianth) 0.4–0.8 mm; leaf stomata on both sides (not absolute), shape ovate-caudate, length to width ratio usually < 2.

Subsp. *orientalis* — star-shaped hairs on the outside of the flower (perianth) 0.1–0.3 mm; leaf stomata on the under surface, shape ovate-acuminate to ovate-lanceolate, length to width ratio > 2.

The species is described and illustrated by Guymer (1988) and Brock (1988).

Natural occurrence. The species has an extensive distribution in tropical northern Australia. Subsp. *diversifolius* has a wide range from the Kimberley region of Western Australia through into the northern half of the Northern Territory, and a small extension into Queensland. The subsp. *orientalis* is limited to inland north Queensland and Cape York Peninsula.

- Latitude. Subsp. *diversifolius* Range: 11–18°S.
  Subsp. *orientalis* Range: 13–19°S.
- Altitude. Subsp. *diversifolius* Range: from sea level to 200 m.
  Subsp. *orientalis* Main occurrence: sea level to 200 m.
  Subsp. *orientalis* Range: sea level to 500 m.

Climate. The distribution is in the sub-humid and hot humid climatic zones in coastal regions of northern Australia, while inland the populations extend into the hot semi-arid zone. The mean maximum temperature of the hottest month in inland areas is 32–36°C, while the coastal temperatures are cooler at 31–32°C. The mean minimum varies 19–24°C. The area is frost-free.

The 50 percentile rainfall is 440–1500 mm, the 10 percentile 270–860 mm, and the lowest on record 138–760 mm. Rainfall has a strongly developed monsoonal pattern with a distinct dry season in inland semi-arid areas. Rain is recorded for inland areas on average from 40–79 days, while for coastal regions it increases to 82–90 days.

Physiography and soils. The distribution of subsp. *diversifolius* lies in the Kimberley, North Australian Plateaux, Carpentaria Fall and Lander–Barkly Plains provinces of the Western Plateau physiographic division. In Queensland subsp. *orientalis* is restricted to the northern part of the Eastern Uplands. The topography is generally flat to gently undulating, but it is also known to occur on rocky hillsides, low tablelands and on coastal dunes. Soils vary from well drained sands, red basalt soils and lithosols.

Vegetation type. *B. diversifolius* occurs mainly as scattered individuals in woodlands and open forests dominated by eucalypts. Dominant associate species are *Eucalyptus tetrodonta*, *E. miniata*, *E. polycarpa*, *E. alba* and *E. dichromophloia*. Species such as *E. tectifica*, *E. ferruginea*, *E. grandifolia* and *E. jensenii* are associated with subsp. *diversifolius*. *E. cullenii*, *E. leptophleba* and *E. nesophila* are associates of subsp. *orientalis* (Guymer 1988). Other types are deciduous woodlands dominated by *Terminalia* spp. and vine thickets (Pedley and Isbell 1970; Story 1969; Wilson 1992).

Utilisation.

Fodder: Leaves are eaten by stock (Brock 1988; Wilson 1992). It is a close relative of *B. populneus*, one of Australia's pre-eminent native trees for stock fodder during drought.

Fuelwood: This species has not been tested for its fuelwood potential, but its low density of 450 kg/m^3 (Cause et al. 1974) suggests that it would not make good firewood.

Wood: It is probably similar to the wood of *B. populneus*, which is a light soft timber of poor strength and low durability, once used for interior furnishings (Boland et al. 1984).

Other uses: Has been used in the revegetation of mine sites in the Northern Territory (Langkamp 1987). Although semi-deciduous in the dry season, it is a neat, stable shade tree for streets, parks, rural properties and shelter belts (Brock 1988). The tree was utilised extensively by Australian Aboriginal people. The seeds were

eaten raw or roasted once the hairs around the seeds were removed. The seeds contain 32% oil and 38% protein containing nutritionally useful quantities of amino acids (Rao et al. 1989). The roots of young plants were also eaten raw or cooked. Firesticks and spears were made from the wood, and string from the bark. The leaves, bark and gum were used medicinally to treat open and infected skin lesions and fevers. A preparation from the inner bark was used as an eyewash (Aboriginal Communities of the Northern Territory 1993).

Silvicultural features. A hardy plant adapted to a wide range of well-drained soils (Brock 1988). Coppices and root suckers after clearing (Hearne 1975). Propagation is by seed (Wrigley and Fagg 1988). Near Darwin, growth is reported to be rapid and, with regular watering and fertilising, trees reach adult height in four to five years (Hearne 1975).

Pests and diseases. The species is susceptible to termite attack, and grasshoppers in the early dry season can severely damage young growth (Hearne 1975).

Limitations. The hairs around the seeds are prickly and are a potential skin irritant.

Related species. *B. diversifolius* is most closely related to *B. populneus*, which has similar-shaped leaves and flowers (Guymer 1988). *B. diversifolius* is readily distinguished by the dense pubescence on the outside of the flowers (perianth), and the short stalk beneath a larger follicle.

Capparis mitchellii

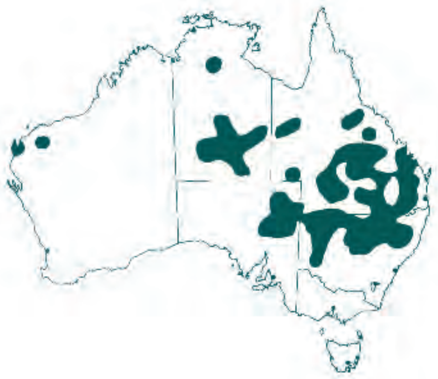
Main attributes. A compact, evergreen shrub or small tree which is drought- and frost- tolerant and adapted to heavier soils. It will tolerate alkalinity. Useful for emergency drought fodder for stock, shade, ornament and soil protection.

Botanical name. *Capparis mitchellii* Lindley was published in T. Mitchell's *Exped. E. Austral.* 1: 311 (1838). The generic name was derived from the Arabic *kapar*, the name for *Capparis spinosa* L. (Hewson 1982). The species was named after Sir Thomas Mitchell (1792–1855), the explorer who first collected it (Boomsma 1981).

Common names. Wild orange, native orange, bimbil, bumbil, native pomegranate, bumble tree, mondo, karn-doo-thal, small native pomegranate, tree caper.

Family. Capparaceae.

Botanical features. *C. mitchellii* is a small shrub or low tree to 10 m. Shrubs are erect, sprawling or climbing with many tangled branches from which a central stem or stems emerge later. The branches may grow up adjacent trees with the aid of axillary spines before the development of a main stem. Small-leaved spiny growth develops on stems of older trees in response to stock browsing. The tree has a short, straight trunk with dark rough bark and a dense rounded canopy. Immature growth is covered with short hairs, giving a downy appearance that frequently disappears with age. The leaves are elliptic, ovate, wider below the middle, 2–7 cm long by 1.2–3.8 cm broad, dully green, rigid, leathery, tapered at the base into a short stalk 6–11 mm; usually with 2 small recurved spines at the base of the stalk. Inflorescence 1–4 large flowers in the upper axils, on stalks 3–4 cm long. The flower has 4 white or creamy petals, 2.5–3 cm long, with numerous stamens on stalks 3–4 cm. The style is 5.5–7.5 cm long with a pubescent ovary 5 mm deep. The fruit is a globose to spherical berry, deep green, 2–7.5 cm in diameter, smooth or covered with irregular wart-like protuberances, hairy to glabrous, on a stalk 4–8 cm long. It contains several 10-mm-long seeds, deeply embedded in pulp enclosed by the thick outer skin. Flowering period is from late September to February (Cunningham et al. 1981). Fruits are available in December in Queensland (Pearson and Pearson, undated) and February to April in South Australia (Bonney 1994).



The species is described and illustrated by Boomsma (1981), Cunningham et al. (1981) and Holliday (1989b).

Natural occurrence. *C. mitchellii* is distributed in central Australia in the Northern Territory, central and southern Queensland, western New South Wales and northern South Australia. It has a restricted distribution in the Pilbara region of Western Australia.

- Latitude. Main occurrence: 20–34°S.
  Range: 15–34°S.
- Altitude. Main occurrence: 40–515 m.

Climate. The principal distibution lies in the hot semi-arid and warm arid climatic zones. Some populations occur in the hot arid zone in central and Western Australia, while those in eastern and northern Queensland lie in the warm sub-humid zone. The mean temperature of the hottest month is 24–36°C and the mean minimum of the coolest month 5–11°C. Frosts occur in most inland localities and average 1–23 annually.

The 50 percentile rainfall is 120–630 mm, the 10 percentile 55–430 mm and the lowest on record 21–285 mm. Rainfall incidence varies from a moderate summer maximum in the north to a well-defined winter maximum in the south. In semi-arid areas rainfall distribution is variable from year to year. The annual average number of raindays is 15–60.

Physiography and soils. Most of the distribution occurs on the Interior Lowlands physiographic division. This extends in the east to central parts of the Eastern Uplands and in the north to the Lander–Barkly plains and west in the Pilbara within the Western Plateau division. The topography varies from plains, drainage lines, levees and banks of major rivers, terraces away from major, low tablelands or undulating country to sandstone plateaux, ironstone ridges and dissected ranges. It occurs on sandy or skeletal soils with high organic content, yellow, brown or grey podzols, rarely solodic soils, cracking clay and sandy red and yellow earths. Soils on alluvial plains include deep alluvials with grey or brown cracking clays and non-calcic brown soils with sandy surfaces (Beadle 1981; Neldner 1984; Story 1967). The species is common on texture-contrast soils with thin sandy surface and neutral subsoils.

Vegetation type. In inland semi-arid regions *C. mitchellii* is found mainly in the low tree or shrub understorey in woodland, mixed shrub woodlands and tall scrubs in association with low woodlands. These are usually dominated by *Eucalyptus populnea*, *E. moluccana*, *E. tereticornis*, *Acacia cambagei*, *A. aneura*, *Callitris columellaris*, *Flindersia maculosa*, *Geijera parviflora* and spinifex (*Triodia* spp.) dominated associations on sandy ridges and dunes (Beadle 1981; Neldner 1984; Story 1967). Both *C. mitchellii* and *C. lasianthos* are widespread, but not gregarious. They grow as scattered individuals, rather than many individuals within the type. Associated shrub species are *C. lasianthos*, *Eremophila mitchellii*, *Alectryon oleifolius*, and *Santalum lanceolatum*. *C. mitchellii* is also found in closed microphyll vine forest or semi-evergreen vine thicket or closed microphyll forest in central and northeast Queensland (Beadle 1981; Neldner 1984). This type is found on steep upper and middle slopes, where heavy clays have formed from shales, siltstones or basalt. It is prominent on steep slopes of sandstone ranges. Dominant species are *Cadellia pentastylis* and *Brachychiton* spp. in a low tree or tall shrub layer with an understorey of low shrubs such as *Alectryon subdentatus* and *Alphitonia excelsa*.

Utilisation.

Fodder: The species is regarded as an excellent fodder tree for sheep, cattle and goats (Cunningham et al. 1981). It is of moderate nutritive value and palatability (Askew and Mitchell 1978).

Fuelwood: No data available, but its high density should make it an excellent species for fuel.

Wood: The heartwood is whitish and hard with a uniform close grain. It is suitable for carving and engraving and has been used to make smokers' pipes. It

has an average density of 815 kg/m^3 (Boomsma 1981; Cunningham et al. 1981).

Other uses: It is a useful tree for shade, shelter, soil protection and ornament (Cremer 1990). The fruit is reported to have a pleasant to sickly smell and to be quite astringent. It is said to have been eaten by Aborigines (Cunningham et al. 1981).

Silvicultural features. A handsome tree but straggly when young. Drought- and frost-tolerant and adapted to medium to heavy soils, sometimes occurring on limestone. The species is thought to have a fairly long lifespan (Stannard and Condon 1958), and is capable of regenerating by coppice.

Establishment: Propagation is by cuttings or seed (Wrigley and Fagg 1988). If propagating by seed, the seeds must be physically removed from the mature fruit and cleaned, as they are naturally indehiscent. No pre-germination treatment is required.

Yield: Not widely planted but reported to be easily established and of slow to moderate growth rate (Simpfendorfer 1992).

Pests and diseases. The species is a host tree for the caper white butterfly larvae, which may cause severe defoliation (Wrigley and Fagg 1988).

Limitations. Spines on young plants. Small size will restrict use to mainly fuelwood and non-wood uses such as forage and soil protection.

Related species. *Capparis* is a pantropical genus that extends into subtropical regions. There are about 250 species, 17 of which are either native or endemic in Australia. *C. mitchellii* is closest to *C. shanesiana*, a little-known species from central Queensland (Hewson 1982).

Casuarina cristata

Main attributes. A medium-sized nitrogen-fixing tree adapted to self-mulching heavy neutral to alkaline soils. It is tolerant of frost, periodic waterlogging, salinity and drought. It produces excellent firewood and is a useful shelterbelt species.

Botanical name. *Casuarina cristata* Miq. was published in *Rev. Crit. Casuarinarum* 70: t. 10 (1848). The species was subdivided into two subspecies, namely *cristata* and *pauper* by L.A.S. Johnson in *Nuytsia* 1: 265 (1972). The latter was raised to species status by Wilson and Johnson (1989). The genus name is from the Latin *casuarius* — a cassowary, likening the pendulous branchlets to the drooping feathers of the cassowary. The species name is from the Latin *cristatus* — crested, perhaps alluding to the long pointed bracteoles of the 'cones'.

Common names. Belah (standard trade name).

Family. Casuarinaceae.

Botanical features. *C. cristata* is a tree 10–20 m tall, with an erect habit, that frequently propagates by root suckers to form dense, monospecific stands. The bark is finely fissured, grey-brown, dark grey to almost black. The branchlets are drooping in vigorous trees, but spreading in depauperate specimens, to 25 cm long. The articles slightly wrinkled, 8–17 mm long, 0.6–0.9 mm diameter, somewhat waxy, occasionally sparsely pubescent, leaf teeth erect in whorls of 8–12. The male inflorescence is in spikes 1.3–5 cm long, in whorls of 6–10 per cm. The juvenile fruiting cones are reddish-pubescent, nearly glabrous at maturity on stalks 1–4 mm long, woody, somewhat rounded or sub-cylindrical 13–18 mm, sometimes up to 25 mm long by 10–16 mm wide, with woody long thin bracteoles. The seed is winged, 6–10.5 mm long, pale-coloured. Mature seed has been collected in June (Searle 1989).

The species is illustrated in Boland et al. (1984), Holliday (1989b) and Anderson (1993).

Natural occurrence. This is a species of eastern Australia, where it grows in a belt 1300 by 400 km on the central and northern slopes of New South Wales. It also occurs in southeastern Queensland and north to Rockhampton on the coast.

- Latitude. Main occurrence: 26–34°S.
  Range: 22–34°S.
- Altitude: Main occurrence: 175–325 m.
  Range: near sea level to 400 m.

Climate. Most of the distribution in New South Wales is on the higher rainfall side of the warm semi-arid climatic zone, but with an extensive occurrence in the drier part of the warm sub-humid zone. The mean maximum temperature of the hottest month is 30–35°C and the mean minimum of the coolest, 1–11°C. Temperatures exceed 37°C on 10–25 days on average per year. Heavy frosts occur and range in frequency from 2 to 50 per year.

The 50 percentile rainfall is 310–1180 mm, the 10 percentile 275–450 mm and the lowest on record 200–300 mm. Seasonal incidence varies from nearly uniform in the south to a strongly developed summer maximum in the far north where the ratio of the wettest month to the driest is 6:1. The average number of raindays is 50–75 per year.

Climatic conditions within the species natural distribution were estimated by Booth and Jovanovic (1988b) — mean annual rainfall: 300–1178 mm; dry season: 0–12 months; mean maximum hottest month: 30–35°C; mean minimum coldest month: 1–11°C; mean annual temperature: 15–23°C.

Physiography and soils. The distribution extends across the boundary of the Interior Lowlands and the Eastern Uplands physiographic divisions. The landscape is one of plains, gentle slopes and scattered small hills and mesas. *C. cristata* occurs on heavy grey or black soils with calcium carbonate in the lower horizons. It occupies rims of large depressions within large areas of red brown earths, non-calcic brown soils with sandy surface horizons and waterlogged sites (Beadle 1981). Other soils include deep fine textured grey clays that are gilgaied, skeletal soils, red and grey loams, light grey sand, gravelly clays and red clay on river flats.

Vegetation type. A dominant or co-dominant with *Eucalyptus populnea* and *Acacia harpophylla* in woodlands. Low shrubs of acacia and *C. cristata* are present in rainforest-derived communities, such as microphyll vine woodlands and semi-evergreen vine thickets. The species is locally common in tall scrubs to low woodlands in association with *Flindersia maculosa* and *Geijera parviflora*. *C. cristata* is commonly co-dominant with *A. harpophylla* around waterlogged sites. Within shrub woodlands common associates of *C. cristata* belong to the genera *Acacia*, *Atalaya*, *Brachychiton*, *Eremophila* and *Flindersia*. *C. cristata* may also occur as dense stands which can completely suppress the herbaceous sward (Beadle 1981).

Utilisation.

Fodder: *C. cristata* is browsed by livestock and has a high palatability (Wilson and Harrington 1980), but it must be used in mixture with other fodder that is less astringent, to be of most value. The predicted in vivo dry matter digestibility is a low 39.1%, as determined by Vercoe (1989). Livestock are unlikely to digest this species easily (Leigh and Wilson 1983). However, the foliage has reasonable levels of crude protein (11.9%), which may be of significance to livestock during times of drought and low feed availability.

Fuelwood: An excellent fuelwood (Bootle 1983).

Wood: The heartwood is a dark chocolate brown, durable, with a narrow creamy sapwood. The sapwood is not susceptible to lyctid borer attack. The grain is straight, with fine inconspicuous rays. It has an air-dry density of about 1150 kg/m^3 (Bootle 1983). Although not a commercial timber, it has been used for shingles, staves, mauls, tool handles, ornamental items and craftwork. The heartwood can be used for fencing, but is not of high durability.

Other uses: Extremely useful plant for shelterbelts, and an attractive ornamental (Cremer 1990).

Silvicultural features. A moderately fast-growing species. Performs best on lowland areas which have greater water storage than slopes or ridges. Tolerant of drought, frost, periodic waterlogging and flooding and saline soils. Becomes chlorotic on calcareous soils. Moderately salt-tolerant; expect reduced growth at EC_e about 10 dS/m and reduced survival at about 15 dS/m (Marcar et al. 1995).

Establishment: There are 111 900 viable seeds/kg and they can be stored for long periods of time with little adverse effect on viability. The optimum germination temperature is 25°C (Turnbull and Martensz 1982). It coppices and root suckers (Cremer 1990).

Roots of *C. cristata* form a symbiotic partnership with the nitrogen-fixing soil bacterium, *Frankia*. Coyne (1983) found that, while cross-inoculation with *Frankia* strains from other casuarinas was possible, *C. cristata* nodulated most effectively in the presence of its own strain. Nodulation of *C. cristata* was unsatisfactory in untreated nursery soils in central Sudan (Miettinen et al. 1992). Inoculation of nursery soils with appropriate *Frankia* when establishing this species is recommended.

Yield: In trials in southeastern Queensland *C. cristata* grew moderately fast, giving a mean annual increment for height growth of 1.2 m. In central Queensland it survived well on the acidic red earths and averaged 1.2 m in height at 1.5 years. On an alkaline cracking clay the species failed without irrigation but was about 1 m tall with 86% survival at 1.5 years, with irrigation (Ryan and Bell 1991).

The vigour and survival of *C. cristata* in the central coastal plain of Israel on red loamy sand was reported to be good. At 28 years, height was 19 m and dbh was 19 cm (Weinstein 1983). On Hainan Island in southern China, three provenances averaged 1.3 m in height after 1 year (Zhong 1990a).

Pests and diseases. None are recorded.

Limitations. Its ability to root sucker could make it a pest in some areas. Young trees must be protected from grazing animals.

Related species. See under *C. cunninghamiana*.

Casuarina cunninghamiana

Subsp. *cunninghamiana*

Subsp. *miodon*

Main attributes. A tall, potentially fast-growing, relatively cold-tolerant evergreen tree adapted to warm humid and sub-humid climates. It fixes atmospheric nitrogen and is adaptable to a wide range of soil conditions in cultivation. It is used for windbreaks, shelterbelts, riverbank stabilisation, and as an ornamental. The wood is easy to split and makes an excellent fuel but is difficult to saw and season.

Botanical name. *Casuarina cunninghamiana* Miq. The species name was published in *Rev. Crit. Casuar*. 56, t. 6A (1848) after Alan Cunningham (1791–1839) an explorer and botanical collector. Subsp. *miodon* (L. Johnson) comes from the Greek *meion* (Latinised as *mio-*) — few, and *odous*, *odontis* (Latinised as *odon*) — a tooth, referring to the relatively few leaf-teeth.

Common names. The standard trade name is river she-oak. Other common names are river oak, creek oak, and fire oak.

Family. Casuarinaceae.

Botanical features. In Australia, *C. cunninghamiana* is the largest species of the family, reaching 20–35 m in height and with a diameter up to 1.5 m. It attains its best development in southeast Australia. Two subspecies have been recognised: subsp. *cunninghamiana* in eastern New South Wales and Queensland and subsp. *miodon* in the Northern Territory (Wilson and Johnson 1989). Subsp. *miodon* rarely exceeds 12 m in height and has a straggly appearance, less angular branchlets in cross-section and fewer, shorter leaf-teeth per whorl. *C. cunninghamiana* has finely fissured and scaly, grey-brown bark. Teeth on new shoots are erect. Deciduous branchlets are thin and soft and droop in vigorous specimens. Leaf-teeth, 0.3–0.5 mm long, are in whorls of 8–10 in subsp. *cunn inghamiana* and 6–7 in subsp. *miodon*. The species is dioecious with individuals bearing unisexual flowers. Male flowers are borne in terminal spikes, 0.4–4 cm long, at the tips of shoots and are arranged in whorls with 11–13 whorls per cm of spike; female flowers are small, reddish and oval-shaped. Fruiting cones are small, subglobose, about 7–14 mm in length and 4–6 mm diameter. The individual fruit is a small, pale greyish, winged single-seeded samara 3–4 mm long. Seed shed is rapid at maturity. Mature seed may be collected from northern populations around February to March and from southern areas from April to May.

The species is described by Wilson and Johnson (1989) and illustrated by Boland et al. (1984).

Natural occurrence. *C. cunninghamiana* subsp. *cunninghamiana* is native to eastern and northern Australia from southern New South Wales to northern Queensland. Typically it occurs fringing freshwater streams and rivers. Subsp. *miodon* is found along the larger rivers in the Northern Territory.

- Latitude. Main occurrence: 23–37°S.
  Range: 12–38°S.
- Altitude. Main occurrence: 100–500 m.
  Range: About 20–1000 m.

Climate. *C. cunninghamiana* is found mainly in the warm sub-humid climatic zone. Some coastal localities are in the warm humid, while further inland some populations are in the warm semi-arid zone. Populations at higher altitudes in New South Wales tolerate up to 50 frosts per year and temperatures as low as −8°C. Northern coastal localities are frost-free. In the hotter parts of its distribution, temperatures exceed 32°C for up to 100 days per year and are over 38°C on 1–10 days.

The 50 percentile rainfall is 600–1100 mm per year and the 10 percentile 350–675 mm. The rainfall alone is no indication of the moisture available to the tree since the species is found in riverine habitats. Seasonal distribution of rainfall is more or less uniform for southern coastal localities, but for northern areas it changes to a moderate summer maximum, becoming almost monsoonal in the extreme north during December to March.

Marcar et al. (1995) summarise the climatic requirements of subsp. *cunninghamiana* under natural and cultivated conditions; mean annual temperature: 12–29°C; min. temp. of coldest month –2–19°C, max. temp. of hottest month: 25–40°C; mean annual precipitation: 360–2180 mm; dry season 0–12 months.

Physiography and soils. Most populations of *C. cunninghamiana* are found in the Eastern Uplands physiographic division, with a few northern localities in the Interior Lowlands and Western Plateau divisions. This species is restricted to rivers and stream banks and adjacent valley flats. It may extend for a short distance up rocky hillsides above watercourses. Surrounding topography varies from tablelands, dissected sandstone plateaux, hills and lower slopes to coastal lowlands and alluvial plains. The soils are mainly sands or sandy loams, but include clayey loams and gravel terraces of old river courses. The species has also been recorded infrequently growing on clays. The soils are mainly acidic or near neutral. *C. cunninghamiana* is only moderately tolerant of saline conditions and, under natural conditions, is usually replaced by *C. glauca* where the water becomes brackish in coastal rivers. It also becomes chlorotic on highly calcareous soils (Weinstein 1983).

Vegetation type. *C. cunninghamiana* is generally a dominant in river bank vegetation. Surrounding vegetation types are eucalypt open-forest, woodland and open-woodland together with melaleuca woodland. It is also found along watercourses in deciduous vine forest in inland northern areas, associated with *Eucalyptus camaldulensis* and gallery rainforest assemblages. *C. cunninghamiana* has no regular associates over its entire range but in the southern coastal lowlands it may grow with *E. elata* and further north with *E. tereticornis*, *Tristania neriifolia*, *Lophostemon confertus*, *L. suaveolens*, *Tristanopsis laurina* and *Leptospermum* spp. (Beadle 1981).

Utilisation.

Fodder: Young trees are grazed by livestock and the foliage is useful as drought fodder, although not of high nutritive value. Analysis of the foliage from trial plantings in southeast Queensland indicates a moderately low digestibility (29% predicted in vivo) and relatively low levels of crude protein (10%) (Vercoe 1989).

Fuelwood: An excellent fuelwood which was once favoured for firing bakers' ovens in Australia. *C. cunninghamiana* gives a charcoal yield of 33.6% and an ash content of 1.9% with an estimated fuel value of 4870 kcal/kg in Egypt (El-Osta and Megahed 1990).

Wood: Sapwood is narrow and pale with dark reddish or purplish-brown heartwood. In Australia the wood has a reputation of being moderately strong but tough and fissile, fine-textured, straight-grained and with wide medullary rays. It is hard to work and dress but takes a good polish, with a green density of 800–900 kg/m^3. It requires care in glueing and pre-boring for nailing is necessary. Excessive movement of sawn timber is common during seasoning. The heartwood is extremely resistant to preservative treatment but is durable and may last for 15–25 years in the ground (Keating and Bolza 1982). It has been used for casks, axe handles and ornamental turnery, as well as a general utility farm timber.

Fast-growing trees are considerably less dense with average wood density of about 500 kg/m^3. In Egypt, particle board is made from wood of *C. cunninghamiana* (El-Osta and Megahed 1990) and in Argentina it is recommended for use in parquet flooring, packing cases, veneer, and barrel staves (Mendonza 1983).

Other uses: The habit of *C. cunninghamiana* makes it suitable for ornamental use as well as for wind protection, shelterbelt, and riverbank protection. In Egypt it is an important species for preventing irrigation channels from being clogged up with sand (El-Lakany 1983). It is also suitable for sand-dune stabilisation (Kosmer 1975) and is an important agroforestry species in China (Cao and Xu 1990). In California, *C. cunninghamiana* has proven particularly valuable for planting as windbreaks to protect high-value horticultural crops (Merwin et al. 1996).

Craft dyers in Australia have used the foliage to produce attractive colours in wool using different mordants (Cribb and Cribb 1981). The species provides valuable supplies of pollen for apiculture (Clemson 1985).

Silvicultural features. *C. cunninghamiana* is a long-lived, relatively fast-growing tree. It is moderately drought resistant but is unable to tolerate semi-arid conditions unless some additional groundwater is available to supplement rainfall. The hybrid *C. cunninghamiana* × *C. glauca* has proved to be more drought-resistant than *C. cunninghamiana* and more attractive than *C. cristata* (Forestry Commission NSW 1980). It is relatively fire-sensitive especially when young. Older trees are capable of producing root suckers (NAS 1984) but this characteristic is far less evident than in *C. glauca*. It displays fair to good coppicing ability when young. Tropical provenances coppiced strongly in trials in Thailand (K. Pinyopusarerk, pers. comm.). Marcar et al. (1995) rate its salt tolerance as moderate (expect reduced growth at EC_e about 5–10 dS/m and reduced survival above about 10 dS/m).

River she-oak, like other members of this plant family, has a symbiotic relationship with the N-fixing actinomycete, *Frankia*. This symbiosis provides nitrogen to the host plant and, assists casuarina to grow on low fertility soils. However, casuarinas introduced into exotic localities are commonly unnodulated due to a lack of native *Frankia*. Inoculation of the seedlings with pure culture of effective strains of *Frankia* is recommended when the species is introduced to a new area. This is done by applying a water suspension of the inoculant to the seedlings. A less ideal method is to apply a solution of crushed nodules (see papers in Midgley et al. 1983 and El-Lakany et al. 1990b). Reddell et al. (1988) reported on a field trial in Zimbabwe of seedlings of *C. cunninghamiana* inoculated with liquid homogenised whole cell cultures of several different *Frankia* strains. Fourteen months after planting into nitrogen-deficient soils, trees inoculated with three *Frankia* strains grew 50–70% better in height than uninoculated plants. Results using a fourth *Frankia* strain (ORS 020607) were even more spectacular; tree growth was three times better than that of the uninoculated controls and nearly double that of other '*Frankia*-assisted' trees. The recent discovery of aerial nodules on *C. cunninghamiana* trunks opens the way to a new and promising approach to enhancing nitrogen fixation (Dommergues et al. 1990).

Consistent with other wide-ranging species, *C. cunninghamiana* exhibits substantial inter- and intra-provenance variation and careful selection of the origin of planting stock is to be recommended. Results at 2 and 5 years from provenance trials of mainly southern seed origins in California indicated significant genetic variation in growth and survival both between and within provenances (Merwin 1990, Merwin et al. 1996). Major differences in frost tolerance amongst provenances have been observed in these trials with inland high altitude provenances tolerating temperatures of −7°C to −12°C while low elevation or coastal provenances were severely damaged or killed. Best-ranking provenances at year 5 were Wagga, Cowra, Bathurst, Dubbo and Coonabarabran (Merwin et al. 1996). In a range-wide trial of 18 provenances of subsp. *cunninghamiana* in Egypt, a clinal pattern of 7-year growth and survival from north to south was found (El-Lakany 1990). The best provenances were from Queensland; Dululu, Oasis and Mareeba. A negative correlation between height growth (at 2.5 years) and latitude of provenance was also reported for this species in China (Pan and Lu 1990). Patterns of variation reported from the field trials complement results of allozyme analysis by Moran et al. (1989a) and Moore and Moran (1989). Allozyme analysis indicated a relatively high level of genetic diversity between populations from different river systems (26.4%), a contrasting low level of genetic variation among populations in a single-river drainage system, and a latitudinal cline in genetic diversity consistent with the taxonomic separation of subsp. *miodon* from subsp. *cunninghamiana*. These results have implications for seed collecting, tree improvement and conservation strategies.

Establishment: Seed from *C. cunninghamiana* is relatively small compared with other casuarinas; there is an average of 607 200 viable seeds/kg. The optimum temperature for germination is around 30°C (Turnbull and Martensz 1982). Propagation is usually from seed, since seed production is so prolific and germination occurs easily. If selected pure cultures of *Frankia* are not available, it is advisable to inoculate seedlings with a suspension of crushed nodules collected from the host trees preferably at the original collection site (Coyne 1983; Torrey 1983b). This will improve seedling establishment and ensure rapid growth during the initial stages of the plantations.

Vegetative propagation by air-layering has been attempted with limited success (Syed 1957). Treatment of terminal branchlets, heel cuttings or basal sprouts especially from juvenile plants with root-inducing hormone powder has proved successful (Torrey 1983a). Cuttings must be maintained on a mist bench with bottom heat.

Yield: A number of studies have been conducted on growth and biomass production of *C. cunninghamiana*. Most reports indicate a height growth of 1–2 m per year in the early years (El-Lakany et al. 1990b). It is regarded as fast-growing under suitable conditions in South Africa where it has a mean annual growth increment of 1.2–1.5 m in the first 10 years (Poynton 1972). In Zimbabwe *C. cunninghamiana* averaged 3.9 m tall and 5.4 cm in diameter at 30 months from planting (Gwaze and Stewart 1990) while annual growth in height was in the range of 1.8–2.4 m in Uganda (Okorio et al. 1994). In Argentina it has reached 22 m at 24 years (Marlats 1972). A 19-year-old plantation had a mean annual increment of 20.4 m^3/ha while 4-year-old plants in an irrigation ditch measured 9.9 m height and 13.9 cm diameter (Mendonza 1983). Egyptian data indicate a biomass production of 268 t total dry weight (295 m^3 of wood and 34 t of green foliage) at 12 years of age (El-Osta and Megahed 1990). Maximum volume increment is reached in 6–12 years and harvesting at 18 years of age is recommended (Badran and Tawfik 1971).

Pests and diseases. In Egypt, young trees are mainly free of serious pests and diseases. However, trees over 14–15 years old are vulnerable to attack by many wood-destroying insects including the dry wood termite, *Kalotermes flavicollis*, and *Coleopterus* pests, *Stromatium fulvum* and *Macrotoma palmata* (Hassan 1990). Its roots are susceptible to infection by nematodes (El-Lakany 1983).

The species is susceptible in China to bacterial wilt disease, *Pseudomonas solanacearum*. This is a serious disease of 2–15-year-old trees affecting 10–100% of trees depending on location and causing losses in yield of 10–50% (Zhong 1990b). No effective control measures have been found thus far.

Limitations. Seedlings require protection from browsing stock and fire in initial stages of growth. *C. cunninghamiana* is not as tolerant of saline and calcareous soils as *C. glauca* and *C. equisetifolia*. Its utilisation as sawn wood is limited by its tendency to warp, twist and split during seasoning.

Related species. *C. cunninghamiana* belongs to a genus which comprises 17 tree species native to Southeast Asia, Malaysia, Melanesia, Polynesia, New Caledonia and Australia. Closely related to *C. glauca*, which differs in having larger cones, 12–16 leaf-teeth and generally coarser and subglaucous foliage. *C. glauca* tends to grow in estuarine locations, tidal reaches, and brackish water. Natural hybrids occur between *C. cunninghamiana* and both *C. glauca* and *C. cristata* (Wilson and Johnson 1989) and hydrids with *C. glauca* are quite common in cultivation.

Casuarina grandis, which is native to southeastern Papua New Guinea, was formerly regarded as a tropical form of *C. cunninghamiana* and has a similar distribution along freshwater rivers.

Casuarina equisetifolia

Subsp. *equisetifolia*

Subsp. *incana*

Main attributes. A fast-growing, nitrogen-fixing tree of wide adaptability, *C. equisetifolia* is a species of considerable importance for agroforestry and reclamation of unstable coastal ecosystems in the tropics and subtropics. It is salt-tolerant and can grow on sands so is especially useful for erosion control and windbreaks along coastlines and estuaries. The wood has many uses but is renowned as a fuel. The bark is a source of tannin.

Botanical name. *Casuarina equisetifolia* L. Johnson. The species was first described in *Amoen. Acad*. 4: 143 (1759). The name is derived from the Latin *equinus* — pertaining to horses, and *folium* — a leaf, in reference to the fine drooping twigs which are reminiscent of (coarse) horse hair. Subsp. *incana* (Benth.) L. Johnson is from the Latin *incanus* — hoary or white, alluding to the very tomentose young shoots.

Common names. Australia: coast she-oak. Fiji: nokonoko. Japan: mokumao / ogasawara-matsu. India: casuarina (Hindi: jangli saru Bengali: jau. Tamil: savukku). Indonesia cemara / tjemara laut. Malaysia: ru / rhu laut. Myanmar: tin-yu. Papua New Guinea: yar. Philippines: agoho. Sri Lanka: kasa ghas. Thailand: son thale. Tonga: toa. Vietnam: filao.

Family. Casuarinaceae

Botanical features. In Australia subsp. *equisetifolia* is mainly a smallish tree, 8–16 m tall. This is in contrast to some populations elsewhere which attain heights of 35 m with diameters to 50 cm. The subsp. *incana* is typically a small tree and may be reduced to only a large shrub 6–10 m tall on poor sites. Form in wild populations is very variable from crooked low branching trees on exposed sea shores to straight-stemmed forest trees in more sheltered situations. Crowns are finely branched. The bark is light grey-brown, smooth on small trunks, becoming rough and thick furrowed on older trees. Encircling bands of lenticels are prominent on young bark. The inner bark is reddish and astringent. Branchlets are drooping, needle-like, furrowed, 1 mm in diameter and 23–38 cm long and angular to rounded in cross-section, glabrous or pubescent. The minute teeth-like reduced leaves are in whorls of 7–8 per node. Male flowers occur on simple terminal, elongated spikes 7–40 mm long and are arranged in whorls with 7–11.5 whorls per cm of spike. Female flowers are borne on lateral woody branches. The 'cones' are globose 10–24 mm long, 9–13 mm diameter, with acute bracteoles more or less protruding from the surface of the cone. Fruitlets bear a single, dull brown samara 6–8 mm long. In subsp. *incana* the young shoots and 'cones' are frequently covered in a fine white pubescence.

The species is described by Wilson and Johnson (1989) and illustrated in Doran and Hall (1983). Pinyopusarerk and House (1993) have compiled a comprehensive bibliography on the species and summary information is provided by Dommergues (1990), Geary (1993) and Midgley and Sylvester (1997).

Natural occurrence. *C. equisetifolia* subsp. *equisetifolia* occurs naturally on subtropical and tropical coastlines from northern Australia throughout Malesia, southern Myanmar and the Kra Isthmus of Thailand, Melanesia and Polynesia (Pinyopusarerk and House 1993). It has been introduced to a large number of countries outside this range and is now a common feature of the coastal landscape of most tropical countries. In Australia, subsp. *equisetifolia* occurs in a narrow coastal strip from the Darwin area of the Northern Territory along the northern coast of Queensland to the Cairns region. From Cairns to Mackay there is some intergradation with subsp. *incana*. The latter subspecies extends southwards along the coast to near Port Macquarie, New South Wales. Subsp. *incana* also occurs in Vanuatu and New Caledonia.

- Latitude. Range: 20°N–31°S.
- Altitude. Range: sea level to 100 m. (Planted to 1500 m.)

Climate. Within the natural range of subsp. *equisetifolia*, the climate is hot humid to hot sub-humid, while subsp. *incana* falls mainly in the warm sub-humid zone. Temperatures are warm throughout the year with the mean maximum of the hottest month 30–35°C. In Australia, the mean minimum of the coolest month varies from 19.5°C at Darwin to mainly 10–16°C along the Queensland coast south of Cairns and as low as 6°C on parts of the northern coast of New South Wales. Frosts are absent on all of the coastal strand, though in New South Wales there may be 1–3 heavy frosts per year within a few kilometres of the sea.

In Australia the 50 percentile rainfall is 1000–1670 (–2150) mm, the 10 percentile 700–1100 (–1350) mm. The lowest on record is 760–925 mm (185–215 mm in some Queensland localities) for subsp. *equisetifolia* and 600–740 mm for subsp. *incana*. Seasonal distribution varies from a moderate summer maximum in the south to a strong monsoonal pattern in the north. The average annual number of raindays is 90–120. In parts of Southeast Asia near the equator the annual rainfall can be as high as 3500 mm.

Physiography and soils. *C. equisetifolia* is commonly confined to a narrow strip adjacent to sandy coasts rarely extending inland to lower hills (e.g. in Fiji). It is found on sand dunes, in sands alongside estuaries behind fore-dunes and gentle slopes near the sea. It may be found at the leading edge of dune vegetation, subject to salt spray and inundation with sea water at extremely high tides. Subsp. *incana* has been recorded growing on rocky head-lands up to 30 m above sea level.

Soils are well-drained and rather coarse textured, principally sands, of 2 m or more in depth, often covering a more moisture-retentive layer of sandy loam. The species tolerates both calcareous and slightly alka-line soils but is intolerant of prolonged waterlogging and may fail on poor sands where the subsoil moisture conditions are unsatisfactory.

Vegetation type. *C. equisetifolia* may be the only woody species on the coastal dunes growing over a ground cover of dune grasses and broadleaved herbs, or can be part of a richer association of trees and shrubs collectively termed the Indo-Pacific strand flora. Tree associates in this vegetation include *Barringtonia asiatica*, *Calophyllum inophyllum*, *Heritiera littoralis*, *Hibiscus tiliaceus*, *Thespesia populnea* and *Pandanus* spp..

In Australia, additional tree associates may include *Acacia oraria*, *A. solandri*, *Eucalyptus tetrodonta*, *E. polycarpa* and *E. leptophleba*, *Lophostemon suaveolens*, *Alphitonia excelsa*, *Melaleuca* species including *M. quin-quenervia*, and *Banksia robusta*.

Utilisation. *C. equisetifolia* is a popular and widely grown species throughout the tropics and parts of the subtropics. It is a truly multipurpose species, providing a range of products and services for industrial and local end-users.

Fodder: Unlikely to play a significant role as a fodder species.

Fuelwood: The wood is highly regarded as a fuel and produces high quality charcoal, and the leaf litter is used to fuel brick kilns. Calorific value of the wood is 5000 kcal/kg and that of the charcoal exceeds 7000 kcal/kg.

Wood: The wood is hard and heavy with an air-dry density of 900–1000 kg/m^3. Rays are prominent on the radial faces of sawn timber. It is difficult to use for fine carpentry. Poles are popular as masts for fishing boats, piles, posts and tool handles. The wood is split and used for roofing shingles. It is used to produce paper pulp using neutral sulfate and semi-chemical processes, and as a raw material for rayon fibres.

Other uses: The most common uses of *C. equisetifolia* are for sand dune stabilisation, shelterbelts, land reclamation and erosion control. In Sarawak the species is protected because of its importance in controlling coastal erosion. Many areas of occurrence are susceptible to tropical cyclones or typhoons and *C. equisetifolia*'s general toler-ance to strong winds has encouraged its use in protective plantings. With high productivity and soil fertility-enhancing properties, *C. equisetifolia* shows promise as an agroforestry species for arid and semi-arid areas (Goor and Barney 1976). Experiments at Prabhunagar, India showed citrus trees grew larger under casuarina than in pure stands. Mandarin trees grown under casuarinas produced an average of 154 flowers per 5 branches, compared to 111 for mandarins grown alone. They averaged 42 fruits per tree at the marble stage, with 16% fruit set, compared to 40 fruits per tree and a fruit set of 9%. However, fruits from trees in pure stand were of higher quality (Allolli et al. 1991).

Root extracts are used for medical treatment of dysentery, diarrhoea and stomach ache. In West Malaysia a decoction of the twigs is used for treating swelling and the powdered bark is used for treating pimples on the face. *C. equisetifolia* bark contains 6–18% tannin and has been used extensively in Madagascar for tanning purposes.

Silvicultural features. In addition to its wide natural distribution, *C. equisetifolia* has been introduced for firewood, beautification and other purposes to many regions including East, Central and West Africa, China, India, Pakistan, Sri Lanka, Vietnam and the West Indies as well as parts of the USA and islands in the Indian Ocean. It is relatively fast-growing on poor soils, tolerates salt-laden winds and, despite occuring naturally near the coast, can be grown over a remarkable altitudinal range. For example, in Tanzania it has been cultivated to nearly 2000 m elevation but is susceptible to frost damage on these sites. Generally, most success has been achieved with the species in coastal zones with 1000–1500 mm of rainfall annually. However, it has succeeded in semi-arid climates with annual rainfall of <300 mm/year where sea spray and humidity supplements meagre ground water supplies.

Root nodules containing the actinorhizal symbiont, *Frankia*, enable *C. equisetifolia* to fix atmospheric nitrogen. These root nodules can be prolific. Extrapolations from experimental data indicate that 90 kg/ha of atmospheric nitrogen can be fixed annually at a planting density of 2000 trees/ha.

A study of two *C. equisetifolia* plantations of age 5 and 8 years in India concluded the root nodules contribute significantly to below ground production. Peak nodule biomass ranged from 87 to 155 kg/ha in the month of September–October and production varied from 92 to 170 kg/ha/year in the 8-year-old and 5-year-old stands, respectively. N release was 7% more in the 8-year-old than in the 5-year-old stand (Srivastava and Ambasht 1995).

The effects of inoculation with *Frankia* and of four establishment treatments on survival and early growth of *C. equisetifolia* were examined at a coastal site in tropical north Queensland (Reddell 1990). Six months after planting, inoculation had considerably increased seedling survival, irrespective of establishment treatment. Inoculation also increased height growth by between 38 and 80% above that of uninoculated trees. Considerable variation exists in effectiveness of different *Frankia* strains and screening of *Frankia* strains for effectiveness is a research priority (El-Lakany et al. 1990b). *Frankia* collections are maintained by ORSTOM Laboratories in France, CSIRO Division of Soils in Townsville, Australia and at Yale University, USA.

Proteoid roots have also been observed in their root systems. As in other actinorhizal plants, endomycorrhizal (VAM) infection occurs easily in *C. equisetifolia*. Dual inoculation with both symbionts, *Frankia* and VAM, was found to enhance growth of *C. equisetifolia* more than a single inoculation with either organism (Vasanthakrishna et al. 1994). A cooperative rather than competitive interaction between the two symbionts was shown by Sempavalan et al. (1995).

Until recently there has been little research done on genetic variation and improvement. Tumaliuan (1985) observed provenance variation in *C. equisetifolia* in the Philippines.

Coordinated international provenance trials of subsp. *equisetifolia* commenced in 1992 with 40 trials established in 19 countries by 1995 (Pinyopusarerk et al. 1995). These trials have displayed large phenotypic variation (e.g. in growth rates, branching habits and age to first flowering) between populations that can be exploited for tree improvement. A 2-year measure of the trial at Ratchaburi, Thailand showed Malaysian, Thailand and Papua New Guinea sources to be the best ranked for growth traits of the natural provenances under trial, while Indian sources were the best, on average, of the land races (K. Pinyopusarerk, pers. comm.) Considerable improvements in growth of *C. equisetifolia* should follow conventional plant breeding and screening of elite individuals followed by vegetative propagation.

Establishment: C. equisetifolia is wind pollinated. Trees are mostly monoecious. Female cones mature about 18–20 weeks after anthesis, and open shortly after this, releasing small samara (winged seeds). There are 268 200 viable seeds/kg but viability is often low, even for fresh seed, and averages 50%. The fruits on one tree do not all mature at the same time, often presenting a problem for seed collection.

Seed is mainly used for propagation; however, there is an increasing use of cuttings. Seed requires no pretreatment. Germination takes up to two weeks and is epigeal. In Thailand and India cuttings are made from small branchlets (2 mm diameter and 10–15 cm length) and rooting is enhanced through use of the hormones IBA or IAA. In southern China cuttings are taken from branchlets (1 mm diameter, 5 cm length) and soaked in a solution of NAA before being placed in polythene tubes.

Inoculation of the seedlings with pure culture of effective strains of *Frankia* is recommended when the species is introduced to a new area. This is done by applying a water suspension of a pure culture of the inoculant to the seedlings. A less ideal method is to apply a solution of crushed nodules. Early growth can be doubled as a response to inoculation.

Plantations can be established using containerised seedlings, bare-root seedlings or rooted cuttings. Plants are typically suitable for outplanting when 25–30 cm tall. A planting density of 2500 stems/ha is commonly used but some farmers plant up to 8000 to 10 000 stems/ha when fuelwood and small poles are the required product.

C. equisetifolia is a poor self-pruner. Pruning in plantations is necessary up to 2 m to make plantations accessible for maintenance. Pruning may, however, allow infection of fungal pathogens (especially *Trichosporium vesiculosum*). *C. equisetifolia* is not fire-resistant and protection is necessary.

It coppices only to a limited extent and best results are obtained when cut young.

Yield: C. equisetifolia has a life span of 40–50 years and displays fast early growth rates (about 2 m/year in height) and good form in cultivation. On favourable sites, it can yield an annual increment of 15 m^3/ha at 10 years. In India, plantations using 1 × 1 m or 2 × 2 m spacing on 6–15 year rotations yield 50–200 t/ha. Dry weight per tree ranges from 15 to 25 kg at 3 years of age, depending on site quality (Pinyopusarerk and House 1993). In South China, where an estimated one million hectares of plantation have been established since 1954 in shelterbelts along the coastal dunes, heights of 7–8 m and diameters of 5–7 cm are achieved at about 4 years. The rotation period ranges from 4–5 years for fuelwood and 10–15 years for poles. MAIs usually fall in the range of 4–5 m^3/ha/year (Midgley and Sylvester 1997).

In Asia leaf litter from plantations is often removed as fuel and this draws heavily upon soil phosphorus and potassium reserves. This can result in reduced yields in the subsequent rotation.

Pests and diseases. Day et al. (1994) and Midgley and Sylvester (1997) review the literature. *C. equisetifolia* is generally not prone to serious pests and diseases except when grown in unfavourable conditions. Over 50 species of insect are known to feed on the species, but serious pest problems have not occurred except in Taiwan where a stem borer and a defoliator cause damage. The most serious disease threatening *C. equisetifolia* plantations in India is the blister bark disease. Infected trees die rapidly after exhibiting symptoms of foliar wilt and cracking of the bark where blisters develop enclosing a black powdery mass of spores (Bakshi 1976). The identification of the causal agent as the fungus *Trichosporium vesiculosum* is now in doubt (Boa and Ritchie 1995). Maintenance of soil pH between 6.5 and 6.8 and treatment with fungicidal sprays from the third year onwards are reported to help control this disease. Blister bark disease has also been reported recently from Vietnam and Kenya (Boa and Ritchie 1995). Bacterial wilt disease (*Pseudomonas solanacearum*) is characterised by yellowing foliage and wilting and death has been reported in China and India (Liang and Chen 1982). Other serious recorded diseases include stem canker and dieback caused by *Phomopsis casuarinae* and pink disease (*Corticium salmonicolor*). Brown rot caused by *Phellinus noxius* is causing tree decline in Taiwan (Chang 1995).

Limitations. The species grows poorly on sites with impeded drainage. It is frost-tender and can be damaged by cold winds. The species is fire- and browse-sensitive, does not compete well with weeds and gives variable results when coppiced. It is vulnerable to a number of pests and diseases. It has the potential to become a weed under certain conditions. This has occured in Hawaii and in the Florida peninsula of USA.

Related species. The beach strand occurrence, weeping growth habit, moderately small 'cone' and the number of leaf-teeth in a whorl (7–8) are usually sufficient features to distinguish this species from other casuarinas.

A putative hybrid between *C. equisetifolia* and *C. junghuhniana* is grown commercially in Indonesia (Java) and Thailand and possesses vigorous growth and good stem form. The hybrid is not known to occur in the wild.

Casuarina glauca

Main attributes. A moderately fast-growing nitrogen-fixing tree. Tolerant of waterlogging and highly saline soil. Produces excellent firewood and is a valuable shelterbelt and land reclamation species, especially in coastal environments.

Botanical name. *Casuarina glauca* Sieber ex Sprengel was published in *Syst. Veg*. 3: 803 (1826). The species name is derived from the Greek *glaukos* — in reference to the glaucous or bluish-green foliage.

Common names. Swamp she-oak (standard trade name), swamp oak.

Family. Casuarinaceae.

Botanical features. A tree 8–20 m high, rarely a shrub to about 2 m, that frequently regenerates through vigorous root suckers. The bark is hard, grey or grey-brown, finely fissured and scaly, with a tessellated appearance. The leaf-teeth on new shoots are long and recurved. The branchlets are spreading or drooping, to 38 cm long. The articles are 8–20 mm long, 0.9–1.2 mm in diameter, glabrous, with the leaf-teeth in whorls of 12–17, rarely 20, erect, 0.6–0.9 mm long. The male inflorescence is in spikes 1.2–4 cm long, 7–10 whorls per cm. The cones are reddish- to white-pubescent, becoming glabrous, on stalks 3–12 mm. The mature woody cones are subglobose to shortly cylindrical, 9–18 mm by 7–9 mm, the bracteoles are broadly acute. The winged seed is 3.5–5 mm long (Wilson and Johnson 1989). Mature seed may be collected over several months.

The species is described by Wilson and Johnson (1989) and illustrated by Boland et al. (1984).

Natural occurrence. *C. glauca* is restricted to a narrow coastal belt in eastern Australia, from central Queensland to southern New South Wales. The distribution extends inland along some river valleys (Wilson and Johnson 1989).

- Latitude: Range: 23–37°S
- Altitude: Main occurrence: from sea level to 25 m.

Climate. The distribution is in the warm humid and sub-humid climatic zones. The mean maximum temperature of the hottest month is 27–30°C and the mean minimum of the coolest 4–11°C. The number of days a year when 32°C is exceeded lies in the range 14–20, except in the northern sector where temperatures exceed 37°C for 1–4 days. Areas on the sea front are frost-free, while inland there may be 1–5 frosts per year.

The 50 percentile rainfall is 900–1700 mm, the 10 percentile 525–700 mm and the lowest on record 325–500 mm. The rainfall incidence varies from a weak summer-autumn maximum in the south to a well-defined summer maximum in the north. In the extreme north there is a strongly defined summer maximum. The number of raindays per year is 100–120, though with lower values at the extremes of the distribution.

Climatic requirements for the successful cultivation of the species were given by Marcar et al. (1995).

Physiography and soils. The typical topography consists of swampy flats, often only 10–100 m wide, near estuaries and along tidal reaches of rivers and river terraces. Stands are known to occur in areas exposed to the sea. The soils are typically humic gleys, other types recorded include hard-setting loamy soils with red clayey subsoils, dark cracking clays in association with friable earths, dunes of leached sands with a compacted or pan-like layer below the bleach, dark friable porous loamy soils with associated loam and sand soils on flood plains and swamps, and acid grey earths.

Vegetation type. *C. glauca* is found in woodlands associated with communities along coastal, brackish lakes and estuaries. Tall eucalypt forest, with species such as *E. botryoides*, *E. robusta* and *E. tereticornis*, surrounds areas where *C. glauca* is found (Beadle 1981). Pure stands of *C. glauca* occur in a narrow zone with *Phragmites australis*. Other associated species in woodland are *Melaleuca quinquenervia* and *M. nodosa*.

Utilisation.

Fodder: Foliage has value as a drought fodder (Cremer 1990).

Fuelwood: It is an excellent fuel (Gardner 1989). The wood is used as firewood in rural areas of Egypt

(El-Osta and Megahed 1990). The average calorific value is 4700 kcal/kg.

Wood: The sapwood is narrow, pale, not susceptible to *Lyctus* attack; the heartwood is brownish and has conspicuous rays, hard, tough and fissile, very dense (air-dry density 900–980 kg/m^3, basic density 650–700 kg/m^3). Formerly used in Australia for handles, fencing rails, shingles, stakes, small piles in sea water and for flooring and turnery (Boland et al. 1984; Churchill 1983; Davis 1994). El-Osta and Megahed (1990) studied the properties of fast-grown wood of *C. glauca* in Egypt. Particle board from this species had adequate strength and stability.

Other uses: An excellent tree for amenity planting, shelterbelts, dune-soil stabilisation and land reclamation work, especially in coastal or salt-affected situations.

Silvicultural features. Moderately fast-growing. Tolerates a wide range of conditions: periodic waterlogging, frost, drought, sea spray, acid, alkaline or highly saline soils (expect reduced growth at EC_e 10–15 dS/m with reduced survival 15 dS/m Marcar et al. 1995). Coppices and root suckers vigorously. Significant inter- and intra-provenance variation in survival and growth has been found in field trials. Naturally spontaneous hybrids between *C. glauca* and *C. cunninghamiana* are of commercial importance in Egypt.

Establishment: There is an average of 414 900 viable seeds/kg. Seeds store well for long periods. Each cone contains about 70 seeds, with an average germination rate of 60% (El-Lakany et al. 1990a). Germination is best at a temperature of 20° or 25°C (Turnbull and Martensz 1982).

C. glauca has a symbiotic relationship with the nitrogen-fixing actinomycete, *Frankia*. Growth of *C. glauca* will be optimised in the presence of specific strains of *Frankia* (Coyne 1983). Inoculation of seedlings with *Frankia* is recommended when introducing the species to new areas. There are reports of poor nodulation in untreated soils (e.g. McCluskey and Fisher 1983; Miettinen et al. 1992).

Successful asexual propagation techniques with casuarinas have been developed in China using water and soil cultures (Zhong 1990b). An 80% strike within 15 days was achieved using 10–100 ppm NAA or IBA solutions. Cuttings taken from near the base of seedlings or the base of a root sucker (*C. cunninghamiana* × *C. glauca*) rooted readily under standard glasshouse conditions in 4–7 weeks (Pryor 1989).

Yield: In trials in southeastern Queensland, a single provenance of *C. glauca* averaged 2 m in height at 2 years (Ryan and Bell 1991). Seven-year results of a provenance trial under irrigation in Egypt indicated significant inter- and intra-provenance differences in survival, height and diameter. Average values were 71%, 5.01 m and 4.59 cm respectively (El-Lakany 1990). Merwin (1990) also reported significant within and between provenance differences for height growth at six months in California. Susceptibility of seedlings to frost damage is a limiting factor in California. Performance of the species in China has been variable. On Hainan Island *C. glauca* has performed relatively well in terms of volume growth (Zhong 1990 a,b). but was slowest of the three casuarinas under trial in Guangdong (Pan and Lu 1990).

Pests and diseases. In Egypt serious insect pests of *C. glauca* are the dry wood termite, *Kalotermes flavicollis*, and the coleopterous wood borers, *Stromatium fulvum* and *Macrotoma palmata* (Hassan 1990). Attack by the termites *Macrotermes michaelseni* and *Ancistrotermes latinotus* has reduced survial of the species to 33% on some sites in Zimbabwe (Mitchell et al. 1988). The species is susceptible to *Casuarina* bacterial wilt disease in China (Cao and Xu 1990).

Limitations. Sensitive to frost. Can become weedy under some circumstances.

Related species. *C. glauca* is closely related to *C. obesa* and *C. cristata*. It will hybridise with *C. cunninghamiana*.

Davidsonia pruriens

Main attributes. A small to medium-sized tree native to the rainforests of northeastern Queensland and northern New South Wales. Grows best in warm to hot humid or sub-humid conditions and is drought and frost tender. The wood is hard and durable but available only in small sizes. The fruits are edible and make a delicious jam.

Botanical name. *Davidsonia pruriens* was described by F. von Mueller in his *Fragm*. 6: 4 (1867). *D. pruriens* var. *jerseyana* was described by F.M. Bailey in *Queensland Flora* 2: 538 (1900b). The genus is named after J.E. Davidson, a pioneer sugar grower at Rockingham Bay, north Queensland where the first specimen was collected; and the species name from the Latin *pruriens* — itching, referring to the effect of prickly hairs covering the young fruits, leaves and shoots.

Common names. Davidson's plum, ooray, Queensland itch tree.

Family. Davidsoniaceae.

Botanical features. A small to medium-sized tree up to 10 m tall with light brown, corky, slightly scaly bark, seldom greater than 30 cm diameter at breast height. The outer surface of live bark is light green. It has a creamy or almost pale brown blaze with numerous vertical white lines. The outer layer of dead bark separates freely from the live bark and there is no change in colour on exposure. The inner bark has a very astringent taste with a turnip smell.

The branchlets are smooth and greenish. On young stems the branchlets, leaf rachis and leaves are densely hairy, and cause skin irritation when handled. Leaves are compound, alternate or opposite, 50–60 cm long, the main stalk flanged with irregularly toothed wings. The leaf stalks are subtended by semicircular toothed stipules, 1.5–3.0 cm in diameter with a broad base. There are 9–19 opposite leaflets, irregularly toothed around the edge, hairy, ovate-lanceolate or oblong-lanceolate, 10–25 cm long, upper leaflets being the largest, sessile or with very short stalks. Var. *jerseyana*, which is the southern race from New South Wales, is smaller in all parts and less hairy. The midrib and lateral venation are distinct, but raised and more conspicuous on the lower side. The flower buds are densely covered with long pinkish hairs. Flowers pink-red, clustered in long hairy pendulous panicles, 30 cm long in the upper axils or on the leafless trunk. The deep pink-red flowers have 4–5 sepals and are 1 cm long, with no petals. The flowering period is from October–January (Floyd 1989). The fruit is drupe-like, blue, purplish or black, egg-shaped, hairy with loose short brown hairs when young, up to 5 cm long, the pulp crimson. The stone consists of a seed within each of the 2 cells, surrounded by a fibrous covering. The seed is dark red, round and pointed, 2 cm long, flat on one side and keeled on the other with a fringed border. Fruit of var. *pruriens* ripen April–August while those of var. *jerseyana* ripen January–February (A. Floyd, pers. comm.).

The species is illustrated by Floyd (1989) and Jones (1986).

Natural occurrence. The var. *pruriens* occurs in several disjunct locations in northeastern Queensland and Fiji (Floyd 1980). The var. *jerseyana* is confined to a small area in valleys of the Tweed River and Richmond Rivers extending to the foothills of the Macpherson Range in northeastern New South Wales.

- Latitude. Main occurrence: 15–18°S (var. *pruriens*); 28°16'–28°30'S (var. *jerseyana*).
- Altitude. Range: near sea level to 800 m.

Climate. The type variety, var. *pruriens*, occurs in the warm and hot humid climatic zones, while var. *jerseyana* in the south lies in the sub-humid climatic zone. The mean maximum temperature of the hottest month is 32–34°C and 29–30°C for each variety respectively, and the mean coolest 14–15°C and 8–11°C in the south. The area is virtually frost-free, but in areas of high elevation there may be 1–2 frosts annually.

The 50 percentile rainfall is 1265–2035 mm, the 10 percentile 865–1330 mm and the lowest on record 545–900 mm. Rainfall in the north has a strong monsoonal pattern, with January to March very wet and August–October very dry. In the south the incidence changes to a strong summer maximum. The average number of raindays is 110–135 annually.

Physiography and soils. This species has a limited distribution within the Eastern Uplands physiographic division. It is found on steep slopes and among residual quartzite outcrops on metamorphic rocks of foothills. In lowlands it occurs on fertile, well-drained, basaltically-enriched alluvia along creeks, rivers and floodplains (Floyd 1989, 1990; Tracey 1982). Examples of soil types are brown and yellow earths and heavy clay alluvium.

Vegetation type. In New South Wales *D. pruriens* var. *jerseyana* is found as a small tree in luxuriant, complex mesophyll vine forests. These are dominated by canopy species such as *Argyrodendron trifoliolatum*, *Geissois benthamii*, *Pseudoweinmannia lachnocarpa* and associates *Dendrocnide photinophylla*, *Ficus watkinsoniana* and *Araucaria cunninghamii* or the *Castanospermum–Dysoxylum muelleri* alliance. Climbers are well developed and vines cling tightly to tree trunks and rocks (Floyd 1990). The upper layer of emergents is discontinuous to 50 m, and the lower, continuous and reaching to 20 m with some emergents to 30 m (Beadle 1981). *D. pruriens* var. *jerseyana* is also found in gallery rainforest fringing watercourses. In northern Australia *D. pruriens* has been recorded in mesophyll and notophyll vine forests (Tracey 1982).

Utilisation.

Fodder: The species has not been recorded as a fodder species utilised by stock animals.

Fuelwood: No data available, but probably suitable.

Wood: Dark brown, hard, tough, durable and suitable for items such as tool handles and mallets (Floyd 1989).

Other uses: The fruit has a juicy brilliant red pulp with an acid taste. It makes a delicious jam (Floyd 1989) and can be used to produce a full-flavoured dry red wine (Kajewski 1992). The flushes of pink new growth make it an attractive indoor plant when young (Jones 1986; Wrigley and Fagg 1988). Because of its foliage it has potential to be used in combination with other plants in the design of attractive gardens (Jones 1986).

Silvicultural features. Davidson's plum requires warm conditions and well-watered, well-drained fertile soils for best growth (Wrigley and Fagg 1988). It responds well to mulching and fertilisers (Jones 1986). The species produces root suckers and is drought and frost tender.

Establishment: Propagation is by fresh seed or cuttings (Floyd 1989; Wrigley and Fagg 1988). There are 15–22 fruit/kg and 1400–2700 seeds/kg when cleaned of the pulp (Floyd 1989). Root cuttings and transplantation of suckers are also successful (Jones 1986). The young plants require protection from the hot sun and strong winds. They do not tolerate competition from grass.

When cultivated for fruit production in northern New South Wales, both subspecies are planted together to extend the fruiting season (B. Milgate, pers. comm.). Regular fertilisation, mulching and irrigation can induce fruit set in 3–4 years (Nicholson and Nicholson 1985).

Yield: Cultivated plants in northern Queensland are slow to establish but grow rapidly after two years (G. Sankowsky, pers. comm.). In dry tropical regions the MAI of non-irrigated, cultivated plants is 0.43 m in height and 0.6 cm in diameter, over 21 years. This could be increased to 0.8 m/year in favourable conditions (A. Irvine, pers. comm.).

Pests and diseases. None are recorded.

Limitations. Drought and frost tender, and requires high rainfall and well-drained fertile soils for best growth. It is not suitable for windbreaks. Small size will limit use as a wood to small posts and poles and small joinery items.

Related species. *D. pruriens* is related to an undescribed species that is found from near Ballina, NSW to Carrumbin Creek in southeastern Queensland (Floyd 1989).

Elaeocarpus angustifolius

Main attributes. A large, fast-growing pioneer tree species of tropical and subtropical rainforests. The pale timber is very useful for a range of purposes including plywood, furniture, joinery and boat building.

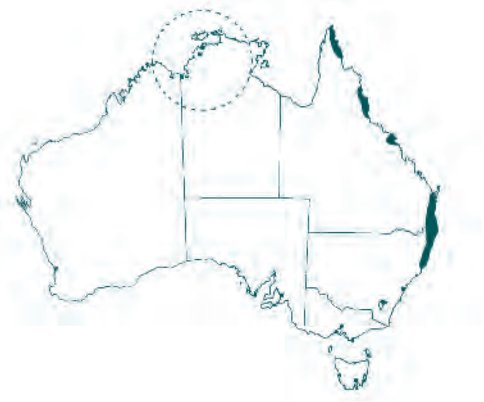
Botanical name. *Elaeocarpus angustifolius* Bl. was published in Bijdr. 120 (1825). Better known as *E. grandis* F. Muell. This name was relegated to synonymy by Coode (1984). The generic name is derived from the Greek *elaia* — the olive tree, and *karpos* — fruit, as its fruit resembles an olive. The species name *angustifolius* — is derived from the Latin *angustus* — narrow, and *folium* — leaf, probably alluding to the leaf shape.

Common names. Silver quandong (standard trade name), blue quandong, blueberry ash, caloon, brush quandong, white quandong, blue fig, genitri, Indian oil fruit.

Family. Elaeocarpaceae.

Botanical features. *E. angustifolius* is a tall tree 35–40 m high, with wide-spreading buttresses 5–6 m up the trunk from the ground. Bark is light-grey, parchment-like, finely fissured with longitudinal indentations. It has a thin canopy with leaves mostly at the end of the branches. Branchlets are finely pubescent with noticeable leaf scars. Leaves are alternate, finely toothed, elliptical, glossy dark green above, paler beneath, 6–18 × 2.5–5 cm, on a 5–20 mm flattened stalk. Old leaves turn red before falling. The midrib and lateral veins are raised on the lower surface. The inflorescences are axillary or terminal on the branches, spreading, 6–10 cm long, bearing 12–36 pendulous white, cream or green flowers on slender stalks 9–12 mm long, often turned to one side. The flowering period is variable and there may be more than one flowering in a year: from March–June and also December in New South Wales (Floyd 1989); late May–August (lowland) and September– January in Queensland (A. Irvine, pers. comm.). The fruit is a succulent drupe, bright blue or purplish, globular, 15–30 mm diameter, 5–7 compartments each with 4 ovules. There are usually 2–5 seeds. Each seed is dark-coated and narrowly ovate. Fruits ripen 7–12 months after flowering. The seedcoats are hard and pitted.

The species is described and illustrated by Boland et al. (1984), Francis (1970), Hyland and Whiffin (1993) and Floyd (1989).



Natural occurrence. The distribution in Australia is mainly along the coast and hinterland of eastern Australia, with an isolated occurrence in the Northern Territory south of Darwin. The most southerly part of the range is Taree in New South Wales, north to Maryborough, Queensland. There is a small occurrence around Mackay and Proserpine on the central Queensland coast and further populations in northern Queensland, between Ingham and Cooktown and from around Coen to the tip of Cape York. It also occurs in Papua New Guinea and elsewhere from India to New Caledonia (Coode 1984).

- Latitude. Range: 10–31°S (Australia).
- Altitude. Range: near sea level to 800 m.

Climate. The distribution is mainly in the warm humid climatic zone in the south and the warm humid and hot humid winter-dry zones in the north. In the southern part of its range the mean maximum temperature of the hottest month is about 28–30°C and the mean minimum of the coldest month 5–8°C. Frosts are quite rare, with up to 5 annual frosts in some localities. In the northern parts of the distribution corresponding temperatures are 30–33°C and 10–18°C respectively (Boland et al. 1984).

The 50 percentile rainfall for the southern localities and the Northern Territory is 1200–1600 mm and for Queensland 1600–2400 mm. The 10 percentile for the major part of the distribution is 800–1200 mm, and 1200–1600 mm for coastal regions in far north Queensland. There is a strongly developed summer monsoonal rainfall pattern with a marked dry season in both the Northern Territory and northern Queensland. Southern localities from central Queensland to New South Wales have a well-defined summer maximum with no prolonged dry seasons. Average annual number of raindays is 80–145.

Physiography and soils. The major part of the distribution is in the Eastern Uplands physiographic division. This species is usually associated with permanent streams or gullies in foothills and uplands on flat or steep sites. Coastal plains behind beach ridges where there is impeded drainage constitute another habitat. Rock outcrops on basalt uplands, sometimes with much basaltic scoria on the surface, are common. Other rock types include mixtures of acid and basic rocks, granite or granodiorite or a mixture of metamorphic and granite rocks. Soil types include red and yellow earths some with grey-brown topsoil derived from metamorphic and granite rocks, sandy grey earths, basaltic red earths and kraznozems and calcareous beach sands (Tracey 1982).

Vegetation type. *E. angustifolius* is commonly found along stream banks in tropical mesophyll vine forests or gallery forests and subtropical notophyll vine forests. These types have even or uneven dense canopies 20–45 m high with many tree layers. Associate species include *Alstonia scholaris*, *Cardwellia sublimis*, *Castanospermum australe*, *Diploglottis cunninghamii*, *Ficus virens*, *Nauclea orientalis* and *Ristantia pachysperma*. It also occurs in the lee of coastal beach ridges on calcareous beach sands as a canopy species in wet lowlands. *E. angustifolius* is present in small areas of mesophyll vine forests among swampy coastal plains dominated by *Melaleuca quinquenervia*. Dominants are the palms *Archontophoenix alexandrae* and/or *Licuala ramsayi*.

Utilisation.

Fodder: It is not known to be used as a fodder species for livestock.

Fuelwood: No data available, but its low density suggests that it may not be well suited to this purpose.

Wood: The heartwood is white, pale straw or pale brown with a pinkish tinge (Keating and Bolza 1982). The sapwood similar and up to 100 mm wide. Air-dry density is about 500 kg/m^3. It very easy to work, nails and glues well and is good for steam-bending. The heartwood is not suitable for external use, but is easily impregnated with preservatives. The sapwood is occasionally attacked by lyctid borers. Used for decorative veneer, plywood, joinery, furniture and boatbuilding (Bootle 1983). The timber dries slowly if kiln-dried, without surface checking or twisting.

Other uses: The blue fruits were a source of food for Australian Aboriginal people and are an important source of food for native bird species. The deeply pitted ‘stone’ is used for such ornaments as necklaces.

Silvicultural features. Silver quandong is a fast-growing pioneer species of moist to very wet rainforests. It prefers medium to heavy soils in a protected, sunny position, and is frost-tender. It does not tolerate drought.

Establishment: Propagation is by seed or tip cuttings. There are 210–225 fruit/kg. Germination of fresh untreated seed may be slow (6–12 months) and erratic (8–16% germination rate). Germination may be hastened by cracking the endocarp, but care is needed to avoid damage to seed. Seed is often pre-germinated in moist conditions in a plastic bag before transplanting to containers (Nicholson and Nicholson 1988).

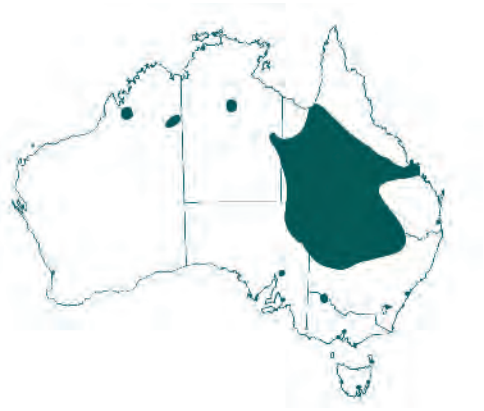
Yield: Various trials in Queensland, Australia have shown good plantation potential for the species, with average annual increments of 1–2 m in height and 1.3–3 cm in diameter over 3 to 32 years (Cameron and Jermyn 1991).

Pests and diseases. None are recorded.

Limitations. The species is susceptible to drought and frost.

Related species. *E. angustifolius* is a highly variable species that intergrades to some extent with *E. ptilanthus* in New Guinea (Coode 1984).

Eremophila bignoniiflora



Main attributes. A shrub or small tree of arid and semi-arid regions. It is adapted to heavy clay soils which may be alkaline or saline. Tolerant of drought and frost. The dense, attractive foliage and rounded shape make it a potential hedge or screen species in dry areas.

Botanical name. *Eremophila bignoniiflora* (Benth.) F. Muell. was published in *Rep. Babbage Exped*. 17 (1859). The genus was named after the Greek *eremophiles* — solitude or desert loving. The species name is a reference to the flowers resembling those in the genus *Bignonia*.

Common names. Eurah, bignonia emubush, dogwood, gooramurra, creek wilga, river angee, quirramurra, pombel, berrigan, white-tree fuchsia, swamp sandalwood.

Family. Myoporaceae.

Botanical features. A single or multi-stemmed shrub or small tree, 1–8 m high, commonly 3–7 m, with a dense rounded crown. Mature bark is dark-grey, rough and somewhat tessellated, the branches and foliage drooping, the young shoots resinous. The leaves are alternate, green and slightly paler beneath, linear or linear-lanceolate, 3–20 cm long by 2–14 mm wide, narrowed at the base, apex acute to acuminate. The flowers are 20–30 mm long, tubular, fuschia-like in shape, cream-coloured, tinged pink or brown above, with carmine, yellow-brown or purplish spots on the inner surface, on sticky stalks 5–25 mm long in the leaf axils. The stamens extend to just beyond the tube or are enclosed by it. The fruit is a non-hairy (glabrous) ovoid, almost globular dry, indehiscent drupe, 15–20 mm long by 10–15 mm diameter, split towards the apex, 4-celled with 2–3 whitish seeds in each cell (Smith 1975). The flowering time is mainly from May to November (Black 1986; Costermans 1981). Mature fruits have been recorded in July (Rye 1992).

E. bignoniiflora is illustrated by Anderson (1993), Cunningham et al. (1981) and Costermans (1981).

Natural occurrence. *E. bignoniiflora* has a wide distribution within mainland Australia. The major part of the distribution is in central and southern Queensland with extensions into northern New South Wales, north-eastern South Australia and central Northern Territory. There are limited occurrences in the Kimberleys of Western Australia and just over the New South Wales border in northwestern Victoria. It is an endangered species in Victoria, and populations in South Australia are vulnerable (Margules and Partners 1990).

- Latitude. Main occurrence: 20–31°S.
  Range: 17–35°S.
- Altitude. Main occurrence: 5–200 m.
  Range: near sea level to 500 m.

Climate. The major part of the distribution is in the hot arid and semi-arid climatic zones. Some occurrences are in the hot humid (Gulf of Carpentaria) and warm sub-humid zones towards the coast in eastern Queensland. The mean maximum of the hottest month lies in the range 31–39°C and the mean minimum of the coolest, 6–17°C. Some central localities have an average of 2–12 frosts per year, while for other sites, no frosts occur.

The 50 percentile rainfall is mainly 450–650 mm, although in humid areas the range is 650–940 mm and in arid regions decreases to 120–350 mm. The 10 percentile is 240–380 mm, 440–580 mm in higher rainfall areas and 53–180 mm in central drier parts of the distribution. The lowest recorded annual rainfall values are 24–33 mm. Seasonal incidence varies from almost monsoonal in the extreme north to a summer maximum in the majority of localities. A winter maximum of rainfall occurs in the extreme south.

Physiography and soils. *E. bignoniiflora* is found in three physiographic divisions, namely, Eastern Uplands, Western Plateau and the major proportion of the distribution, in the Interior Lowlands. It occurs on lower alluvial plains subject to flooding for varying periods of time or on flat plains inundated by high-level general floods, on occasionally flooded grey clay soils near inland watercourses and depressions or along drainage lines between sand dunes or undulating downs, channels and interchannel areas, or on terraces away from main watercourses. The soils are usually grey, brown or red alluvial clays and fine-textured neutral to alkaline deep cracking clays, often intermixed with texture contrast soils (Boyland 1984; Gunn and Nix 1977; Neldner 1984; Pedley 1967, 1974b).

Vegetation type. *E. bignoniiflora* is commonly found as scattered individuals in a sparse to dense shrub understorey of 1–2 m beneath eucalypt open-woodlands, dominated by such species as *Eucalyptus camaldulensis*, *E. coolabah* and *E. largiflorens*. It can form thickets around gilgais beneath *Acacia cambagei*. It is also found in communities adjacent to streams and halophytic shrublands, dominated by saltbushes such as *Atriplex nummularia* (Beadle 1981; Neldner 1984). Other associate species include *Acacia stenophylla*, *Atalaya hemiglauca*, *Casuarina cristata*, *Chenopodium auricomum*, *Flindersia maculosa* and *Muehlenbeckia cunninghamii*.

Utilisation.

Fodder: The leaves are eaten readily by sheep and cattle. *E. bignoniiflora* was among those species that yielded the highest in vitro estimates of dry matter digestibility, nitrogen, phosphorus and ash from leaf samples of trees growing in southeastern Queensland (McLeod 1973). These were 67.4%, 2.63%, 0.22% and 7.5% respectively. This indicates *E. bignoniiflora* shows promise as a good fodder species, but animal trials are required to determine its palatability. Anderson (1993) states that the plant has been suspected of being poisonous, but there is no conclusive evidence of this. The crushed leaves of the species are reputed to smell somewhat like canine urine. In Kenya elephants were observed to be repelled by this species.

Fuelwood: No data available.

Wood: The wood is fragrant, fine-grained, fairly hard and pale brown, often with green and yellowish figure. It takes a high polish and is decorative (Anderson 1993; Maiden 1889).

Other uses: The species is an excellent screen or hedge plant for dry areas (Wrigley and Fagg 1988). It is a good nectar producer and is a valuable supporting species for honeybees (Clemson 1985).

A decoction of the leaves was used by Australian Aborigines to relieve the symptoms of colds and influenza (Aboriginal Communities of the Northern Territory 1993). In some areas a decoction of the fruits has been taken as a laxative (Lassak and McCarthy 1983).

Silvicultural features.

Establishment: This species has proved difficult to germinate from seed, even after the standard pretreatments. The most effective seed pretreatment is a 16-hour soak in warm water. Optimum germination temperature is 30°C, and germination takes place in 18–38 days (Langkamp 1987). It grows readily from cuttings (Wrigley and Fagg 1988).

E. bignoniiflora is a frost-hardy species that will tolerate down to −7°C in conditions of normal rainfall (Wrigley and Fagg 1988).

Yield: A species that has not been planted widely. *E. bignoniiflora* gave excellent survival (100%) and had increased by 21 cm in height over 7 months from planting in a trial on acid red earths in arid central Queensland. On alkaline cracking clays in the same area, survival was a poor 29% at 7 months (Ryan and Bell 1991). It grew satisfactorily on black cracking clays in Kenya.

Pests and diseases. None are recorded.

Limitations. Small size and moderate growth rate will limit use to low shelter and erosion control. Its palatability to stock may cause difficulties in establishment (Langkamp 1987).

Related species. The closest relative of *E. bignoniiflora* is *E. polyclada*, which differs in being a horizontally branched shrub with linear sparse leaves and whitish flowers (Smith 1975).

Eucalyptus argophloia

Main attributes. A large attractive tree of restricted natural distribution in the warm sub-humid climatic zone. It is tolerant of drought, frost and heavy soils. The wood is useful for poles, posts, general construction and firewood. The tree has amenity value and is widely planted for shade and shelter.

Botanical name. *Eucalyptus argophloia* Blakely was published in *A Key to the Eucalypts*, 256 (1934). The generic name is from the Greek *eu* — well and *calyptos* — covered, referring to the cap or lid (operculum) which covers the stamens in the bud. The specific name is derived from the Greek *argos* — bright, white, and *phloios* — bark. Both botanical and common names refer to the bark.

Common names. Queensland western white gum, lapunyah, scrub gum, white gum.

Family. Myrtaceae.

Botanical features. *E. argophloia* is a tree that attains 40 m or more in height. The trunk is usually clear of branches for half or more of the total height. The bark is shed over the whole trunk, except for 1 m of decorticating bark at the base. It is usually white, but varies according to the season to brown, yellow or pink-grey. The older bark has attractive bluish grey, brown and yellowish patches during the time when the bark is shed. The juvenile leaves are linear to narrow-lanceolate, alternate, petiolate, 7–9 × 0.3–1.4 cm, greyish-green, with a slight difference in shading between the upper and lower surface. The adult leaves are alternate, petiolate, narrow-lanceolate in shape, 10–15 × 1.5–2.5 cm, glossy green on both surfaces, with intramarginal vein remote from leaf edge; reticulation dense, fine, broken, with numerous small island oil glands. The inflorescence is usually simple axillary, but sometimes may appear terminal, 7–flowered. The flowers are on stalks 1–5 mm long, the buds ovoid or almost globular in shape, 3.5–4 × 3–4 mm, the opercula hemisperical, sometimes apiculate. The flowering time is May to August (Brooker and Kleinig 1994). The fruit is a woody capsule, on stalks, hemisperical to cupular, 3.5–5 mm long by 4–7 mm wide. There are 4–6 valves, to the rim level of the capsule or slightly exserted. Mature fruits may be collected during summer (Searle 1989).

The species is described by Blakely (1934) and Chippendale (1988), and is illustrated by Boland et al. (1984), Brooker and Kleinig (1994) and Stanley and Ross (1986).

Natural occurrence. *E. argophloia* has a very restricted distribution in southeastern Queensland. The area is around 40 km long to 12–15 km wide to the northeast of Chinchilla, including Burncluith and Pelican, and around Burra Burri. It is listed as a vulnerable species inadequately reserved (Leigh and Briggs 1992), given the few remaining scattered stands and its potential value in amenity and wood production.

- Latitude. Main occurrence: 26–26°30'S.
- Altitude. Main occurrence: 300–340 m.

Climate. The distribution is in the warm sub-humid zone, with the mean maximum temperature of the hottest month around 32°C and the mean minimum of the coolest month around 4°C. There are 10–15 frosts on average each year.

The 50 percentile rainfall is 657 mm, the 10 percentile 475 mm and the lowest on record 300 mm. Rainfall incidence is a moderate summer maximum with high variability. Rain falls on an average of 63 days per year.

Physiography and soils. *E. argophloia* is found in the Eastern Uplands physiographic division. The species favours edges of flats in country of low topographic relief that has been developed for crops and pastures. Soils are grey or brown cracking clays with self-mulching surfaces or red loams.

Vegetation type. The vegetation type is open-forest. Common associate species are *Acacia harpophylla*, *Callitris glaucophylla*, *Eucalyptus moluccana* and *E. populnea*.

Utilisation.

Fodder: No data available, but is unlikely to be suitable.

Fuelwood: Dense wood and good coppicing ability make it a candidate for fuelwood production.

Wood: The heartwood is deep red, hard and strong (Boland et al. 1984). Air-dry density is 1055 kg/m^3 (Cause et al. 1974). It is used locally for fencing and general construction (Stanley and Ross 1983).

Other uses: The species is extensively planted for ornament and shade in western areas of Queensland (Stanley and Ross 1986). The rectified oil from the leaves has potential for medicinal use, but concentration of oil in the leaves is low (0.6% w/w% fresh leaves) (Boland et al. 1991).

Silvicultural features. This species has the ability to grow rapidly when conditions are suitable. It is drought- and frost-resistant and can tolerate heavy clay soils. It coppices readily (Ryan and Bell 1989).

Establishment: Propagation is by seed of which there are about 1 297 800 viable seeds/kg; they germinate within 21 days in suitable conditions and require no pretreatment. In common with other eucalypts, *E. argophloia* is best raised as containerised stock in the nursery. It benefits from cultivation and weeding during the early years of establishment.

Yield: The species was not well adapted to conditions in trials near Gympie in southeastern Queensland, where survival over several plots was 53%. Here height growth averaged 1 m/year over 4.5 years. Better growth was evident near Longreach in central Queensland. With irrigation, survival was 100% after 1.5 years and growth rate was 1.7 m/year and 1.3 m/year on the acid red earth and cracking clay soils, respectively. Survival and growth dropped away without irrigation to 79% and 1.6 m/year and 50% and 0.71 m/year on the red earth and cracking clay soils, respectively (Ryan and Bell 1991).

Several trial plantings of the species in central, central-eastern, southeastern and southern Queensland were assessed by the Queensland Forest Service. Ages of these stands varied from almost 5 to 20 years. The highest growth rate was MAI of 1.4 m/year in height and 2 cm/year dbh in central Queensland in 6.6 years.

The lowest MAI was 0.56, m/year in height and 1.4 cm/year dbh in 16 years, also in central Queensland.

Pests and diseases. The species proved to be highly susceptible to termite attack in Zimbabwe, with 82% mortality at 18 months (Mitchell 1989). The mean height of the remaining trees was 0.97 m.

Limitations. It appears to be sensitive to site conditions and may give poor survival when planted off-site. Highly susceptible to termites.

Related species. Relationships of this species with other eucalypts are not clearly defined. Three analyses follow:

Pryor and Johnson (1971) placed this species in a monotypic subseries (Argophloinae), within series Odoratae. It is somewhat taxonomically isolated but has some resemblance to *E. bosistoana*, a coastal species from southern New South Wales and eastern Victoria. Chippendale (1988) places *E. argophloia* in Ser. 87 Subbuxeales, a somewhat heterogeneous series of eight species including, *E. bosistoana*, *E. porosa*, *E. sparsa*, *E. odorata E. polybractea*, *E. froggatii* and *E. viridis*. *E. argophloia* is anomalous in this group of box-barked species, as it is notably smooth-barked. It shares the large valve number with *E. bosistoana*. Brooker and Kleinig (1994) state that *E. argophloia* is without close relatives in the Section Adnataria, the eastern boxes.

Eucalyptus camaldulensis

Main attributes. *E. camaldulensis* is a medium-sized to large tree. It has the widest geographical range of any eucalypt. The species is extensively planted outside Australia. Its tolerance of extreme drought and high temperature combined with rapid growth when water is available, deep penetration of roots, tolerance of periodic waterlogging and soil salinity, some tolerance of frost, good coppicing ability and usefulness of the wood are the keys to its success. The wood of planted *E. camaldulensis* is used mainly for poles, posts, firewood, charcoal and paper pulp. Logs may be sawn for construction timber, furniture and packing cases, although quality is sometimes poor. It is widely planted for shade, shelter and amenity purposes and as a source of nectar in honey production. Some tropical provenances produce medicinal-grade *Eucalyptus* oil.

Botanical name. *Eucalyptus camaldulensis* Dehnh. The species name derives from a cultivated tree at Camalduli, in Tuscany, Italy. It was published in *Cat. Pl. Hort. Camald*. 2nd edn, 6: 20 (1832).

Common names. River red gum, red gum, Murray red gum, river gum (WA).

Family. Myrtaceae.

Botanical features. In Australia, *E. camaldulensis* is a tree commonly 20 m tall and occasionally reaching 50 m, while diameter at breast height can reach 1–2 m or more. In open formation, it usually has a short, thick bole which supports a large, spreading crown. In plantations, it can have a clear bole of 20 m with an erect, lightly-branched crown. 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. Juvenile leaves are petiolate, ovate to broadly lanceolate, green, grey-green or blue-green, slightly discolorous. Adult leaves are lanceolate to narrowly lanceolate, acuminate, lamina 8–30 cm long, 0.7–2 cm wide, green or grey-green; petiole terete or channelled, 12–15 mm long. Umbels are axillary, 7–11 flowered; peduncles slender, terete or quadrangular, 6–15 mm long; pedicels slender, 5–12 mm long. Buds are globular-rostrate (typical) or ovoid-conical (var. *obtusa*); operculum hemispherical, rostrate or conical, obtuse, 4–6 mm long, 3–6 mm wide; hypanthium hemispherical, 2–3 mm long, 3–6 mm wide. Fruits are hemispherical or ovoid, 5–8 mm long and wide; disc broad, ascending; 3–5 exserted valves. The small and abundant (15 per fruit) seed are yellow-brown in colour.

Time of flowering in natural stands depends on locality. Flowering peaks in summer in the south, in autumn in the far north-west and winter-spring in the far north-east (Banks 1990). Outside Australia, the indigenous flowering pattern may be disrupted. For example, peak flowering moved from summer to winter for provenances from temperate Australia when planted in a summer rainfall climate in Zimbabwe (Mullin and Pswarayi 1990). In Thailand, some provenances flower throughout most of the year on a range of sites, although autumn (September–November) is the peak period (Wasuwanich 1989). Pollination is mainly by insects but also by birds and small mammals. Fruit development and maturation time can be as short as four months. Generation time may be as short as three years from planting to the production of the first seed crops.

The species is illustrated by Boland et al. (1984) and Brooker and Kleinig (1983, 1990, 1994).

Natural occurrence. River red gum is the most widely distributed of all eucalypts. It occurs throughout inland mainland Australia, typically along watercourses and on flood plains, but occasionally extends to slopes in relatively higher country, as in the Mt Lofty Ranges near Adelaide.

- Latitude. Range: 12°30'–38°S.
- Altitude. Range: 20–700 m.

Climate. This species grows under a wide range of climatic conditions from warm to hot, sub-humid to semi-arid, with the mean maximum temperature for the hottest month in the range 27–40°C and the mean minimum for the coldest month around 3–15°C. Up to 20 frosts per year may be experienced in southern and inland areas.

The mean annual rainfall range is mostly 250–600 mm, while a few areas receive up to 1250 mm and some as little as 150 mm. In low rainfall areas the species relies on seasonal flooding and/or the presence of a high watertable. Rainfall distribution varies from a winter maximum in southern areas to a monsoonal type in northern Australia falling mostly between November and March. Variability is very high in the inland regions with frequent long dry spells. Booth and Pryor (1991) and Marcar et al. (1995) describe the climatic requirements of *E. camaldulensis* under natural and cultivated conditions.

Physiography and soils. *E. camaldulensis* occurs on a variety of soil types. It is common on heavy clays in southern Australia, but more generally on sandy alluvial soils in the north. It infrequently occurs on the margins of salt lakes. Except for a few populations in South Australia on shallow soils over limestone, the species is not adapted to calcareous soils.

Vegetation type. River red gum is typically a riverine species and in arid Australia it has a ribbon-like distribution across the landscape. It also occurs in open-forest or woodland formation on flood plains. On adjacent higher ground in parts of eastern Australia it may be associated with *E. coolabah*, *E. largiflorens*, *E. leucoxylon*, *E. microcarpa* and *E. melliodora*.

Utilisation.

Fodder: Not suitable for fodder

Fuelwood: The wood burns well and makes a good fuel. *E. camaldulensis* is used in several countries for the large-scale production of charcoal for the iron and steel industry. Its dense wood and ability to coppice readily make it an excellent species for fuelwood production.

Wood: The timber from natural stands 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, 50–75 mm wide, is susceptible to attack by *Lyctus* borers (Keating and Bolza 1982).

Unfavourable characteristics of the wood of small diameter plantation-grown *E. camaldulensis* such as growth stresses, shrinkage on drying, collapse, spiral grain and starch in the sapwood can be ameliorated by post-harvest procedures (Qadri 1983). Correctly handled, the wood is useful for specialty 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)

Other uses: It is widely planted for shade, shelter and amenity purposes and as a source of nectar for honey production. Some tropical provenances of *E. camaldulensis* (e.g. Petford) give 1,8-cineole-rich leaf oils and are potential sources of medicinal-grade *Eucalyptus* oils (Doran and Brophy 1990).

Silvicultural features. With an estimated one million ha of plantation established and extensive unrecorded plantings for shade and shelter in many countries, *E. camaldulensis* is perhaps the world's most widely planted tree in arid and semi-arid lands. In addition to a high level of drought tolerance, it has some tolerance of frost, coppices well and can withstand seasonal waterlogging and soil salinity. Marcar et al. (1995) class the species as moderately salt-tolerant with reduced growth at EC_e about 5 dS/m or above and reduced survival about 10–15 dS/m. Best performing provenances in the presence of salinity include DeGrey River, Western Australia in the tropics and Silverton, New South Wales for temperate regions.

Selection of the correct genetic material for the particular planting conditions is of paramount importance in this species. If this is done properly, seedling growth may exceed 3 m/year for well-adapted provenances on favourable sites. Two main forms of the species are recognised: a northern tropical form that is lignotuberous and has relatively obtuse opercula, and a southern temperate form that is non-lignotuberous and has rostrate opercula (Pryor and Byrne 1969). It is the better-performing tropical provenances like Petford and Katherine that are the most sought-after sources for breeding programs in the seasonally dry tropics, while provenances from southern temperate Australia like Lake Albacutya are required in Mediterranean zones. Physiological studies are helping to explain the basis for some of the variation in growth and survival between provenances of *E. camaldulensis* which have been observed in many countries. For example, studies show that seedlings have a range of genetically determined responses to water stress depending on their origin, that combine to produce strategies appropriate for survival and growth under the conditions at their origin (Gibson 1991; Gibson et al. 1995).

E. camaldulensis 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 or fuelwood. The species coppices well for five or more rotations. The season of felling affects coppice regeneration. 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 is best. Reduction of the number of coppice shoots on a stool is a most important and time-consuming operation in coppice management (Evans 1982). In Nepal, a single reduction at 3–6 months to one shoot per stump is recommended (White 1988). Thinning schedules for *E. camaldulensis* plantations on longer rotations for larger logs are given by White (1988).

Establishment: E. camaldulensis is usually propagated from seed. There are about 700 000 viable seed/kg of seed and chaff mixture. As a rule-of-thumb, 1 kg of *E. camaldulensis* seed is sufficient to provide plants for 100 ha of plantation at routine spacings (3 m × 2 m) and typical seedling recovery rates (25%). 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. No pre-sowing treatment is required. Seed should be sown under shade (optimum temperature 32°C) on a free-draining and sterilised medium and covered very sparingly with inert material (e.g. sand). Germination should be complete after seven days and then shade can be reduced. Germinants are transplanted at the second leaf-pair stage to containers filled with sterilised potting mix. Shade cover is needed for the first week after transplanting after which time plants should be fully exposed. Growth is fast under tropical conditions and plants could reach plantable size (30 cm) in six weeks, although 12 weeks is more usual. Common mistakes in propagation are over-watering, leading to disease problems, over-shading, and allowing the germinants to become too large for easy transplanting resulting in malformed tap roots or root curling.

E. camaldulensis is one of several eucalypt species suited to mass vegetative propagation. Cuttings from juvenile shoots (i.e. below the 100th node in this species) root readily in 30% of genotypes (Doran and Williams 1994). A major reforestation project in Morocco is based entirely on cuttings of *E. camaldulensis* (Marien 1991). In Southeast Asia propagation by cuttings is an integral component of breeding programs (Kijkar 1991). Protocols for the successful tissue culturing of this species are also available.

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. When pulpwood is the principal objective, a spacing of 3 m × 2 m (1667 stems/ha) is often applied. Wider spacings of 4 m × 2 m (1250 stems/ha) or 5 m × 2 m (1000 stems/ha) are recommended when larger trees are required. Wider spacing between rows facilitates mechanical cultivation for weed control. *E. camaldulensis* in plantation has a relatively narrow crown and pendulous leaves which allow light through to the forest floor. This permits weed growth but can be turned to advantage with intercrops. A wide range of crops can be grown under *E. camaldulensis*; a spacing of 5m × 2m is recommended for intercropping to age three years (White 1988). While clearfelling is usual, White (1988) recommended the use of coppice-with-standards in Nepal to supply a range of wood products. A thinning from below of 700 stems/ha at half rotation age (5 years) provided posts, poles, fuelwood and pulpwood, leaving the better trees to grow-on to 10 years for sawn timber and other products.

The ability of the species to compete with weeds is poor. This combined with an open crown means that frequent (3 times per year) and extensive weeding must be applied until crowns close (3–5 years). Inadequate weed control may lead to complete failure of the planting. Mechanical or manual cultivation is the main means of controlling weeds.

Application of 100 g of NP or NPK (3:2:1) fertiliser to each tree at planting to assist establishment and growth is common. Crown die-back during the dry season as a result of boron deficiency is prevalent in parts of Africa, Asia and South America and must be corrected. A dosage of 10–20 g of borax per tree depending on soil type is applied.

Yield: Very high productivity is possible under favourable conditions: growth of 70 m^3/ha/year of wood in a four-year-old plantation at a 3 m × 2 m spacing on a fertile, well-watered site has been recorded in Israel (Zohar 1989). Seldom are these conditions duplicated on the broad scale, and yields are generally much less. In the drier tropics, yields of 5–10 m^3/ha/year on 10–20 year rotations are common, whereas in moister regions up to 30 m^3/ha/year may be achieved on 7–20 year rotations (Evans 1982). In southern Vietnam, overall yield for the species is 12 m^3/ha/year at four years but better adapted provenances give yields of 20 m^3/ha/year. A fourfold increase in growth rate in less than 10 years was achieved in Brazil through tree breeding and better husbandry (Nambiar 1993).

Pests and diseases. In the nursery, *E. camaldulensis* is susceptible to diverse fungi causing damping-off, collar rot and leaf diseases. Insects (e.g. termites and aphids) and rodents may be troublesome, and both physical and chemical control measures may be needed.

In Australia, natural stands and plantations of *E. camaldulensis* are affected by many insects and fungi. Where the tree is well adapted outside Australia, it is relatively free from problems. In parts of Africa and Asia termites affect young trees and must be chemically controlled (Day et al. 1994). In Africa the *Eucalyptus* snout beetle, *Gonipterus scutellatus*, of Australian origin, feeds on young shoots but is controlled biologically, and moribund or newly felled trees may become infested with the Australian stem borer or longicorn beetle, *Phoracantha semipunctata* (Poynton 1979).

Disease is most common where the species is planted off-site or where inappropriate provenances are used. Stem cankers and leaf diseases proliferate where rainfall and humidity are much higher than normally encountered in the natural habitat. For example, in humid regions of southern and Southeast Asia many *E. camaldulensis* plants are defoliated by fungi including *Cylindrocladium* species during the wet season, e.g. in India (Sharma and Mohanan 1991). The most susceptible provenances suffer mortality and general decline, but some provenances (e.g. Katherine) are little affected, allowing selection and breeding for resistance to the disease.

Limitations. The inability of the species to compete with weeds when young, compounded by a crown type that takes several years to shade-out weed growth, are major limitations, especially in the tropics.

Related species. *E. camaldulensis* was placed by Pryor and Johnson (1971) in Sect. Exertaria, subseries Tereticorninae, one of the two subseries of the southern and eastern red gums. Better known close relatives include *E. tereticornis*, *E. amplifolia*, *E. exserta*, *E. brassiana* and *E. rudis*.

Zones of introgression occur with *E. tereticornis* in the east and *E. rudis* in the west, where the species distributions overlap. *E. camaldulensis* has been recorded in 13 naturally occuring hybrid combinations (Griffin et al. 1988). A manipulated hybrid with *E. grandis* is being trialed in South Africa in order to extend the range of economic plantings of eucalypts to hot, dry, 'marginal' areas (Darrow 1995).

Other botanical information. Blakely (1965) published a formal description of six varieties of *E. camaldulensis*. These have been largely ignored by contemporary botanists because of difficulties in determination but some texts discriminate between var. *camaldulensis* and var. *obtusa* (e.g. Brooker and Kleinig 1994). Var. *camaldulensis* has rostrate (strongly beaked) opercula and predominates in southeastern Australia while var. *obtusa* has obtuse or rounded opercula and is widespread in inland and northern Australia.

Several red gum populations in far northern Queensland, previously known as *E. tereticornis*, have been renamed *E. camaldulensis* subsp. *simulata* (Brooker and Kleinig 1994) including the provenances of Laura River, Palmer River and Walsh River. Doran and Burgess (1993) have also recommended that a number of fast-growing red gum provenances formerly considered *E. tereticornis* such as Kennedy River and Morehead River be named *E. camaldulensis*, based largely on the morphology of their floral buds (var *obtusa*).

Eucalyptus jensenii

Main attributes. A small tree of moderate growth rate which tolerates dry, infertile conditions in hot semi-arid and sub-humid tropical areas. Has good potential for the production of fuelwood, durable posts, and poles.

Botanical name. *Eucalyptus jensenii* Maiden in *Crit. Revis. Eucalyptus* 6: 255 (1922). The specific name honours Dr H.I. Jensen (1879–1966), a geologist who made plant collections in northern Australia.

Common names. Wandi ironbark.

Family. Myrtaceae.

Botanical features. A small to medium-sized tree usually 6–18 m tall with a single stem, which is commonly somewhat crooked. The crown is moderately dense, bluish to blue-green. The bark is of the 'ironbark' type, compact in texture, hard, thick, grey-black, with deep vertical fissures on the trunk and persistent to the small branches.

Juvenile leaves petiolate, opposite for many pairs, then alternating, lanceolate then ovate 10 × 2.5 cm. Adult leaves are alternate, broadly lanceolate, 5–10 cm long, 1–3 cm wide, and grey-green. There are 3–7 more or less glaucous buds in axillary clusters or in short terminal panicles. Flowering occurs from March to May. The fruits are very small, 3 × 3 mm, woody, pedicellate, cup-shaped, with 3–4 valves and slightly glaucous when young. They mature in June–September. The seeds are grey-brown, roundish to elliptical, flattish and shallowly reticulate.

The species is described by Chippendale (1988), and illustrated by Brock (1988), Brooker and Kleinig (1994), Hall and Brooker (1972), Kelly (1983) and Petheram and Kok (1983).

Natural occurrence. *E. jensenii* is found in the Kimberley area of northern Western Australia and extends into the north of the Northern Territory. It is unusual in being the only typical ironbark eucalypt in Western Australia and the Northern Territory.

- Latitude. Range: 11–18°S.
- Altitude. Range: near sea level to 600 m.

Climate. The distribution is mainly in the hot semi-arid and sub-humid climatic zones, with an extension into the hot humid zone in coastal areas of the Northern Territory. The mean maximum temperature of the hottest month is in the range 34–38°C and the mean minimum of the coolest month is 13–20°C. There are 100–280 days over 32°C each year and from 1 day to over 100 days over 38°C. The area is frost free.

The 50 percentile rainfall is in the range 550–1550 mm, the 10 percentile 300–1050 mm, and the lowest on record 110–1000 mm. The rainfall has a strong summer monsoonal pattern, but with high variability in some Western Australian localities. Rain is recorded on 45–95 days, and the dry season extends for 5–7 months.

Physiography and soils. The species is confined to the Kimberley and Northern Australian Plateaux provinces of the Western Plateau physiographic division. Within this area it grows mainly on gentle to moderate slopes and low stony ridges, but is also found on tablelands and flats. The soils are principally lithosols, earthy sands and red earths, sometimes with ironstone gravels, derived from laterites and sandstone. They are usually acidic or neutral, well-drained and of low fertility.

Vegetation type. *E. jensenii* grows in open-forest, woodland and low woodland in more or less pure stands, or sometimes in association with other eucalypts including *E. confertiflora*, *E. grandifolia*, *E. latifolia*, *E. polycarpa*, *E. tectifica*, and *E. tetrodonta*. On shallow stony soils it occurs with *E. brevifolia* (Beadle 1981), and on sandstone it may be reduced to a very small tree up to 4 m associated with *E. zygophylla*, *Callitris intratropica*, and *Erythrophleum chlorostachys* (Kabay and Burbidge 1977). On Groote Eylandt in the Gulf of Carpentaria it occurs on the fringe of *Melaleuca* swamp (Specht 1958).

Utilisation.
Fodder: No data available, but unlikely to be suitable.
Fuelwood: Has dense wood and good potential for fuelwood production on a coppice system.
Wood: The wood is hard, heavy and durable. It is used for fence posts (Petheram and Kok 1983).
Other uses: A useful tree for low shade.
Silvicultural features. *E. jensenii* is a very hardy small tree. The stem is often crooked, but trees 18 m tall with a straight trunk of 12 m have been recorded south of Maningrida in the Northern Territory (G. Stocker, pers. comm.) and in Western Australia. It is fire-tolerant and will coppice readily.
Establishment: Propagation is by seed. Trees flower within two years of planting (Ryan and Bell 1989). There are about 172 900 viable seeds/kg and they germinate readily without pretreatment. Seedlings can be raised following routine nursery practices for eucalypts. Weed control around the seedlings is essential after planting.
Yield: In trials in southeastern Queensland the species recorded a modest growth rate of 2.6 m in 4.5 years. Overall survival was 83% (Ryan and Bell 1991). It gave good height growth, 2.4 m in 18 months, and reasonable survival (71%) without irrigation on acidic red earths near Longreach in central Queensland (Ryan and Bell 1991). Irrigation was to no advantage to this species on this site. It failed on the alkaline cracking clay soils in the same region.

This species has not been tested widely outside Australia but showed some promise in trials in tropical dry West Africa. In Upper Volta the trees reached 2.5 m in 8 months and had a very high survival rate (Delwaulle 1979).

Pests and diseases. Minor to occasionally serious damage by defoliators *Liparetrus* spp. (Scarabaeidae: Coleoptera) has been recorded on planted trees in southeastern Queensland (Ryan and Bell 1991). Appears to be termite-resistant.
Limitations. The stem form of this species is often crooked, and some provenance selection is desirable. The hard bark may make harvesting with primitive tools a difficult operation.
Related species. *E. jensenii* is related to several other ironbarks including *E. staigeriana*, *E. shirleyi*, and *E. cullenii*, but is readily distinguished from them on the basis of leaf and fruit characteristics (Hall and Brooker 1972), as well as by area of natural occurrence.

Eucalyptus pellita and *E. urophylla*

Main attributes. *E. pellita* and *E. urophylla* currently play an important role in afforestation in only a few countries but they have potential to be much more widely used in humid and sub-humid tropical regions. Their fast growth, coppicing ability, adaptability to a range of environments, relative resistance to fire, pests and diseases and suitability for a variety of wood products place them among the most useful tropical trees.

Eucalyptus pellita

Botanical name. *Eucalyptus pellita* F. Muell. First published in *Fragm*. 4: 159 (1864), the name comes from the Latin *pellitus* — cover with skin, which probably refers to the epidermis of the leaves; the type description refers to the moderately thick covering.

Common names. Australian standard trade name is red mahogany; also called large-fruited red mahogany.

Family. Myrtaceae

Botanical features. *E. pellita* is a medium-sized to tall tree up to 40 m in height and 1 m in diameter. At its best 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.

Distinctive features of the tree are its fibrous red-brown bark to the small branches, discolorous leaves, broad peduncles and strongly exserted valves on large fruit with broad rims. Juvenile leaves are petiolate, ovate. Adult leaves are lanceolate to broadly lanceolate; lamina 10–15 cm long, 2–4 cm wide; lateral veins faint, 45–60°; intramarginal vein up to 2 mm from margin; petiole channelled, 15–25 mm long. Umbels are usually 7-flowered, occasionally 3-flowered; peduncle broadly flattened, 10–25 mm long; pedicels thick, angular, 1–9 mm long, rarely absent. Buds fusiform; operculum conical, rostrate, or hemispherical, 10–12 mm long, 6–10 mm wide; hypanthium obconical, 6–8 mm long, 6–10 mm wide. Fruits hemispherical or obconical, 7–14 mm long, 7–17 mm wide; disc prominent and level. In Australia, *E. pellita* flowers in April–June and mature seed is harvested in August–November.

The species is described by Chippendale (1988) and illustrated by Boland et al. (1984) and Brooker and

Kleinig (1994). Johnson and Hill (1990) have described a new species (*E. scias*) with three subspecies from what was originally *E. pellita*, based on populations in the south of the taxon's range in eastern coastal Australia. It is probable that the material from New Guinea and the northern part of Cape York Peninsula will be recognised as a separate taxon with further taxonomic revision of the group (Johnson and Hill 1990). *E. pellita* remains the name for all occurrences north of the Queensland border and in New Guinea at the present time and will be treated as such in this monograph.

Natural occurrence. *E. pellita* has two main natural occurrences. In New Guinea it is found from as far north as the Muting area of Irian Jaya and 60 km northwest of Morehead in Western Province, Papua New Guinea. In Queensland it extends from Iron Range near the top of Cape York Peninsula to Ingham north of Townsville.

- Latitude. Australian Range: 12°45'–18°40'S.
  New Guinea Range: 7°30'–8°35'S.
- Altitude. Range: near sea level to 800 m.
  New Guinea Range: 30–60 m.

Climate. The distribution is in the warm humid climatic zone, experiencing a mean maximum temperature of the hottest month in the range 24–34°C with the mean minimum of the coldest month around 4–19°C. Frosts are absent. Mean annual rainfall ranges from 1000–4000 mm with a very distinct summer maximum in the north. Locations on Cape York Peninsula may experience a severe dry season of several months duration.

Physiography and soils. In New Guinea it is common as scattered populations, occupying a specific niche between open areas of impeded drainage and rainforest. It is therefore confined mostly to narrow strips less than 100 m wide. In Queensland the species occurs mainly on gentle to moderate topography and is only found 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, hotter parts of its occurrence.

Soils vary from shallow sands on sandstone ridges to shallow sandy podzols and deep forest loams. In Irian Jaya it occurs on red clays and clay loams.

Vegetation type. Red mahogany occurs mainly in open-forest formation. Associated eucalypts include *E. tereticornis*, *E. tessellaris*, *E. intermedia* and *E. torelliana*. On Cape York Peninsula it is an uncommon component of transitional forests and woodlands mainly on the western side of ranges. In New Guinea it is associated with species such as *E. brassiana*, with which it occasionally hybridises (B. Gunn, pers. comm.), *Acacia aulacocarpa*, *A. mangium*, *Lophostemon suaveolens* and other species of the monsoon vine forest alliance (Paijmans 1976).

Eucalyptus urophylla

Botanical name. *Eucalyptus urophylla* S.T. Blake. The name was published in *Austrobaileya* 1: 7 (1977). It is derived from the Latin *ura* — tail, and *phyllon* - leaf, and refers to the 'drip tips' of the leaves. The species is sometimes erroneously referred to as *E. decaisneana* and *E. alba*.

Family. Myrtaceae.

Common names. Timor mountain gum (En), ampupu and palavao preto (Indonesia).

Botanical features. Over most of its natural range *E. urophylla* is a forest tree usually reaching 25–45 m in height and up to 1 m in diameter, with a straight bole for half to two-thirds of tree height. Exceptional specimens attain 55 m in height and over 2 m in diameter. In extreme environments *E. urophylla* may be reduced to a gnarled shrub only a few metres tall.

There is extreme variation in bark characteristics apparently associated with differences in moisture conditions and altitude. Below 1000 m on Alor and Flores a large proportion of trees exhibit relatively smooth boles with a variable (0–1/2 tree height) stocking of rough bark at the base. Between 1000 m and 2000 m on Timor, where conditions are moister, the trees are usually covered with sub-fibrous, shallowly and closely fissured longitudinally, red brown bark extending to the smaller branches. A wide range of bark types is also found within some stands on other islands. In some localities *E. alba*

occurs in association with *E. urophylla* and the interspecific hybrids which are produced occasionally may have a range of intermediate bark characters.

There is considerable variation in other morphological features such as fruit size and shape, bud characteristics, adult leaf characters such as length, width and expression of a 'drip-tip'. There are differences between the seedling, juvenile, intermediate and adult leaves. The adult leaves are dark green above and paler green below, sub-opposite to alternate on the branch, stalked, broad-lanceolate, 12–20 cm long × 2–5 cm wide, narrowing abruptly to a short point or lanceolate and tapering to a narrow point or 'drip-tip'. The leaves have visible lateral veins 45–50° to the midrib and an intra-marginal vein. The white-cream flowers are in clusters of 7–11 forming an umbel which has a flattened stalk. The buds are globular to ovoid and the fruits cup-shaped with a wide, flat or oblique disc and 3–5 valves more or less at rim level. *E. urophylla* flowers in January–March and mature seed is collected August–September.

The species is described and illustrated by Turnbull and Brooker (1978) and Turnbull and Doran (1997). Recent taxonomic revision of the species has seen two new taxa described, *E. wetarensis* Pryor and *E. orophila* Pryor, from populations formerly called *E. urophylla* (Pryor et al. 1995). *E. wetarensis* occurs on the more xeric sites on Wetar and is distinguished from *E. urophylla* by the narrower leaves and larger fruit. *E. orophila* occurs above 2200 m on Timor. It is distinguished by its mostly smooth greyish decorticating bark, shorter leaves and drip-tip and shorter pedicel length.

Natural occurrence. The natural distribution is confined to Indonesia. *E. urophylla* occurs principally on the islands of Timor, Alor and Wetar, but smaller occurrences are on the islands of Flores, Adonara, Lomblen and Pantar. The natural range extends about 500 km between longitudes 122°E and 127°E. *E. urophylla* has the largest altitudinal range of any eucalypt.

- Latitude. Range: 7°30'-10°S.
- Altitude. Range: 90-2200 m.

Climate. The natural range is in the hot, humid to sub-humid climatic zone. There is variation in mean annual temperature according to altitude: at 1900 m it is 15°C, while at 400 m it is about 25°C. In Timor many of the *E. urophylla* forests occur above 1000 m where mists and fog are common, annual rainfall is 1300–2200 mm and the dry season 3–4 months. On the other islands drier conditions prevail with rainfall 800–1500 mm and a dry season of 5–8 months. Rainfall follows a summer monsoonal pattern.

Physiography and soils. *E. urophylla* is mainly found as the dominant species in secondary montane forest. It grows on mountain slopes and in valleys. Its best development is on deep, moist, well-drained acidic or neutral soils derived from volcanic or metamorphic rocks. It is commonly found on basalts, schists and slates but rarely on limestone.

Vegetation type. Timor mountain gum is frequently the dominant species of the secondary montane forest; associated species include *Casuarina junghuhniana*, species of *Palaquium*, *Planchonella*, *Pygeum* and conifers (*Podocarpus* spp.). Below 1500 m *E. urophylla* may form a mosaic distribution pattern with *E. alba* which dominates the more xeric sites.

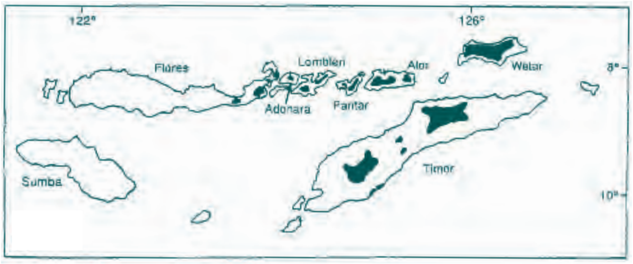
Utilisation (*E. pellita* and *E. urophylla*).

Fodder: No data available, but unlikely to be suitable.

Fuelwood: Young trees provide satisfactory firewood and charcoal.

Wood: The red mahoganies have wood properties which are very suitable for a wide range of purposes.

The sapwood of *E. pellita* is pale red and susceptible to *Lyctus* attack while the heartwood is dark red and durable. Air-dry density of wood from natural stands is about 960 kg/m^3. The timber is moderately coarse-textured with somewhat interlocking grain but is easy to work and finishes well and is used for flooring, cladding, panelling, sills and general construction purposes. In Brazil, the wood is regarded as having good papermaking properties.



The wood of *E. urophylla* is less dense than most eucalypts. The basic density is in the range 540–570 kg/m^3. The heartwood is pinkish-brown to red brown and contains little gum. Fibres are relatively short, about 1.0 mm in length. The wood is very suitable for producing bleached chemical pulp and has good pulp yield (49.5%). The timber of older trees can be sawn and used for general construction purposes. In the round, the wood is suitable for building poles and fence posts.

Other uses: The summer flowers of *E. pellita* are a minor source of honey in Queensland and an important source of pollen for bee colonies.

Silvicultural features. Selection of provenance is known to be very important in *E. urophylla*. The main outcomes from provenance trials have been the demonstration that provenances from altitudes above 1500 m perform poorly in the lowland tropics and that provenances from low altitude (300–1100 m) and from drier climatic conditions grow well in humid–sub-humid, tropical and subtropical conditions with a dry season of 1–5 months in the coolest part of the year (Vercoe and House 1992).

Although seed from the full geographic range of *E. pellita* including some New Guinea occurrences has only recently become available, it can be assumed that selection of the appropriate provenance for particular planting conditions will be of great importance in ensuring optimum growth rates. It is already known that some provenances from northern Queensland perform well in the humid–sub-humid tropical lowlands of coastal northeast Brazil (Jacobs 1981), and the recently acquired provenances from New Guinea are thought also to offer significant potential for plantation forestry on similar sites. For example, in a provenance/family trial in China a provenance from Ggoe, Papua New Guinea and one from Kuranda in northern Queensland produced significantly more volume at three years than the other provenances (Pegg and Wang 1994).

Both species coppice well and trees can be expected to produce at least three coppice rotations.

Establishment: The red mahoganies are usually propagated by seed and established using containerised stock. Flowering usually starts within two years and seeds are produced abundantly by age four years. Summer flowering in the natural habitat and insect pollination results in mature seed six months later. *E. pellita* has on average 266 000 viable seeds/kg while *E. urophylla* has an average of 450 000 viable seeds/kg.

Nursery establishment is generally by sowing untreated seeds in germination beds. The resulting seedlings are transplanted into containers when they have two pairs of leaves. The potting medium is usually a free-draining loam–sand mix. Seedlings usually reach planting-out size (25 cm) in 10–12 weeks. In Brazil *E. urophylla* or hybrids of *E. urophylla* and *E. grandis* are raised using rooted cuttings derived from stump sprouts.

Intensive site preparation by ploughing is beneficial, and on compacted sites deep ripping may also be used. Fertiliser (NPK) is applied in each planting hole. Boron deficiency has been identified as one of the more important causes of poor stem form and malformed leaves in *E. urophylla* plantings in Guangdong Province, China, requiring the addition of boron to the soil (Dell and Malajczuk 1994). Spacing between planting spots varies; it is commonly 3 × 2 m in pulpwood plantations but may be closer in fuelwood or pole plantations. The tree is highly sensitive to competition in the early stages, and the plantations must be kept weed-free for 6–12 months after planting. After that time, the dense crown inhibits competing weeds.

Yield: E. urophylla grows fast and under average conditions produces 20 to 30 m^3/ha/year wood with bark at 5–10 years of age. The better provenances can yield up to 50 m^3/ha/year on favourable sites. High yields have been recorded in South America (e.g. Brazil) and Africa (e.g. Cameroon, Congo and Ivory Coast). Low altitude sources from Flores, Alor and Timor have usually grown the fastest (Vercoe and House 1992).

Relatively little is documented on the performance of *E. pellita*. On a poor site on Melville Island, northern Australia, trees averaged 5 m height and 5.1 cm dbh after 31 months, and survival was 70% (Haines and Harwood 1992), better than other eucalypts including *E. urophylla* planted at the same time. On a krasnozem soil at Innisfail in north Queensland, trees from provenances in Papua New Guinea and Cape York Peninsula averaged 6.7 m and 6.1 m respectively after 18 months growth (K. Robson, pers. comm.). Early results from trial plantings in Sumatra also show promise (Werren 1991).

Pests and diseases. A canker disease caused by *Cryphonectria cubensis* is found on *E. urophylla* in West Africa and South America. Although it is much more resistant than *E. grandis* or *E. saligna*, some provenances are quite susceptible, especially in humid tropical lowland conditions. In Indonesia, the death of seedlings about two months after planting has been attributed to attack by root fungi such as *Botryodiplodia* sp., *Fusarium* sp. and *Helminthosporium* sp.

Seedlings and small trees of *E. urophylla* are susceptible to termite attack and wood borers such as *Zeuzera coffae* cause damage to older trees. In parts of South America leaf cutting ants, *Atta* spp. and *Acromyrmex* spp. can destroy the trees, and control measures are essential where they are present.

E. pellita appears to be less susceptible than other tropical eucalypts to fungal diseases and insect attack, but will no doubt attract some problems once it is more widely planted and reported.

Limitations. Use of the species is limited to humid, seasonally dry tropical zones with moderate dry season. The availability of seed of well-adapted provenances has been a limitation in the past but will soon be alleviated with the availability of seed from seed orchards (Harwood et al. 1994).

Related species. The genus *Eucalyptus* has been divided into several subgenera. *E. pellita* and *E. urophylla* are included in the section Transversaria, subseries Resiniferinae within the subgenus *Symphyomyrtus* (Pryor and Johnson 1971). Other species in the subseries are *E. resinifera*, *E. scias*, *E. notabilis* and several undescribed species. These species are commonly referred to as the red mahoganies because the red-coloured wood supposedly resembles the wood of the central American mahoganies, *Swietenia* spp.

In Brazil, *E. urophylla* has been hybridised to produce vigorous crosses for clonal pulpwood plantations. There is interest also in using *E. pellita* in hybrid combinations, e.g. with *E. urophylla*, *E. grandis* and *E. grandis* × *E. urophylla* (Pegg and Wang 1994).

Eucalyptus thozetiana

Main attributes. A medium-sized tree of moderate growth rate, adapted to a wide range of soil types, including alkaline, heavy clay soils, in arid and semi-arid areas. Drought and frost tolerant. Has heavy durable wood suitable for fuel, fencing and heavy construction. Useful for shade and shelter.

Botanical name. *E. thozetiana* F. Muell. was published in *Proc. Linn. Soc. N.S.W*. 31: 305 (1906). The species was named after an amateur French botanist, Anthelme Thozet (about 1826–1878), who made extensive collections in the Rockhampton area. The common name 'yapunyah' is Aboriginal in origin (Boland et al. 1984).

Common names. Mountain yapunyah (standard trade name), Thozet's box, Thozet's ironbox, napunyah, lapunyah.

Family. Myrtaceae.

Botanical features. *E. thozetiana* is a medium-sized tree to 25 m tall with a clear trunk that exceeds one-half of the total height, while on poorer inland sites it is a small tree 8–12 m tall. The bark is mainly smooth, white to grey, sometimes pink-grey, that is shed in plates; or in southern Queensland occurrences, the bark is rough, tessellated, black at base, rarely rough over whole trunk and to larger branches (Brooker and Kleinig 1994). The trunk is often fluted or shallowly buttressed at the base.

The juvenile leaves are petiolate, linear, alternate, with an even shade of green on both surfaces. The adult leaves are narrow-lanceolate, 7–16 cm long × 5–18 mm wide. The inflorescence consists of 7–11 flowered umbels in axils or in terminal panicles. The buds are on angular stalks, 2–6 mm long, faintly ribbed, more or less ovoid to club-shaped, 4–9 mm × 2–3 mm. The operculum is conical or slightly beaked. The woody fruits are on stalks, truncate-ovoid to cylindrical, sometimes urn-shaped, 3–6 mm long × 3–4 mm broad with 3–4 deeply enclosed valves. Flowering occurs September to November and mature seed is available February to May (Boland et al. 1980).

The species is described by Chippendale (1988), and illustrated by Boland et al. (1984), Brooker and Kleinig (1994) and Stanley and Ross (1986).

Natural occurrence. The major part of the distribution is in central and eastern Queensland. A disjunct

population occurs in central Australia, about 80 km northeast of Alice Springs in the Northern Territory.

• Latitude. Range: 21–28°S.
• Altitude. Range: 100–650 m.

Climate. The distribution is in the warm arid, warm semi-arid and warm sub-humid climatic zones. The mean maximum temperature of the hottest month is 34–37°C and the mean minimum of the coolest month 3–7°C, the lowest on record –5 to –7°C. There are up to 15 frosts annually on average in some areas.

The 50 percentile rainfall is 256–650 mm, the 10 percentile 135–470 mm and the annual lowest on record, 60–380 mm. There is a distinct summer maximum.

Physiography and soils. The Queensland distribution is in two physiographic divisions, the Eastern Uplands and Interior Lowlands. The localities in central Australia are in the Western Plateau division. *E. thozetiana* occurs on a variety of topographical sites. These include Tertiary erosional or depositional land systems, hilly stony rises, stony broken hills, rocky slopes below lateritic mesas, upper parts of lateritic breakaways in hilly country and lateritic remnants and breakaways and sandstone ridges. Rolling and undulating country with low scarps, lowlands and gilgaied clay plains are other sites where *E. thozetiana* may be found, also within stony broken hills, depressions in gently undulating weathered clay with gravel, associated sandy aprons and fans and lower slopes of sandstone ridges. There are extensive rock outcrops in places.

The species has been frequently recorded growing in shallow or moderately deep texture contrast soils, sometimes with loamy surfaces and strong alkaline subsoils, or strongly to extremely acid, dark brown and grey-brown earths on parent rocks subjected to intense weathering and leaching, shallow red and yellow earths, skeletal soils and cracking clay soils, both gilgaied and not gilgaied (Pedley 1967, 1974b; Story et al. 1967; Speck 1968).

Vegetation type. *E. thozetiana* is a co-dominant with *Acacia harpophylla* and *Casuarina cristata* in open-forests with a canopy 12–20 m high, or in layered open-forest 10–15 m with *E. populnea* and *C. cristata*. It is sometimes an emergent species to 25 m. *E. thozetiana* is found typically in woodland as a dominant or codominant species with *E. microcarpa*. In this type there is a lower, moderately dense tree layer of *C. cristata* and *A. harpophylla* beneath the canopy species. An understorey of shrubs such as *Eremophila mitchellii* and *Carissa ovata* may be present. There are small areas of *E. thozetiana* woodland associated with *E. populnea* and *A. harpophylla* on flooded alluvial plains.

Utilisation.

Fodder: No data, but is unlikely to be suitable.

Fuelwood: The wood is very dense and makes a satisfactory fuel. However, it has an interlocked grain that makes splitting difficult.

Wood: The sapwood is yellowish-white and the heartwood dark brown to almost black. The air-dry density is 1120 kg/m^3 (Cause et al. 1974). The timber is strong and heavy and one of the hardest of all eucalypts (Keating and Bolza 1982). It dries without distortion. It is resistant to termites, and the heartwood is extremely resistant to impregnation. It has been used for general construction, interior fittings where it takes a good polish, and poles and posts (Boland et. al. 1984).

Other uses: A species that can be used as a shade tree on farms (Hall et al. 1972).

Silvicultural features. The species has not been widely cultivated, so little is known of its silvicultural features. It should prove drought- and frost- tolerant and adaptable to most soils and positions. It is presumed to be fire-tolerant, with satisfactory coppicing ability like its close relative *E. ochrophloia*.

Establishment: Propagation is by seed. There are approximately 409 300 viable seeds/kg that germinate rapidly under favourable conditions without the necessity of pretreatment. Seedlings are best raised in containers. Cultivation of the planting site and regular weeding until canopy closure should aid growth.

Yield: Little information is available. A provenance from the northeast of Alice Springs grew slowly on acidic red earths near Longreach in central Queensland. It averaged 1.2 m in height and gave 64% survival when irrigated, and 0.8 m and 50% survival with no additional water at 18 months (Ryan and Bell 1991). Local provenances were not included in the trial.

Pests and diseases. None are recorded.

Limitations. There is a lack of information on provenance variation and optimum establishment methods. Interlocking wood grain will make splitting difficult for small-sized fuelwood.

Related species. This species is related to *E. ochrophloia* in the series Ochrophloiae in the classification of *Eucalyptus* by Pryor and Johnson (1971). *E. ochrophloia* occurs in different habitats, i.e. drainage channels and close to watercourses, and has a well-developed stocking of basal bark.

Flindersia maculosa

Main attributes. A graceful, pendulous small tree of slow initial growth while in a 'grass' stage preceeding development of a main stem. It is a species of sub-humid, semi-arid regions and is drought and frost hardy and tolerant of heavy soils of alkaline pH. It is a useful fodder, ornamental and shade tree.
Botanical name. *Flindersia maculosa* (Lindley) Benth. is named in G. Bentham's *Flora Australiensis* 1: 339 (1863). The genus was named after Captain Matthew Flinders (1774–1814), the prominent navigator and explorer. The species name is derived from the Latin *maculosus* — speckled, in reference to the distinctive bark.
Common names. Leopardwood, spotted tree, spotted dog, leopard tree, prickly pine.
Family. Rutaceae.
Botanical features. This is a small tree, usually 6–10 m high but at times may reach 13 m, that develops from a spiny multi-branched shrub. The shrub form is the 'grass' stage of development, from which one stem grows upwards to form the primary trunk (Cunningham et al. 1981; Hartley 1969). At maturity it usually has a single trunk and an open pendulous crown, and while often much narrower than the tree is high, at times the crown may be much wider. The bark is very distinctive, shed in small round scales, 3–5 mm in diameter, leaving a white spot, to give a mottled white, orange or light-grey appearance. The branchlets, leaves and inflorescences are glabrous or minutely pubescent. The leaves are simple, opposite, narrow–elliptic or narrow-obovate, 1–8 cm long × 0.25–1 cm wide, the apex rounded or obtuse, occasionally with a small notch in the apex, on stalks 1–12 mm long. The upper leaf surface is shiny dark green, lower dull and light green, papery to almost leathery. The cream flowers are in loose terminal inflorescences, tubular, 4–4.5 mm long by about 7 mm in diameter. The fruit is a woody capsule about 25 mm long, drying dark reddish-brown and opening into 5 boat-shaped valves at maturity, the surface rough with pointed protuberances, 1–1.5 mm long. There are 2 flat seeds in each valve, winged at both ends, about 1.8 cm long. Flowering time is October and November (Clemson 1985; Cunningham et al. 1981), and ripe seed can be harvested in December.

It is described by Hartley (1969), and is illustrated by Hall et al. (1972) and Cunningham et al. (1981).
Natural occurrence. The principal distribution of this species is in the drier zones of New South Wales with extension into central Queensland.
• Latitude. Range: 20–33°S.
• Altitude. Main occurrence: 120–360 m.
Range: 75–360 m.
Climate. The principal occurrence of this species is mainly in the warm semi-arid region, with a very limited extension into margins of the warm arid and warm sub-humid regions. The mean maximum temperature of the hottest month is 33–37°C and the mean minimum of the coldest month is 3–6°C. The average number of days when 32°C is exceeded is 60–115, and there are 20–40 days over 37°C . The northern Queensland distribution is relatively frost-free, but elsewhere the average annual number of frosts is 1–12.

The 50 percentile rainfall is 275–474 mm, the 10 percentile 150–300 mm, and the lowest on record 100–200 mm. There is a summer maximum precipitation, but the ratio of the wettest to the driest month varies from 15:1 in the north sector of the distribution to 3:1 or 2:1 towards the centre and the south. The average number of raindays a year is 40–60.
Physiography and soils. Most of the distribution is in the central basin of the Interior Lowlands physiographic division. The eastern edge is along the Eastern Uplands division. The area has been dissected into a landscape of rolling lowlands and plains, broken by small tablelands and mesas. The Murray–Darling river

system drains most of the area where the species occurs. In Queensland the topography is gentle, with small hills and ridges. *F. maculosa* has been recorded on open plains, undulating topography and the edges of claypans, and is locally common on stabilised sand dunes. Soil types include black cracking clays, acid and neutral red earths, desert loams, shallow sandy soils, red-brown earths, calcareous red earths and solonized brown soils.

Vegetation type. *F. maculosa* is mainly found in woodland, low open-woodland and tall shrubland. It is a major species in tall scrub to low woodland with the dominants *Geijera parviflora* and *Alectryon oleifolius* on river alluvium (Beadle 1981). *F. maculosa* is also found in pure stands or with *Geijera parviflora*, *Eremophila mitchellii* or *Atalaya hemiglauca* in low open-woodlands on elevated areas. Other dominant associates are *Eucalyptus intertexta*, *E. cambagei* and *E. populnea*, *Acacia pendula*, *A. aneura* and *A. excelsa*. A shrub layer of 3–5 m is present in wetter areas.

Utilisation.

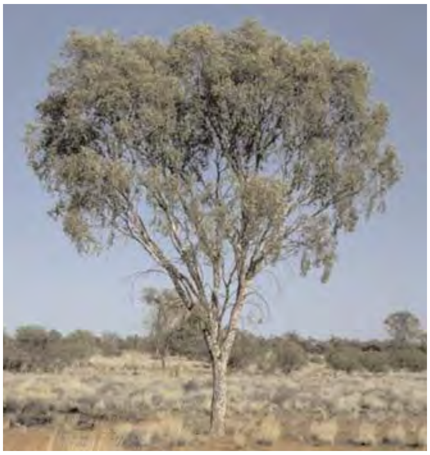
Fodder: The leaves are eaten by stock and it is considered to be an excellent fodder species (Everist 1969). McLeod (1973) estimated an in vitro dry matter digestibility of 57.4% and 2% nitrogen from leaf samples from trees in a southeastern Queensland arboretum. These predicted values require confirmation in animal trials.

Fuelwood: The wood is heavy and should be a good fuel.

Wood: The wood of this species is of a bright yellow colour, and exceedingly tough (Maiden 1889). Air-dry density is 960 kg/m^3 (Cause et al. 1974). It is elastic and was used for the poles and shafts of drays and buggies, and also as posts for fencing and for pick handles. The timber is considered unsuitable for exterior use, because of susceptibility to insect attack, but can be used for interior work (Maiden 1889).

Other uses: It is suitable for use as a shade tree and as an ornamental (Cremer 1990). It is a useful source of nectar and pollen in apiculture (Clemson 1985). The tree produces a potentially useful soluble gum (Maiden 1904), used by the early settlers to treat diarrhoea (Lassak and McCarthy 1983).

Silvicultural features. Growth is slow, straggly and bushy with long thin stems for the first few years, then it forms a strong leader of moderate growth rate



(Simpfendorfer 1992). Once established the tree is hardy, drought- and frost- tolerant and suitable for a wide range of soil types including alkaline cracking clays. It produces root suckers in its natural habitat, perhaps as a response to wind erosion of the surface sandy soil (Beadle 1981). Pollarding was recommended when cutting foliage for stock (Maiden 1904).

Establishment: Propagation is by seed or transplanted root suckers. Seeds are winged. There are 56 800 viable seeds/kg of about 90% germination rate when collected fresh. No pre-germination treatment of the seed is necessary. The seed is best stored in air-tight containers at 3–5°C.

Yield: There are few published records of growth rate. In trials in central Queensland on coarse-textured acid red earths, plants of *F. maculosa* had survived well (86%), but were only 13 cm tall after 7 months (Ryan and Bell 1991).

Pests and diseases. *F. maculosa* may be adversely affected by infestations of native species of mistletoe (*Amyema* spp.) (Cunningham et al. 1981).

Limitations. Very slow growth in the early years may discourage the planting of this species. Small size may limit use of timber to fuel and small posts and poles.

Related species. *F. maculosa* is in the group of related species, *F. bennettiana*, *F. collina* and *F. dissosperma*. They appear to be related in a linear sequence that begins with the rainforest species *F. bennettiana* and ends with the xerophytic species *F. maculosa* (Hartley 1969). The three close relatives have characteristic compound leaves, while in *F. maculosa* the leaves are simple.

Geijera parviflora

Main attributes. An attractive, deep-rooted and drought-resistant tree or shrub with a dense rounded canopy that grows on a range of soils in semi-arid areas. It is moderate- to slow-growing and is appropriate for a wide range of uses especially in windbreaks, for shade and as a source of forage for stock.

Botanical name. *Geijera parviflora* Lindl. was named in T.L. Mitchell's *J. Exped. Int. Trop. Aust*. 102 (1848). The generic name is after J.D. Geiger, a Swedish botanist, and the specific name is based on the Latin *parvus* – small, and *florus* — flowered, alluding to the small flowers of this species.

Common names. Wilga (standard trade name), shrub wilga, lavender bush, greenheart.

Family. Rutaceae.

Botanical features. A shrub or small to medium-sized tree to 10 m with pendulous leaves and branches forming a large, rounded dense canopy. The shrub grows to about 5 m. Bark is dark and rough on lower trunk, paler on upper trunk and branches. Leaves strongly aromatic when crushed, linear to linear-lanceolate, 3.5–18 cm long by 0.4–1 cm wide, narrowed or wedge-shaped at the base, shiny dark green, with a prominent mid-vein on lower surface, on stalks 3–12 mm long, the margins recurved. There are numerous oil glands on the surface. Flowers white, small, with 5 petals in open terminal panicles, the flowers emitting a rather foetid smell. The fruits are globular, 4–5 mm in diameter, outer skin thick, drying to expose a single ovoid shiny black seed. Immature fruit is green and dark brown when mature. Flowering usually occurs during June to November (Porteners 1991). Mature fruit is produced from January to May.

It is described by Porteners (1991) and illustrated by Anderson (1993) and Cunningham et al. (1981).

Natural occurrence. It occurs in inland areas of New South Wales and southern and central Queensland. It is also found in South Australia and in the extreme northwest of Victoria.

- Latitude. Range: 21–35°S.
- Altitude. Main occurrence: near sea level to 200 m.
  Range: near sea level to 500 m.

Climate. The major part of the distribution lies in the warm semi-arid climatic zone in South Australia, central New South Wales and western Queensland. Localities in the northeast of New South Wales and eastern Queensland are in the warm sub-humid zone, with some extension into the warm humid zone in the extreme northern part of the species' distribution. The mean temperature of the hottest month is 30–35°C, decreasing to 28–29°C in Victoria. The mean minimum of the coolest is 4–8°C, with frosts 1–23 per year in many areas. A maximum of 52 annual frosts has been recorded in northeastern New South Wales.

There is a marked difference in precipitation between the drier and sub-humid climatic zones of the distribution. For the drier parts of the semi-arid zone the 50 percentile rainfall is 175–410 mm and 515–715 mm for moister regions in the northeast. Similarly, the 10 percentile values are 65–267 mm and 440–470 mm respectively. The average annual number of raindays is 29–70 and 53–76, respectively. Rainfall incidence varies from a weak winter maximum in the south to a summer maximum in the north.

Physiography and soils. The species is found in undulating or rolling country and in the lowlands and alluvial plains and levees surrounding major river systems (Pedley 1974b). The levees are generally not flooded. It occurs on hills and escarpments with frequent rock outcrops. It has been recorded on weathered indurated sediments, laterised sediments, Tertiary sandstones, conglomerates, quartzose sandstone, siltstone and weathered basalt and andesites.

The upland soils include shallow brown and grey-brown soils, loams and light clays grading into medium to heavy clays, red and yellow earths, texture contrast and shallow, gravelly skeletals, sometimes with surface gravel and stones. The plains have uniform sands, skeletals and massive earths, deep texture-contrast sometimes with thin sandy or loamy surface horizons over strongly acid to neutral subsoils, mosaics of gilgaied cracking clays and red earths, brown and grey-brown shallow to moderately deep uniform clays to loams grading to clays generally with strong alkaline calcareous subsoils. *G. parviflora* is less common on alluvial plains of cracking clays with or without gilgais.

Vegetation type. Wilga grows in semi-evergreen vine thicket (Beadle 1981; Pedley 1974b), open- forest, woodland and shrublands. Semi-evergreen vine thickets are rainforest relicts and have a nearly continuous canopy of slender, densely packed trees, with complex layering of species. Common species occurring with *G. parviflora* are *Flindersia australis*, *Alstonia constricta*, *Alphitonia excelsa*, *Macropteranthes leichhardtii* and *Brachychiton rupestre*. Open-forest is dominated by species such as *Callitris columellaris*, *Casuarina cristata*, *Acacia harpophylla*, *A. shirleyi* and low *A. cambagei*. Woodlands are dominated by eucalypts such as *E. populnea*, *E. intertexta*, *E. thozetiana*, *E. pilligaensis*, *E. albens*, *E. microcarpa* and *E. coolabah* subsp. *coolabah*. Other species include *A. harpophylla*, *C. columellaris* and *C. cristata*. Shrublands are a common feature of the Queensland habitat for this species. *E. populnea* shrub woodland has a dense understorey but with an upper tree layer of *Ventilago viminalis*, *G. parviflora*, *Albizia basaltica*, *Eremophila mitchellii* and *Alectryon oleifolius*.

Utilisation.

Fodder: The foliage has high nutritive value and is readily utilised by sheep but rarely by cattle. There is variation in the palatability of individual trees (Cunningham et al. 1981; Porteners 1991; Simpfendorfer 1992). A substantial loss of leaves during summer and autumn can provide a low-maintenance fodder.

Fuelwood: Should be a satisfactory fuel.

Wood: Maiden (1889) described the wood as light-coloured, hard, close-grained and with an agreeable fragrance, but subject to gum veins and splitting on drying. Air-dry density is 895 kg/m^3 (Cause et al. 1974).

Other uses: The species is recommended for use in

windbreaks, as shade and shelter plants and in parks as an ornamental. In apiculture it is a useful source of nectar and pollen and is particularly important in the supply of pollen to increase the capacity of bee brood-rearing (Clemson 1985). The honey produced is strongly flavoured and dark amber in colour (Clemson 1985; Cunningham et al. 1981; Simpfendorfer 1992).

Silvicultural features. A deep-rooted, drought- and frost-hardy species of moderate to slow growth rate. It grows on a wide range of soils and will tolerate heavy soils of high pH. It has shown excellent growth on low-lying sites that may become wet during the rainy season (Cremer 1990). *G. parviflora* can withstand heavy trimming.

Establishment: Propagation is by seed (Simpfendorfer 1992) or by cuttings, with difficulty (Wrigley and Fagg 1988). A germination rate of 50% providing 48 000 viable seeds/kg was recorded of the single seedlot tested by CSIRO.

Yield: Although slow-growing in Canberra, it has been known to form a healthy rounded specimen 3 m high at 10 years of age. It is grown widely in Texas, USA (Wrigley and Fagg 1988).

Pests and diseases. None are recorded.

Limitations. Slow growth and palatability to stock may hinder establishment in some areas. Small size of bole may restrict use of wood to fuel. The foetid smell of the flowers attracts blowflies (Cunningham et al. 1981). Its spreading crown may be a disadvantage in some amenity uses (Cremer 1990).

Related species. There are three species, *G. linearifolia*, *G. parviflora* and *G. salicifolia*, in Australia.

Grevillea parallela

Main attributes. A small tree or bushy shrub adapted to semi-arid, sub-humid and humid climatic conditions and a range of soil types in the subtropics and tropics. Its wood is hard, durable and attractively marked. Has potential for fuel, small posts, turnery items and amenity uses.

Botanical name. *Grevillea parallela* J. Knight (syn. *G. polystachya* R. Br., *G. ceratophylla* R. Br. and *G. heteroneura* W.V. Fitzg) was first published in *Cult. Prot*. 121 (1809). The genus, *Grevillea*, honours C.F. Greville (1749–1809), one of the founders of the Horticultural Society of London and Vice-President of the Royal Society. The specific name is from the Latin, *parallelus* — parallel, alluding to the parallel venation in the leaves.

Common names. Silver oak, beefwood, narrow-leaf beefwood.

Family. Proteaceae.

Botanical features. *G. parallela* is a slender, small tree usually 5–8 m, but can grow to 15 m, with a straggly, open-branched canopy. It also grows as a bushy shrub 2.5–8 m tall and with a crown spread of up to 8 m. The bark is dark, hard and conspicuously furrowed. The foliage is silvery, rather pendulous. The leaves are linear to linear-lanceolate, undivided or irregularly divided into 3–9 linear-lanceolate segments, the whole leaf usually 10–40 cm long by 1.5–10 mm wide, pale and more or less silky below, midrib and 2–6 longitudinal veins visible. The inflorescence consists of cylindrical slender racemes 7–13 cm long, usually borne in terminal bunches. The flowers are small, white or cream, and the flowering time is July–October (Radke and Radke 1983). The fruit is a woody oblong follicle, 12–24 mm in diameter, sometimes persistent. There are 1–2 seeds in each follicle, and each seed is completely surrounded by a membranous wing. Mature seed has been harvested in November–December (Searle 1989).

It is described by McGillivray (1993) and illustrated by Boland et al. (1984), Brock (1988) and Hocking (1970).

Natural occurrence. This tree is widely distributed across northern Australia from the Kimberley region in Western Australia to Cape York Peninsula, Queensland.

The species also occurs in central and eastern Queensland as far south as Charleville.

- Latitude. Main occurrence: 14–19°S.
  Range: 10–27°S.
- Altitude. Main occurrence: near sea level to 250 m.
  Range: near sea level to 900 m.

Climate. Most populations occur in the hot semi-arid and sub-humid zones, but in northern coastal areas their occurrence is in the hot humid zone. Populations in central Queensland are in the warm semi-arid zone. The mean maximum temperature of the hottest month is 33–38°C and the mean minimum of the coolest, 10–22°C. Average number of days per year over 32°C is 100–280, and for over 38°C is 0–80 days. Most of the area is frost-free, but inland areas at higher altitudes may have an average of one frost per year.

The 50 percentile rainfall is 600–1150 mm, the 10 percentile 450–650 mm, and the lowest on record 200–400 mm. For most of the area there is a strong summer monsoon, with January or February the wettest months in central Queensland. The rainfall has a strong summer maximum. The average number of raindays per year is 60–90.

Physiography and soils. *G. parallela* is found in the northern provinces of the Western Plateau, Interior Lowlands, and Eastern Uplands physiographic divisions. It occupies a wide range of habitats such as dissected sandstone plateaux, coastal high ranges or tableland complex of volcanics, basalitic or lateritic hilly lowlands, and sand plains, undulating clay or alluvial plains with scattered hills. Soils are chiefly deep sandy or loamy red or yellow earths (Pedley and Isbell 1970), granitic yellow earths, colluvium or alluvium derived from metamorphics, lithosols on granite, gravelly clay loam on schist on ridge tops (Tracey 1982), and laterite overlain by red clay-loam (Beard 1979).

Vegetation type. *G. parallela* is usually a component of an understorey of low trees or shrubs in open-woodland, woodland and low woodland (Pedley and Isbell 1970; Tracey 1982). These are dominated by eucalypts such as *E. acmenoides*, *E. alba*, *E. brownii*, *E. cullenii*, *E. intermedia*, *E. leptophleba*, *E. miniata*, *E. nesophila*, and *E. polycarpa*. Similar communities in which *G. parallela* occurs are those dominated by *Melaleuca* spp., *Angophora melanoxylon* or *G. striata* and *Acacia bidwillii. G. parallela* also grows as a low tree or shrub in open-forest in which the canopy trees are *E. tetrodonta*, *E. nesophila*, *E. dichromophloia*, and *E. phoenicea*. Common associates are: *A. aulacocarpa*, *A. flavescens*, *A. holosericea*, *Alphitonia excelsa*, *G. glauca*, *Persoonia falcata*, *Petalostigma pubescens* and *Planchonia careya* (Pedley and Isbell 1970).

Utilisation.

Fodder: It is regarded as a reasonable top feed and is grazed by stock in drought periods (Anderson 1993).

Fuelwood: A dense wood, which should burn satisfactorily.

Wood: The heartwood is brown to pink-brown with an attractive oak-like grain. It has a density of about 880 kg/m^3. The sapwood is susceptible to *Lyctus* attack. The timber is very hard and durable when exposed to the weather and in ground contact (Boland et al. 1984), and should prove suitable for fencing.

Other uses: G. parallela is a rich nectar producer and has potential for honey production. Its attractive creamy-yellow flowers make it useful as an ornamental for landscaping parks, gardens and streets.

Silvicultural features. The silvicultural characteristics of this species are poorly known. It will grow on relatively infertile well-drained soils and appears to tolerate fires. Its coppicing ability is not recorded.

Establishment: Readily grown from seed, although the seeds germinate slowly. Pretreatment is not a prerequisite for germination, but soaking in cold water for 24 hours before sowing may enhance germination. There are about 29 000 viable seeds/kg.

Yield: Fast-growing under suitable conditions (Brock 1988). A provenance from Weipa in north Queensland, however, did not do well in trials in southeastern Queensland. Survival averaged 50% and height reached only 1.6 m in 4.5 years (Ryan and Bell 1991). The same provanance grew much better on two seasonally dry sites in Thailand, reaching 1.6 m in 12 months, but failed on a third site (Pinyopusarerk 1989).

Pests and diseases. None recorded on this species, although grevilleas in general are very susceptible to *Phytophthora* root and collar rot (Hocking 1970).

Limitations. Limited information on growth rate and provenance variation suggests that this species will require extensive testing before it can be recommended confidently for use.

Related species. *G. parallela* is closely related to *G. coriacea* D. McGillivray, a slender plant with leathery leaves and larger flowers (McGillivray 1975).

Grevillea pteridifolia

Main attributes. A fast-growing, short-lived small tree of tropical Australia that is adapted to a wide variety of soils and will tolerate periodic waterlogging. It has potential for soil reclamation and amenity planting, and the small-sized wood should make suitable fuel.

Botanical name. *Grevillea pteridifolia* Knight was published in *Cult. Proteae* 121 (1809). The species name is in reference to the Latin, *pteris* — a species of fern, and *folium* — a leaf, in allusion to the divided, fern-like leaves of this species (McGillivray 1993).

Common names. Ferny-leaved silky oak (standard trade name), fern-leaved grevillea, yinungkwurra, golden grevillea, golden tree, Darwin silky oak.

Family. Proteaceae.

Botanical features. *G. pteridifolia* is usually a shrub or small tree 2–18 m high. It has an open habit with silvery foliage and a single main stem. The bark is rough, dark grey or black (Brock 1988). Young branchlets are pubescent. Leaves are 24–45 cm long, with 6–14 linear or narrow ovate lobes on one side of the axis. Margins are curved outwards. Venation of two prominent longitudinal veins and the midrib are visible on upper surface only. Upper is usually glabrous, lower silvery, hairy. The bright orange-yellow flowers, 6.5–11.5 mm long, are arranged on one side of a terminal inflorescence, 8–22 cm long. Flowering time is from May to September, extending to October (Brock 1988), but can occur throughout the year (McGillivray 1993). The fruit is a thin-walled, persistent, dark brown follicle, ovate to oblong, 14–21 × 9–10.5 mm, 4–6 mm thick, with a persistent style. The surface is densely hairy. Fruits are produced from July to October (Brock 1988). The shiny, winged seed is oblong or sometimes narrowly ovate, 9–10.5 × 3–3.8 mm.

The species is described by McGillivray (1993) and illustrated by Brock (1988) and Wheeler et al. (1992).

Natural occurrence. *G. pteridifolia* has a wide distribution across northern Australia from the coast inland. The range includes the Kimberley region in northern Western Australia, the north of the Northern Territory and, in Queensland, around the Gulf of Carpentaria and Cape York Peninsula and south to Townsville and inland to central Queensland.

- Latitude. Main occurrence: 11–21°S.
  Range: 11–24°S.
- Altitude. Range: sea level to 500 m.

Climate. The distribution is mainly in the hot humid climatic zone, but inland, at higher altitudes away from the coast, the climate is hot sub-humid. Central Queensland populations are in the warm sub-humid zone. The mean maximum temperature of the hottest month is 33–36°C and 30–33°C on the coast. The mean minimum of the coolest month is 27–30°C, and 24°C in central Queensland. The area is largely frost-free, but in southern inland areas frosts may occur on 1–5 days each year.

The 50 percentile rainfall is generally 800–1200 mm, but 1200–1600 mm in monsoonal areas close to the coast. Inland areas have a 50 percentile value of 400–800 mm. The 10 percentile is 600–800 mm and 800–1200 mm in coastal areas. The inland 10 percentile value is 300–400 mm. The rainfall has a monsoonal pattern with most falling December–March in the coastal, northern areas of the distribution. There is a summer maximum inland.

Physiography and soils. This species is found on low foothills, undulating to flat plains, as well as on the slopes of sandstone or quartzite hills and stony ridges. Drainage lines are another habitat as well as seasonally inundated areas around swamps and lagoons, and on the exposed, seaward slopes of high coastal sand dunes. Soils include deep yellow sands, red or sandy mottled yellow earths, skeletal or lithosols from sandstones or quartzites, red sandy or dark brownish grey sandy loam, lateritic podsols or clay loam or gravel, yellow podsols and deep white sand (Beadle 1981; Pedley and Isbell 1970).

Vegetation type. *G. pteridifolia* is a common shrub or small tree beneath open-forest and woodland in tropical eucalypt communities. Dominant eucalypts include *Eucalyptus tetrodonta*, *E. polycarpa* and *E. ptychocarpa*. Associate low trees or shrubs are *Alphitonia excelsa* and *Erythrophleum chlorostachys*. *G. pteridifolia* is found with *Lophostemon lactifluus* and *Banksia dentata* in low woodlands associated with aquatic grasslands or sedgelands near streams, swamps and lagoons in tropical Northern Territory (Beadle 1981). In open-woodlands present in drier areas, *G. pteridifolia* grows as scattered shrubs in an ill-defined shrublayer. Eucalypt dominants in these woodlands include *E. grandifolia*, *E. phoenicea*, *E. ferruginea* and *E. brevifolia*. A closed heath community on Cape York Peninsula is dominated by *Myrtella obtusa* and *Neofabricia myrtifolia*. A 2 m canopy of these species grows over shrubs like *Acacia calyculata*, *Boronia bowmanii*, *Morinda reticulata*, *E. tetrodonta* and *G. pteridifolia* (Pedley and Isbell 1970).

Utilisation.

Fodder: Dried foliage is eaten by stock (Gardner 1923).

Fuelwood: Should be satisfactory for small-diameter fuelwood.

Wood: Basic density of the wood is 630 kg/m^3 (Davis 1994).

Other uses: A beautiful, flowering ornamental tree useful for landscaping in the tropics. It is used in the revegetation of bauxite mining sites in Australia (Langkamp 1987) and India (Prasad and Chadhar 1987a,b). The flowers produce large quantities of nectar (Gardner 1923) and attract many birds (Levitt 1981) and bees. Australian Aboriginal people suck the flowers for nectar or shake the nectar into water which is then drunk. The flowers may be eaten (Brock 1988).

Silvicultural features. Fast-growing in favourable conditions, the species grows best in well-drained loams. Plants are frost-tender and sensitive to wet winters (Wrigley and Fagg 1988). *G. pteridifolia* is moderately fire-sensitive, sometimes resprouting from axillary or epicormic buds after low-intensity fires (McGillivray 1993). It has good coppicing ability (Ryan and Bell 1989), although poor coppicing of 5–6 year-old plants has been reported in India (Prasad and Chadhar 1987a).

Establishment: It is cultivated from seed or tip cuttings (Brock 1988). Flower buds appear as early as 17 months after planting (Ryan and Bell 1989). There is an average of 14 000 viable seeds/kg at an average germination rate

of 50%. Germination is enhanced by soaking the seed for 24 hours in cold water before sowing. Seed can be stored for up to 2 years in cool storage (Prasad and Chadhar 1987a). It has been successfully grafted on to root stock of *G. robusta* (Makinson and Boland 1992).

Yield: In trials in southeastern Queensland, *G. pteridifolia* grew rapidly to average 5.8 m in height and 16 cm basal diameter in 4.5 years. The species has also grown quickly in trials in Thailand (Pinyopusarerk 1989), Zimbabwe and Kenya, and has shown tolerance of termites in Zimbabwe (D. Boland, pers. comm.). In India, the species has proved very hardy and suitable for mined sites. It attained an average height of 5.7 m and girth at breast height of 19.8 cm by 6.5 years with 94–96% survival (Prasad and Chadhar 1987a, b).

Pests and diseases. Various species of leaf-hopper are reported to attack this species in Australia (Halfpapp 1967). Large numbers of ants are attracted to the honey dew produced by leaf-hoppers. The plant is parasitised by a species of mistletoe, *Dendropthoe acacioides* (McGillivray 1993).

Limitations. The species may be short-lived. Hearne (1975) reported that plants in Darwin have a useful garden life of only 6–8 years. Weediness may be a problem in some areas (Neel and Will 1978). Natural regeneration from plantings as young as 3.4 years has been noted in India (Prasad and Chadhar 1987a).

Related species. *G. pteridifolia* belongs to a group of some 47 grevilleas often known as the 'toothbrush-inforescence group' (Makinson and Boland 1992).

Grevillea robusta

Main attributes. *G. robusta* has gained widespread popularity in warm temperate, subtropical and tropical highland regions of many countries formerly as a shade tree for tea and coffee and now as an agroforestry tree for small farms. It provides economically valuable products including timber, poles, firewood and leaf mulch; 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; it does not compete strongly with adjacent crops; and it tolerates heavy pruning of its roots and branches.

Botanical name. *Grevilea robusta* A. Cunn. ex R. Br. The name was published in *Suppl. Prodr. Fl. Nov. Holl.* 24 (1830). It is derived from the Latin *robustus* — hard, strong, robust, in reference to the size of this species in a genus where many species are shrubs.

Common names. Australian standard trade name is southern silky oak. Other common names are silky oak, silk oak and river oak.

Family. Proteaceae.

Botanical features. An erect single-stemmed tree 20–30 m in height and 80 cm in diameter but occasionally reaching 37 m tall and 1 m 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 lace-like pattern. Young branchlets are angular and ridged, subsericeous to tomentose but glabrous on older growth. The fern-like foliage of this species is very distinctive in the forest. Leaves are 10–34 cm long and 9–15 cm wide, variably pinnate to bipinnate, with a glabrous green upper surface and subsericeous silvery undersurface. Petioles are 1.5–6.5 cm long. The species is semi-deciduous, being almost leafless shortly before flowering in the period October–November. The inflorescences are racemes, simple to 4-branched from near the base, and borne on older wood. The bright orange flowers, about 2 cm in length, are borne in numerous pairs along the flower spikes, on pedicels 1.5 cm long. The perianth consists of 4 narrow tepals, 0.6–1 cm long, with the concave summit of each tepal holding a small anther 0.1 cm long. The ovary surmounts a gynophore 0.2–0.3 cm long. Fruits are two-seeded follicles 2 cm in length, with a slender persistent style.

Seeds are winged, 13–19 mm long × 8-10 mm wide and 0.8–0.9 mm thick, with a papery wing around the brown, ovate central seed body. Mature seed is available in late December and January.

Grevillea robusta is described and illustrated by Boland et al. (1984). An annotated bibliography is available (Harwood 1989) and proceedings of an international workshop on agroforestry and forestry applications of *G. robusta* (Harwood 1992a). Harwood (1997) provides summary information on the species.

Natural occurrence. The natural habitat of *G. robusta* is in northern New South Wales and southern Queensland where it occurs from the coast to the Bunya Mountains in Queensland, some 160 km inland. The highest altitude occurrences are at inland localities. The north–south range of the species is some 470 km from north of Gympie to the Guy Fawkes and Orara Rivers (tributaries of the Clarence River). A reported occurence near Gladstone (24°30'S)(Swain 1928b) was unable to be verified (Harwood 1992a). Silky oak is now relatively rare in its natural state.

• Latitude. Range: 26–30°S.

• Altitude. Range: from near sea level to 1100 m.

Climate. 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 mean maximum temperature of the hottest month is about 29–32°C and the mean minimum of the coldest month is 4–12°C. Occasional frosts are experienced in most localities with an annual range of 1–5.

The 50 percentile rainfall is 750–1670 mm, the 10 percentile 500–1065 mm and the lowest on record

325–740 mm. Maximum precipitation is in the summer with a pronounced dry spring. Stream bank occurrences have better access to soil moisture than indicated by the rainfall data, while high elevation stands on slopes away from streams suffer severe drought stress aggravated by dry winter winds and culminating in crown dieback.

Sites with the following ranges of climatic factors should provide conditions for satisfactory growth: mean annual rainfall 700–1700 mm, a dry season of 0–6 months (0–4 months on shallow soils or towards the hotter extreme of the acceptable temperature range), mean max. temp. of hottest month of 25–31°C, mean min. temp. coldest month of 2–12°C, mean annual temp. of 14–23°C and absolute min. temp. no lower than –8°C (Booth and Jovanovic 1988b).

Physiography and soils. Silky oak typically occurs along streams but can also occur on dry exposed hillsides. 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 podzolic soils derived from sedimentary material. The proteoid roots of this species are thought to increase the plant's ability to take up water and nutrients under harsh conditions.

Vegetation type. At Bunya Mountain, Queensland, and elsewhere the species can be found growing in rainforests as well as associated with river she-oak (*Casuarina cunninghamiana*) in the drier creeks which flow from the mountain into woodland. Common associates of more mesic sites include bunya pine (*Araucaria bidwillii*), hoop pine (*Araucaria cunninghamii*), black bean (*Castanospermum australe*) and brush kurrajong (*Brachychiton discolor*). The species seeds well and regenerates strongly after any site disturbance in rainforests.

Utilisation.

Fodder: Some farmers in Kenya use fresh leaves as a dry-season fodder supplement for cattle. The leaves are also used as a mulch for crops.

Fuelwood: The wood is tough, elastic and moderately dense and is used for fuel in Sri Lanka and several African countries.

Wood: The sapwood is up to 25–38 mm wide and cream in colour while the heartwood is yellow-brown to red-brown on drying. The timber seasons without

difficulty. Broad medullary rays give the wood an attractive figure. Air-dry density of heartwood is around 550–600 kg/m^3. Its value as a timber tree has been well appreciated in Australia where, in earlier days, it was popular for cabinet work, indoor fittings, coach building and cooperage, but supply is now limited. Logs are good for peeling and slicing and the wood makes good pulpwood (Keating and Bolza 1982). The wood from relatively young, fast-growing woodlots outside Australia comes with some notable drawbacks: the sapwood is very susceptible to attack by borers and fungi, and even the heartwood is only moderately durable, and the wood is light. It is, therefore, of relatively low economic value. Currently, the wood is used to a minor extent for medium-quality veneer and as general construction and joinery timber.

Other uses: G. robusta is one of the top priority tree species for agroforestry development in the humid and sub-humid highlands in Eastern, Central and Southern Africa. It is an important species in social forestry development in many parts of India. The traditional use of *G. robusta* at elevations of 1200–2300 m as a shade tree for tea and coffee plantations in Asia and Africa is declining because of competition and disease problems. It is increasingly being grown in mixtures with other crops such as maize, beans and potatoes or in rows along farm boundaries and between fields. It is regarded as being more compatible with crops on small farms than most other tree species.

The dense, brilliant golden-yellow or orange (rarely reddish) 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 most tropical and subtropical countries for park and roadside plantings. In the United Kingdom and Europe it is commonly available as an indoor plant. The flowers are rich producers of nectar, making this an important honey plant. Commercial harvesting of *G. robusta* gum has apparently been developed in India.

Silvicultural features. The tree is relatively short-lived, reaching senescence at about the age of 50 years. It appears to grow best when planted singly or in lines on sites with deep and well-drained soils. Soils should be of moderate to high fertility with pH in the range 4.5–8: heavy clays and waterlogging are not tolerated. On acid soils, symptoms of boron deficiency and manganese toxicity have been observed.

Farmers in the African highlands commonly harvest branches by high pruning and pollarding every 3–4 years from age 4–6 years onwards The branches are removed to regulate shading and competition with adjacent crops and are used for firewood and poles, while the leaves are used for mulching or sometimes for cattle fodder. The main trunk of the tree may be harvested as a sawlog from age 15–25 years. The tree coppices well up to two years after being cut back to ground level, but this ability declines sharply thereafter.

Establishment: Propagation is usually from seed. First flowering occurs when the tree is about 3–6 years old. Birds are believed to be the principal pollinating agents. The period from fertilisation to fruit maturity is two months. Hot dry weather stimulates seed release immediately the fruits mature. It seeds prolifically. There are about 42 500 seeds/kg with an average germination rate of 66%. Seed will retain viability for at least two years if dried to below 8% moisture content and stored in a dry, cool (20°C or lower) environment.

No pretreatment is required for germination. Seeds are usually germinated on loamy soil with a shallow covering of sand. Seedlings are pricked out, when their second leaf-pair starts to develop, into tubes with a fertile loamy potting mix. Seedlings are grown on in the nursery until planting out at a height of 20–40 cm during the rainy season. Farmers also obtain planting stock by digging up wildings. Cuttings can be easily struck using shoots of seedlings or saplings, which can also be air-layered. Rajasekaran (1994) reported a successful method of micropropagation through axillary bud activation.

Some control of competing vegetation is required for the first 1–2 years after planting. This is normally achieved by manual weeding. Fertiliser is seldom applied: 50 g per tree of an NPK fertiliser (12:12:12) applied shortly after planting would be appropriate for infertile soils. If there are symptons of boron deficiency, an application at planting of 10 g per tree of elemental boron as borax or, preferably, the less soluble ulexite is recommended.

Yield: When grown at close spacings in plantations and woodlots the growth rate of the species is relatively modest. For example, the estimated mean annual wood yield in tropical highlands is only some 10–12 m^3/ha over 10–15-year-rotation at recommended stocking of 800–1200 trees/ha. It is unlikely, therefore, that *G. robusta* will be a high priority plantation timber species.

It appears to grow better when planted singly or in lines, which complements its use as an agroforestry species. In this situation, annual growth rates of 2 m (height) and 2 cm (diameter) over the first 5 years are commonly acheived in a number of countries where climate and soils are suitable. In a six-year rotation in Rwanda with 300 trees/ha (50 trees being harvested each year), annual bole yields of around 5 m^3/ha and additional bough and prunings totalling about the same volume were achieved (Neumann 1983). Yield of food crops was reduced by 5% in these experiments.

In all but the most favourable conditions growth slows greatly after 10–15 years.

Pests and diseases. In the lowland humid tropics and other regions with high humidity, *G. robusta* is vunerable to attack by fungal diseases such as *Corticium salmonicolor*. In lowland environments in the Caribbean it is severely attacked by the scale insect *Asterolecanium pustulans*. Pathogenic fungi such as a *Amphichaeta grevilleae*, *Cercospora* sp. and *Phyllostica* sp. have been observed to cause considerable damage to leaves and stems of young plants in Sri Lanka, particularly if they are overwatered in the nursery. Attack by termites can be a problem when the species is planted on dry sites in Africa.

Grevillea robusta boundary plantings around fields of coffee and maize, Embu, Kenya.

Limitations. It is an effective colonising species and, in some cases, threatens to be a noxious weed (e.g. in Hawaii). The trees have brittle branches and can be damaged by high winds. It grows poorly in lowland tropical environments.

Related species. There are about 250 *Grevillea* species most of which are endemic to Australia. *G. robusta* is the largest species in the genus. It has no recognised subspecies or varieties, and no hybrids with other species have been recorded.

Grevillea striata

Main attributes. A small shrub or medium-sized tree with moderate to slow growth. It is tolerant of drought and frost and adaptable to a wide range of soils, including heavy soils. The timber is moderately heavy, splits easily and is very durable. It can provide emergency drought fodder for stock and makes an attractive ornamental in arid regions.

Botanical name. *Grevillea striata* R.Br. was published in *Trans. Linn. Soc. London* 10: 177 (1810). The species name is derived from the Latin *striatus* — grooved, with reference to the channel between the parallel veins on the lower side of the leaf (McGillivray 1993).

Common names. Beefwood (standard trade name), western beefwood, beef oak, beef silky oak, silvery honeysuckle.

Family. Proteaceae.

Botanical features. A single-stemmed shrub to 3 m or small to medium-sized tree 15 m tall. Diameters (b.h.) usually 10–30 cm, although diameters of up to 60 cm were common in the recent past (Maiden 1911). Bark rough, coarsely furrowed dark grey or black. The silvery, grey-green leaves are linear to broadly linear, ascending to erect, almost without stalks or with short stalks, 10–45 cm long by 2–15 mm wide. Both surfaces are longitudinally ridged, the lower hairy with 5–13 parallel longitudinal veins, midvein sometimes prominent. The inflorescences are terminal or axillary, cylindrical, 1.5–2 cm diameter, erect with 4–12 branches each being 5–14 cm long. The flowers are 1.8–2.3 mm long, on hairy stalks, cream, about 5 mm long. Flowering time is from October to November (Brock 1988). The fruit is a woody follicle, oblong to ovate, 13–21 mm long by 10–14 mm broad, 5–6 mm thick, thin-walled with a beaked tip. At maturity the fruits are brittle and easily snapped between the fingers. Fruiting time is from December to January (Brock 1988). The seed is oblong to ovate, 12–16 mm × 8–11.5 mm. It has a membranous or brittle wing, 1–4 mm wide, broadest at the apex.

The species is described by McGillivray (1993) and illustrated by Brock (1988) and Wheeler et al. (1992).

Natural occurrence. This species grows in an extensive belt which covers nearly half of the continent of

Australia. The area is nearly 3000 km from northwest to southeast and about 1400 km west to east. The distribution is from the Kimberley region in Western Australia across into central Australia and Queensland and extending southwards over most of western New South Wales. There is a disjunct occurrence in central Western Australia.

- Latitude. Range: 15–33°S.
- Altitude. Range: 100–600 m.

Climate. This species occurs throughout most of the driest and hottest parts of Australia. The distribution includes both the warm and hot arid zones, both the warm and hot semi-arid zones and the warm sub-humid zone (near the central east coast of Queensland). The mean maximum temperature of the hottest month is 33–37°C and the mean minimum of the coolest month 4–9°C. The average number of days over 32°C is 75–150 and for over 37°C is 10–40. Throughout the southern part of the range and especially at higher altitudes in central areas, heavy frosts range from 1–12 a year. In northern coastal areas of the distribution, frosts are absent.

The 50 percentile rainfall is mainly 200–500 mm, the 10 percentile is 125–350 mm, and the lowest on record 50–225 mm. The average number of raindays a year is 30–60, and the seasonal distribution varies from uniform in southern localities in New South Wales, to a mainly summer maximum. A strong monsoonal pattern is present in the far north, with the driest month August or September.

Physiography and soils. *G. striata* grows in topography which varies considerably and includes central plains and sand dunes. This species is only rarely found on steep, rocky hillsides. The soils vary from clays in wetter areas to sands in dry areas, red and yellow earths, lithosols, non-calcic brown soils with a sandy surface, deep sands and calcareous and alluvial soils.

Vegetation type. This species is found in open-woodlands and shrublands. It is a dominant species with *Atalaya hemiglauca* and *Ventilago viminalis* which occur singly or in combination in scrub or woodland communities that are derived from rainforest in the arid and semi-arid zone. Within low woodland dominated by *Eucalyptus pruinosa* or *E. brevifolia* there are mosaics formed with *Melaleuca* spp. scrub. These contain mixtures of *Atalaya hemiglauca*, *G. striata* and *Terminalia canescens*. A shrub layer of *G. striata*, *G. pteridifolia* and *Cochlospermum fraseri* grows as an understorey beneath these woodlands. In other woodlands and shrublands dominated by *E. drepanophylla*, *E. intertexta*, *E. populnea*, *Acacia aneura*, *A. cambagei*, *A. excelsa* and *Casuarina luehmannii*, *G. striata* can often be found as a small tree or shrub beneath the open canopy.

Utilisation.

Fodder: Cremer (1990) states that the foliage is only eaten by stock during serious drought conditions. Chippendale and Jephcott (1963) recorded that the foliage is moderately palatable, with moderate to fair nutritive value and a high fibre content, providing variety and light grazing for cattle. Everist (1969) reports that the leaves are eaten readily by sheep.

Fuelwood: G. striata is not suitable for fuelwood (Cremer 1990).

Wood: The timber is of moderate weight (air-dry density 880 kg/m^3), fissile and very durable (Cause et al. 1974; Cremer 1990). It is a first-class material for posts and other items, such as house blocks, that are in contact with the ground.

Other uses: The tree is ornamental and has potential for use in parks and large gardens, especially in areas of 375–650 mm rainfall (Cremer 1990). The flowers attract nectar-eating birds and bees.

Australian aboriginal people extracted an adhesive resinous gum from the trunk and roots. As well as being used to attach flints to cutting tools, it was used medicinally to dry up lesions and promote clean healing (Aboriginal Communities of the Northern Territory 1993). The seeds are edible (Brock 1988).

Silvicultural features. Small tree of moderate to slow growth rate suitable for hot dry areas, tolerant of frost and heavy soils. It is fire-resistant. Coppicing ability is unknown.

Establishment: Propagation is best from seed but care must be used to avoid the damping-off of seedlings (Wrigley and Fagg 1988).

Yield: In field trials in central Queensland, trees had reached 0.8 m and 0.4 m in height on acid red earths and alkaline cracking clay respectively in 18 months, with irrigation. Survival averaged 67%. Survival and growth were significantly less without irrigation on those soils (Ryan and Bell 1991).

It has been planted near Embu, Kenya and found to grow slowly (Makinson and Boland 1992).

Pests and diseases. Processionary caterpillars (*Ochrogaster* spp.) are commonly in this tree in its natural habitat (Aboriginal Communities of the Northern Territory 1993).

Limitations. Little is known of the genetic variation in the species and it has not been widely planted. Seed collections throughout the range and provenance tests may identify faster-growing seed sources.

Related species. Makinson and Boland (1992) place *G. striata* in a group of 14 tropical and arid zone species closely related to *G. mimosoides* and *G. parallela*.

Lysiphyllum carronii and *L. cunninghamii*

Main attributes. *Lysiphyllum carronii* and *L. cunninghamii* are hardy, slow-growing semi-deciduous tall shrubs or small trees of semi-arid regions of the tropics and subtropics. They are treated together here because of their considerable similarity. They tolerate a wide range of soils including heavy cracking clays. They provide forage for stock, their wood is suitable for general purpose use and they show ornamental and apicultural potential.

Botanical name. *Lysiphyllum carronii* (F. Muell.) Pedley is a new combination in *Austrobaileya* 1: 33 (1977) based on the species *Bauhinia carronii* F.Muell. (1858). *L. cunninghamii* (Benth.) de Wit was transferred to the genus *Lysiphyllum* in *Reinwardtia* 3: 431 (1956). The genus is derived from the Greek *lysis* — a loosing or separation, and *phyllon* — leaf, alluding to the partial separation of the leaf into two leaflets. The name *carronii* — commemorates W. Carron (1823–1876), a Queensland botanist and only European survivor of the Kennedy expedition. The name *cunninghamii* — honours A. Cunningham (1791–1839), King's Botanist and explorer, mainly in eastern Australia.

Common names. *L. carronii*: northern beantree, red bauhinia. *L. cunninghamii:* beantree, small-leaved bauhinia.

Family. Caesalpiniaceae.

Botanical features. *L. carronii* is a semi-deciduous shrub or small tree, 5–10 m tall, while *L. cunninghamii* is a tree to 12 m tall. The former is open-branched, while the latter has pendulous branchlets. The bark is grey, rough, tessellated to fissured. The leaves are rounded and made up of two asymmetrically rounded leaflets joined at the base. Northern populations are distinctly deciduous. The following characteristics separate the species: *L. cunninghamii* has leaflets broadest about the middle, equally tapering to each end, 1.2–1.7 times as long as wide, calyx lobes and buds ribbed; *L. carronii* has leaflets broadest below the middle and tapering to a narrow apex, 1.5–3.5 times as long as wide, calyx lobes and buds not ribbed (Pedley 1977).

The leaflets are shaped like butterfly wings, mostly 16–30 mm long and 10–20 mm wide for *L. carronii* (McCune and Wiecek 1991), and 14–33 mm long by 9–27 mm wide (Wheeler et al. 1992) for *L. cunninghamii*, dull blue-grey to grey-green (Brock 1988). The flowers are in axillary racemes, the petals 5, pink to red (*L. cunninghamii*) or rusty brown (*L. carronii*), 10–15 mm long, two of them longer than the others, densely hairy outside, the stamens projecting beyond the lobes. Pod narrowly oblong, flat or slightly convex, 11–20 × 3.5–6.3 cm, reddish-brown turning black on maturity and remaining on the tree for several months (Brock 1988). Seeds are transverse in the pod, brown or black, oblong-elliptic, 13 × 10 mm. Flowering varies from spring to summer (McCune and Wiecek 1991), April–October (Wheeler et al. 1992) and June–September (Brock 1988). Fruits are present February–March (Brock 1988) and May–December (Wheeler et al. 1992).

The species are described by Pedley (1977) and Wheeler et al. (1992) and illustrated by Brock (1988), Williams (1979) and Aboriginal Communities of the Northern Territory (1993).

Natural occurrence. The two species have an extensive distribution across central and northern Australia, from the Kimberley region in Western Australia to central Queensland (Perry and Lazarides 1964). *L. carronii* is concentrated in southern Queensland.

- Latitude. Range: 13 – 29°S.
- Altitude. Range: near sea level to 500 m.

Climate. Most of the distribution lies in the warm and hot semi-arid climatic zones. Some populations grow in warm sub-humid to hot sub-humid zones in northern Queensland. The mean maximum temperature of the hottest month is 32–39°C and the mean minimum of the coolest 11–15°C. In southern

Queensland the minimum decreases to 7–9°C. Most of the distribution is frost-free, but in some inland areas at higher altitudes there are 1–4 frosts per year.

The 50 percentile rainfall is 340–965 mm, the 10 percentile 220–720 mm and the lowest on record 30–95 mm in extremely dry inland areas and 187–439 mm elsewhere. The northern part of the distribution has a summer monsoon, while inland and in south-eastern areas the incidence is a well-developed summer maximum. The annual number of raindays is 30–65.

Physiography and soils. The species' distribution lies mainly on rocky hills, undulating clay plains, or undulating lowlands and extensive sand plain and dune fields. Soils include grey to black medium to heavy cracking clays, often with strongly alkaline subsoils, and sands including red earthy sands, deep red and yellow siliceous sands and shallow sands, often with abundant gravel.

Vegetation type. *L. carronii* usually occurs as scattered understorey shrubs, and *L. cunninghamii* sometimes occurs in pure stands in open-forest, woodland, tall shrubland, sparse herbland and grassland. Dominant species are from the genera *Eucalyptus*, *Acacia*, *Flindersia*, *Geijera* and *Terminalia* (Neldner 1984; Beadle 1981). On hilly topography *L. carronii* is a component of semi-evergreen vine thicket or microphyll vine woodlands dominated by *Brachychiton rupestre* (Beadle 1981; Gunn and Nix 1977; Speck 1968). *L. cunninghamii* and *Excoecaria parviflora* also occur in *Melaleuca* woodlands (Perry and Lazarides 1964). *L. cunninghamii–Gyrocarpus americanus* is a 7-m-high woodland on lateritic sands on the Barkly Tableland region in the Northern Territory. A transitional zone between the sand plain woodland and the flood plain is marked by a low tree layer of *L. cunninghamii* and *Grevillea striata* (Beard 1979). Sparse herbland with scattered trees of *Acacia harpophylla* and *L. carronii* 2–4 m high is found on undulating plains (Neldner 1984).

Utilisation.

Fodder: Leaves and pods are eaten by sheep and cattle and have moderate nutritional value (Everist 1969; Anderson 1993). However, the trees can be leafless during late winter and early spring and during severe droughts.

Fuelwood: There are no reports on burning properties, but they have potential for use as fuelwood.

Wood: Light-brown, but becoming much darker towards the centre, hard, heavy, close grained; suitable for cabinet work (Maiden 1889). *L. cunninghamii* has been used for tool handles (Kamminga 1988).

Other uses: The trees have an ornamental appearance and can be used for amenity planting, as well as for shade and shelter. The nectar of *L. carronii* attracts birds and insects and was used as a drink by Aborigines (Wrigley and Fagg 1988). Apicultural potential is suggested.

Silvicultural features. These are species for harsh sites in semi-arid zones. Although not fast-growing they are drought-hardy and will grow on a range of soil types including heavy cracking clays. They will tolerate some seasonal flooding but are generally frost-tender. Both species are semi-deciduous. Coppicing ability has not been recorded.

Establishment: Propagation is by cuttings or seed treated with near-boiling water. There are approximately 2400 viable seeds/kg at a germination rate of about 78%.

Yield: Little definitive trial data are available. The species when planted off-site in southeastern Queensland grew slowly to average 0.59 m tall in 2 years (Ryan and Bell 1991). *L. cunninghamii* failed when planted in trials in central Queensland.

Pests and diseases. None are recorded.

Limitations. Variation in growth of provenances can be expected in species with such a large geographic range, but no studies have been undertaken. Provenances tested have been relatively slow-growing.

Related species. A close relative is *L. gilvum*. It is distinguished by yellow hairs on the outside of the sepals, smooth buds and relatively narrow pods (Pedley 1977).

Macadamia integrifolia and *M. tetraphylla*

Main attributes. Small medium-sized trees adapted to sub-humid and humid conditions and well-drained, fertile soils. The source of highly nutritious edible nuts. Both species make attractive ornamental and shade trees.

Botanical name. *M. integrifolia* Maiden and Betche was published in *Proc. Linn. Soc. NSW* 21: 624 (1897). *Macadamia* was named in honour of J. Macadam (1827–1865), Secretary of the Philosophical Institute of Victoria. The name *integrifolia* is from the Latin *integri* — entire, *folium* — a leaf, referring to the entire margins of the adult leaves. *M. tetraphylla* Johnson in *Proc. Linn. Soc. NSW* 79: 15 (1954): the name is derived from the Greek, *tetra* — four, and *phylon* — leaf, in allusion to the grouping of leaves in whorls of four.

Common names. Queensland nut, macadamia nut, Australian bush nut, rough-shelled bush nut (*M. tetraphylla*).

Family. Proteaceae

Botanical features. *M. integrifolia:* a very bushy tree to 20 m tall, with slightly rough brown bark. The shiny, mature leaves are oblong to obovate with a blunt apex, stiff textured with entire, wavy or slightly prickly margins, in whorls of 3, and 10–30 cm long by 2–4 cm wide. Juvenile foliage is usually serrated on the margins and usually pale green in colour. The white flowers are borne in spring in long, pendulous, cylindrical, axillary racemes up to 30 cm long. The perianth or tube is slightly hairy on the outside, up to 12 mm long. Globular fruits are green at first, maturing brown, up to 35 mm in diameter. They have a hard outer covering and also a hard inner shell which conceals the seed or kernel. Fruits ripen autumn and early winter (Stephenson and Winks 1992).

M. tetraphylla: a small to medium-sized tree, densely branched up to 18 m and with a diameter to 45 cm. The outer bark is greyish-brown, smooth or finely wrinkled, with numerous cream horizontal lenticels. Branchlets are brown to greyish-brown, young shoots are hairy. Leaves are in whorls of 4 (Harden 1991), simple, the margins always prickly-toothed with 35–40 teeth on each side, oblong or

oblong-lanceolate, 7–25 cm long, 2–5 cm wide, abruptly rounded to a short sharp point at the tip, rigid in texture (Floyd 1989). The inflorescences are axillary or on the branches, 10–25 cm long, the flowers creamy-pink to mauve, 10 mm long. The fruit is 20–35 mm diameter, greyish-green, turning brown. Seed 15–30 mm long, pointed at the apex and warty. Flowers August–October and fruits ripen in January (Harden 1991).

The species are described by Floyd (1989), Harden (1991) and Stephenson and Winks (1992), and illustrated by Holliday (1989b).

Natural occurrence. The species are restricted to eastern Australia. *M. integrifolia* occurs in southeast Queensland. *M. tetraphylla* extends from extreme northeastern New South Wales to overlap with *M. integrifolia* in southern Queensland. Intermediates are known to occur (Stanley and Ross 1986).

M. integrifolia:

- Latitude. Range: 25–28°S.
- Altitude. Main occurrence: 400–600 m.
  Range: 10 – 1000 m.

M. tetraphylla:

- Latitude. Range: 27– 29°S.
- Altitude. Main occurrence: 5–200 m.
  Range: near sea level to 500 m.

Climate. *M. integrifolia* and *M. tetraphylla* occur in warm sub-humid and humid zones, where the mean maximum temperature of the hottest month is 26–30°C and the mean minimum of the coolest month 8–12°C. The average annual number of frosts varies 1–4. Both species are able to withstand mild frosts, but only for short periods.

The 50 percentile rainfall is 1130–1670 mm, the 10 percentile 750–1065 mm and the lowest on record

324–797 mm. The average annual number of raindays is 119–128. Rainfall is distributed throughout the year, with a summer maximum.

Physiography and soils. *M. integrifolia* and *M. tetraphylla* are found on subcoastal low hills and plateaux, basaltic shelfs, rocky slopes, ravines, rocky off-shore islands and headlands and in warm, protected fertile valleys of coastal river systems. Soils are well drained, fertile red loams or alluvia derived largely from basic igneous rocks such as basalt (Floyd 1990).

Vegetation type. Much of the natural habitat has been cleared. Both species occur as scattered individuals in coastal tall closed-forest or closed-forest. They are found generally in drier situations of the rainforest (McDonald and Elsol 1984) and in fringing rainforest along creeks. Dominant species are *Argyrodendron trifoliolatum*, *Dysoxylum muelleri* and *Castanosperum australe*. In the drier notophyll vine forest dominant genera are *Ficus*, *Streblus*, *Dendrocnide* and *Cassine*. Other associates include *Cryptocarya glaucescens*, *Doryphora sassafras*, *Orites excelsa*.

Utilisation.

Human food: Raw kernels (macadamia nuts) are used either alone or in a wide range of confectionery and processed foods. Macadamia oil is also produced. Hawaii dominates the macadamia industry (70% of production: 20 400 t nuts in shell from 8100 ha in 1987), followed by Australia and Costa Rica (Stephenson and Winks 1992).

Fodder: Not known to have any value as fodder.

Fuelwood: Not used as fuel.

Wood: The wood is reddish, hard and tough, attractively marked, and has been used for small turnery jobs. The timber is not generally exploited (Floyd 1989; Wrigley and Fagg 1989).

Other uses: Macadamia trees are beautifully proportioned with handsome foliage, and make fine shade trees.

The decomposed husk is used in potting soils (Stephenson and Winks 1992), and the ground shell supplied to the plastics industry.

Silvicultural features. Hawaiian cultivars have dominated plantings but higher-yielding Australian selections are now available. Soils should be deep, well drained with high organic content and pH of 5.0–6.0 for optimum nut production. Trees are prone to breakage and wind-throw on exposed sites (Stephenson and Winks 1992; Trochoulias et al. 1990).

Establishment: Budding and grafting are the preferred techniques used (Trochoulias et al. 1990). The rootstocks are seedlings 9–12 months old (Stephenson and Winks 1992). They are produced by sowing freshly harvested, dehusked nuts of selected cultivars that have been soaked in tap water for 24 hours in seed boxes containing coarse river sand. Mature seed may be stored in airtight containers at 1–2°C for several months (Trochoulias 1991; Trochoulias et al. 1990). Grafted trees come into production after three years.

Conventional harvesting is from the ground and mechanical dehusking takes place within 24 hours of harvest, followed by drying to 10% moisture content (Trochoulias et al. 1990).

Yield: In Australia a light crop can be harvested at 4–5 years after planting and commercial yields 2–3 years later (Chalker et al. 1983). Present varieties will yield 35 kg of nuts in shell per tree at full maturity, which is a yield of 6 t/ha/year at 14 × 4 m spacing. *Macadamia* orchards are expected to give 20–40 years of productive life (Chalker et al. 1983).

Pests and diseases. There are 10 economically significant insect pests of macadamia in Australia. They attack flowers, fruit, foliage and girdle twigs (Stephenson and Winks 1992; Trochoulias et al. 1990). There are several fungal diseases including *Phytophthora cinnamomi*, husk spot, blossom blight and husk rot (Trochoulias et al. 1990).

Limitations. They have a narrow temperature range for optimum productivity (i.e. around 25°C) and are sensitive to frost and wind damage.

Related species. There are eight species of the genus in Australia, seven of which are endemic (Gross and Hyland 1993).

Melaleuca arcana

Main attributes. A shrub or small tree of the hot, humid tropics that tolerates infertile, often poorly drained sites and coastal exposure. Has potential for fuelwood, posts and rails, and sand stabilisation.

Botanical name. *Melaleuca arcana* S.T. Blake in *Contr. Qd Herb* 1: 54 (1968). The generic name is derived from the Greek *melas* — black, dark, and *leucon* — white, alluding to the white branches but black on the burnt trunk of the first named species, *M. leucadendra*. The specific name is from the Latin *arcanus* — shut up, hidden, and refers to the apparent rarity of the species, being found only four times in nearly two centuries.

Common names. Winti (Aboriginal).

Family. Myrtaceae.

Botanical features. A shrub, sometimes 1–3 m tall, or a small tree 8–12 m with erect branches and thick, pale, layered papery bark, underbark brown. The stiff twigs have 9–13 leaves, spirally arranged, which are obtuse, oval-shaped (obovate to elliptical), 1.8–5 cm long, 8–15 mm wide, commonly 5-nerved and with a short stalk. The inflorescence is terminal in a short spike 6–8 mm long. The fruits are densely crowded into globose heads 8–13 mm long, 8–10 mm wide. Each fruit is more or less cup-shaped, about 2.5 mm by 2.5 mm, with well-included valves. Flowers have been observed on planted specimens in March–May (Ryan and Bell 1989), and mature seed has been collected in August–September (Searle 1989).

The species is described and illustrated by Blake (1968).

Natural occurrence. This species has a very limited known natural occurrence on the northern coast of Cape York Peninsula in northern Queensland.

- Latitude. Range: 11–16°S.
- Altitude. Range: near sea level to 100 m.

Climate. Climatic data are sparse for the area of natural occurrence of *M. arcana*. It is found in the hot, humid climatic zone. The mean maximum temperature of the hottest month is about 31°C and the mean minimum of the coolest month is 19–22°C. There are probably 50–70 days over 32°C but it is unlikely that the temperature exceeds 38°C. The area of natural occurrence is frost-free.

The 50 percentile rainfall is 1700–1900 mm, the 10 percentile 1150–1250 mm, and the lowest on record 800–925 mm. There is a strongly developed summer monsoon and about four months in winter when the mean rainfall is less than 30 mm. The estimated number of raindays each year is 125–140.

Physiography and soils. The distribution is entirely within the Eastern Uplands physiographic division, with *M. arcana* occurring in a restricted range of topography. It is found in depressions behind frontal sand dunes, on low swampy plains and undulating slopes. The soils are sandy podzols and groundwater podzols, which are frequently waterlogged, and deep sands or sandy loams. The soils are acidic and infertile.

Vegetation type. *M. arcana* sometimes grows in dense, more or less pure stands. The structural form of the vegetation is commonly open-heath, open-scrub or low woodland. Associated species include *Acacia calyculata*, *Asteromyrtus brassii*, *Grevillea pteridifolia*, *Banksia dentata* and *M. saligna*. *M. arcana* and *Eucalyptus pellita* are sometimes found as emergents from open-scrub fringing open-heath (Pedley and Isbell 1970).

Utilisation.

Fodder: No data, but unlikely to be suitable.

Fuelwood: Has potential to produce small fuelwood on a coppice system.

Wood: Wood properties are unknown. Has been used for posts, poles, and rails in Australia.

Other uses: Like many other *Melaleuca* species it is a potential source of honey. It may have a role to play in the stabilisation of coastal sands, especially in wetter areas. Yield and composition of the essential oil of *M. arcana* is such that no commercial potential for its distillation is suggested (Brophy et al. 1989).

Silvicultural features. This shrub or small tree has a moderate growth rate and the ability to coppice after fire or felling (Ryan and Bell 1989).

Establishment: The species is normally propagated by seed, although reported to be easy to strike from cuttings (Wrigley and Fagg 1993). Flower buds have been recorded on planted specimens as early as 2 years (Ryan and Bell 1989). There are 3 900 000 viable seeds/kg.

Yield: The species survived well (85%) and grew at reasonable rates to reach an average of 4.6 m in height and 13.3 cm in basal diameter at 4.5 years in trials in southeastern Queensland (Ryan and Bell 1991). Faster growth rates might be achieved on sites better suited to the species.

Pests and diseases. None recorded.

Limitations. *M. arcana* is likely to be frost-tender, and under certain circumstances has the potential to become a weed.

Related species. *M. arcana* is a member of a group that includes among others *M. quinquenervia*, *M. leucadendra*, *M. saligna* and *M. viridiflora*. Its closest relative is *M. saligna*, which has leaves that are acute and narrower, and terminal and axillary inflorescences (Byrnes 1984).

Melaleuca argentea

Main attributes. A medium to large spreading tree. It appears to be moderately fast-growing and is tolerant of periodic inundation. Suitable for planting in hot humid to semi-arid areas in the tropics where it has access to supplementary groundwater. The species has potential for post, poles, fuelwood, and honey production. It makes a graceful ornamental and shelterbelt tree.

Botanical name. *Melaleuca argentea* W.V. Fitzg. was published in the Western Mail (Perth) on 16 June 1906 and also the *J. Roy Soc. W. Aust*. 3: 187 (1918). The species name is derived from the Latin *argenteus* — silvery, in allusion to the silvery appearance of the leaves and canopy.

Common names. Silver-leaved paperbark, silver cajeput.

Family. Myrtaceae.

Botanical features. *M. argentea* is usually a tall spreading tree 10–20 m in height with slender, pendulous branchlets and silvery-green foliage. It occurs rarely as a shrub. The bark is papery, creamy white to grey, soft, layered. Branchlets are silvery, with long straight appressed hairs. The leathery leaves are alternate, silvery, grey-green and covered in silky hairs when young, becoming smooth at maturity, narrow-elliptic, widest at middle, tapering evenly to both ends, 5–14 cm × 0.6–2 cm, mostly 7–13 times as long as wide, with 3–5 main longitudinal veins. The tip is pointed. The hairy stalk is convex beneath, flat or slightly convex above, 4–10 mm long. The short hairs on the stalk are persistent. Inflorescences occur in up to 4 terminal spikes or singly in the upper leaf axils. The flowers are cream to greeny-cream, that often wither or dry reddish, strongly scented, stalkless, 1.2–1.5 cm long, on cylindrical spikes, 5–12 cm × 2.5–3 cm. The fruits are small, stalkless, cup-shaped woody capsules, 2–4 mm by 2–4 mm, the valves enclosed, clustered along the stem, grey-brown when mature, with numerous small seeds.

Flowering time is mainly June to October (Brock 1988; Wheeler et al. 1992). Fruits mature mainly July–August (Wheeler et al. 1992) or October–January (Brock 1988).

The species is described by Blake (1968) and Byrnes (1986) and illustrated by Brock (1988) and Holliday (1989a).

Natural occurrence. It is distributed in a more or less continuous band across northern Australia in northern Queensland, the Northern Territory and Western Australia.

- Latitude. Main occurrence: 11–20°S.
  Range: 8–25°S.
- Altitude. Range: 5–200 m.

Climate. The climate is mainly hot sub-humid with extension to the hot humid and hot semi-arid climatic zones. The mean maximum temperature of the hottest month is 33–36°C, but inland localities are higher, 38–39°C. The mean minimum of the coolest month is 19–24°C. Most of the area is frost-free, except for inland sites where about 10 frosts occur annually.

The 50 percentile rainfall in the sub-humid and semi-arid regions is 300–1150 mm, the 10 percentile 200–650 mm and the driest on record about 125 mm. The mean annual rainfall can exceed 1500 mm in humid areas. The northern part of Australia has a marked summer monsoonal incidence of rainfall, while in the southern part of the distribution it is more uniform, although still with a well-defined summer maximum inland. The average number of raindays per year is 30–75.

Physiography and soils. The distribution of *M. argentea* is in three physiographic divisions, namely, Western Plateau, the extreme north of the Interior Lowlands and the northern region of the Eastern Uplands in Queensland. Most stands occur on flat or very gentle topography, especially river flats. Trees often occur in river flood channels, and as a consequence tree form is usually poor due to flood damage. The species is found commonly along banks of freshwater creeks and rivers in gravelly, deep sandy or sandy-loam soils that have a clay substrate. While the species tolerates seasonally waterlogged conditions it does not appear to favour low-lying swampy areas where *M. leucadendra* is the main species.

Vegetation type. This species sometimes occurs as a belt of trees behind *M. leucadendra* around swamps and along rivers. Other associates in these riparian habitats include *Acacia auriculiformis*, *Buchanania obovata*, *Eucalyptus camaldulensis*, *E. papuana*, *Ficus racemosa*, *Lophostemon floribunda*, *Lysiphyllum cunninghamii*, *Pandanus* sp., *Syzygium eucalyptoides* and *Terminalia* spp.

Utilisation.

Fodder: No data, but unlikely to be suitable.

Fuelwood: There is no information on the burning qualities of the wood, but some melaleuca species give satisfactory fuels.

Wood: The wood is heavy with an air-dry density of 1010 kg/m^3 (Cause et al. 1974). Bark has been used by Australian Aboriginal people for many purposes: to make shelters, bedding, covers, for carrying items and for wrapping or storing foodstuffs (Brock 1988).

Other uses: It has been used in northern Australia as a graceful ornamental and shelterbelt tree, and is a suitable species to replace weeping willows in frost-free conditions (Wrigley and Fagg 1988). It is a potential source of honey. Australian Aboriginal people used a decoction with leaves as a bath to treat headaches, colds and influenza. The leaves were also used as a flavour in cooking. However, the essential oils responsible for the flavour and therapeutic action are present in relatively low concentrations and are of no economic significance (Aboriginal Communities of the Northern Territory 1993).

Silvicultural features. The species has only very recently been planted in formal trials, so little is known about its silvicultural features.

Establishment: Propagation is by seed. There are approximately 778 300 viable seeds/kg.

Yield: Three provenanances of *M. argentea* from north-western Western Australia and Northern Territory (Doran and Gunn 1994) were amongst the fastest-growing seedlots, averaging 1.8 m in height after 12 months, in a trial of melaleuca species on high mounds in the Mekong Delta of Vietnam (H. Chuong, pers. comm.).

Pests and diseases. None are recorded.

Limitations. Like many melaleucas it has the potential to become a weed. It may be sensitive to frost. Little is known about the genetic variability of this species.

Related species. The species is a member of the *M. leucadendra* complex and is most similar to *M. nervosa*. Barlow (1988) originally proposed a division of *M. argentea* into three separate taxa based on broad geographic areas within the overall range of the species. The most recent proposal is that *M. argentea* be segregated into two separate taxa (L.A. Craven, pers. comm.), the first being *M. argentea* found in Western Australia, Northern Territory and the western region of Queensland. The second is restricted to the eastern side of the Queensland distribution, and provisionally named as *M.* 'fluviatilis' by Barlow (1988).

Melaleuca bracteata

Main attributes. An excellent ornamental and shelter tree or shrub for planting on heavy clay soils in subhumid and semi-arid climates. It is moderately tolerant of frost, salinity and high pH. Produces a useful essential oil.

Botanical name. *Melaleuca bracteata* F. Muell. (Syn. *M. glaucocalyx* Gandoger, *M. genistifolia* Sm. var. *coriacea* Ewart, Kerr and Derrick, *M. monticola* Black, and *M. daleana* Blakely) in *Fragm*. 1: 15 (1858). The specific name is derived from the Latin *bractea* — bract, and refers to the conspicuous floral bracts.

Common names. River tea-tree (standard trade name), black tea-tree, white cloud tree, prickly-leaved tea-tree, and bracteate honey-myrtle.

Family. Myrtaceae.

Botanical features. Typically a large shrub or small bushy tree 5–10 m tall. In particularly favourable situations in eastern Queensland it may reach about 20 m in height (Williams 1979) but in the harsh environment of the arid zone it may be only 2–3 m high and of very bushy habit. The bark is dark grey, hard and deeply furrowed. Branchlets and leaves are often hairy. The leaves are sessile, lanceolate, pointed, 3–12 mm long, thick, concave and with 5–11 obscure nerves. Inland specimens differ from some of those of the coast in having conspicuous felty hairs on the branchlets, thicker, shorter and relatively broader leaves with faint venation. The inflorescence consists of terminal spikes of white flowers, 5–15 mm long, with the axis growing out into a leafy shoot. Flowering time is spring to early summer. The fruit is a capsule, cup-shaped, 2–3 mm long. Mature seed has been collected January–March and in September in northern Queensland (Searle 1989), and fruits are present in May–July in northwestern Western Australia (Wheeler et al. 1992).

It is fully described botanically by Blake (1968) and illustrated by Carrick and Chorney (1979), Holliday (1989a) and Williams (1979).

Natural occurrence. It is one of the most widely distributed species of the genus in Australia. The main distribution is in eastern Australia, from the central slopes of northeastern New South Wales to Cape York, Queensland. There are disjunct occurrences in western Queensland, central Australia, and the Pilbara and Kimberley areas of Western Australia.

- Latitude. Main occurrence: 17–29°S.
  Range: 16–30°S.
- Altitude. Main occurrence: 50–550 m.
  Range: near sea level to 900 m.

Climate. Many occurrences are in the warm subhumid climatic zone, especially in the southern areas of the range in eastern Australia, and it may be found in the warm humid zone in coastal areas. The northern and central distribution includes hot semi-arid and warm arid climates.

The mean maximum temperature of the hottest month is mainly 30–34°C (range 29–41°C) and the mean minimum of the coolest month 5–10°C (range 3–12°C). The average number of days over 32°C is mainly 50–130 (but up to 280), and over 38°C mainly 4–30 (but up to 150). Light frosts are experienced in many parts of the distribution and heavy frosts occur on 1–12 days each year.

The 50 percentile rainfall is mainly 400–900 mm (range 250–1150 mm), the 10 percentile 200–700 mm (range 130–900 mm), and the lowest on record 100–350 mm (range 30–450 mm). The seasonal incidence varies from a moderate summer maximum in the south to a strong summer maximum in the north. In the arid zones the distribution of rainfall may be extremely variable from year to year.

Physiography and soils. Occurs mainly in the Eastern Uplands and Western Plateau physiographic divisions. The overall topography varies from rugged to undulating and moderately hilly. In some areas it extends to the plains. *M. bracteata* is frequently found growing around waterholes and along watercourses, and may be confined to them in arid areas. Grows on soils derived from basalt, granite, granodiorite, quartz, sandstone and serpentine. In general the soils are rather heavy-textured deep clays, krasnozems, and fine alluviums and have a wide range of fertility. It tolerates sites with high pH and salinity.

Vegetation type. *M. bracteata* may occur in the lower storey of eucalypt open-forest or woodland. It is often dominant or prominent in groves, thickets or narrow belts amongst other vegetation types. In eastern Australia it is found along watercourses with *Casuarina cunninghamiana* (Beadle 1981) and in drier areas with *Eucalyptus camaldulensis*. Other associates include *Acacia excelsa*, *A. pendula*, *Senna* spp., *E. crebra*, *E. orgadophila*, *Ficus platypoda* and *Lophostemon suaveolens*.

Utilisation.

Fodder: Not a fodder species.

Fuelwood: Its burning properties have not been reported.

Wood: There is limited information. It is close-grained, hard and durable with an air-dry density of 1010 kg/m^3 (Cause et al. 1974), and could be useful for posts and poles.

Other uses: It is an excellent ornamental and there are registered cultivars with a dwarf habit suitable for low screens and growing in containers (Wrigley and Fagg 1988; Swane 1993). It makes a good shelter tree and has potential for erosion control on stream banks and in gullies.

It produces large amounts of pollen but is of minor importance for honey, which has poor flavour and light density (Blake and Roff 1958).

The leaf oil of *M. bracteata* has been shown to exist in four chemical forms: (i) methyl eugenol, (ii) trans-methyl isoeugenol, (iii) elemicin and (iv) trans-isoelemicin (Brophy 1995). *M. bracteata* has been suggested as a source of these compounds, but low oil yield mitigated against its commercial use (Penfold et al. 1950). High-yielding forms (1.3–2.4% w/w % DW) have now been located (Brophy et al. 1989) and may be of commercial importance. The existence of several chemical forms in this tree, however, means that great caution must be exercised in the selection of germplasm for oil production.

Silvicultural features. *M. bracteata* is a relatively fast-growing, hardy shrub or small tree that tends to retain live branches to near ground level. It coppices readily and suckers from the roots. It has been cultivated in Indonesia and California (Blake 1968).

Establishment: Propagation is by seed or cuttings. Flower buds have been observed as early as 7 months in this species (Ryan and Bell 1989). There are 10 500 000 viable seeds/kg.

Yield: Survival was excellent (average 96%) but growth was slow with the best provenance averaging 2.2 m in 4.5 years in trials in southeastern Queensland. On coarse-textured, acidic soils in central Queensland survival was excellent (average 97%) under irrigated or non-irrigated conditions, but the best growth was attained under irrigation where trees reached 1.1 m in 18 months. The species also survived well (86%) under irrigation on the alkaline cracking clay soils, reaching 0.8 m in height in 18 months, but it failed in the non-irrigated plots (Ryan and Bell 1991). The fastest growing seedlots in trials on various sites in Thailand reached 1.36 m in height in 12 months and 2.2 m in 24 months (Pinyopusarerk 1989). There is evidence from these trials of provenance variation in growth rate and survival.

Pests and diseases. None recorded.

Limitations. The free-seeding and suckering habit of this species combined with its tolerance of a wide range of soil conditions make it a potential weed species. Provenance testing will be essential to determine the optimal seed sources.

Related species. Similar to *M. decora* and *M. styphelioides*, but readily distinguished from these papery-barked species by its hard bark (Byrnes 1986).

Melaleuca cajuputi

Main attributes. A moderately fast-growing tree particularly adapted to grow on waterlogged soils in the lowland tropics. It is the primary source of the medicinal Cajuput oil, but also useful for fuel, posts and poles, shade, shelter and ornamental purposes.

Botanical name. *Melaleuca cajuputi* Powell in *Pharm. Lond. Transl*. 22 (1809). The specific name is from the Malayan Caju puti — white tree, referring to the pale bark of the tree. Numerous synonyms have been applied. It is often treated in the older literature as *M. leucadendron*.

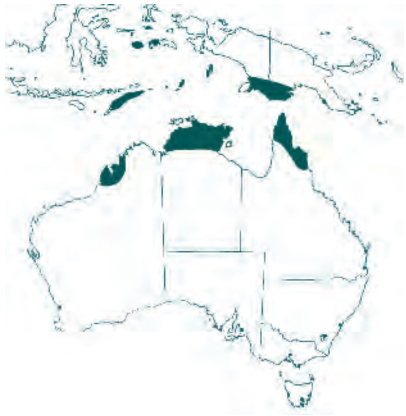
Common names. Swamp tea-tree, paperbark tea-tree and cajuput tree. The former names are often applied to other species of *Melaleuca*, and cajuput tree is sometimes used as the vernacular name for *M. leucadendra*. In Indonesia it is known as kaya putih.

Family. Myrtaceae.

Botanical features. In Australia *M. cajuputi* is usually a medium-sized tree up to about 25 m tall with a single stem. In some situations it may be reduced to a shrub, but in the Northern Territory it can be over 40 m tall and 1.2 m diameter (Stocker 1972). The bark is layered and papery. The crown has a somewhat silvery appearance, the smaller branches and twigs slender but not drooping. The leaves are straight or curved, often hairy, mainly 5–10 cm long and 1–4 cm wide, and 3–5 nerved. Young shoots are covered in dense silky hairs. The inflorescence consists of 1–3 spikes up to 9 cm long, with white, greenish-white or cream-coloured flowers. Fruits are capsules about 3 mm long and 4 mm wide, with thinner valves than most *Melaleuca* species. It flowers between March and June and from August to December. Mature seeds have been collected in Australia in October–November (Searle 1989; Brock 1988).

It is described and illustrated by Blake (1968).

Natural occurrence. *M. cajuputi* occurs in northern Queensland, the Northern Territory and northern Western Australia. The Australian occurrence is only the southern part of an extensive distribution in Southeast Asia including Indonesia, Malaysia, Thailand, Vietnam and Papua New Guinea. It has been cultivated from early times and is possibly not indigenous in parts of its present range (Blake 1968).



The distribution map provided in this treatment shows only the eastern part of the occurrence of *M. cajuputi*.

- Latitude. Range: 12°N–18°S (10°–18°S Australia).
- Altitude. Main occurrence (Australia): near sea level to 50 m.
  Range (Australia): near sea level to 200 m.

Climate. Most of the occurrences of *M. cajuputi* in Australia are in the hot humid climatic zone, but it does extend into the hot sub-humid zone. The mean maximum temperature of the hottest month is usually within the range 31–33°C and the mean minimum of the coolest month 17–22°C. In coastal areas there are up to 230 days over 32°C, but very few days exceed 38°C. Inland there are up to 280 days over 32°C and up to 70 days over 38°C. The area is frost-free.

The 50 percentile rainfall is about 1300–1750 mm, the 10 percentile 850–1250 mm, and the lowest on record 600–900 mm. There is a strong summer monsoon with the majority of rainfall in January–March. The average number of raindays per year is 90–125.

Physiography and soils. It occurs in all three Australian physiographic divisions. Most stands are found along drainage lines or on low, swampy coastal plains. In the Northern Territory it can form extensive stands on the heavy-textured black soils that are subject to flooding for six or more months each year (Stocker 1972). In Malaysia and Indonesia it occurs in and bordering freshwater and brackish swamps, and on Ceram and Buru Islands (Indonesia) it occurs extensively in hilly terrain on dry, rocky and infertile soils. In southern Irian Jaya and Papua New Guinea it is found commonly in areas of seasonal flooding, but attains its best development on slightly elevated terrain with better drainage.

Vegetation type. In wet swamps *M. cajuputi* forms pure forest or mixed open-forest or woodland associated with *M. leucadendra*, *Barringtonia acutangula*, *Lophostemon* sp., and *Nauclea* sp. On less swampy sites it grows with other melaleucas including *M. dealbata*, *M. saligna*, and *M. viridiflora*, and other species such as *Asteromyrtus symphyocarpa*, *Banksia dentata*, *Eucalyptus intermedia*, *E. nesophila*, *E. tessellaris*, *E. tetrodonta*, *Petalostigma* sp. and *Terminalia* spp.

Utilisation.

Fodder: Not suitable for fodder.

Fuelwood: Makes a good fuelwood and has been used for this purpose in Indonesia, Malaysia and Vietnam. May be difficult to split.

Wood: The wood properties are similar to those of *M. leucadendra*. The wood is pale brown, fairly heavy, fine-textured, hard, tough, difficult to season but relatively easy to work (Stocker 1972). It is durable in contact with fresh or salt water (Blake 1968). Generally used in the round or roughly fashioned. The soft bark is a promising source of fibreboard, paper, and packing material (Keating and Bolza 1982).

Other uses: A major use of *M. cajuputi* is as a source of Cajuput oil, produced by steam distillation of the leaves and terminal branchlets. Active constituents of the oil are 1,8-cineole and alpha-terpineol. It has medicinal properties, makes a good antiseptic and can be used in insect repellents (Lassak and McCarthy 1983). Indonesia is the major producer of Cajuput oil, where about 300 t oil are obtained annually from natural stands and 9000 ha of plantation on Java. Several non-commercial chemical forms have been reported from various parts of the natural occurrence (Brophy 1995). Caution should be exercised in selecting planting stock for oil production.

M. cajuputi makes an attractive ornamental tree, can be used for shade and shelter, and is a source of honey.

Silvicultural features. A medium-sized tree that has been widely planted in Malaysia and parts of Indonesia (Blake 1968) and southern Vietnam.

M. cajuputi is resistant to fire and tolerates exposure to wind. It has the ability to compete with weeds and will regenerate in *Imperata* grassland. It has an extensive root system, and on soils subject to prolonged waterlogging it develops aerial adventitious roots, which can form buttresses on the lower trunk. It will coppice, and has the ability to reproduce from suckers.

Establishment: Propagation is usually by seed. Trees set

their first flower buds as early as 13–14 months (Ryan and Bell 1989). There is an average of 2 692 000 viable seeds/kg. Plantations have been established with small stump plants, and it can be reproduced vegetatively from stem and branch cuttings (von Wulfing et al. 1943). For oil production the shoots are cut back to ground level or to a height of one metre. The cutting cycle is 6–10 months.

Yield: M. cajuputi grew well in trials in southeastern Queensland, reaching 5.4 m in height in 4.5 years (Ryan and Bell 1991). It was trialed on various sites in Thailand, where the best growth was 2.7 m in height in 12 months (Pinyopusarerk 1989). In the Mekong Delta of southern Vietnam the best of the local provenances reached 1.3 m (no mounds) and 1.9 m (low mounds) in 24 months and 1.8 m (high mounds) in 12 months, but in each instance they were slower-growing than several introduced melaleucas, and especially *M. leucadendra* (H. Chuong, pers. comm.).

Pests and diseases. None recorded.

Limitations. The wide adaptability and regenerative capacity of this species make it a potential weed in some environments.

Related species. Closely related to *M. leucadendra* and *M. quinquenervia*. There are plans to recognise three subspecies within *M. cajuputi*: subsp. 'cajuputi' from northwestern Australia and eastern Indonesia, subsp. 'cumingiana' from Vietnam to western Indonesia, and subsp. 'platyphylla' from northern Queensland, southwestern Papua New Guinea and southeastern Irian Jaya (Barlow 1988).

Melaleuca dealbata

Main attributes. *Melaleuca dealbata* is a relatively slow-growing member of the genus. It is adapted to humid or sub-humid tropical and subtropical climates. It tolerates periods of inundation with brackish water and wind-borne salt spray and is a candidate for soil reclamation, shelterbelts and amenity plantings close to the coast.

Botanical name. *Melaleuca dealbata* S.T. Blake in *Contributions from the Queensland Herbarium* 1: 41. (1968). The name is from the Latin *dealbatus* — whitened or whitewashed, and presumably refers to the pale greyish appearance of the stems and foliage due to the presence of hairs.

Common names. Soapy tea tree, cloudy tea tree.

Family. Myrtaceae.

Botanical features. *Melaleuca dealbata* is a moderate-sized spreading tree 5–25 m with blue-grey foliage and densely hairy, pendulous branchlets. The juvenile foliage and stems have a short, dense felt of spreading or somewhat crooked hairs. The bark is papery, whitish, cream, grey or pale brown, layered. Adult leaves are alternate, densely hairy, becoming smooth with age, broadly elliptic and leathery. The blade is 5.5–13 cm × 1.5–2.7 cm with 5–7 primary longitudinal veins, dull blue-grey, hairy petiole 6–10 mm long. Flowers creamy-white, scented, 5–10 mm long, on cylindrical spikes 7–12 cm × 2 cm. The spikes are in terminal groups of 1–6, or solitary in the upper leaf axils. Flowering occurs during an extended period, July to December (Blake 1968; Brock 1988; Ryan and Bell 1989; Wheeler et al. 1992). Fruit small, sessile, hairy capsules, cup-shaped, 3–4 mm × 3–5 mm, grey when mature, numerous seeds. There appears to be variation in the time of fruit maturation. Brock (1988) indicates October–December, while Wheeler et al. (1992) give May–June and November–December.

It is described by Blake (1968) and Byrnes (1986) and is illustrated by Brock (1988).

Natural occurrence. It occurs mainly in lowland coastal areas in southern Papua New Guinea and Irian Jaya, Indonesia. In Australia its distribution is from Cape York Peninsula to as far south as Maryborough in Queensland, in the north of the Northern Territory, and in the far north of Western Australia.

- Latitude. Range: 7–26°S.
- Altitude. Range: 5–550 m.

Climate. The major part of the distribution lies in the hot to warm humid and sub-humid climatic zones. The mean temperature of the hottest month is 26–35°C. The average of the coolest month is 15–23°C. The area is frost-free.

The 50 percentile rainfall is 1135–1750 mm, the 10 percentile 690–1240 mm and the lowest on record 324 mm (southern) and 697 mm (northern). The highest mean annual rainfall is 3500 mm. The northern part of the distribution has a strong summer monsoon, with most rain falling during January–March, and in the south a moderate summer maximum. There are 84–151 raindays per year, on average.

Booth and Jovanovic (1988b) suggest the range of suitable climatic conditions for *M. dealbata* cultivation is as follows: mean annual temperature 21–28°C, minimum temperature of coldest month 10–21°C, maximum temperature of hottest month 28–37°C, mean annual precipitation 693–2250 mm.

Physiography and soils. It occurs in all three physiographic divisions in Australia, chiefly on wet sites along the banks of streams, on seasonally swampy ground and on the edges of coastal lagoons that may be brackish. It frequently occurs close to the sea. In Papua New Guinea it extends to the Sogeri Plateau.

It is found on sand or sandy soils on the leeward side of coastal dunes. Other soils include silty sandy loams and clays and yellowish friable loams at the base of granitic hills.

Vegetation type. *M. dealbata* is commonly found in coastal medium and low-layered woodland of the coastal flood plains, beach ridges and swales in the humid tropical region of north Queensland. It has a more restricted occurrence in tall open-forest of *M. leucadendra* and *M. dealbata* on the wet swales behind the fore dunes (Tracey 1982). *M. dealbata* is also found in wet and very wet zones on colluvial and alluvial soils of lower coastal slopes and lowlands. On the Sogeri Plateau in Papua New Guinea *M. dealbata* occurs in eucalypt–casuarina woodland. Associates in the coastal flats and flood plains include *Brachychiton* sp., *Eucalyptus papuana*, *E. polycarpa*, *E. terminalis*, *E. tectifica*, *Ficus virens*, *Grevillea mimosoides*, *Livistona floribunda*, *Lysiphyllum cunninghamii*, *Mallotus philippensis*, *Melaleuca cajuputi*, *M. leucadendra* and *Pandanus* sp.

Utilisation.

Fodder: No data are available, but it is unlikely to be suitable.

Fuelwood: Has potential to produce a useful fuel.

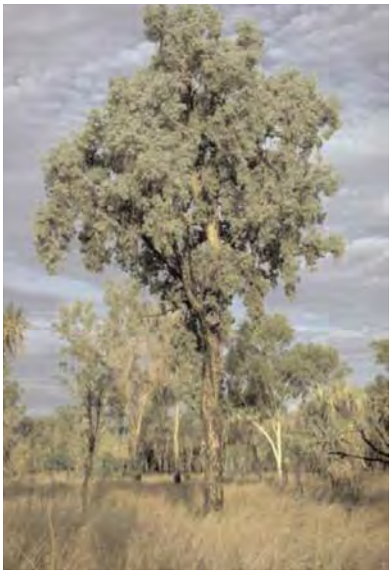
Wood: It has been described as a very strong wood that never rots (Brock 1988), and has an air-dry density of 750 kg/m^3 (Gerard 1991). Its main potential use is for posts and small poles.

Other uses: A very decorative tree useful for amenity plantings, shelterbelts and soil stabilisation work, especially in coastal areas (Hearne 1975; Brock 1988). Has been used for the restoration of bauxite mining sites in northern Australia (Langkamp 1987), and is an excellent source of nectar in honey production.

Silvicultural features. *M. dealbata* tolerates salt spray and poorly drained soils. Open-grown plants branch from near the ground and a multi-trunked tree usually develops. Competition forces them upwards (Hearne 1975). Coppicing ability was reported to be fair (Ryan and Bell 1989).

Establishment: Propagation is from seed. First flower buds were observed forming at 42 months (Ryan and Bell 1989). There is an average 4 446 300 viable seeds/kg.

Yield: In southeastern Queensland one provenance showed excellent survival but only modest growth rate,



with the best plot averaging 3.6 m in 4.5 years (Ryan and Bell 1989, 1991). There was a similar result on a range of sites in Thailand where, on all but the harshest sites, the species survived well (av. 76%) but grew relatively slowly, reaching only 2.6 m in 2 years (Pinyopusarerk 1989). It is amongst the slowest-growing of the *Melaleuca* species under trial in the Mekong Delta of Vietnam, and has survived poorly on sites subject to extended inundation (H. Chuong, pers. comm.).

Pests and diseases. None are recorded.

Limitations. Growth rates appear to be modest although this observation is based on limited data from a limited range of provenances. Like many melaleucas, it has the potential to become a weed.

Related species. *M. dealbata* resembles *M. nervosa* very closely, but has longer twigs, larger leaves and persistent hairiness, longer and narrower flower spikes and shorter and more numerous stamens (Blake 1968). It is a member of the *M. leucadendra* complex.

Further research is needed to clarify the status of subspecies in *M. dealbata* as proposed by Barlow (1988) (L. Craven, pers. comm.).

Melaleuca leucadendra

Main attributes. A fast-growing tree that will tolerate waterlogged soils including those with acid sulfate and salinity problems in the lowland tropics. Useful for posts, poles, fuelwood, shade, shelter and honey production. The essential oils of some provenances may have commercial potential.

Botanical name. *Melaleuca leucadendra* (L.) L. in *Mantissa Plantarum* 1: 105 (1767). This species is the type for the genus *Melaleuca*. The species name is derived from the Greek *leucon* — white, and *dendron* — tree, in allusion to the white bark. The name *M. leucadendra* (or *M. leucadendron*) has been used in a very broad sense, but correctly refers to one of a complex of 10 species (Blake 1968).

Common names. Long-leaved paperbark, broad-leaved paperbark, paperbark, broad-leaved tea-tree, river tea-tree, weeping tea-tree, kaya putih (Indonesia).

Family. Myrtaceae.

Botanical features. On favourable sites *M. leucadendra* is a tall tree, 25–40 m, with a straight stem of up to 1.5 m diameter. Elsewhere it may be a small to medium-sized tree with crooked or twisted bole. The bark is white-layered and papery. The long, slender branchlets may droop, giving the crown a weeping appearance. There is usually a complete absence of hairs except on the very youngest shoots. The leaves are light green, 5-nerved, thin, narrowly lanceolate, mainly 10–19 cm long, 1–2 cm wide, on a petiole 6–12 mm long. The leaves are widest below the middle. The inflorescence consists of 1–3 spikes, 6–15 cm long and 2–3 cm wide, bearing white or creamy-white flowers with stamens 5–7 per bundle and 10–13 mm long. Fruits are sessile, thin-walled cylindrical capsules about 3–4 mm by 3–4 mm. Flowering occurs throughout the year but chiefly during winter, May–September. Mature capsules have been collected in April– November (Searle 1989).

The species is fully described by Blake (1968) and Byrnes (1986), and illustrated by Boland et al. (1984), Brock (1988) and Holliday (1989a).

Natural occurrence. It occurs mainly in coastal or subcoastal areas of tropical Queensland, the Northern Territory and Western Australia, but extends inland for up to 350 km along major rivers. It is also found in Papua New Guinea, and Irian Jaya and Maluku provinces, Indonesia.

- Latitude. Range: 3–23°S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 500 m.

Climate. The distribution is in the warm sub-humid climatic zone in coastal Queensland and the hot humid zone in the north, but where there is adequate groundwater it may extend into the warm and hot semi-arid zones. The mean temperature of the hottest month is 31–38°C, and the mean minimum of the coolest month 9–19°C. There are 30–275 days over 32°C and 1–30 days over 38°C. Heavy frosts are absent from most of the area, but some inland locations may have 1–2 per year.

The 50 percentile rainfall is 650–1500 mm, the 10 percentile 400–1100 mm, and the lowest on record 175–900 mm. In the north there is a strong summer monsoon with a majority of the rainfall concentrated in three months, and elsewhere there is a pronounced summer maximum. Rain is recorded on 40–145 days per year.

Marcar et al. (1995) summarise the climatic requirements of the species under natural and cultivated conditions.

Physiography and soils. Most stands occur on flat or very gentle topography, especially river flats, coastal plains or seasonal swamps. Coastal occurrences are chiefly along the lower reaches of rivers or in swampy areas with seasonally fluctuating water levels. The soils are silty to loamy clays or sandy loams over clay. It is found on old sand dunes and sometimes extends to rocky foreshores where the groundwater may be somewhat saline (Boland et al. 1984).

Vegetation type. The largest trees are found in tall open-forest adjacent to rainforest or along river banks. *M. leucadendra* is often the dominant species and commonly occurs in almost pure stands. On the coastal flood plains it is found along the larger watercourses, sometimes associated with *Acacia auriculiformis*, *Eucalyptus alba*, *E. camaldulensis*, *E. tereticornis*, *Lophostemon suaveolens*, *Nauclea orientalis*, *Terminalia* spp., *M. dealbata*, *M. quinquenervia* and *Dillenia alata*. In Papua New Guinea it is found in tall woodland and tall open-forest with *M. cajuputi*, *L. suaveolens* and *D. alata*.

Utilisation.

Fodder: Not a fodder species.

Fuelwood: Makes good firewood although it is often difficult to split (Keating and Bolza 1982). Gough et al. (1989) report that the light wood is quick to ignite, with sooty acrid smoke initially from the burning bark.

Wood: The yellowish sapwood merges into a pinkish-grey heartwood, which is hard, medium to fine-textured, of moderate strength, difficult to season but durable in the ground and in water. The wood has a high silica content and interlocked grain. Air-dry density is 725–800 k/m^3 (Keating and Bolza 1982).

The wood is suitable for a wide range of purposes. It is generally used in the round or roughly fashioned, and is suitable for sleepers, house and fence posts, mine timbers, boat building, joinery, poles, piles and pulpwood (Fenton et al. 1977).

Other uses: Flowers regularly and is a source of light amber honey with a strong flavour and light density (Roff 1966). *M. leucadendra* has been used for shelterbelts, in coastal plantings, and as a street or avenue tree. It is also a good shade tree (Cornford 1991).

Three chemical forms occur in the leaf oils, depending on area of occurrence; (i) mostly methyl eugenol, (ii) mostly isomethyl eugenol, and (iii) mostly terpenoid. The eugenol forms from mid-Northern Territory eastwards to the Queensland coast may have commercial potential in the flavour and fragrance industry (Brophy et al. 1989; Brophy 1995).

Silvicultural features. *M. leucadendra* is relatively fast-growing and has the ability to tolerate acidic, infertile swampy conditions. In waterlogged and flooded areas it forms aerial adventitious roots. It has reasonable coppicing ability, but is variable in performance (Ryan and Bell 1989). It is fire-tolerant and moderately to highly salt-tolerant; expect reduced growth at EC_e about 10–15 dS/m and reduced survival above 15 dS/m (Marcar et al. 1995).

Establishment: Propagation is from seed or cuttings. There are about 1 825 600 viable seeds/kg. Low temperature (1–4°C) storage of the seed is recommended. The seed germinates readily in wet conditions and the seedlings grow rapidly. They are usually raised in containers.

Yield: Trial plantings reached 7.9 m at 5 years on the coastal plains in the Northern Territory of Australia (Fenton et al. 1977), and 5.0 m at 4.5 years in south-eastern Queensland (Ryan and Bell 1991). On poorly drained, acid grassland in Papua New Guinea trees averaged 10.2 m tall and 9.5 cm diameter 5 years after planting (Lamb 1975). In Thailand and Zimbabwe a growth rate of 1–3 m per year was achieved (Pinyopusarerk 1989; Gwaze 1989). *M. leucadendra* is showing early promise in species/provenance trials on the seasonally inundated acid sulfate soils of the Mekong Delta of Vietnam. Planted on low mounds it was 2.6 m tall in 24 months compared with 1.9 m for the best of the local provenances of *M. cajuputi*. When planted without mounding it reached 1.8 m in 24 months compared to 1.3 m for *M. cajuputi* (H. Chuong, pers. comm.). Significant provenance variation in growth is indicated in most trials.

Pests and diseases. Damage by grasshoppers and leaf rolling caterpillars occurs and can be severe during the dry season in northern Australia.

Limitations. Like many melaleucas, it has the potential to become a weed.

Related species. Nine species closely allied to *M. leucadendra* are described by Blake (1968). The leaves of *M. leucadendra* are thinner and paler green than the other species.

Melaleuca quinquenervia

Main attributes. A moderately fast-growing, fire-tolerant tree capable of growing on nutrient-deficient sites with continuous or periodic flooding in the humid and sub-humid tropics. It is moderately salt-tolerant. This species is most likely to be grown on relatively short coppice rotations that maximise the production of small-sized logs. Makes excellent fuelwood, provides useful timber and is a good source of honey and medicinal oil.

Botanical name. *Melaleuca quinquenervia* (Cav.) S.T. Blake in *Proceedings of the Royal Society of Queensland* 69: 76 (1958). The specific name is from the Latin *quinque* — five, and *nervis* — nerved, and refers to the common number of longitudinal veins in the leaves.

Common names. Five-veined paperbark, broad-leaved paperbark, paperbark tea-tree, broad-leaved tea-tree, numbah, belbowrie (Australia), niaouli (New Caledonia), kaya putih (Indonesia).

Family. Myrtaceae.

Botanical features. A small to medium-sized tree, commonly 8–12 m tall but ranging 4–25 m depending on local growing conditions. The stem is moderately straight to crooked, the crown is narrow and open, or fairly dense. The thick, pale-coloured bark is made up of many papery layers that split and peel, and on large trunks becomes rough and shaggy.

The leaves are dull green, stiff, narrowed at each end, 4–9 cm by 2–3.5 cm, with entire margins, and 5 (rarely 3 or 7) more prominent parallel veins from base to tip, on a petiole 6–24 mm. The flowers are produced in thick, fluffy spikes 4–8.5 cm by 2.5–3.5 cm, usually white or creamy-white, rarely, greenish or reddish. The conspicuous part of each flower consists of five bundles of stamens 10–20 mm long. The spike grows out into a leafy twig beyond the fruits. Each inflorescence results in 30–70 densely packed woody, stalkless capsules. They are short, cylindrical 3–4 mm by 4–5 mm, grey-brown, hard and persistent, opening by 3–4 slits at the end. The seeds are pale brown, very small, about 1 mm by 0.3 mm, tapering from the dorsal end. The usual flowering time in Australia is March–July (Blake and Roff 1958), but may occur at other times or throughout the year. Seed ripens in spring and summer.

The species is described and illustrated by Blake (1968), Boland et al. (1984), Holliday (1989a) and Little (1983).

Natural occurrence. *M. quinquenervia* is a native of the coastal region of eastern Australia, from near Sydney in New South Wales to Cape York in northern Queensland. It extends into southern Papua New Guinea and Irian Jaya, Indonesia, and also occurs extensively in New Caledonia, especially on the north-west of the island (Blake 1968; Holloway 1979; Cherrier 1981). In Australia and Papua New Guinea this species is generally confined to the lowlands, below 100 m, but in New Caledonia it forms extensive stands in the uplands up to an altitude of 900–1000 m.

- Latitude. Range: 8–34°S.
- Altitude. Main occurrence: near sea level to 100 m.
  Range: near sea level to 1000 m.

Climate. In the south of the distribution, *M. quinquenervia* occurs in the warm sub-humid and humid climatic zones, and in the north it is found in the hot humid zone. The mean maximum temperature of the hottest month ranges from 26°C in the south to about 34°C in the north. The corresponding minimum temperatures of the coolest month are 4°C and 20°C. There are few days over 38°C in coastal areas, and the number over 32°C varies from about 20 in the south to 100 or more in the north. Heavy frosts are absent in northern coastal areas, but there are 1–5 per year a few kilometres inland in southern occurrences in Australia. The 50 percentile rainfall is 900–1250 mm, the 10 percentile 550–775 mm, and the lowest on record mainly 400–650 mm. The seasonal incidence varies from a moderate summer–autumn maximum in the south to a strong monsoonal pattern in the north. The number of wet days is mainly in the range 105–140. Booth and Jovanovic (1988b) summarise the natural climatic variability for the species range in Australia, and Marcar et al. (1995) give climatic indicators for the successful cultivation of the species. They were as follows: mean annual temperature 17–26°C, minimum temperature of the coldest month 4–20°C, maximum temperature of the hottest month 27–34°C, mean annual precipitation 840–3440 mm, length of dry season 0–7 months.

Physiography and soils. In Australia, *M. quinquenervia* is confined to the Eastern Uplands physiographic division where it normally occurs on level or gently undulating coastal lowlands. It grows along streams, fringing tidal estuaries, and frequently forms pure stands in freshwater swamps. It often grows close to the beach and will tolerate wind-blown salt. The soils are often peaty humid gleys, sandy at the surface but silty or clayey below and with a high organic matter content. The watertable is near or above the surface for most of the year. It appears to tolerate a low level of groundwater salinity, but this condition is suboptimal for growth.

Occurrences in Papua New Guinea are on coastal, non-tidal, highly organic alluvial clay plains with poor drainage and very low fertility. The plains may be flooded to over one metre in depth during the wet season (Bleeker 1983).

In contrast to Australia and Papua New Guinea, *M. quinquenervia* in New Caledonia occurs extensively on well drained slopes and ridges in the uplands (Gillison 1983). It grows on all soil types, but is rarely found on soils derived from ultrabasic rocks (Cherrier 1981).

Vegetation type. The best-developed stands of *M. quinquenervia* occur as open-forest and woodland on favourable sites, but elsewhere are reduced to low woodland or tall shrubland. It is usually the dominant species and frequently occurs in more or less pure stands. It is found associated with *Eucalyptus robusta*, *E. signata*, *E. tereticornis*, *M. viridiflora* and *Lophostemon suaveolens*. There may be a sparse shrub layer or lower storey including species such as *Banksia robur*, *M. glomerata*, *M. thymifolia*, *Dillenia alata* and *Barringtonia racemosa* (Beadle 1981; Tracey 1982; Gillison 1983).

Utilisation.

Fodder: Not a fodder species.

Fuelwood: The wood is an excellent fuel and makes good quality charcoal. The reported calorific values for the wood and bark are 4400 and 6160 kcal/kg (18.4–25.8 MJ/kg), respectively (Wang et al. 1981), but there is great variability of these values between trees (Wang and Littell 1983).

Wood: The sapwood is pale yellow to pink. The heartwood is pink to reddish-brown rippled with light and dark tones, hard, fine-textured and diffuse, porous, tough, tending to warp and difficult to season. The wood contains silica that rapidly blunts saws and planes. The basic specific gravity is generally within the range 0.49–0.55, and an air-dry density of 700–750 kg/m^3. Florida-grown wood has a basic specific gravity of 0.49, a density of 1070 kg/m^3 (green), 640 kg/m^3 (air-dry) and 620 kg/m^3 (oven-dry) (Huffman 1981). Durability of untreated posts in the ground is high for one year but declines thereafter, and replacement is necessary after about three years (Cherrier 1981).

The wood has been used for a wide range of purposes including mine timbers, fence posts and rails, flooring, house timbers and pulp (NAS 1983). The bark has a variety of potential uses such as an additive to plant potting mixes, packaging, and insulation. Investigations of the utilisation of the wood and bark are detailed by Huffman (1981).

Other uses: This melaleuca is a good source of nectar and pollen for bees and is made more valuable by its extended flowering period (Robinson 1981). The honey has a strong flavour and weak density (Blake and Roff 1958).

The foliar leaf oils of *M. quinquenervia* fall into two classes, based on their chemical composition. One chemotype is rich in nerolidol (90%), while the other chemotype is rich in 1,8-cineole (30–70%) and sometimes viridiflorol (0–60%) (Brophy et al. 1989; Brophy 1995). It is the cineole-rich chemotype that is the source of Niaouli oil which is produced in New Caledonia. Niaouli oil is similar to Cajuput oil in composition and medicinal use.

The trees can be used for windbreaks, may have a role in erosion control on degraded and poor soils, and are ornamental. A red-flowering form is becoming popular for use in landscaping (Wrigley and Fagg 1993).

Silvicultural features. *M. quinquenervia* has been planted in tropical regions, especially in the dry tropical lowlands, of the Philippines, India, and West Indies (Little 1983). In Hawaii, almost 2 million trees have been planted on State Forest Reserves alone, between sea level and 1400 m. The trees grow well where the mean annual temperature is 18–24°C and where the mean annual rainfall exceeds 1000 mm. The largest area of *M. quinquenervia* is in Florida, USA, where it is the dominant species over almost 200 000 ha, with pure stands covering about 16 000 ha (Cost and Carver 1981).

Trees are highly fire-tolerant during all but the early seedling stages. The species can successfully compete with weeds, but early weed control will improve growth rates. It will tolerate prolonged flooding and a fluctuating water table. *M. quinquenervia* is moderately salt-tolerant; expect reduced growth at EC_e about 5 dS/m and reduced survival at 10 dS/m (Marcar et al. 1995). In waterlogged and flooded areas it forms aerial adventitious roots. The species has the ability to coppice readily, but root suckers are not commonly produced.

Given the variation in natural habitats where the species is found, genetic differences in growth and adaptation are highly likely, and careful selection of seed sources for specific planting environments will almost certainly lead to improved performance.

Establishment: The minute seeds (about 2 661 400 viable seeds/kg) are produced from when the trees are 3–4 years old and are released from the fruits when the branches they are on die after fire, frost, etc. (Woodall 1981). Propagation is by seed, which can be sown either on to germination beds or directly into nursery containers. When germinating seedlings are 2–3 cm tall (4–8 weeks after sowing), they are either transplanted or thinned, depending on the method used. Seeds are very small so care is needed to ensure that the sowing mix does not dry out, any diseases are avoided or controlled, and that seed and small seedlings are not damaged or washed away by careless watering. Watering from below may be used in preference to overhead systems to avoid this problem. Many species within this genus are vegetatively propagated from cuttings or by micropropagation, and these techniques should also be successful with *M. quinquenervia*.

Yield: Growth is relatively fast on sites where water is abundant and soils are deep, but is not impressive under marginal conditions. Morton (1966) cites reports of seedlings growing 0.9–1.8 m per year and 45 cm diameter logs being produced in 10–12 years. In trial plantings in southeastern Queensland, a provenance from northern Queensland averaged 4.3 m in height and 15 cm in diameter at ground level over two sites at 4.5 years (Ryan and Bell 1989, 1991). First-year coppice yields from established stands in Florida have averaged 3–4 dry t/ha (Conde et al. 1981). Trees in Hawaiian plantations on good sites average 18 m in height and 50 cm in diameter at 40 years (NAS 1983).

Pests and diseases. As an exotic, *M. quinquenervia* is relatively free of pests and diseases. A large number of insects feed on this species in Australia, but damage is localised (Habeck 1981). The heartwood lacks resistance to damage by termites, fungi and marine borers (Bultman et al. 1983).

Limitations. This species seeds profusely and can become a weed, especially where periodic fires provide a suitable seedbed. Severe frosts will defoliate and kill the branches, but the tree generally recovers by epicormic sprouting. The silica in the wood rapidly blunts saws and planes. The wood requires care in drying to minimise checking and warping.

Production of essential oils from various *Melaleuca* species can be a valuable primary or secondary product from *Melaleuca* plantations.

Related species. *M. quinquenervia* is a member of a group that includes, among others, *M. cajuputi*, *M. dealbata*, *M. leucadendra* and *M. viridiflora*. It has frequently been confused with *M. viridiflora*, and intermediates exist between these two species.

Melaleuca stenostachya

Main attributes. This species is a shrub or tree adapted to harsh conditions in the seasonally dry tropics. It tolerates seasonal waterlogging and is used in the round for posts and rails.

Botanical name. *Melaleuca stenostachya* S.T. Blake in *Contributions from the Queensland Herbarium* 1: 50–52 (1968). The variety *pendula* Byrnes was published in *Austrobaileya* 2(1): 74 (1984). The name is from the Greek *stenos* — narrow, straight and *stachys* — spike, in allusion to the narrow flower spikes.

Common names. Paperbark.

Family. Myrtaceae.

Botanical features. *Melaleuca stenostachya* is a tree 4–25 m high, with a small crown and stiff spreading branches, bark layered, fibrous and/or papery. The two varieties are apparently related to ecological conditions (Byrnes 1986). The var. *stenostachya* is an erect, hard-barked shrub or small tree with narrow, closely spaced leaves. The var. *pendula* has pendulous branchlets and papery bark, but otherwise is similar to type. The young shoots are covered by dense silky hairs. The leaves become glabrous, scattered, the blades stiff but not thick, narrowly elliptic-lanceolate, acute, straight or oblique or somewhat curved, 3.5–10 cm long, 4–9 mm wide, 5-nerved with nerve-like margins, other veins fairly prominent. The inflorescences are in terminal spikes, 1–4 together, 2–4.5 cm long, 1.5–1.9 cm wide, fairly densely flowered, the axis loosely silky with long hairs. The flowers are creamy-white or greenish-white, withering reddish. The stamens are in bundles of 5–9, rarely 10. The flowering time is January to July. The fruit is an ovoid-globose capsule, 2–2.5 mm long and up to 3 mm wide, sometimes retaining the persistent sepals, the valves shortly enclosed. Mature seed has been collected September–November (Searle 1989).

The species is described by Blake (1968) and Byrnes (1986), and illustrated by Blake (1968).

Natural occurrence. It is native to Cape York in northern Queensland with extension to the coastal and subcoastal areas of the Gulf of Carpentaria, where part of the distribution is in the Northern Territory.

- Latitude. Range: 11–19°S.
- Altitude. Range: sea level to 500 m.

Climate. This melaleuca is mainly in the hot humid to sub-humid climatic zones. The mean maximum temperature of the hottest month, November to December, is 32–33°C, with a few localities attaining 39°C. The mean minimum temperature of the coolest month is 13–21°C. Most of the area is frost-free, but light frosts have been recorded at elevated areas in the south.

The area has a marked summer monsoonal incidence of rainfall, from November to April. For most localities the 50 percentile falls within the range 750–1750 mm, the 10 percentile 500–1250 mm, and the lowest on record 350–950 mm.

Physiography and soils. *M. stenostachya* is found in three physiographic divisions, namely, on the Carpentaria Fall of the Western Plateau, the Carpentaria Lowlands of the Interior Lowlands, and on the eastern side of the Great Dividing Range in the Peninsular Uplands. The Carpentaria plain is part of the Great Artesian Basin that is underlain by sandstones (Perry and Lazarides 1964). *M. stenostachya* is found on lowlands and delta country surrounding broad outwash plains, extensive old alluvial plains with levees and shallow depressions, undulating country, shallow open valleys, on slopes and interfluves and among stony hills, and on colluvial footslopes among closely dissected low hills on volcanics, greywackes and other sediments (Galloway et al. 1970). *M. stenostachya* is often seasonally inundated for short periods each wet season.

Soils include alluvium, texture contrast, leached grey and brown earths, and deep uniform sandy soils such as acid brown and grey sands. On Cape York Peninsula soils include granitic deep bleached sands, loamy or sandy bleached yellow earths and yellow podzolics (Pedley and Isbell 1970). A hard subsoil is a characteristic of some soils where *M. stenostachya* is found in the Mitchell–Normanby area.

Vegetation type. *M. stenostachya* is a common species in the low tree stratum of the *Eucalyptus tetrodonta–E.* aff. *polycarpa* low woodland with *M. viridiflora* and *Grevillea glauca*. A common shrub is *Petalostigma banksii* (Pedley and Isbell 1970). In the Mitchell–Normanby River area it is one of the lesser species of melaleucas found in paperbark woodland. This vegetation type is the second-largest type in the area and the most widespread, dominating most of the lowlands west of the Dividing Range (Galloway et al. 1970). The most common co-dominant is *M. viridiflora*; other less common species include *M. saligna* and *M. nervosa*. There is generally a scattering of emergent eucalypts such as *E. argillacea* among the woodlands of paperbarks.

Utilisation.

Fodder: There is no data available, but it is unlikely to be suitable.

Fuelwood: Has the potential to produce a useful fuel.

Wood: No quantitative data available, but the wood is used in the round for posts and rails in northern Queensland.

Other uses: Has been used for the revegetation of bauxite mining sites in northern Queensland (Langkamp 1987).

The leaf oils of some provenances are present at reasonable concentrations (1.5% w/w, fresh weight) and are rich in 1,8-cineole (53–62%), and could be used in similar applications to those of Cajuput and *Eucalyptus* oils (Brophy et al. 1989; Brophy 1995).

Silvicultural features. *M. stenostachya* has rarely been cultivated, so little is known of its silvicultural features. In native stands it is noted for its relatively straight stem and fire tolerance. It has the ability to coppice, and will tolerate seasonal inundation.

Establishment: The species is propagated from seed. There are on average 5 200 000 viable seeds/kg.

Yield: One provenance in trials in Zimbabwe grew slowly to record an average of 1.3 m in 1.5 years (Gwaze 1989). Survival was 60%. It was the slowest-growing species in a melaleuca trial on high mounds in the Mekong Delta of Vietnam, where it reached 1 m in 12 months (H. Chuong, pers. comm.).

Pests and diseases. None are recorded.

Limitations. Initial growth rates appear to be slow, although this is based on limited data of few provenances. Like many melaleucas, it has the potential to become a weed.

Related species. It bears a superficial resemblance to *M. cajuputi*, *M. nervosa* and *M. argentea*. The flowers are like those of *M. saligna* (Blake 1968). It is closely related to *M. sericea* and *M. lasiandra*.

Melaleuca viridiflora

Main attributes. A small tree tolerant of infertile, seasonally waterlogged sites in the humid and sub-humid tropics. Has the potential to produce fuel, posts and poles. Useful for shelter and amenity planting.

Botanical name. *Melaleuca viridiflora* Sol. ex Gaertner in *Fruct. Sem. Pl.* 1: 173, t. 35 (1788). The specific name is derived from the Latin *viridis* — green, and *florum* — a flower, and refers to the greenish-cream flowers. Byrnes (1984) recognised five varieties of this species, two of which were new. Byrnes (1986) included *M. quinquenervia* (Cav.) S.T. Blake within *M. viridiflora* var. *rubriflora.* In a current revision of the genus it is unlikely that any infra-specific taxa will be recognised (L. Craven, pers. comm.).

Common names. Broad-leaved paperbark, coarse-leaved paperbark, swamp paperbark.

Family. Myrtaceae.

Botanical features. Typically a small tree 5–10 m tall. It ranges from a crooked shrub, 1–2 m, to a medium-sized tree of 25 m (Stocker 1972). The thick, pale brown bark has many papery layers, which split and peel. Branchlets are mostly thick and erect. Leaves alternate, dull green, usually oval or elliptical 6–15 cm long by 2.5–6 cm wide, mainly thick, leathery or stiff, with 5–7 prominent longitudinal nerves and a short petiole. The mature leaves are the largest and coarsest in the genus. Young shoots and leaves usually have fine silky hairs but become glabrous later.

The flowers are borne in spikes 7–10 cm by 4–6 cm, usually greenish-cream but also white, greenish-yellow, red and crimson. The flowers are large and stamens exceed 15 mm in length. The spikes are mainly terminal, but vegetative growth continues from the end of them. The fruit is a stalkless, woody capsule that is short, cylindrical, 3–5 mm by 4–7 mm, and opens by slits at the end. Flowering occurs usually November to June but may occur irregularly throughout the year; fruits mature March to December.

The species is described by Blake (1968) and illustrated by Boland et al. (1984) and Brock (1988).

Natural occurrence. *M. viridiflora* occurs throughout much of northern Australia and extends into south-western Papua New Guinea and Irian Jaya, Indonesia. It is restricted to northern localities in Western Australia and the Northern Territory, but extends

southwards along the coastal plains of Queensland to its southern limit.

- Latitude. Main occurrence: 9–20°S.
  Range: 8–26°S.
- Altitude. Main occurrence: near sea level to 300 m.
  Range: near sea level to 1000 m.

Climate. The climatic range of this species is from wet to semi-arid, with the majority of the distribution in the warm to hot sub-humid to humid climatic zones. The mean maximum temperature of the hottest month is 29–38°C and the mean minimum of the coolest mainly in the range 11–16°C. There are 15–280 days over 32°C and 0–80 days over 38°C. Frosts are absent or infrequent and light.

The 50 percentile rainfall is 325–1750 mm, the 10 percentile 100–800 mm, and the lowest on record 50–500 mm. The incidence in the north is monsoonal, but in the south the pattern changes to a moderate summer maximum and a less severe dry season.

Physiography and soils. *M. viridiflora* typically occurs in the lowland coastal marshes, seasonal swamps and estuarine plains and other areas where there is surface water for several months of the year. On drier inland sites the topography may be undulating, with slopes and small ridges.

In wetter areas the soils may be acidic organic sands and loams over clay, and include solodics and the margins of black fine-textured soils. On drier sites *M. viridiflora* grows on sandy soils derived from sand-stone, quartzite, and micaceous granites, and on laterites and red gravels. Most sites are low in nutrients and are acidic, but it is found on alluvial alkaline duplex soils.

Vegetation type. This melaleuca is widespread in the solodic flood plain areas of northern Australia where it forms low woodland 3–7 m tall over a grassy ground layer. It occurs as pure stands or mixed with close relatives such as *Asteromyrtus symphyocarpa*, *M. nervosa*, and *M. tamarascina* and various eucalypts (Gillison 1983). In humid tropical Queensland it forms low open-forest, low woodland and low open-woodland in association with *Acacia brassii*, *E. alba* and *E. leptophleba*, *Grevillea glauca* and *Petalostigma banksii* (Pedley and Isbell 1970). Further south it occurs with *E. alba* and *Lophostemon suaveolens* in a mosaic with communities dominated by *M. leucadendra*, *M. quinquenervia*, *E. acmenoides* and *E. intermedia* (Tracey 1982).

Utilisation.

Fodder: Not a fodder species.

Fuelwood: Has potential for fuel and charcoal.

Wood: Wood properties likely to be similar to those of *M. quinquenervia* (Bootle 1983). Basic wood density is 730 kg/m^3 (Davis 1994). It has potential for small posts and poles.

Other uses: M. viridiflora is an ornamental tree recommended for planting in streets and parks in coastal areas in northern Australia. Red-flowering types are available for horticultural use. It is a good source of pollen, but the honey has a poor flavour (Roff 1966). The Australian Aboriginal people used the bark for many purposes and the trunk for making canoes (Brock 1988). An infusion from leaves was drunk, inhaled or used as a bath to treat colds and influenza, headache and also fever, also to treat sores and cuts (Aboriginal Communities of the Northern Territory 1993).

Studies of essential oils of *M. viridiflora* have shown them to be variable in constitution with several chemotypes present throughout the species' range (Brophy et al. 1989). One chemotype produces an oil rich in methyl cinnamate and at reasonable concentrations (4% w/w DW). This type could be a useful source of natural methyl cinnamate.

Silvicultural features. *M. viridiflora* grows readily in moist infertile soils. It tolerates periodic waterlogging and is fire-resistant. It reproduces from seeds, coppice or root suckers. Initial growth is slow. The tree has an open habit and casts light shade. The branches are brittle but the tree is generally windfirm (Williams 1979).

This species has been rarely tested as an exotic, and little is known of its silvicultural requirements. Silvicultural techniques applied to *M. quinquenervia* should be appropriate for this species.

Establishment: The seed is very small. There are about 2 481 100 viable seeds/kg, and no pretreatment is required. Planted specimens bear flower buds after only 13 months from planting (Ryan and Bell 1989).

Yield: In southeastern Queensland, the species showed excellent survival, fair coppicing ability and reasonable growth rate in trials, with the best plot averaging 6.3 m in 4.5 years (Ryan and Bell 1989, 1991). It was less well adapted to conditions in Zimbabwe (Gwaze 1989), and on three of four sites where it was trialed in Thailand (Pinyopusarerk 1989). Best growth in Thailand was at Si Sa Ket, where it reached 2.9 m in 24 months. Marked provenance variation has been shown by the species in trials on the seasonally inundated acid sulfate soils of the Mekong Delta of Vietnam, where the species appears to prefer the better-drained conditions of high-mounded sites (H. Chuong pers. comm.). Under these conditions the best-performing *M. viridiflora* provenance had reached 2.2 m in 12 months, compared to 1.5 m for the slowest-growing provenance.

Pests and diseases. A sap sucker *Monophlebulus* sp. and leaf-tier, *Epipaschia lithochlora*, caused minor damage to planted trees in southeastern Queensland (Ryan and Bell 1991).

Limitations. The free-seeding and suckering habit of this species makes it a potential weed. Its small size will limit its use to fuel, posts, and poles.

Related species. *M. viridiflora* has frequently been confused with *M. quinquenervia*, but can be distinguished from it by its coarse leaves, thick spikes and flower colour (greenish or reddish flowers rare in *M. quinquenervia*).

Melia azedarach var. *australasica*

Main attributes. A fast-growing, deciduous, drought-hardy and moderately frost-resistant tree. It is suitable as an ornamental, street tree, and shade species in drier regions of Australia. The timber is used for cabinet work and joinery and has potential for domestic fuel-wood, while the leaves provide forage for stock.
Botanical name. *Melia azedarach* L. var. *australasica* (A. Juss.) C. DC. (syn. *M. dubia* Cav.) in *Mong. Phan.* 1: 452 (1878). The generic name is derived from the Greek *Melia* — manna ash, referring to the resemblance of the leaves to *Fraxinus ornus*. The specific name is from the Persian, 'Azad-darakht', — meaning 'noble tree'. The type is a native of Asia and widely cultivated in the tropics and subtropics, including northern Australia.
Common names. White cedar (standard trade name), other names are tulip cedar, Cape lilac, Persian lilac, Texas umbrella and umbrella cedar.
Family. Meliaceae.
Botanical features. A large, deciduous tree 20–45 m in height with a diameter up to 1.2 m in moist rainforest. In drier conditions the maximum height is 10–15 m. Bark grey-brown, thick, and longitudinally fissured. Branchlets brown with prominent leaf scars and reddish-brown lenticels. Leaves, bipinnate, alternate, about 40 cm long, with pairs of opposite, ovate or lanceolate leaflets, 2–7 cm long; The inflorescence is an axillary, loose panicle 10–15 cm long, the fragrant flowers are pale mauve to white. Flowering is in spring. The mature fruit is a yellowish globular berry, 10–15 mm long. A thin, succulent outer part surrounds a hard 5-celled stone, each of which contains a seed. The fruit matures in March to June. The species is described and illustrated by Holliday (1989b) and Wheeler et. al. (1992).
Natural occurrence. Occurs in eastern Australia and Papua New Guinea. It extends from northern Queensland to southern New South Wales, usually within 100 km of the coastline. The type is reported growing in the Kimberley region in northern Western Australia (Wheeler et al. 1992), northern areas of the Northern Territory, and around the Gulf of Carpentaria in northwestern Queensland (Anderson 1993), but these are presumed to be local land races from seed introduced from Asia many years ago.

- Latitude. Range: 11–35°S (in Australia).
- Altitude. Main occurrence: 25–400 m. Range: near sea level to 900 m.

Climate. South of the Tropic of Capricorn it occurs mainly in the warm humid and sub-humid zones and farther north in the hot humid and hot wet zones. Average maximum temperature of the hottest month is 26–32°C and the mean minimum of the coolest month ranges from 3–10°C and up to 19°C for northern areas. Average number of days a year where the temperature is over 32°C is 25–82. Frost occurrence is extremely variable; on the coast and to about 450 m in northern Queensland is frost-free, and elsewhere there are mainly 1–15 frosts each year.
The 50 percentile rainfall is mainly 800–1200 mm and up to 2100 mm for northern areas. In contrast in the drier localities, it is much lower at 385–570 mm. The 10 percentile is in the range 600–900 mm, increasing to about 1300 mm for the north. Lowest on record values are 365–600 mm. Southern areas of New South Wales have a weak summer maximum, which increases to a strong summer maximum in the far north of Queensland. There is an average of 105–120 raindays per year.
Physiography and soils. The natural distribution is on dissected plateaux of basalt, sandstone or metamorphics, undulating low hilly country with alluvial and sandy plains, to coastal lowlands with alluvial plains. This species is commonly found along stream banks, in valleys and on the lower slopes of coastal ranges. Soils are mainly acidic and neutral red earths, acidic red friable earths (krasnozems), and shallow loamy soils.
Vegetation type. *M. azedarach* var. *australasica* is widely distributed as single and scattered trees in, or on

the margins of, closed-forest (rainforest). In New South Wales it is found in riverine, dry and littoral rainforest (Floyd 1979), and in northern Queensland in rainforest formations including those with emergent *Agathis robusta* (Tracey 1982). Common associates include *Castanospermum australe*, *Grevillea robusta*, *Dysoxylum fraserianum* and *Toona ciliata*.

Utilisation.

Fodder: The leaves were found to be palatable and nutritious for stock with in vivo dry matter digestibility of 77% (Vercoe 1989). Cattle have been fed the bitter fruits without serious effects, but they can be highly poisonous (Everist 1974) and should not be accessible generally to pigs, sheep and poultry. Annual lopping of the branches will reduce the danger as flowering is confined to second-year wood (Cunningham et al. 1981). Fruit poisoning has also been reported in children who have eaten the fruits (Cremer 1990).

Fuelwood: A good species for domestic fuelwood (Keating and Bolza 1982). The Asian form is widely utilised for fuel.

Wood: A soft, relatively strong and easily worked pinkish and decorative timber. It is light in weight with a density of 510–570 kg/m^3. The sapwood is susceptible to *Lyctus* borer. Lasts only 1–15 years in the ground, but is rarely attacked by termites (Keating and Bolza 1982). Has been used in Australia for framing and boards, flooring, cabinet work, fixtures and interior joinery.

Other uses: Grown as an ornamental and shade plant in habitats much drier and hotter than in its normal coastal locations. Planted as a street tree in areas of Australia with an annual rainfall of 350–400 mm. It is also suitable for use in windbreaks and in avenue plantings. The flowers are attractive to bees for pollen and honey.

Other varieties of *M. azedarach* are popular in home gardens and agroforestry systems in Africa and Asia, where the leaves are used to produce an extract used as an insect repellent on crops.

Bark, leaves and roots have been used for medicinal purposes, such as in the treatment of rheumatism and fever, swellings and inflammation (Lassak and McCarthy 1983).

Silvicultural features. A fast-growing tree, can be irrigated in hot dry areas, is fairly tolerant of salinity (Zwar 1975) and frost, and withstands moderate coastal exposure. The tree can be pollarded and pruned. It root suckers and coppices vigorously (Ryan and Bell

1989). The deciduous habit of white cedar may give it an advantage on very dry sites.

Establishment: Although propagation from seed is easy, extended germination due to embryo-cover dormancy often results in uneven-sized plants (Moncur and Gunn 1990). Endocarp removal followed by seedcoat scarification (slitting) is recommended to promote rapid germination (Milimo 1994). Each fruit can produce up to five seedlings. There are about 3500 fruits/kg (airdried) and 4000–10 000 seeds/kg. Viability is best maintained in cold storage.

Yield: In trials in southeastern Queensland a provenance from the Atherton Tableland gave 91% survival and grew to an average of 4.7 m tall and 9.5 cm basal diameter in 4.5 years (Ryan and Bell 1991). Substantial variation in growth amongst provenances was noted in field and glasshouse trials (Milimo 1994). In Thailand, the Atherton Tableland provenance outperformed a provenance from Mt Garnet, giving a range of MAI for height growth of 0.9–2.6 m. This was comparable to the growth of the local *M. azedarach* and *Azadirachta indica* (Pinyopusarerk 1989).

Pests and diseases. White cedar is subject to periodic defoliation by the larvae of the white cedar moth (*Leptocneria reducta*) and a spider mite.

Limitations. Fruits are highly toxic. Regenerates vigorously and has the potential to become a weed. The flowers may cause discomfort to asthma sufferers, and the wood dust can induce dermatitis (Cunningham et al. 1981).

Related species. It is related to neem, *Azadiracta indica* (Little 1983).

Paraserianthes lophantha

Main attributes. *P. lophantha* is a small, fast-growing, nitrogen-fixing tree or sprawling shrub adapted to warm temperate to subtropical lowlands. It is moderately drought-resistant and tolerates seasonally waterlogged and infertile soils, including alkaline sands near the coast. A useful tree for soil protection and rehabilitation and an attractive ornamental species. Has potential as a browse plant.

Botanical name. *Paraserianthes lophantha* (Willd.) I. Nielsen, formerly *Albizia lophantha* (Willd.) Benth., was renamed by I. Nielsen et al. in *Bulletin du Muséum National d'Histoire Naturelle*, Section B, *Adansonia botanique phytochimie*, 4e série, t. 5, no 3: 303–329 (1983). It is the type species for the genus *Paraserianthes*. The genus is from the Greek *para* — beside, and the genus *Serianthes* — being closely related to this Southeast Asian genus. The species name is from the Greek *loph* — crest-bearing, and *anthos* — a flower, possibly in reference to the crested appearance of the flowers.

Common names. Crested wattle, cape wattle, spike acacia, albizia, stinkbean (South Africa), brush wattle (New Zealand).

Family. Mimosaceae.

Botanical features. *P. lophantha* is a sprawling shrub 1–2 m tall on adverse sites, but on favourable sites it grows rapidly into a small tree 4–15 m tall, with a straight trunk and large, spreading crown. It has bipinnate leaves up to 20 cm long, with 6–12 pairs of pinnae each with 20–40 leaflets. The leaflets are linear-oblong, 6–13 mm long and 1–3 mm wide, the main vein near the upper margin, glabrous above, silky hairy beneath, sessile. Leaves become sparse on older plants and on younger plants during times of stress.

The flowers are similar to those of *Acacia*, but the filaments are joined at the base, whereas those of *Acacia* are free. They are in dense, cylindrical axillary spikes 4–8 cm long, 1–3 per axil and greenish-yellow in colour. Flowering time is April–August. The pod is 5–11 cm long and about 8 mm broad, flat and blunt-ended with the edges raised and thickened, a small but distinct point projecting from the blunt end of the pod. There are 8–12 hard, brown or black seeds arranged transversely in the pod. Each seed possesses a dull reddish funicle.

It is described and illustrated by Taylor (1980), Nielsen et al. (1983) and Powell (1990).

Natural occurrence. *P. lophantha* has a limited natural occurrence in coastal areas of southwestern Western Australia including offshore islands of the Archipelago of the Recherche. Elsewhere in Australia it has become naturalised in coastal regions of South Australia, Tasmania, Victoria, and central New South Wales. It is also naturalised in South Africa, southern California, the Canary Islands, and several South American countries from Colombia and Venezuela to Chile.

- Latitude. Range: 31–35°S.
- Altitude. Range: near sea level to 200 m.

Climate. Most of the distribution is in the warm humid and sub-humid climatic zones. Mean maximum temperature of the hottest month is about 24–26°C and the mean minimum of the coolest 7–10°C. Coastal areas are frost-free, while inland there are 1–4 frosts recorded annually.

The 50 percentile rainfall is 670–1120 mm, the 10 percentile 550–870 mm, and the lowest on record 440–760 mm. The seasonal occurrence is a well-developed winter maximum and a dry summer. In areas where *P. lophantha* has become naturalised the rainfall ranges are slightly wider and rainfall distribution may be more or less uniform.

Physiography and soils. *A. lophantha* is found naturally in a restricted distribution within the Western Plateau physiographic division. The topography is mainly dissected plateaux, granitic headlands and hills, and low ranges of granite and metamorphic rocks. Also found on undulating to low hilly country with alluvial and sandy littoral plains. Grows mostly on soils derived from granite and sometimes on sandy soils overlying siliceous rock (Beadle 1981). Soil types are yellow earthy sands, ironstone gravels in a sand matrix, calcareous sands, lateritic podzols, solodized solonetz and solodics and well-drained clays and silts (Sheppard 1987).

Vegetation type. This species grows naturally in eucalypt open-forest, woodland or open-shrublands. Well-formed trees are found along river and stream banks or around swampy areas. It is associated with *Eucalyptus cornuta* and *E. lehmannii*, where the soils may be subject to a period of winter waterlogging. On the Recherche Archipelago it forms part of the understorey with such species as *Acacia acuminata*, *Agonis marginata* and *Callitris preissii* (Beadle 1981). It occurs as an introduced tree in eastern Australia in open-forest and woodland.

Utilisation.

Fodder: Cattle browse the leaves of this tree (Maiden 1889).

Fuelwood: Regarded as a poor fuelwood in South Africa (Taylor 1980).

Wood: A soft wood that is not suitable for house construction (Taylor 1980).

Other uses: The fast-growing capability of this species has been utilised in the rehabilitation of mine-sites in Western Australia (Langkamp 1987) and of sand dunes after mining in coastal dunes of northern New South Wales. In New Zealand it has been used for temporary horticultural shelterbelts and for sand dune and gully stabilisation (Anon. 1984; Sheppard 1987).

Dried roots have a 10% saponin content and are utilised in silk and wool factories (Cribb and Cribb 1981). A useful amenity shrub or small tree for shade and ornament.

Silvicultural features. This fast-growing but short-lived tree is killed by fire but then regenerates prolifically from seed, sometimes producing ‘carpets’ of seedlings. It does not reproduce from coppice. It is lime-tolerant and has been recommended for growing in clay soils (Wheller 1969). It thrives in alkaline sands in near-coastal situations. Although moderately resistant to salt winds, it is relatively brittle and requires protection from the wind in very exposed coastal situations (Sheppard 1987). It can be drought- and frost-tender until established.

Establishment: P. lophantha begins producing seed within 2 years. The seed requires manual scarification or the standard boiling water treatment to enhance germination. There are 10 000–15 000 viable seeds/kg (Langkamp 1987). Large seed, good germination and rapid growth make it an excellent candidate for direct seeding. Seedlings require protection against herbivores (Vita 1977).

Yield: Initial growth rates are typically 2–3 m/year on suitable sites. After fire in the Helena Valley of Western Australia, some regeneration grew as tall as 7 m in four years (Powell 1990).

Pests and diseases. In Western Australia, trees may die at an early age as a result of black smut-fungus and swift moth larvae that burrow and feed in the stems and grow into large grubs up to 9 cm long (Powell 1990). Seed-feeding weevils, *Melanterius* spp., are being trialed as a biological control measure in South Africa (Dennill and Donnelly 1991). It is known to be affected by the wood borer *Xyleborus truncatus* (Zondag 1977) and *Fusarium* sp. (Hepting 1971).

Limitations. *A. lophantha* is a potential weed especially in moist, fertile valley situations. It has invaded areas of the southwestern Cape of South Africa (Taylor 1980; McDowell and Moll 1981). The soft timber is a poor fuel and is not recommended for house construction. It is a short-lived species and prone to wind damage on exposed sites. On highly exposed coastal sites it becomes reduced to a shrub with dead branches on the windward side.

Related species. In the taxonomic revision of Nielsen et al. (1983), *P. lophantha* comprises two subspecies, subsp. *lophantha* and subsp. *montana*. The latter occurs in Indonesia and was formerly known as *Acacia montana*.

Parinari nonda

Main attributes. This species is usually a small tree. It is adapted to a wide range of sites in the hot, humid lowland tropics. The timber can be used for structural building material, joinery, sleepers, poles and piles, and turnery. It is a good fuel and splits easily. The fruit is edible.

Botanical name. *Parinari nonda* F. Muell. ex Benth. published in *Fl. Aust*. 2: 426 (1864). *Parinari* is from the native name of a species in Guyana, and the specific name *nonda* is from an Australian Aboriginal name for a tree with a similar appearance.

Common names. Nonda or nonda-tree. It is also known as Solomon Islands parinari and nonda plum.

Family. Rosaceae, but sometimes placed in the family Chrysobalanaceae.

Botanical features. A tree up to 34 m tall, but usually 6–15 m, with pendulous branches. Open-grown specimens typically have a spreading crown, as wide as the height. On adverse sites, such as on exposed sea cliffs, its habit is that of a low woody shrub to 1 m. The bole is slightly tapering and cylindrical. Bark grey or grey to yellowish-brown, shallowly or deeply fissured with prominent lenticels. Branchlets are covered with dense long hairs; branches are glabrous. Adult leaves are leathery, ovate, upper surface glossy, lower surface white or pale, 3.5–7.5 cm long by 1.5–5 cm wide, rounded at the base, with a prominent midrib, 11–20 pairs of lateral nerves. The leaf margins have scattered tiny, round glands or protruding, small black tissue dots. Petiole 2–7 mm long, densely hairy, usually with two small, black protruding glands at the middle or lower down.

The inflorescence is in slender, open terminal or axillary panicles up to 6–10 cm long, densely hairy with brownish-yellow scented flowers. Fruit is a brown, fleshy 2-celled drupe, often flattened laterally, up to 3 cm long, bumpy and irregular, covered with pale scabs and enclosing 2 seeds. The cells are densely hairy inside. The flowers appear principally in July–November (Boland et al. 1984; Searle 1989) and fruits are mature from July to December (A. Morton, pers. comm. 1982).

The species is described and illustrated by Kostermans (1965), Boland et al. (1984), Hyland and Whiffin (1993) and Wheeler et al. (1992).

Natural occurrence. In Queensland this species is moderately common on the lowlands of Cape York Peninsula, especially near the eastern coast from Thursday Island to near Cooktown. There are disjunct occurrences in the Northern Territory on the Daly River and east of Darwin, and in the Kimberley region of far northwestern Western Australia. Outside Australia it is a native of New Guinea, where it is recorded up to 1300 m (Kostermans 1965), and the Solomon Islands.

- Latitude. Main occurrence: 10–16°S.
  Range: 6–19°S.
- Altitude. Main occurrence: 5–300 m.
  Range: near sea level to 1300 m.

Climate. Much of the distribution lies in the hot humid climatic zone, with an extension into the warm and hot sub-humid zones. The mean maximum temperature of the hottest month is 30–37°C. The coolest month has a mean minimum temperature of 15–22°C, with some localities slightly cooler at 12°C. The area is frost-free.

The 50 percentile rainfall is 1150–1725 mm and the 10 percentile 700–1300 mm. Lowest recorded rainfall is 500–925 mm. There is a strong monsoonal pattern in the seasonal occurrence of rainfall, with an average of 85–125 raindays per year.

Physiography and soils. In Western Australia, nonda-tree is restricted to the Kimberley and North Australian Plateaux physiographic provinces, growing on undulating to hilly plateaux of either sandstone or basalt. Northern Territory occurrences are on alluvial plains in dissected lateritic lowlands. The majority of the Queensland distribution lies in the Carpentarian Lowlands and Peninsular Uplands physiographic provinces. The topography varies from plateaux or a complex of tablelands of sandstone, granite or laterite-capped, to undulating clay plains. Soils are usually of low fertility, mainly acid and neutral red and yellow earths and shallow sandy soils (lithosols). Other soil types include, neutral and alkaline red friable earths (euchrozems), deep red and yellow friable loams, and solodized and solonetz soils.

Vegetation type. In Australia, *P. nonda* is a conspicuous component of eucalypt and melaleuca woodland and open-woodland, and eucalypt open-forests. It usually grows as an understorey species beneath such eucalypts as *E. nesophila*, *E. papuana*, *E. polycarpa* and *E. tetrodonta*. Elsewhere it occurs on the edges of monsoon forests and rainforests. Other small trees and shrubs growing in association with *P. nonda* are *Acacia brassii*, *A. holosericea*, *A. polystachya*, *Banksia dentata*, *Erythrophleum chlorostachys*, *Syzygium suborbiculare* and species of *Melaleuca*. It has also been recorded in a *Callitris* pine community.

Utilisation.

Fodder: Not known to have been utilised by stock. The fruit is eaten by insects and birds.

Fuelwood: It splits easily and is a good fuel. *P. nonda* was found to ignite easily and produced relative small amounts of residual matter after combustion (Gardner 1989).

Wood: The timber is heavy and hard, yellow-red or red with an interlocked grain and air-dry density of 660–816 kg/m^3. It is difficult to saw, especially when seasoned, and it is recommended that saws with tungsten-tipped teeth be used. Treatment of the timber using a combination of air- and kiln-drying processes gives good results. The timber glues satisfactorily but is difficult to nail. It has good wearing and weathering properties and lasts 1–15 years in the ground. The sapwood may be subject to attack by pinhole borers and termites. It is probably not susceptible to *Lyctus*, and moderately resistant to marine borers. It is used for structural building material, agricultural implements, joinery, sleepers, poles and piles, and turnery (Keating and Bolza 1982).

Other uses: The fruit, which resembles a plum, was extensively eaten by Australian Aboriginal people (Cribb and Cribb 1982). This species is used for

rehabilitation of bauxite mining sites in northern Queensland (Langkamp 1987).

Silvicultural features. This species is scarcely known in cultivation and little is known of its silvicultural features or requirements.

Establishment: Propagation is by sowing freshly collected, depulped seed. Obtaining good quality seed is difficult, as the natural stands are remote and therefore difficult to monitor for crop maturity (Searle 1989). Seed appears to lose its viability quickly, but temporary (4 months) storage at 5°C still gives good results in the nursery (N. Dahl, pers. comm.). However, results have been poor (7% germination rate) with longer time intervals between collection and sowing (Ryan and Bell 1989).

Direct sowing of fruits has been used to regenerate this species in northern Queensland (Morton 1982).

Yield: No data currently available.

Pests and diseases. None recorded.

Limitations. The difficulty in obtaining viable seed has hampered field evaluations, and more research is needed on this aspect. The wood dust may cause dermatitis, probably because of irritation by silica deposits.

Related species. Kostermans (1965) has reduced *P. papuanum* and *P. salomonense* to synonymy under *P. nonda*. The nearest relative of *P. nonda* is *P. insularum* from which it can be distinguished by its leaf shape. *P. nonda* is the only species of *Parinari* in Australia.

Santalum album

Main Attributes. A small tree of the seasonally-dry tropics of India, eastern Indonesia and northern Australia. It is hemiparasitic and needs a suitable host plant for successful cultivation. Sandalwood is prized for the fragrant oil extracted mainly from the heartwood and used in perfumery. The timber is also used in handicrafts.

Botanical Name. *Santalum album* L. was described in *Species Plantarum* 1: 349 (1753). The generic name is derived from the Greek *santalon* — sandalwood, and the species name from the Latin —*albus* — white, in allusion to the bark.

Common Names. East Indian sandalwood, sandalwood, sandal, cendana.

Family. Santalaceae.

Botanical Features. *S. album* grows as an evergreen shrub or small tree to 4 m in Australia (Barrett and Fox 1995). In India it is much larger and can grow to a height of 20 m and attain a girth of over 1.5 m (Rai 1990). The bark is tight, rough and fissured, dark grey or nearly black, reddish in the fissures. The leaves are opposite, ovate or broadly lanceolate, mostly 2.5–7 cm long by 1.5–4 cm wide, light green above, slightly paler underneath, the tip rounded or pointed on a grooved stalk 5–15 cm long. Venation is noticeably reticulate. The flowers are small, reddish or green, about 4–6 mm long, up to 6 in small terminal or axillary clusters. Flowers appear December to January and also June–August. Fruit are fleshy drupes, almost stalkless, smooth, roundish, 7–10 mm in diameter, and coloured shiny dark red, purple to black when ripe, single-seeded. Mature fruit are available June to September.

S. album in Australia is described by George (1984b) and illustrated by Brock (1988).

Natural occurrence. The Australian distribution is limited to the extreme northern coastline of the Northern Territory. There is still debate as to whether *S. album* is endemic to Australia or introduced by fishermen or birds from eastern Indonesia centuries ago (McKinnell 1990). The main distribution is in the drier tropical regions of India and the Indonesian islands of Timor and Sumba. The following habitat description refers specifically to the Australian distribution.

- Latitude. Range: 11–14°S.
- Altitude. Range: near sea level to 250 m.

Climate. The distribution lies in the hot humid climatic zone, where the temperatures are high throughout the year. The average maximum of the hottest month is 32–34°C and the mean minimum of the coolest, 17–22°C. There are many days when 32°C is exceeded, but few over 38°C. There are no frosts.

The 50 percentile rainfall is 1000–1500 mm, the 10 percentile 700–1000 mm. Rain is recorded on an average of 89–100 days per year. The rainfall has a strong monsoonal pattern, most rain falling in the months December to March.

Physiography and soils. *S. album* has been recorded on coastal sand dunes immediately above the normal high water mark and close to mangroves. It also grows on low lateritic cliffs above the beach. On Timor it grows on very stony, grey clay and red loam soils derived from coral parent material, well-drained and having a pH of 8–9 (Applegate et al. 1990). In India it usually grows on free-draining red loams with a pH of 6–6.5, and occasionally on sandy soils associated with laterites (Singh 1995).

Vegetation type. The vegetation type is a typical monsoon vine thicket growing on pure sand. A most probable natural host is *Drypetes lasiogyna*, observed to be the most prolific species in the vicinity of *S. album*.

Utilisation.

Fodder: The foliage of *S. album* is palatable to grazing animals such as rabbits, sheep, goats, cattle, pigs, horses and camels (Hamilton and Conrad 1990).

Fuelwood: The timber has been used as a fuel but is generally considered too valuable for this purpose.

Wood: The wood is used for carving, incense and oil. The heartwood of *S. album* is prized as a source of sandalwood oil used in the fragrance industry. The sapwood is used in the production of incense such as joss-sticks (Coppen 1995). The oil also has medicinal uses and is employed in aromatherapy. It is produced by steam distillation of the wood after it has been chipped and ground to powder. India and Indonesia are the major producers. *S. album* has a wood density of 930–950 kg/m^3 (FAO 1992).

Heartwood is usually formed in trees after about 20 years of growth. When they are 40–60 cm in girth or about 30–60 years old, the trees are suitable for oil extraction (Gupta 1993). Whole-tree harvesting is employed, and both live and dead trees are utilised. Between-tree variation in heartwood content and oil yields is high (Haffner 1994), indicating considerable scope for selection and breeding. Average commercial oil yield ranges 4–6% w/w (Hughes and Richmond 1980; Rai 1990).

Other uses: Grown as an ornamental and as a low-branching windbreak species. The seeds yield an oil that can be used in the paint manufacturing industry, and the leaves make good green manure (Gupta 1993). The fruits are edible.

Silvicultural features. There is substantial literature on *S. album*. An annotated bibliography (Ross 1985), literature survey (Barrett 1988) and regional reviews (Hamilton and Conrad 1990; McKinnell 1993) are available. Present state of knowledge regarding cultivation of sandalwood is provided by Gjerum et al. (1995). A selective summary follows.

S. album is a root parasite. Host plants that provide a light shade and fix nitrogen are preferred. It is slow-growing, coppices freely when young, and root suckers. It is killed by prolonged drought and fire. Tolerates a wide range of soils but is intolerant of waterlogging.

Establishment: Propagation is mainly by seed. Viable seed production starts when the tree is 5 years old (Applegate et al. 1990). Seed should be depulped immediately after collection. There are approximately 6000–6800 seeds/kg of 70% germination rate. Fresh seed has a dormancy period of 2 months. This can be broken by manual scarification or gibberellic acid. Seed longevity declines rapidly at room temperature. The nursery phase to raise sturdy 30-cm plants is usually 8 months. Primary host species are grown alongside *S. album*

seedlings in each pot (Fox et al. 1995). *S. album* has been propagated vegetatively by tissue culture, branch cuttings and cleft grafting. Direct sowing in the field is used in some situations.

Secondary host species should be well established on the planting site before planting. *Acacia*, *Casuarina*, *Paraserianthes* and *Sesbania* spp. are amongst a wide range of successful hosts. Weed control and protection from grazing and fire are essential.

Yield: Girth increments for *S. album* in India are 1.0–1.3 cm/year in natural stands and up to 5 cm annually in cultivated trees. The yield of heartwood varies according to age and locality. As a rule of thumb, each tree adds 1 kg of heartwood to its weight each year after the age of 15 years.

Pests and diseases. Spike disease that shortens the internodes, reduces leaf size, kills haustoria and blocks vascular tissue is a serious pathogen in India (Parthasarathi 1979). Nursery pests include pathogenic fungi, *Fusarium* and *Phytopthora* and nematodes (Nayar et al. 1980). A wide range of insect pests is reported on *S. album* in India (Fox and Barrett 1995).

Limitations. Slow growth and the time lag until harvestable amounts of heartwood are formed are deterrents to wider cultivation. Sensitivity of young trees to fire and grazing animals is a disadvantage. Superior genetic material is not generally available.

Related species. Of the 29 species and varieties in the genus, six are native to Australia, including the commercial species *S. spicatum*, *S. lanceolatum* — oil, and *S. acuminatum* — edible fruit.

Sesbania formosa

Main attributes. A very fast-growing, nitrogen-fixing tree adapted to moist sites in the hot arid to humid tropics, and tolerant of alkaline, saline and waterlogged conditions. It is an excellent species for fodder and green manure production; is useful for shade, shelter, as a live fence and for erosion control; and has the potential to produce fuelwood and pulpwood.

Botanical name. *Sesbania formosa* (F. Muell.). N.T. Burbidge is published in *Aust. J. Bot.* 13: 115 (1965). The genus name is from the Arabic name, 'seisabân', of *S. aegyptiaca*. The species name is from the Latin *formosus* — handsome, beautiful, in allusion to the flowers being the largest in the Australian pea family.

Common names. Swamp corkwood, white dragon tree, dragon-flower tree, water tree.

Family. Fabaceae.

Botanical features. A small to medium-sized tree of moderate life-span (> 15 years), usually 8–12 m tall but sometimes to 20 m, with few, more or less upright branches. The bark is pale grey, deeply furrowed and corky. Young twigs are finely hairy. Leaves are pinnate, 15–40 cm long with 5–20 or more pairs of leaflets; the leaflets are elliptic to ovate or narrow, 3–6 cm long by 8–15 mm wide, and hairless. The inflorescence is a raceme of 2–7 flowers on a stalk to 10 cm long. The flowers appear in May–June. They are pea-shaped, white or yellowish-white, 7–12 cm long and are the largest of any Australian native legume. The pods are narrow and curved, hanging down, 40–60 cm long, pointed at both ends. They mature in August– September. The seeds are bean-like, smooth, shining, dark brown, 6–7 mm long, flattened but turgid and oblong-rectangular in shape.

The species is described by Burbidge (1965) and illustrated by Brock (1988), Crisp (1981), and Petheram and Kok (1983).

Natural occurrence. *S. formosa* is found from the Pilbara and Kimberley areas in the north of Western Australia, eastwards to Arnhem Land in the Northern Territory. It is rare in Queensland and has been recorded only on Cape York.

- Latitude. Range: 13–23°S.
- Altitude. Range: near sea level to 550 m.

Climate. The distribution covers a range of climatic zones including hot arid, hot semi-arid, hot sub-humid

and hot humid. The mean maximum temperatures of the hottest month are 33–39°C, and the mean minimum of the coolest 12–29°C. The average number of days when the temperature exceeds 32°C is 160–255, and there are 1–70 days over 38°C. The area is frost-free.

The 50 percentile rainfall is in the range 230–1570 mm, the 10 percentile 60–1210 mm, and the lowest on record 15–1050 mm. The rainfall is monsoonal in the north and has a strong summer maximum elsewhere. The number of raindays is 21–125, and the dry season extends over 5–8 months. The rainfall data do not provide a good indication of water availability, as this species frequently occurs along river banks, in depressions or where a high groundwater table exists, and can readily supplement incident rainfall.

Physiography and soils. *S. formosa* is found principally on alluvial plains and river banks of perennial, or more commonly, seasonally dry watercourses and fringing brackish or freshwater springs associated with salt marshes, plains and sand deserts. The soils range from deep loose alluvial sands to heavy black, alkaline (pH 7.5–10) clays. Its ability to fix atmospheric nitrogen enables it to grow well on impoverished soils.

Vegetation type. This species is a component of open-woodland, open-forest or closed-forest. Common associates include *Eucalyptus camaldulensis*, *Melaleuca leucadendra*, *Pandanus aquatica*, *Terminalia platyphylla*, *Ficus* spp. and *Nauclea* spp. Some of the ecological conditions where *S. formosa* occurs are illustrated by Beard (1975) and Kabay and Burbidge (1977).

Utilisation.

Fodder: Not widely used for forage in Australia. In Thailand, dry matter digestibility and crude protein contents of *S. formosa* leaves were 55–58% and 21–22% respectively, somewhat lower than its close relative *S. grandiflora*, but still suggesting high value stock fodder (Akkasaeng et al. 1989). In a glasshouse experiment, in vitro dry matter digestibility (>50%) and protein (> 20%) contents of *S. formosa* leaves remained high under highly saline conditions (T. Vercoe, unpublished data).

Fuelwood: Has potential to produce fuelwood rapidly, although low density suggests that it will be used only when high-quality fuel supplies are scarce.

Wood: The wood is whitish, soft, light, density 400 kg/m^3, and non-durable. Probably suitable for pulpwood (Logan et al. 1977), although it is unlikely to be used for this purpose.

Other uses: S. formosa has been used as a fast-growing, expendable plant in amenity and horticultural plantings (e.g. nurse crop for mangoes) in coastal parts of north-western Australia (Thomson 1989b). It has also been used as a secondary host for sandalwood (*Santalum album*). It makes an attractive ornamental for gardens and is useful for mixed shelterbelts, soil stabilisation and rehabilitation work, and as a green manure. The flowers are edible raw or cooked. An infusion from the inner bark of *S. formosa* was used by Australian Aboriginal people for treating sores and general illness (Brock 1988).

Silvicultural features. A versatile tree of moderate life span (> 15 years) foreshortened by droughts, *S. formosa* has most potential for production of fodder and green manure in suitable climates. *S. formosa* has an ability to coppice but it did not survive regular pruning-back to 1 m in trials in northeastern Thailand (Akkasaeng et al. 1989). Thomson (1989b) reviewed the international research experience with *S. formosa*. In India, Nepal, Tuvalu and West Timor, *S. formosa* showed promising growth on a range of difficult sites affected by alkaline or sodic soils and waterlogging. However, it was often outperformed in height and survival by *S. grandiflora*. On alluvial soils of moderate fertility in southern Nepal, *S. formosa* displayed outstanding growth, attaining a height of 7 m (9.7 cm diameter) in 12 months.

Establishment: Propagates readily from seed and cuttings. There are 30 900 viable seeds/kg at an average germination rate of 81%. Germination may be improved by immersing the seed in boiling water.

S. formosa fixes atmospheric nitrogen through symbiosis with rhizobia. Inoculation of nursery seedlings

with effective strains of the symbiont may help to improve establishment after outplanting. Propagation and management practices developed for *S. grandiflora* (e.g. Hocking 1993) can probably be applied to *S. formosa*.

Yield: In two trials in southeastern Queensland, the Maitland River provenance of *S. formosa* grew rapidly. After 2 years mean height was 4–5 m, basal stem diameter was 12–16 cm and survival 63–85% (Ryan and Bell 1991). Mild frosts were responsible for mortalities in these trials. In central Queensland, *S. formosa* failed on the alkaline cracking clays but attained 2 m and 1.6 m in irrigated and non-irrigated plots on acidic red earths at 18 months (Ryan and Bell 1991). Under irrigation in northern Western Australia, *S. formosa* grew extremely rapidly in the first year to reach a mean height of 4.9 m. A further 1.2 m was added in the second year (Thomson 1989b). A nearby spacing trial began dying back at 18 months from unidentified causes.

Pests and diseases. Birds (cockatoos), grasshoppers, stem borers and termites damage trees.

Limitations. Has the potential to become a weed under certain conditions. It is frost-sensitive and adapted only to tropical conditions. Susceptibility to various pests and diseases may preclude its extensive use (Thomson 1989b).

Related species. *S. formosa* and *S. sesban* (L.) Merrill are the only large woody perennial members of the genus found in Australia. The endemic *S. formosa* is very closely related to *S. grandiflora* (L.) Poir. but differs in various floral, legume and seed characters (Burbidge 1965).

Syzygium suborbiculare

Main attributes. A small tree adapted to infertile, sandy soils in the humid and sub-humid tropics. Has potential for fuelwood and for shade and shelter. The fruits are edible and a source of vitamin C.

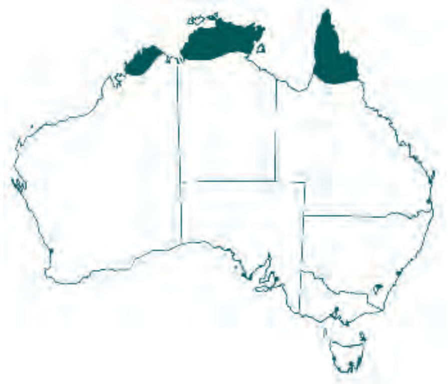
Botanical name. *Syzygium suborbiculare* (Benth.) Hartley and Perry was originally named *Eugenia suborbicularis* by Bentham in *Flora Australiensis* 3: 285 (1867). The species was then considered to belong to the genus *Syzygium* by Hartley and Perry in *J. Arnold Arboretum* 54: 189 (1973). *Syzygium* from the Greek *suzugos* — joined, because the perianth segments in the type species *S. caryophyllaeum* has the perianth segments cohering to form a cap. The leaves of this species are round and flat, hence the specific name *sub* — almost, and *orbiculare* — circular.

Common names. Forest satinash, apple, lady apple, wild apple, oloorgo, pudginjacker, yinumaninga, e-sie, murl-kue-kee.

Family. Myrtaceae.

Botanical features. Usually a small tree up to 12 m, which occasionally reaches a diameter of 80 cm, but also occurs as a prostrate form on sand dunes. The bark is flaky on the trunk. Branchlets are smooth, becoming scaly and longitudinally cracked with age. The adult leaves are variable in shape, orbicular, oblong, ovate, elliptical, lanceolate with a tapering point, the base truncate or tapering, shiny green above, dull below, 7–19 cm long and 4–13 cm broad, the petioles 7–34 mm long. The lateral veins are in 12–27 pairs and with a well-developed intramarginal vein (sometimes 2). There are numerous visible oil dots on the surface of the leaf.

Inflorescence is terminal, sometimes in the upper axils, with cream-coloured flowers, the buds sometimes pink or red. Flowering time is from June to November. The fruit is a succulent drupe, red or reddish, calyx lobes persistent, depressed globular to ovoid, 3–7 cm long and 3.5–9 cm in diameter. Large size fruits are conspicuously longitudinally ribbed, while the ribs on small fruits are seen only towards their base. There is only one seed per fruit, transversely oblong, 30–55 mm in diameter. Fruits have been collected August–November and January, March, and June (Hyland 1983).



It is described and illustrated by Hyland (1983), Boland et al. (1984) and Brock (1988).

Natural occurrence. *S. suborbiculare* is distributed throughout coastal and inland areas of Cape York Peninsula in Queensland. It is also found in the extreme north of the Northern Territory and in the Kimberley region of northern Western Australia. It also occurs in southern Papua New Guinea (Boland et al. 1984).

- Latitude. Range: 10–17°S (Australia).
- Altitude. Range: near sea level to 220 m.

Climate. The distribution is mainly in the hot humid and hot sub-humid climatic zones. The mean maximum temperature of the hottest month is 31–38°C and the mean minimum of the coolest, 12–22°C. There are 50–280 days over 32°C and 0–70 days over 38°C each year. The incidence of higher temperatures is greatest in the more inland parts of its distribution in the Northern Territory. No frosts have been recorded in the area of natural occurrence.

The 50 percentile rainfall is 880–1760 mm, the 10 percentile 560–1270 mm, and the lowest on record 345–775 mm. Rainfall has a distinct monsoonal pattern, with most rain falling during the summer months and a clearly defined dry season during the winter. There are on average 60–125 raindays per year.

Physiography and soils. *S. suborbiculare* is found in three physiographic divisions, i.e. Western Plateau, Eastern Uplands, and Interior Lowlands. It is associated with creeks and gullies in dissected sandstone plateaux and favours sand dunes and old sandridges in coastal areas and offshore islands. Other habitats are in the lowlands on alluvial and sandy plains along drainage channels. Soils are shallow sandy soils, yellow earthy sands, acid and neutral red and yellow earths, and sandy podzolics of low fertility.

Vegetation type. This species is found in low closed-forest, open-forest and woodlands. It is not a dominant species and is found associated generally with rainforest-type species such as *Carallia brachiata*, *Alphitonia excelsa*, *Glycosmis pentaphylla*, *Parinari nonda* and *Randia cochinchinensis*. Associated eucalypts include *E. tetrodonta*, *E. miniata*, *E. nesophila*, and *E. ptychocarpa* in open-forest communities. In other communities it occurs with *Casuarina equisetifolia*, *Syzygium banksii*, *Acacia crassicarpa*, *A. oraria*, *Mimusops elengi* and *Terminalia muelleri* (Boland et al. 1984).

Utilisation.

Fodder: Not used as a fodder tree.

Fuelwood: There are no reports to indicate whether it has been used as fuelwood, but it has potential for this purpose.

Wood: The heartwood is pale brown or pale grey-brown with a density of 770 kg/m^3. The sapwood is probably susceptible to *Lyctus* attack (Boland et al. 1984). There are lenses or rings of bark included in the wood, rendering it unsuitable for conversion to sawn timber. The trunk has been used for canoes by Australian Aboriginal people (Maiden 1889).

Other uses: This species has great potential for use as a shade tree and as an ornamental for amenity purposes. The fruits are edible (Hyland 1983) and were an important Aboriginal food source, containing 17 mg of vitamin C per 100 g of flesh (Wilson 1989). The juice when squeezed out of baked or boiled fruits is used to ease chest congestion (Lassak and McCarthy 1983). An infusion of crushed leaves was used by Aborigines as a remedy for diarrhoea, and the chewed fruit was used to ease sores in the mouth (Aboriginal Communities of the Northern Territory 1993).

Silvicultural features. A fire-tolerant species adapted to infertile, well-drained sites. It develops a lignotuber from which new shoots emerge if the plant is burnt or damaged (Brock 1988). *S. suborbiculare* coppiced well from 0.1, 0.5 and 1 m cutting heights in trials in Queensland (Ryan and Bell 1989).

Establishment: There are about 5–40 viable seeds/kg. Germination is rapid when fresh, e.g. fruit placed in a calico bag immediately after collection from the tree, resulted in 61% germination in 8–10 days while still in the bag (E.G. Cole, pers. comm.). The flesh should be removed from the seed immediately after collection. The seed is then sown beneath a layer of porous gravel. Older seed may take several months to germinate. For the purposes of storage it is suggested that the fruit be stored in airtight containers in a sterile moist medium, such as peat, to which a fungicide has been added. The container is then stored at 2–3°C (G. Sankowsky, pers. comm.). Little work has been published on a method of propagating this species after it has been in storage.

Yield: In trials in southeastern Queensland, two provenances averaged 3.4 m in height and 8.8 cm in basal diameter in 4.5 years (Ryan and Bell 1991).

Pests and diseases. The fruit is subject to heavy insect infestation, which appears not to affect the germinative capacity of the seed (E.G. Cole, pers. comm.).

Limitations. Problems associated with propagation of seed that has been stored for a considerable time may place a limit on the utilisation of this species. The wood contains lenses of bark that limit its conversion to sawn timber.

Related species. *S. suborbiculare* closely resembles *S. eucalyptoides* (F. Muell.) B. Hyland subsp. *bleeseri* (O. Schwarz) B. Hyland, and is sympatric with it. It is more closely related to *S. alliiligneum* B. Hyland and *S. velae* B. Hyland, which are tall trees in the rainforests of northeastern Queensland. They differ in having smaller flowers and fruits (Hyland 1983).

Terminalia arostrata

Main attributes. This species is an attractive, deciduous or semi-deciduous small tree to 12 m. It is adapted to heavy clay soils in the hot semi-arid tropics. It is progressively deciduous through the dry season. Moderately palatable to stock, an excellent fuelwood and with good potential for amenity planting.

Botanical name. *Terminalia arostrata* Ewart and Davies, (syn. *T. rogersii* W.V. Fitzgerald) in *Contrib. Qd Herb.* 20: 23 (1977). The generic name is derived from the Latin *terminalis* — terminal, in reference to the species' habit of bearing leaves at the ends of branches. The specific name is derived from the Greek *a* — without, and the Latin *rostratus* — beaked. The reference is to the mature fruit, which is not beaked as in some closely related species.

Common names. Nutwood, crocodile tree, badijiy (Aboriginal).

Family. Combretaceae.

Botanical features. A small tree 6–12 m, the young branches and branchlets are pendulous and the crown is rounded. The bark on the trunk is grey, deeply fissured and tessellated. The leaves are spirally arranged on the stem, sometimes crowded, somewhat leathery and shiny, narrowly or broadly obovate, obtuse at the apex and markedly narrowed at the base, 3–8 cm long by 1.5–3 cm wide; glands are present at the petiole, which is 0.8–3 cm long.

The inflorescence is a spike, as long as or longer than the leaves, with mixed bisexual and male flowers. Flowering takes place October–January. The fruit is a pseudocarp, though commonly referred to as a drupe. It is globular, smooth, 2–2.5 cm in diameter, 1-seeded, succulent on the outside with many mucilage cells, almost or quite beakless when mature. When immature it is green, with 3–7 obscure angles ripening to dark purple or black (Byrnes 1977). Fruits mature January–May but the fleshy globular fruits may remain on the tree for several months (Brock 1988).

It is described by Byrnes (1977) and illustrated by Aboriginal Communities of the Northern Territory (1993), Brock (1988), and Petheram and Kok (1983).

Natural occurrence. This is a species of northern Australia. It occurs in the northeastern Kimberley region of Western Australia and extends into northern

areas of the Northern Territory between Katherine and Tennant Creek. There are records of two small, disjunct populations near Broome and southwest of Broome on the coast of Western Australia.

- Latitude. Range: 14–20°S.
- Altitude. Range: 80–425 m.

Climate. Most of the distribution lies in the hot semi-arid climatic zone. The mean maximum temperature of the hottest month is in the range 38–40°C and the mean minimum of the coolest, 11–20°C. Average number of days per year when 32°C is exceeded is 190–275, and there are 75–100 days over 38°C. The area is frost-free.

The 50 percentile rainfall is 400–650 mm, the 10 percentile 200–450 mm, and the lowest recorded rainfall 110–250 mm. There is a strong summer monsoonal pattern, with a wet season from January to March. There are 40–60 raindays each year.

Physiography and soils. Nutwood is found only in the northern parts of the Western Plateau physiographic division. Commonly found on flat to gently undulating, low-lying alluvial plains, and less commonly on dissected plateaux. The soils are derived from sandstone, siltstone, shale, laterite, basalt or calcareous rocks. The soils are chiefly black or brown cracking clays, with minor areas of shallow red and brown shallow loamy soils. The heavy clay soils are often very stony on the surface (Perry 1960).

Vegetation type. Often forms pure stands or in association with *Terminalia oblongata* subsp. *volucris* or *Eucalyptus papuana* in open woodland (Byrnes 1977). Isolated trees are found in blue-grass (*Dichanthium* spp.) and barley Mitchell grass (*Astrebla pectinata*) grasslands. It may occur in low eucalypt woodlands either on plains of shale with *E. terminalis* and *E. argillacea*, or along drainage lines with *E. microtheca* and *E. tectifica*. Other associates include *Acacia farnesiana*, *A. stenophylla*, *A. victoriae*, *Atalaya hemiglauca*, *Lysiphyllum cunninghamii* and *Ventilago viminalis* (Perry 1960; Beard 1979).

Utilisation.

Fodder: Cattle are known to eat the leaves and fruit, which have a moderate nutritive value and palatability (Askew and Mitchell 1978; Petheram and Kok 1983).

Fuelwood: Nutwood is an excellent firewood (Hearne 1975; Brock 1988).

Wood: No data available. Can probably be used as small round timber for farm purposes.

Other uses: The weeping branches with the shiny leaves and rounded crown make this an attractive tree suitable for ornamental purposes in heavy soils, particularly in home gardens (Hearne 1975). It is favoured as an indoor plant because of its attractive zig-zag shoot formation.

The kernel and flesh of the fruit is edible (Petheram and Kok 1983), although the flesh is sour (Brock 1988). The Australian Aboriginal people made a medicinal wash by boiling leaves, branchlets and a small amount of inner bark in water. The wash was used to treat itchy skin, boils and localised skin infections, and to reduce fever (Aboriginal Communities of the Northern Territory 1993).

Silvicultural features.

Establishment: Propagation is by sowing fresh seed, which may take several months to germinate (Hearne 1975).

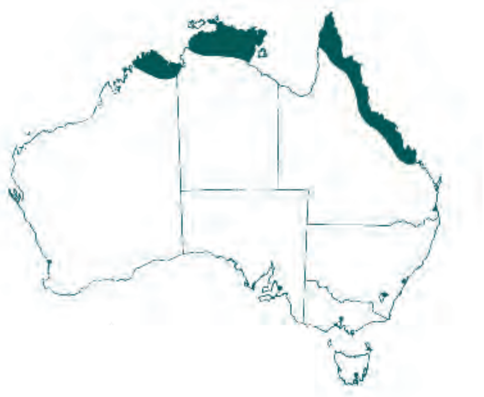
Yield: No data available.

Pests and diseases. The fruit is subject to attack by a species of Eriophydae, which have the effect of distorting them (Byrnes 1977).

Limitations. The small size of this species limits the use of its wood to fuel and small round timbers.

Related species. *T. arostrata* has an affinity with three other species, namely, *T. grandiflora*, *T. savannicola* and *T. cunninghamii*. The major difference is in the beakless mature fruit of *T. arostrata*.

Terminalia sericocarpa



Main attributes. A tree up to 30 m high, adapted to warm to hot humid tropical conditions. The species shows promise as an ornamental or in avenue plantings. The timber is suitable for internal construction and may be of use as a fuel. The purplish fruit are edible.

Botanical name. *Terminalia sericocarpa* F. Muell. in *Fragm.* 9: 159 (1875). The species name is from the Greek *sericos* — silky, hairy, and *carpo*s — fruit, alluding to the fruit that is thinly covered in silky hairs.

Common names. Damson, sovereign wood.

Family. Combretaceae.

Botanical features. A deciduous, medium-sized to tall tree up to 30 m, with a trunk diameter of 1 m, which is buttressed when the individual is fully developed. The bark is black or grey, tessellated and with distinctive longitudinal fissures. Branches are wrinkled with fine fissures, and develop laterally rather than from the apex (sympodial). The leaves are spirally arranged, obovate or broadly obovate to elliptical, 2–20 cm long and 1.5–8 cm wide, the leaf blade discolorous, shiny above and almost leathery. The leaves have small translucent dots due to the presence of calcium oxalate.

The inflorescence is a pubescent spike of white flowers with an unpleasant odour. Flowering occurs from September to November. Mature fruits are red or purple, succulent, thinly hairy or almost glabrous, ovoid and slightly compressed, 1.3–1.8 cm long by 0.8–1 cm wide. Seed is enclosed in a hard nut-like endocarp. Fruits ripen from January to May.

The species is described by Byrnes (1977) and Pedley (1990b) and illustrated by Boland et al. (1984) and Brock (1988).

Natural occurrence. Damson has a wide distribution in tropical regions of northern Australia. The distribution extends from the northern Kimberley region of Western Australia into the Northern Territory, and from Cape York Peninsula to near Rockhampton in central Queensland.

- Latitude. Range: 10–24°S.
- Altitude. Range: near sea level to 750 m.

Climate. The distribution is in the warm humid climatic zone in southern coastal areas and in the warm humid and hot humid climatic zones in the northern parts of the range. The mean maximum temperature of the hottest month is 30–40°C and the mean minimum of the coolest 10–22°C. There are 15–95 days per year over 32°C, and 0–4 days over 38°C. The area is frost-free.

The 50 percentile rainfall is 850–2100 mm, the 10 percentile 600–1300 mm, and the lowest on record 370–1050 mm. In the north of the distribution the rainfall pattern is monsoonal, with the majority of rain from January to March; further south there is a strong summer maximum. *T. sericocarpa* often grows along watercourses where the water available for growth is somewhat greater than the rainfall indicates.

Physiography and soils. This species is found in the Western Plateau, Interior Lowlands, and Eastern Uplands physiographic divisions. Restricted mainly to watercourses within sandstone or laterite-capped plateaux, granite foothills, and lowlands and alluvial plains. It is also found on sandy beach ridges in dry coastal zones. Soils are chiefly alluvials derived from acid and basic rocks. Soil types include yellow podzolics and lithosols on granite, basaltic red earth, sandy grey earth, yellow earth derived from shale, stony red earth, brown earth and calcareous beach sand.

Vegetation type. *T. sericocarpa* grows to canopy height in such rainforest types as complex mesophyll vine forest, semi-deciduous mesophyll vine forest, and complex notophyll vine forest (Tracey 1982). It generally occurs as scattered trees together with other deciduous species, in the vine forest often as discontinuous strips along stream banks. It may be locally dominant (Byrnes 1977). In notophyll vine forest on coastal beach ridges, *T. sericocarpa* is a component of the canopy 10–15 m high. Elsewhere it may be found in fringing low woodland to low open-forest.

Utilisation.

Fodder: Not known to have been used as a stock feed.

Fuelwood: It is not known to have been used as a fuelwood in Australia.

Wood: Heartwood pale brown and yellow sapwood, and has a medium and even texture. The air-dry density is about 640 kg/m^3, is easy to dry and to work, and glues well. In Australia it has been used for internal joinery (e.g. framing, windows and door sills), but is not recommended for use in exposed conditions (Bootle 1983).

Other uses: Shows promise for ornamental use and in mixed shelterbelt plantings. It is recommended for use in avenues (Hearne 1975).

The bark is reputed to have been used as a fish poison. It contains about 8% tannin (Webb 1948). The purplish fruit are edible (Brock 1988).

Silvicultural features.

Establishment: The seeds germinate easily when sown promptly after collection, and seedling growth is rapid. Deciduousness is induced by drought, but regular dry-season irrigation promotes continuous leaf growth, giving an evergreen effect (Hearne 1975). Should the tree be allowed to follow its natural seasonal pattern, then this is one of the few terminalias in which the leaves become brightly coloured before falling (Byrnes 1977).

Yield: No data available.

Pests and diseases. The sapwood is susceptible to *Lyctus* borer attack.

Limitations. Sensitive to drought and frost.

Related species. The marked transverse veins on the shiny upper surfaces of the leaf separate *T. sericocarpa* from the other 28 Australian species of *Terminalia*. It is closely related to *T. microcarpa* from Malaysia and resembles *T. catappa* (Byrnes 1977; Boland et al. 1984).

SPECIES DIGESTS

LIST OF MINOR SPECIES

Acacia ancistrocarpa Maiden and Blakely

Fitzroy wattle, pindan wattle.

Uses This species has potential to produce small-sized firewood and could be used for erosion control and low shelter. Seeds are edible. **Description** A nitrogen-fixing multi-stemmed shrub 2–7 m with grey bark. Shiny green phyllodes, 1–3 nerved. Perfumed yellow flowers are in dense spikes. Pod dark brown, raised over the seeds and opening elastically at maturity. Seeds are shiny light brown, ovate, 5–7 mm long by 3–5 mm wide, oblique. **Distribution** A common species from coastal northwest Western Australia to western Queensland. **Climate** Principally in the semi-arid subtropics. Rainfall range 200–700 mm/year. Seasonal distribution is a summer maximum, somewhat monsoonal in the north. **Soils** On shallow earthy sands over laterite, sand plains, and deep red siliceous sands, mainly acidic and permeable. **Growth** Annual height growth rate of 80–90 cm has been recorded of two Australian provenances introduced into dry areas of Niger and Upper Volta. Low survival rate in years following planting suggests these provenances were poorly adapted to local climatic and soil conditions. **Further information** Turnbull (1986).

Acacia argyrodendron Domin

Black gidyea, blackwood.

Uses It has potential for shelter, erosion control and amenity planting. A good fuelwood and source of charcoal. Wood is heavy, hard and strong and has been used for posts, poles, and rails. Phyllodes and pods are readily eaten by stock. **Description** A tree of 8–25 m, bark hard, furrowed, dark grey or black. Phyllodes straight, linear, 1–3 nerved. Flowers are in globular heads. Pod is linear, seeds with thin seedcoat, oblong and longitudinally arranged. **Distribution** A compact distribution across the Great Dividing Range in central Queensland. **Climate** A species principally of the warm semi-arid climatic zone. Rainfall range 450–650 mm/year. There is a strong summer maximum precipitation and a dry spring. The dry season extends for 4–6 months. **Soils** It grows on sandy alluvium, clay soils and red-brown sandy clay loams. **Growth** This long-lived acacia may regenerate by root suckers, and can coppice. Growth rate is slow and seed difficult to obtain. **Further information** Turnbull (1986).

Acacia bancroftii Maiden

Uses A decorative species that is grown successfully as a garden species in coastal Queensland. No data available on wood properties, but it should be satisfactory as a fuelwood or small round timber. **Description** Tree 5–6 m, single-stemmed, spindly, canopy sometimes dense. Bark rough on lower trunk smooth above, reddish or grey mottled. Branches glaucous or white pruinose. Phyllodes obliquely obovate, bent near the base, often glaucous, prominent midrib. Flowers bright yellow in globular heads. Pods in clusters, straight or curved, often glaucous with nerve-like margins. Seeds longitudinal, black, oblong. **Distribution** A common species in inland central Queensland. **Climate** Distribution is entirely in the warm sub-humid climatic zone. Rainfall range 500–700 mm/year, with a well-developed summer maximum. Dry season of 1–4 months. **Soils** Confined mainly to sandy skeletal soils on stony hillsides and ridges, but occasionally on deeper richer soils. **Growth** Fast-growing in trials in southeastern Queensland. **Further information** Stanley and Ross (1983), Simmons (1981), Ryan and Bell (1991).

Acacia bidwillii Benth

Corkwood wattle.

Uses Useful for light shade, ornamental planting and emergency fodder. The timber is hard, close-grained and takes a good polish. Makes a good fuel. **Description** Small tree, 6–12 m tall, straight trunk, bark dark grey-brown, corky and shallowly furrowed. Phyllodes are bipinnate, with 4–15 pairs of pinnae. Flowers are lemon-yellow, in globular heads. Pod flat, nerved, woody, seeds pale brown, oval, large. **Distribution** A Queensland acacia from the Burnett district in the south to Mt Carbine in the north and west to Mt Isa. **Climate** A warm sub-humid climate. Rainfall range 380–850 mm/year with a well-defined summer maximum. The dry season extends 2–6 months. **Soils** The soils are chiefly of heavier texture: fine grey silts, alluvials, clay loams and stony red clays; less common are yellow earths or uniform sandy soils. **Growth** A drought-tolerant and fire-resistant tree, it proved hard to establish in trials in southeastern Queensland. **Further information** Turnbull (1986).

Acacia blakei Pedley

Uses *A. blakei* has potential as a shade and shelter tree. Little data available on wood properties but should be suitable for fuelwood. **Description** An erect tree to 13 m with dark grey, fissured bark. Phyllodes straight or slightly curved, glabrous or sparsely pubescent on young plants, many-nerved, 2–3 more prominent. The yellow flowers in dense spikes, in early spring. Pod linear, converse over the seeds, seeds longitudinal. **Distribution** The distribution extends from central to southeastern Queensland and into northeastern New South Wales. **Climate** Occurs mostly in the warm sub-humid climatic zone, but in the extreme west adjoins the semi-arid zone. Rainfall range 650–900 mm/year with moderate to well-developed summer maximum. **Soils** Common soil types are sands, sandy loams, shallow sands over sandstone and red lateritic soils. **Growth** A hardy, fast-growing tree (> 2 m/year) for use in subtropical coastal areas. **Further information** Tame (1992), Stanley and Ross (1983).

Acacia concurrens Pedley

Uses *A. concurrens* has potential for use as a stock food during drought, and is useful for site rehabilitation after sand mining. No data available on wood properties, but should be suitable for fuelwood. **Description** A bushy shrub to small tree 2–10 m. Bark is hard, dark and furrowed longitudinally. Phyllodes are obliquely obovate, upper margin curved, lower straight, 3-nerved. Flowers are in cylindrical spikes. Pods are linear, coiled, leathery, seeds longitudinal with large aril. **Distribution** It is limited to coastal southeastern Queensland, extending to north coastal New South Wales. **Climate** Coastal areas are in the warm humid climatic zone and inland in the warm sub-humid zone. Rainfall range is 900–1200 mm/year and incidence is a moderate summer maximum. **Soils** The soils are often sandy, but include brown clay loams and black sandy loams. **Growth** A fast-growing (2.5 m/year) small tree for use in subtropical coastal areas. **Further information** Tame (1992), Pedley (1987).

Acacia crassa Pedley

Uses A species that has potential for use in windbreaks, parks or gardens and on farms in warm temperate and subtropical inland and coastal areas. No data available on wood properties but should be suitable for fuelwood. **Description** An attractive, multi-stemmed shrub 3–5 m or single-stemmed tree to 10 m. Bark is rough, often gnarled. Branchlets usually reddish with distinct lenticels, glabrous or covered with dense hairs. Leaves are falcate, with 3 prominent nerves, basal gland. Flowers in dense spikes, bright yellow, 2 per axil. Pod linear, dark brown, raised over the seed. Seeds are black, oblong, longitudinal in the pod, with yellow terminal arils. **Distribution** Found from central and southeastern Queensland, then south into northeastern New South Wales. **Climate** Occurs principally in the warm sub-humid climatic zone. Rainfall range 560–705 mm/year, falling mainly in summer. **Soils** Soils are skeletal, reddish to brown sandy loams, usually well-drained. **Growth** A hardy, fast-growing (> 2m/year) tree, suckers but coppices poorly. **Further information** Tame (1992), Simmons (1988).

Acacia cretata Pedley

Uses A species that is suitable for growing in subtropical conditions. Its wood is available only in small sizes, but should be suitable for fuel. **Description** A shrub 2–3 m or small tree to 8 m. Bark smooth whitish-grey becoming rough and fibrous with age. Leaves glabrous, glaucous, lanceolate, 2–3 nerved. Branchlets angular, with a chalky white bloom. Flowers in cylindrical spikes, bright to pale yellow. Pod glabrous, linear, somewhat contracted between the seeds. Seeds longitudinal. **Distribution** It is limited to central Queensland, notably the Blackdown Tableland, west of Rockhampton. **Climate** The species is in the warm sub-humid to humid zone. Rainfall range 750–845 mm/year with a well-developed summer maximum. **Soils** Soils include podzols, shallow gravelly sands and light sandy loams. **Growth** This species has grown very rapidly (> 3 m/year) in southeastern Queensland and is worthy of more extensive testing on well-drained soils in subtropical conditions. **Further information** Pedley (1987), Ryan and Bell (1991).

Acacia doratoxylon A. Cunn.

Currawang, lancewood.

Uses A prolific pollen producer and an attractive ornamental tree. Timber is hard, heavy and close-grained. The foliage is eaten by stock. **Descrip - tion** Tall shrub or tree 3–10 m, with dark brown, fissured bark and red-brown branches. Branchlets smooth, reddish, angular but round when mature. Leaves are greyish-green, glossy when fresh, long, leathery and many-nerved. Flowers are dense in cylindrical spikes, bright yellow. Pod dull brown, slightly constricted between the seeds. Seeds black, shiny, longitudinal. **Distribution** It is limited to central slopes and the southern tablelands in New South Wales and northeastern Victoria. **Climate** Occurs mainly in the warm sub-humid and warm semi-arid climatic zones and in the cool sub-humid zone on the southern tablelands. Rainfall range 400–600 mm/year with a weak summer maximum in the north and nearly uniform in the south. **Soils** Soil types include coarse and gravelly sands and lithosols and red earths. **Growth** A fast-growing (2.6 m/year), drought- and frost-tolerant species that requires well-drained soils. **Further information** Simmons (1981), Cunningham et al. (1981).

Acacia falciformis DC.

Broad-leaved hickory.

Uses A species useful for erosion control and shelterbelts on steep slopes and poor soils. Good for fire-wood and charcoal. Timber is heavy, durable, tough and suitable for use in tool handles, posts, and poles. Bark contains tannin once used in the leather industry. **Description** Large spreading shrub 5–8 m or small tree 10–12 m. Bark is hard, rough and dark grey. Phyllodes are grey-green, long, curved, 1-nerved, large gland on upper margin. Flowers in globular heads. Pods are flat, broad, constricted between seeds. Seeds longitudinal. **Distribution** From coast to tablelands from Victoria to southern Queensland with disjunctions north. **Climate** Found in warm and cool sub-humid and humid climatic zones, most areas experience heavy frosts. Rainfall range 600–900 mm/year and varies from a weak winter maximum in the south to a moderate summer maximum in the north. **Soils** Commonly found on lithosols, yellow earths, and sandy podzolics of low fertility. **Growth** It is long-lived and fast-growing in first 5–7 years. Root suckers after fire. Recommended for trial on relatively cool, moist sites. **Further information** Turnbull (1986).

Acacia latzii Maslin

Latz's wattle.

Uses A species that is suitable for low shelter and windbreaks. No data available on wood properties, but it should be satisfactory as a fuelwood or small round timber. **Description** A shrub to 4 m or small tree 6 m. Bark dark grey, rough and fissured. Leaves broad-linear, faint longitudinal venation. Flowers in globular heads. Pod broad linear, leathery, seeds longitudinal, oblong or oval. **Distribution** Restricted to the southern Northern Territory. **Climate** In the warm arid climatic zone, with some heavy frosts. Rainfall range 160–250 mm/year and greatest during summer. **Soils** Occurs on red earths or lithosols of low fertility, high alkalinity and may be somewhat saline. **Growth** A long-lived, drought-tolerant species. This species has not been cultivated widely, so little is known of its silvicultural requirements and growth rate. It gave high survival in one trial in Senegal, but grew slowly. **Further information** Turnbull (1986).

Acacia ligulata A. Cunn. ex Benth.

Sandhill wattle.

Uses The species' primary use is for sand stabilisation in arid areas; potential for low windbreaks. Recommended for planting on saline or alkaline soils. Highly suitable for small-sized fuelwood. Phyllodes are eaten by cattle, unpalatable to sheep. **Description** Bushy shrub 1–5 m with many fine branches. Bark smooth grey, branchlets light brown or yellow. Phyllodes linear or linear-oblong, flat, thick and 1-nerved. Flowers orange-yellow in globular heads. Pods thick, woody, linear. Seeds longitudinal in the pod. **Distribution** *A. ligulata* has an extensive occurrence in dry inland Australia. **Climate** Occurs in warm arid, hot arid and warm semi-arid climatic zones. Rainfall range 100–700 mm/year with a weak to moderate summer maximum. Dry season of 5–11 months. **Soils** It occurs on a range of soil types but is common on sands or loamy sands, neutral or alkaline. **Growth** Moderately salt-tolerant. Fast initial growth, regenerates from root suckers and coppice. Tolerates some of the hottest and driest conditions in Australia. **Further information** Turnbull (1986), Chapman and Maslin (1992).

Acacia macdonnelliensis Maconochie

Irrara, irrkuwartaka.

Uses A very drought-tolerant species with potential for planting on harsh sites in hot, arid areas. The species has potential for low windbreaks. Wood is generally only available in small sizes, but makes good quality fuel. **Description** A spreading shrubby tree 3–6 m. The bark is dark grey and compact to fissured. Phyllodes are linear, finely nerved. Flowers bright yellow in spikes. Pods are narrow, dark brown. Seeds arranged longitudinally, black-brown. **Distribution** Distribution is restricted, in the south of the Northern Territory and the adjacent area of Western Australia. **Climate** It grows in the warm arid zone. Heavy frosts occur in winter. Rainfall range 200–300 mm/year. Most rain is in summer, but is highly variable from year to year. **Soils** Soils are acidic and of low fertility. **Growth** It is slow-growing, long-lived, and coppices poorly. **Further information** Turnbull (1986).

Acacia monticola J.M. Black

Turpentine, pindan minni ritchi.

Uses A species that is quite ornamental. It could provide small-sized firewood, low shelter. Wood has been used for gates and light fences on rural properties. **Description** A spreading, multi-stemmed large shrub or single-stemmed tree 2–8 m. Minni ritchi bark. Phyllodes are grey-green, oblong or obovate, 3–5 nerved. The deep yellow fragrant flowers are on globular heads. Pod is flat, narrow-oblong, resinous, raised over the seeds. Seeds brown to dark brown, transverse. **Distribution** Occurs in northern and northwestern Australia: in the Northern Territory, Western Australia and northwestern Queensland. **Climate** It is found mainly in the hot semi-arid and hot arid climatic zones. Rainfall range 150–800 mm/year. A strongly developed monsoonal rainfall pattern in the north. A 7–9 month dry season. **Soils** Wide variation in soils, but grows mainly on rocky sandstone, acidic sites. **Growth** It has fast to moderate growth, moderate life span and coppices poorly. **Further information** Turnbull (1986).

Acacia pendula A. Cunn. ex G. Don

Myall, boree, weeping myall.

Uses A species useful for windbreaks, shade, shelter and amenity. Wood is heavy, suitable for turnery and as fuel. Foliage provides forage for stock during drought. **Description** An erect tree to 12 m tall, trunk divides at 1–4 m with 2–4 ascending main stems. Foliage is silvery and pendulous. Phyllodes are linear lanceolate, straight or curved with a basal gland, many nerved, 1–3 prominent. Flowers are dull yellow in globular heads. Pods are thin, flat with seeds transverse. **Distribution** Occurs on the inland side of the Great Dividing Range in eastern Australia from Victoria and Central Queensland. **Climate** It is found mainly in the semi-arid climatic zone. Rainfall range 400–650 mm/year. Seasonal rainfall varies from a weak winter maximum in the south to a summer maximum in the north. **Soils** It is restricted to clay soils or better drained, neutral, calcareous or alkaline red earths. **Growth** It is a slow growing species. **Further information** Turnbull (1986).

Acacia podalyriifolia A. Cunn. ex G. Don

Queensland silver wattle.

Uses An ornamental species with potential for windbreaks. Adapted to well-drained soils, usually acidic and of low fertility. Wood used for posts and rails, small joinery items and low quality firewood. A good source of pollen for bees, and the bark has moderate tannin content. **Description** A bushy shrub to small tree 2–6 m with open crown. Bark is thin, smooth, and grey. Phyllodes are glaucous, silvery, broadly ovate, hairy when young. Flowers are fragrant and bright golden-yellow. Pods flat long, hairy or smooth, glaucous, maturing brown, seeds longitudinal, black, oblong-oval. **Distribution** Confined to southeastern Queensland and naturalised in garden escapes from northern Queensland to southern New South Wales. **Climate** Mainly in the warm sub-humid climatic zone. Rainfall range 700–1150 mm/year with a well-defined summer maximum. **Soils** Found on clays, lithosols, sandy loams and shallow podzolics. **Growth** It is fast-growing (> 1 m/year) but short-lived (ca 12 years), and coppices poorly. **Further information** Turnbull (1986).

Acacia pruinocarpa Tindale

Black gidgee, gidgee, tawu.

Uses The species makes an attractive ornamental and shade tree in arid regions. The timber is hard and heavy, useful for posts, small round timber and fuel. **Description** Shrub or small tree 4–12 m, with dense canopy; sometimes multi-stemmed. Dark grey, striated, fibrous bark. Phyllodes falcate or straight, linear, thick, leathery, glaucous, prominently one-nerved, large gland on upper margin. Bright yellow flowers in globular heads. Pod papery, narrow-oblong, blue-grey, waxy surface, not constricted between the seeds. **Distribution** Occurs in central Western Australia, south-western Northern Territory and northwestern South Australia. **Climate** Restricted to the warm arid climatic zone. Rainfall range 200–275 mm/year, mostly falling in winter. **Soils** Soils are red earthy sands, red dune-sands, sandy or gravelly loams. **Growth** A slow-growing species, adaptable to arid conditions in acidic or alkaline infertile soils. It tolerates fire and produces root suckers and coppice. **Further information** Turnbull (1986).

Acacia victoriae Benth

Prickly wattle, bramble wattle.

Uses Wood has potential for small fuelwood. A useful stock forage, low windbreak and sand-dune stabiliser. Seeds are edible and were a seasonally important food source for central Australian Aboriginals. **Description** A dense or straggly, thorny multi-stemmed shrub 1–5 m or tree 4–9 m. Phyllodes greyish green, linear to oblong, spiny stipules at the base. Flowers on pale yellow spherical heads. Pods are papery, flattish, seeds transverse brown to dark brown, almost globular. **Distribution** Grows throughout the dry country of central Australia. **Climate** The species is found in the hot and warm arid and semi-arid climatic zones. Rainfall range 100–1000 mm/year. Seasonal distribution varies from monsoonal pattern in the north to winter–spring maximum in the south. **Soils** Found on a range of soil types from acid to alkaline or moderately saline. **Growth** It is a fast-growing species of moderate life span that coppices and root suckers readily. **Further information** Turnbull (1986).

Acacia xiphophylla E. Pritzel

Snakewood.

Uses Has potential for planting for fuelwood, shade, and shelter in desert conditions. **Description** A spreading, frequently multi-stemmed shrubby tree, 2–7m. Bark grey and fibrous on the main trunk. Phyllodes are thick, straight, 3 prominent nerves, leathery. It has pale yellow flowers in a long spike. Pods straight, seeds longitudinal, almost orbicular and flattened. **Distribution** Occurs in a compact area in northwestern Western Australia. **Climate** The species grows in the warm arid and hot arid climatic zones. Rainfall range 200–350 mm/year. A summer monsoonal pattern in the north changes to a winter maximum in the far south. **Soils** It is typically found on finer-textured soils, particularly clays, which may be alkaline or subsaline. **Growth** This is a slow-growing, long-lived species of fair coppicing ability. **Further information** Turnbull (1986).

Allocasuarina campestris (Diels) L. Johnson

Uses Wood has potential for use as small-sized fuel. The habit makes it most suitable for low-level wind protection for stock and for soil conservation. **Description** A bushy, multi-stemmed shrub, 1–5 m high, sometimes erect, although the crown remains dense. Cones sessile or subsessile, with valves protruding or flush with the surface. Surface of valves divided into four 'protuberances'. **Distribution** The overall distribution is in the southwest of Western Australia. **Climate** The species is found mainly in the warm semi-arid climatic zone. Rainfall range 220–400 mm/year. There is a clearly defined winter maximum. **Soils** Occurs on a wide variety of soils including calcareous sands and red earths, yellow siliceous sands and earthy sands, acid and neutral red or yellow earths, solonized brown soils, and solodized solonetz and solodic soils. Many are infertile. **Growth** No growth data available. It is known to root sucker. **Further information** Turnbull (1986).

Allocasuarina decaisneana (F. Muell.) L. Johnson

Desert sheoak, desert oak.

Uses An attractive drought-tolerant tree useful for park, avenue and shade planting in arid zones. It is sometimes eaten by cattle when fodder is scarce. The heartwood is very hard and durable against termites. It is suitable as a fuel and can be used for round farm timbers. **Description** A distinctive tree 9–12 m with pendulous branchlets and a stout straight trunk of 3–5 m. Bark is thick, deeply fissured, and usually blackened by fire. Cones are large and woody, sessile or with short stalks, cylindrical, largest in the genus. **Distribution** Desert oak is restricted to central Australia in three states: the Northern Territory, Western Australia and South Australia. **Climate** It is found in the arid climatic zone. Rainfall range 200–250 mm/year. Seasonal patterns vary greatly, but a summer maximum is usual. **Soils** Soils are chiefly red earthy sands or red-brown loamy sands. **Growth** The relatively slow growth and intolerance of saline and alkaline conditions will restrict the use of this species. **Further information** Turnbull (1986).

Allocasuarina littoralis (Salisb.) L. Johnson

Black sheoak, black oak.

Uses A drought- and frost-tolerant species useful for wind-breaks and for soil protection. The wood has been used extensively for turnery, handles, structural timbers and fuel. **Description** A shrub or small tree 1–15 m tall, with an erect habit and narrow crown on favourable sites. The bark is dark grey, hard, closely fissured. Cones are more or less cylindrical. **Distribution** It extends from the northern extremity of Queensland in a belt along the eastern coast of Australia to Victoria and Tasmania. **Climate** Most of the occurrence is in the warm sub-humid and humid climatic zones, elsewhere in the cool sub-humid zone and the hot humid zone. Rainfall range 650–1250 mm/year. Incidence varies from north to south from summer maximum to uniform to winter. **Soils** Major soil types are sands, podzolics, yellow earths, solodics, lithosols, and skeletals. **Growth** A fast-growing tree (> 1 m/year) but with poor coppicing ability. **Further information** Turnbull (1986).

Atalaya hemiglauca (F. Muell.) F.Muell. ex Benth.

Whitewood, western whitewood.

Uses It is used mainly for shade, shelter, as drought fodder or as an ornamental. The timber is soft, non-durable, and splits easily. **Description** Small tree 7–9 m tall or bushy shrub 3–6 m with erect trunk or multi-stemmed, rough grey bark on the trunk. Canopy is somewhat narrow, bluish-grey. Leaves compound with 1–3 pairs of leathery leaflets, bluish-green above, and paler beneath. Inflorescence of large panicles of creamy-green flowers. Fruit is a winged hairy samara. **Distribution** Found from northern Western Australia, Northern Territory into central Queensland and northwestern New South Wales. **Climate** It extends from the sub-humid zone southward into subtropical and warm temperate regions to semi-arid and arid zones. Rainfall range 250–650 mm/year. Seasonal incidence varies from a strong summer monsoon in the north to a weak summer maximum in the south. **Soils** Soils are mainly red earthy or siliceous sands, loamy soils and red brown earths. **Growth** A slow-growing, drought-tolerant species. Readily propagated from seed or root suckers. **Further information** Turnbull (1986).

Buckinghamia celsissima F. Muell.

Spotted silky oak, ivory curl.

Uses An excellent species for gardens, street and avenue planting. A hard and durable timber recommended for general building framing, flooring and joinery, which should not be in ground contact. Probably useful as a fuel. **Description** A tree attaining 30 m in rainforest, but often reaching only 10 m with bushy crown in the open. Bark is dark brown, rough and hard, either scaly or with scattered pustules. Leaves are alternate, elliptical-oblong, dark green above, glaucous or silvery beneath. White flowers in spikes, fruit a broad ovate follicle. **Distribution** It has a limited natural distribution in coastal north Queensland. **Climate** It is found in the warm humid to wet climatic zones. Rainfall range 1300–1800 mm/year. Seasonal occurrence shows a strongly- developed summer maximum. **Soils** Soils are brown and yellow earths. **Growth** An evergreen, fast-growing, somewhat drought- resistant and frost-hardy tropical species. Has the ability to coppice and root sucker. **Further information** Turnbull (1986).

Callitris endlicheri (Parl.) Bailey

Black cypress pine.

Uses A species used in either windbreaks or woodlots, which may be of value for watershed protection and erosion control. The wood is suitable for firewood, charcoal, fencing and building timber. Resin is used for varnishes and bark for tannin. **Description** A small single-stemmed, sometimes multi- stemmed tree 6–12 m, or a small bushy shrub on adverse sites. Bark hard and somewhat fibrous, persistent to the small branches. Leaves are in alternating whorls of three, green or glaucous. The flowers are monoecious. Woody cones ovoid to globular, small dorsal point near apex, seeds dark brown, winged. **Distribution** It occurs in south-eastern Australia. **Climate** Found mainly in the warm sub-humid zone, with limited extension into the warm semi-arid and warm humid zones. Rainfall range 550–900 mm/year. Incidence varies from a moderate summer maximum in the north to a winter maximum in the south. **Soils** On soils of low fertility, such as brown podzolics or sandy lithosols. **Growth** A slow-growing but frost-resistant and moderately drought-resistant conifer. **Further information** Turnbull (1986).

Cassia brewsteri (F. Muell.) F. Muell. ex Benth.

Brewster's cassia.

Uses It has potential to produce fuelwood and provide shade and shelter. It is suitable for coastal planting and is an excellent ornamental. A general purpose hardwood and cabinet timber. **Description** A tree of 30 m in lowland rainforest, but in eucalypt woodland is usually 7–8 m, sometimes a shrub of 2–4 m. The bark is dark grey, hard and furrowed on the trunk, flaky above. Leaves are alternate, pinnate with 2–4 leaflets. Flowers yellow, orange or reddish, in pendulous racemes. Pods are circular, straight, with distinct transverse ribs, seeds flat, yellow-brown. **Distribution** It occurs in eastern Queensland. **Climate** It is found in warm humid areas of coastal lowlands. Inland areas are warm sub-humid, extending to the fringes of the warm semi-arid climatic zone. Rainfall range 1100–1350 mm/year with a summer maximum. **Soils** Best development is on deep, fertile clay loams derived from volcanic substrates or on alluvials, but it grows on a wide range of soils. **Growth** This attractive, relatively drought-tolerant tree is very slow-growing. It regenerates freely from root suckers. **Further information** Turnbull (1986).

Casuarina obesa Miq.

Western Australian swamp oak.

Uses A useful species in shelterbelts, avenue and ornamental planting. The wood is very hard, heavy and difficult to work. Used for fence posts and has good potential to produce fuelwood. It is grazed by sheep and cattle. **Description** A 1–2 m shrub or small tree 5–14 m tall. The bark is hard, greyish, slightly tessellated. Cones are woody, globular, truncate. **Distribution** It is found in the southwest of Western Australia and in northwestern Victoria. **Climate** Lies in the warm sub-humid, warm semi-arid and warm arid zones. Rainfall range 250–500 mm/year with a well-defined winter incidence. **Soils** The soils are mainly sandy or silty but include saline loams, calcareous and sandy earths, and grey cracking clays. **Growth** Tolerant of salty and waterlogged soils and salt spray, but intolerant of fire, *C. obesa* is a strong coloniser. It produces root suckers prolifically. **Further information** Turnbull (1986).

Dendrolobium umbellatum (L.) Benth.

Horse bush.

Uses Useful for forage, protection planting and erosion control on beaches and sand dunes. Wood is hard with good tensile strength and potential for use as posts, small poles and fuelwood. **Description** Shrub or small tree, 1–10 m tall. Lower bark is grey, tessellated and flaky. Leaves are 3-foliate, leaflets oval or oval-oblong, hairy beneath, deciduous or semi-deciduous in the dry season. Flowers are white pea-flowers. Pod narrowly oblong, indehiscent, seeds elliptical in corky or woody articles when mature. **Distribution** Pantropical from Africa to the Pacific Islands. In Australia it extends through Cape York to near Townsville in northeast Queensland. **Climate** In warm to hot sub-humid climatic zones. Rainfall range 850–1750 mm/year. A summer monsoonal pattern in the north and a summer maximum in the south. **Soils** Occurs mainly on sandy soils but has been recorded on soils of high pH and also friable loams. **Growth** A drought-tolerant species capable of fast growth. It coppices and can grow on alkaline soils. **Further information** Turnbull (1986).

Dodonaea viscosa Jacq.

Giant hopbush.

Uses A species used for forage, medicines (leaves), as a sand stabiliser and for amenity. The wood is extremely dense, close- grained, durable, used for fuelwood, turnery, toolhandles. **Description** Spreading, dense or erect, multi-stemmed shrub or single-stemmed small tree usually 1.5–5 m but up to 8 m. Seven subspecies are recognised. Leaves variable in shape, linear to obovate or spatulate, bright green, leathery or papery, sticky. Male and female flowers on separate plants. Fruit is a capsule, 3–4 wings, dark red-brown, purple, pink, yellow or light brown. Seeds 2–4 lenticular dull black. **Distribution** It has a widespread distribution over the Australian continent. **Climate** The varieties cover most climatic zones especially the drier types where the rainfall range is 120–500 mm/year. **Soils** Soils are mainly desert sands, red earthy sands, sandy or clay loams, shallow gravelly or stony soils. **Growth** Tolerant of drought, alkaline and saline soils, but intolerant of fire; this aggressive coloniser may become a weed. It coppices and root suckers. **Further information** Turnbull (1986).

Elaeocarpus bancroftii F.Muell. and F.M. Bailey

Kuranda quandong.

Uses The wood is heavy and hard, brown to pale brown, with fine, numerous rays. Used for general construction and flooring. The seed kernel is edible; taste reminiscent of hazelnut. **Description** A rainforest tree to over 30 m. Bole fluted, flanged or buttressed. Bark hard and scaly, rough on large trees. Leaves simple, alternate or whorled, obovate or elliptic, turning red before falling. Inflorescence axillary or terminal, flowers white or cream, irregular. Fruit green or blue, flashy, indehiscent. **Distribution** It is widespread in northeastern Queensland from Cooktown to Tully. **Climate** Occurs in the warm humid to wet climatic zones. Rainfall range is 2000–3600 mm/year. Rainfall incidence is a strongly developed summer maximum. **Soils** Soil types include alluvia or brown and yellow earths. **Growth** No growth data available. The species is sensitive to drought and frost. Propagation is by seed or cuttings. **Further information** Francis (1970), Hyland and Whiffin (1993).

Eucalyptus brevifolia F. Muell.

Northern white gum.

Uses Has potential for fuelwood, light shade and low shelter. The wood is red, very hard, brittle and resistant to termite attack, used for posts and rails. **Description** A tree, 6–12 m tall, bark decorticates to leave a powdery surface, white, pink or yellow. Leaves are alternate, ovate to narrowly lanceolate, grey-green, stalk yellow. Flower buds are in umbels of seven. Mature fruit is woody, cup–shaped, valves small, slightly exserted. Seeds are round to elliptical. **Distribution** It occurs in the Kimberley region of northern Western Australia, extending into adjoining western areas of the Northern Territory. **Climate** Principally in the semi-arid climatic zone, with extension north into the sub-humid zone and southwards into the hot, arid zone. Rainfall range is 450–700 mm/year. Northern parts of the distribution have a well-developed summer monsoon, elsewhere erratic with a summer maximum. **Soils** Chiefly stony, sands and sandy loams. **Growth** Tolerant of drought and infertile soils, but intolerant of frost. Is of moderate to slow growth rate. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus gongylocarpa Blakely

Desert gum, marble gum.

Uses A useful species for shade and shelter. It has the potential to provide fuelwood and roundwood. **Description** Tree 8–12 m tall, sometimes to 20 m, wide crown. Bark is smooth, white to silver-grey, flaky on the trunk and larger branches. Leaves opposite, glaucous or grey-green. The glaucous, club-shaped buds are in 3–7 white-flowered umbels. The fruits globular, valves not exserted. The seeds are grey-black, sometimes with narrow flanges. **Distribution** It is found in desert regions in central and southern Australia. **Climate** Occurs in the warm arid climatic zone with very high summer temperatures. Rainfall range 150–250 mm/year. Long-term mean values indicate a summer maximum. **Soils** Usually found on red or red-brown, sands or loamy sands, often over red and brown massive hardpan. **Growth** This species is fire- and drought-tolerant and adapted to infertile soils. Growth data are not available. It coppices well. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus ochrophloia F. Muell.

Yapunyah, napunyah, lapunyah.

Uses Is suitable for heavy construction timber and is used for fence posts. Provides shade and shelter, is an attractive ornamental and produces good honey. Wood is very heavy and durable. **Description** A tree 6–20 m, bark dark grey and subfibrous to scaly near base, smooth above, grey to coppery. Leaves are alternate, narrow-lanceolate, glossy bright-green. Flowers are in umbels of 3–7. Fruits are woody, club-shaped to cylindrical, valves small, enclosed. Seeds are grey-brown, roundish to elliptical. **Distribution** Mainly in river channels of southwestern Queensland, with some extension into New South Wales. **Climate** Within the warm arid and semi-arid climatic zones. Rainfall range 250–450 mm/year. Seasonal rainfall distribution is a weak summer maximum to uniform. Prolonged droughts are a characteristic. **Soils** Soils are usually deeply cracking grey or brown clays, alkaline in reaction. **Growth** Adapted to alkaline heavy clay soils and low rainfall, and coppices well. It has given variable results in cultivation. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus odontocarpa F. Muell.

Sturt Creek mallee.

Uses A species that has the potential to produce small-sized fuelwood. Wood is dense, dark brown to reddish brown. **Description** A small, multi-stemmed tree (mallee) to 4 m, bark sheds in thin strips to leave a smooth, pale grey or light brown surface. Leaves sub-opposite to alternate, bright shining green. Buds in clusters of three. The fruits are subcylindrical with three deeply enclosed valves, four small teeth on rim projecting beyond top of fruit. Seeds are grey-black. **Distribution** Occurs in Western Australia and the Northern Territory, with extension into western Queensland. **Climate** Found mainly in the hot arid and semi-arid climatic zones. Rainfall range 250–570 mm/year mainly occurring in summer. **Soils** Soils range from gravelly red earths, lateritic gravels and sandy skeletals to deep red sands. **Growth** The species is drought- and fire-tolerant and has a moderate growth rate. It coppices readily. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus oxymitra Blakely

Sharp-capped mallee.

Uses Has potential to produce small fuelwood and could provide low shelter. It has ornamental value. **Description** A multi-stemmed, small tree or shrub 1–6 m tall. Bark decorticates in long strips to leave grey to cream smooth upper stems with a rough basal stocking. Leaves are alternate, ovate to broadly lanceolate. Flowers are in 7-flowered umbels. The buds are glaucous, with a beaked operculum. Fruit hemispherical-subglobular, glaucous, valves strongly exserted, usually with style remnants attached. Seeds are grey-brown, round to elliptical. **Distribution** Occurs in northwestern South Australia and southwestern Northern Territory, extending into Western Australia, **Climate** Occurs in the warm arid climatic zone. Rainfall range 150–250 mm/year mainly in summer. **Soils** Soils are usually red-brown loamy sands or sandy skeletals, common on gravelly soils. **Growth** It is fire- and drought-tolerant and coppices readily. However, growth rate may be slow. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus socialis F. Muell. ex Miq.

Red mallee, pointed mallee.

Uses Has potential for fuelwood, posts, poles, windbreaks, light shade and honey production. **Description** A multi-stemmed shrub or single-stemmed tree 2–12 m. Somewhat fibrous bark, greyish, persistent at the base of larger stems, smooth above, peeling off in narrow ribbons to expose white or pale grey bark. Leaves alternate, lanceolate, thick, dull greyish green. Flowers white or pale yellow, in clusters of 7–15. Fruits are globular or ovoid, woody, with 3–4 strongly exserted valves. Seeds are grey-brown, roundish or elliptical. **Distribution** From central New South Wales and northwestern Victoria into South Australia, into southern Northern Territory and the Pilbara of Western Australia. Scattered localities in Queensland. **Climate** In the warm arid and semi-arid climatic zones. Rainfall range 150– 500 mm/year and varies from a slight summer maximum in the north to a well-defined winter maximum in the south. **Soils** Soils are usually infertile sandy red earths over calcareous rock. **Growth** Growth rate may be slow, and it coppices freely. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Eucalyptus trivalvis Blakely

Desert mallee.

Uses Has potential to provide small-sized firewood from coppice. It can provide low shade and shelter. **Description** A thin-stemmed mallee 3–10 m. Bark is smooth, shiny, grey to pink or reddish brown, with a basal stocking. Leaves are alternate, lanceolate to ovate, green or somewhat glaucous in eastern forms. Buds are in umbels of 7–11; flowers white or cream. The fruit is cylindrical or barrel-shaped, with exserted valves (3). Seeds are grey-brown, roundish or elliptical. **Distribution** A wide distribution from central Australia and Western Australia to South Australia, **Climate** Principally in the warm arid zone. Rainfall range 150–300 mm/year with a slight summer maximum (east), a well-defined summer maximum (north) and slight winter maximum (south). **Soils** Soils include deep red sands, sandy loams, calcareous dune sands and shallow skeletals. **Growth** It tolerates drought, fire and sandy calcareous soils. Growth rate may be slow. **Further information** Brooker and Kleinig (1994), Turnbull (1986).

Grevillea baileyana

McGillivray (Syn. *G. pinnatifida*)

White oak, Findlay's silky oak.

Uses White oak is an attractive garden or park species. The pinkish timber is used in cabinet making and joinery. **Description** A large rainforest tree to 30 m, rarely >10 m in cultivation. Bark rough, grey to red-brown, pitted and pustular, flaky. Leaves are alternate, narrow elliptical to obovate, entire or bi- or trifid-lobed, upper surface glabrous and lower hairy, rusty brown. The white flowers occur in spectacular inflorescences. Fruits are a follicle, oblong-elliptical, hard and brittle, surface subgranulose. Seeds oblong-elliptical, surrounded by a small wing. **Distribution** Found in two coastal areas of northeastern Queensland and in southern Papua New Guinea. **Climate** It grows principally in the hot humid climatic zone. Rainfall range 1500–2150 mm/year with a strong summer maximum. **Soils** Soils include alluvia and brown and yellow earths. **Growth** A fast-growing hardy tree that regenerates profusely after disturbance. It is shade-intolerant, and bushy cultivated trees are vulnerable to strong winds. **Further information** McGillivray (1993), Hyland and Whiffin (1993).

Grevillea glauca Knight

Bushmen's clothes peg, kawoj.

Uses It has potential for use as an ornamental. Wood is moderately hard, heavy and greasy. **Description** Small tree 2–15 m. Bark dark grey to black, with longitudinal furrows. Leaves are grey, narrow ovate or elliptical, light grey or silvery, new growth bronze. Flowers are white in 10–25 cm long cylindrical racemes. The one-seeded fruits are large woody follicles, subglobose, 3–4 cm × 3.5–4.5 cm wide, 2–3.5 cm thick, with a granular surface. Seeds broadly obovate to broadly elliptical, or almost kidney-shaped with membranaceous wing. **Distribution** Found from central to northeastern Queensland and Papua New Guinea and Irian Jaya. **Climate** Occurs in the hot humid, warm humid and the hot semi-arid climatic zones. Rainfall range 490–2090 mm/year and is monsoonal in the extreme north, and a summer maximum elsewhere. **Soils** Soils are typically deep sandy or loamy red or yellow earths. **Growth** A species of moderate growth rate and good survival in the seasonally dry tropics. Regenerates from root suckers. **Further information** McGillivray (1993), Gwaze (1989), Wrigley and Fagg (1988).

Hicksbeachia pinnatifolia F. Muell.

Red bopple nut, ivory silky oak.

Uses Has ornamental potential on account of its foliage, flowers and bright red fruit. Edible kernel has potential as a commercial food crop. **Description** Small tree to 12 m, single- or multi-stemmed from the base. Bark light brown, wrinkled and corky. Leaves leathery, up to 1 m long, pinnate with 10–35 lobes, central axis prominently winged. Flowers purplish brown, sickly odour. Fruit are fleshy, indehiscent, pinkish-red to scarlet, oval, edible kernel. **Distribution** The distribution is confined to the coast and hinterland of central New South Wales, to southeast Queensland. **Climate** Found mainly in the warm sub-humid climatic zone and extending into the warm humid in Queensland. Rainfall range 1200–1700 mm/year with a moderate summer maximum in the north to a weak summer maximum in the south. **Soils** Grows in soils derived from basalt and requires well-drained loamy soil and open sunny situations. **Growth** Intolerant of drought, plants are slow-growing and difficult to establish. **Further information** Floyd (1989), Weston (1988).

Lophostemon suaveolens

(Soland. ex Gaertn.) Peter G. Wilson & J.T. Waterhouse

Swamp box, apple.

Uses A durable hardwood reputedly resistant to termite and marine borer attack. Produces large amounts of soot when burnt. It is suitable for piles, marine structures and underground work. It produces honey of a good quality. **Description** Shrub or small tree 5–15 m, branches sometimes twisted and distorted. Bark is red-brown to grey, fibrous-papery, flaky. Leaves are in false whorls of 3–4 at branch ends; ovate to lanceolate, glossy dark green above, paler beneath. Flowers are white in a hairy cyme, fruit a woody, hemispherical-campanulate capsule. Seeds are few in each cell. **Distribution** Found along the east coast of Australia, from Cape York Peninsula to central New South Wales. **Climate** In the warm humid and warm sub-humid climatic zones. Rainfall range 650–2100 mm/year. **Soils** Soils are chiefly alluvial, deep coarse sands and clays. It tolerates infertile and periodically waterlogged soils and has a moderately fast growth rate (1.5 m/year). **Growth** Has the ability to coppice and produce root suckers. **Further information** Turnbull (1986).

Melaleuca nervosa (Lindley) Cheel

Yellow-barked paperbark.

Uses Has potential for fuel, small round timbers, erosion control and as an ornamental. Wood is dark reddish-brown, hard, heavy; has been used for construction and for poles and rails. **Description** A shrub or small tree 3–10 m. The brownish-white bark is the layered type typical of many melaleucas. Leaves are alternate, lanceolate, more or less straight. The inflorescence is a terminal spike, stamens greenish-cream or red. Fruit is a cylindrical capsule. **Distribution** Distributed across northern Australia from the northwest of Western Australia to the central east coast of Queensland. **Climate** Found in the hot sub-humid and humid zones, but extends into the hot semi-arid climatic zone. Rainfall range 700–1150 mm/year with a strongly developed monsoonal pattern in the north and a moderate summer maximum in the south. **Soils** Grows on drier ridges on sandy podzols and lighter alluvial soils along drainage lines. **Growth** It tolerates infertile, periodically waterlogged and sometimes saline soils in lowland tropics, but is relatively slow-growing. **Further information** Turnbull (1986).

Neofabricia myrtifolia

(Gaertn.) J. Thompson

Yellow-flowered tea tree, untarra.

Uses A species useful for honey production, low shelter and ornamental purposes. Wood has potential for fuelwood and charcoal production. **Description** A large shrub 3–5 m or a small tree up to 13 m. Bark dark brown, thick, hard, more or less fibrous and deeply fissured. The leaves are alternate, spirally arranged on the branchlets, oblong-lanceolate to almost obovate. Flowers yellow, singly, rarely in threes, fruit a somewhat woody capsule with one or many winged seeds. **Distribution** Occurs on Cape York Peninsula. **Climate** mainly in the hot humid climatic zone, but extends into the hot sub-humid zone. Rainfall range 1600–1750 mm/year with a strong monsoonal incidence. **Soils** Soils are infertile, acid and neutral, red and yellow earths, shallow sandy soils or siliceous sands. Commonly found on the better-drained sandy soils, but does occur on periodically flooded plains. **Growth** Adapted to well drained, infertile soils in the hot humid tropics. It will reshoot from the base after moderate-intensity fires. Tolerates mild frosts. Slow-growing (0.5 m/year). **Further information** Turnbull (1986).

Paraserianthes toona (Bailey) Nielsen

Red siris, acacia cedar.

Uses This species has potential as an ornamental tree. The timber is moderately durable and used for furniture, flooring, decorative panelling, turnery, joinery and fencing. **Description** Tall tree 15–30 m or smaller bushy shrub 3–5 m on unfavourable sites. Bark grey or brown, scaly in parts, with a pink blaze. Leaves are alternate and bipinnate, leaflets paler beneath, deciduous. The inflorescence is a panicle, the flowers in spikes at the ends. Pods are flat, reddish-brown, seeds orbicular, central in pod. **Distribution** A species of north-eastern coastal Queensland and adjacent islands. **Climate** Found mainly in the hot humid zone. Rainfall range 1000–1750 mm/year with a summer monsoonal pattern. **Soils** Soils are alluvia, yellow podzolics, yellow earths with grey-brown topsoil and brown earths. **Growth** A fast-growing, nitrogen-fixing rainforest tree adapted to a variety of sites in the lowlands of the humid tropics. Seed has proved difficult to obtain. **Further information** Turnbull (1986) under *Albizia toona*.

Persoonia falcata R.Br.

Wild pear, tarpoon.

Uses It has potential for use as fuel and for amenity plantings. Timber is light-coloured with a reddish heartwood, hard and close-grained, suitable for small posts or ornamental items. Fruits are edible. **Description** Erect tree 3–9 m high, or shrub 2–3 m. The small branches and branchlets are often pendulous. Bark is brown and red, flaky or corky, tessellated or fissured. Leaves linear or lanceolate, falcate, prominent midrib and marginal nerves. Flowers pale yellow in terminal racemes, fruit is an ellipsoid, 1-seeded succulent drupe. **Distribution** Two disjunct areas of occurrence in northwestern Australia and along the east coast of Queensland. **Climate** Found mainly in the hot sub-humid zone, with limited areas in the hot humid and hot semi-arid zones. Rainfall range 600–1300 mm/year with a strong summer monsoonal pattern in the north and a moderate summer maximum in the south. **Soils** Principally on well drained sandy soils such as siliceous sands, red earthy sands and shallow loams. **Growth** It appears to give moderate growth rate while being drought-tolerant and resistant to fire damage. **Further information** Turnbull (1986).

Petalostigma pubescens Domin

Quinine tree, quinine berry.

Uses Wood is brown, hard, shrinks markedly when dried. Bark and fruits have medicinal properties, and dense wood has potential as fuel. **Description** Small tree 5–8 m, with a short trunk. Bark is grey and black, hard, fissured. Leaves are alternate, dark, glossy green above, lower pale grey. Separate male and female, creamy-fawn flowers on the same tree. Fruit is a woody pubescent capsule, ovoid, with an outer bright orange fleshy covering; 1–2 oblong dark-brown seeds in each cell. **Distribution** Widespread distribution in western Papua New Guinea and in northern and eastern Australia. **Climate** Mostly in the hot or warm semi-arid and sub-humid zones, with a limited area in the hot humid zone in the extreme north. Rainfall range 600–1200 mm/year with a well-developed summer monsoonal pattern in the north and a well-developed summer maximum in the south. **Soils** Mainly on well drained sandy soils. **Growth** It is a drought-tolerant species adaptable to well drained sandy soils of low fertility. Relatively slow-growing (0.7 m/year) and coppices poorly. **Further information** Turnbull (1986).

Pleiogynium timorense (DC.) Leenh.

(Syn. *P. cerasiferum*)

Burdekin plum, tulip plum.

Uses The species shows promise as a good shade tree. Wood hard and durable and very difficult to split; once used for pick handles. The flesh of the fruit is used to make jam. **Description** Tree 15–20 m, with large plank buttresses. Bark is hard, grey or grey-brown and fissured. Compound leaves with 5–11 elliptic or ovate leaflets, unequal-sided. Separate male and female flowers, small, greenish-yellow. Fruit a large, brown to black fleshy drupe, 2–5 cm wide. **Distribution** The Australian distribution is restricted to eastern Queensland. **Climate** Present in the warm sub-humid and humid and the hot humid climatic zones. Rainfall range 800–2090 mm/year. The incidence varies from a strong summer maximum in the south to monsoonal in the north. **Soils** Soil types include, yellow podzolic from schist and stony red earths derived from basic volcanics. **Growth** A fast-growing and hardy tree growing in drier situations in subtropical rainforests. It is found on rocky, old beach ridges. It is able to withstand full sun and wind when small. **Further information** Dick (1994), Hyland and Whiffin (1993).

Syncarpia hillii Bailey

Satinay, red satinay.

Uses An effective species for use in shelterbelts and windbreaks. Heartwood is reddish-brown, sapwood paler. Timber has been used for flooring, panelling, decorative veneer, heavy furniture and wharf piles; satisfactory fuel. **Description** Tall straight tree reaching 40 m in height and a diameter to 1.5 m. Bark is thick, somewhat fibrous, deeply furrowed, and extends to the branchlets. Leaves are opposite, elliptical, ovate to ovate-lanceolate, tapered at each end, upper surface dark green, the lower pale and densely hairy, stalks distinctly wrinkled when dry. Flowers are united in globular heads; fruit is made up of seven fused woody capsules. **Distribution** A very limited distribution in southeastern Queensland and possibly New South Wales; it occurs chiefly on Fraser Island. **Climate** The distribution lies in the warm humid climatic zone. Rainfall range 1100–1700 mm/year, mostly in summer. **Soils** Soils include deep pale siliceous sands, podzols, acid red friable earths and hard acid yellow bleached duplex. **Growth** A fast-growing tree adapted to frost-free sites. **Further information** Turnbull (1986).

Syzygium paniculatum Gaertn

Magenta lilly pilly.

Uses In nature this species is too small and rare to be used for wood, but has potential as a structural timber. The flesh of the fruit is edible and used to make jam. It is widely cultivated as an ornamental. Successfully used overseas as a bonsai plant. **Description** Tree to 10–20 m, shrubby habit and dense crown. Bark is flaky, tessellated. Leaves are opposite, lanceolate to obovate, dark glossy green above paler below. Flowers white in terminal and axillary panicles. Fruit a berry, magenta, white, pink, red or dark purple; polyembryonic. **Distribution** Found in coastal areas in central New South Wales, from Jervis Bay to Bulahdelah. **Climate** The area is in the warm humid climatic zone. Rainfall range 755–1160 mm/year with a weak summer maximum. **Soils** Mainly found in littoral or subtropical rainforest on sandy soils. **Growth** Probably the most widely cultivated species of *Syzygium* in Sydney. Generally unsuited for subtropical regions because of insect attack and associated fungal problems. It is frost-sensitive. **Further information** Floyd (1989), Hyland (1983).

Syzygium tierneyanum F. Muell

Bamaga satin ash, river cherry.

Uses A good species for use in parks, windbreaks and for erosion control and rehabilitation of stream banks. Millable logs are sometimes produced. Fruits are edible. **Description** Tree with short trunk to 10–12 m or straight to 25 m. Buttresses on large trees. Bark flaky, outer blaze brown. Young shoots are coppery-bronze, adult leaves lanceolate or elliptical, with numerous visible oil dots. Cream-coloured flowers with numerous oil dots on the petals, borne below the leaves. Mature globular fruit pink to red, occasionally white, to 2 cm diameter. **Distribution** Found in lowland rainforests in northern Queensland, PNG and Solomon Is. **Climate** The distribution is in the hot humid climatic zone. Rainfall range 1715–3560 mm/year, with a strong summer monsoonal incidence. **Soils** Frequently found along stream banks or in running water. **Growth** A fast-growing species for use in subtropical and tropical areas. Psyllid insects can damage young plants. **Further information** Hyland (1983).

Terminalia oblongata subsp. *volucris*

(R.Br. ex Benth.) Pedley

Rosewood.

Uses Regarded as a valuable fodder species, but stock deaths have been recorded. Has good potential for fuel and round timber for farm use. **Description** A bushy shrub 2–5 m to a small tree up to 8 m. Bark on the trunk is grey, finely fissured and tessellated, while that of the branches is finely fissured and smooth. Leaves are spirally arranged, discolorous, obovate to broadly elliptical, deciduous during dry season. Flowers are mixed bisexual and male, in spikes. Mature fruit is a two-winged nut. **Distribution** Extends from Western Australia to the Northern Territory and around the Gulf of Carpentaria into Queensland. **Climate** In the hot semi-arid climatic zone, with only a limited extension into the hot sub-humid zone. Rainfall range 650–850 mm/year of strong monsoonal incidence. **Soils** Major soil type is grey or brown cracking clays, which may be seasonally wet to swampy; less common on deeper sandy soils. **Growth** Little is known of its silvicultural requirements or growth. **Further information** Turnbull (1986) under *T. volucris*.

Ventilago viminalis Hook

Supplejack, vinetree.

Uses An excellent fodder species that can be used for shade, shelter, ornamental purposes and probably for fuel. Wood is dark brown in colour, hard, heavy, and takes a good polish. Root and bark extracts used medicinally. **Description** Tree 5-10 m, and a shrub 4-5 m on adverse sites. Initially resembles a vine in habit, that usually develops into many twisted stems. Lower bark is black, hard, rough and fissured. Leaves narrow-lanceolate, mainly dark glossy-green. Flowers are small, cream-coloured. Fruit is a small, globular, single-seeded nut, with a distinctive straight yellowish-green oblong wing. **Distribution** Extends from the Kimberley through central Northern Territory and central Queensland to western New South Wales. **Climate** Mainly in the hot semi-arid zone and warm semi-arid zone. Rainfall range 400-700 mm/year, varying from monsoonal to summer incidence. **Soils** Major soil types are grey cracking clays, red earths, red earthy sands and black earths. A slow-growing tree that is drought-tolerant and fire-resistant. **Growth** Regenerates from root suckers. **Further information** Turnbull (1986).

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